INTEGRATING ACQUIRED SUBSYSTEMS

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Abstract

Integrating subsystems from external sources into an integrated control system is becoming more commonplace as outsourcing is used to attempt to reduce costs. The functional requirements, integration plans, testing and maintenance must all be considered to insure success. At the Low Energy Demonstrator Accelerator (LEDA) at Los Alamos National Laboratory (LANL), systems were acquired for high power RF, Radio Frequency Quadropole (RFQ) vacuum control and RFQ Resonance Cooling Control System (RCCS). These applications are discussed in order that we may discover good practices for acquiring external subsystems that fit into an integrated environment.

1 INTRODUCTION

Acquiring subsystems from commercial sources is done frequently to take advantage of external expertise, reduce costs, and augment resources. These systems most commonly include some level of control system. They are typically built and tested as stand-alone systems from a set of requirements. Once they are delivered, they are maintained by the receiving institute. The delivered system can occasionally be so difficult to maintain that it has to be replaced or re-engineered, as in the case of the High Power RF at ESRF as reported at the last ICALEPCS[1]. In an attempt to better understand the se costs, a case study is done on three subsystems that were acquired for LEDA at Los Alamos: RFQ vacuum control, RFQ cooling control and the high power RF control.

2 RFQ VACUUM CONTROL

The RFQ vacuum control was developed by the vacuum control group at Lawrence Livermore National Laboratory (LLNL). The requirement was to provide control for the RFQ and the RF windows of the RFQ. This system contains about 1,000 signals and many equipment protection interlocks. A meeting was held to discuss the integration of this subsystem into the LEDA controls. It was agreed that we would use Modicon PLCs and Granville-Phillips Ion Gauge Controllers. It was decided that the equipment protection interlocks would reside in the PLC and the sequential logic for regeneration of the cryopumps and automatic pump down would be done in Labview. The system would be built, delivered, and tested in this fashion. When testing was complete, the integration into the LEDA control system, which is based on the Experimental Physics and Industrial Control System (EPICS), would be done by replacing the Labview system with an EPICS Input/Output Controller (IOC). To accomplish this only required moving the GPIB interfaces to the Ion Gauge Controllers and the serial interfaces to the PLCs from a Mac running Labview, into the IOC.

In an effort to quantify the expense of providing a control system for this, the system engineers were asked for expended time. None were able to give accurate numbers, as time was not tracked at this level of detail. The following estimates were made by LLNL personnel: 15 months to gather requirements, 6 months to implement the vacuum system in the PLC and Labview and 1 month to install. The LANL personnel gave the following estimates: .5 month to plan with LLNL, 2.5 months to develop or adapt drivers, 2.5 months to produce screens and a database to integrate into EPICS and .5 month to integrate.

During the implementation of the vacuum control system, the two control engineers met three times. They worked together to coordinate long wire runs at Los Alamos and to integrate the vacuum system into EPICS. After the integration, several new requirements arrived. Strain gauges were added to the RFQ so that the stress added by the RFQ window vacuum could be measured. These were required with very short delivery time and were done directly in the EPICS IOC. A requirement to provide critical interlock from the vacuum readings to the HPRF was also added. The interlock was to respond within 15 msecs of a rise in pressure. The LLNL and LANL engineers determined that the PLC, with its present load, would respond within 60 msec. The EPICS IOC could respond within 15 msec. Failsafe hardware was used in the IOC that requires an active output be written and additionally uses the state of all critical tasks in the IOC to maintain the interlock.

In all, 22 months were used by LLNL and 6 months by LANL. Of the 22 months used by LLNL, 15 were used to gather requirements and design. It would seem obvious that the engineer working with the vacuum builders would be able to gather those requirements more efficiently than an engineer that was located at LANL would. The 6 months used to implement the ladder logic and Labview screens and sequences had some overlap in the 2.5 months used at LANL to read the PLC values into IOCs and make screens for an EPICS workstation. This is the overlap that has to be compared to having the LLNL engineer learn to use EPICS and develop the application directly. It would be easier to assess this if we knew what part of the 6 months used at LLNL was spent on Labview, as that is the portion that was reproduced in EPICS. In addition, 5 months was spent at LANL on developing drivers for the Modicon PLC, adapting the Industry Pac (IP) GPIB driver, adapting the IP carrier board driver and developing some IP drivers. This time needs to be compared to the time that it would take to use the portable server and treat Labview as an IOC. The point count and number of serial interfaces and GPIB interfaces would have required more than one Labview system. More compelling is the interlock requirement for the high power RF. In addition to the interlock requirement, the modifications that would have been needed to the Labview program to export every piece of data that had been read from the PLC, would have significantly increased the cost of the Labview implementation. Labview only makes data available through explicit commands to export the data. EPICS values are all available to the rest of the network as part of the underlying functionality of the EPICS database and the channel access protocol.

All phases of the implementation were planned and discussed between the LLNL and LANL engineers. In all cases, the requirements were considered along with an interest in keeping the implementation costs low.

3 HIGH POWER RF

The high power was acquired from two commercial companies. The RF system consists of approximately 1,200 I/O signals. Continental Electronics provided the transmitter using an Allen-Bradley PLC5/40. Maxwell Technologies supplied the power supply using an Allen-Bradley SLC5/03. Both PLCs use the DF1 protocol and so the existing EPICS' Allen-Bradley driver was modified to use it. The high power RF system was controlled from an Allen-Bradley Panelmate display. As the Panelmate was left in place and there was no local/remote switch, driver modifications were made to have the EPICS database reflect changes that were made from the Panelmate. Integration was done by adding an EPICS IOC to the DataHighway Plus. No communication was done between groups at LANL and the commercial companies until the systems had been delivered and tested.

Again, we have no accurate time measure to use but only the estimates provided by the engineers involved. The commercial vendors claim that the control effort required 12 months. This was not broken down, so there is no way to know what portion is used for requirements, implementation, or test. LANL used 4 months to modify an existing driver for this protocol and to support the idea that control channels could be changed from another master. An additional 2 months were used to produce a fault logger that behaved like the local dedicated logger, but made the data available over the network and kept all history instead of a limited number of events. Finally, 12 months was used to develop the EPICS database. This time reflects the need to create 4,000 EPICS database records to integrate the 1,000 PLC channels.

The number of EPICS records was mostly inflated and complicated by the fact that the limits and gain factors for each channel came in as separate channels. In addition, the gain factors were not consistent in the PLC. The vendors had used the Panelmate display to change the gain factors. Now these constants had to be first discovered and then kept in EPICS so that the Panelmate display and the EPICS display would match. During integration, several errors were discovered in the ladder logic of the PLC. These included registers being overwritten as scratch pad values in between updates of the Panelmate and control coils not being implemented to affect the ladder logic. Since the commercial companies had underbid the contract and were loosing money, support was very difficult to get. The problems in the ladder logic were found by LANL personnel. Some were fixed by the vendors, some by an RF engineer that was required to take over maintenance. The time spent by the LANL RF engineer is not included in these estimates.

A total of 32 months was spent implementing this subsystem. It is easy to see that a lot of time could have been saved by coordinating some efforts. The support for multiple masters could have been traded for a remote/local switch. The time required to make extra channels for handling gain mismatch could have been handled by cleaning up the ladder logic to be consistent. The time spent debugging the ladder logic could have been done more efficiently by having the vendors involved in the integration.

4 RFQ RESONANCE CONTROL COOLING SYSTEM (RCCS)

The RCCS was developed by Allied Signal using EPICS. The RCCS controls water temperature to hold the RFQ on resonance. In addition to the 1,000 I/O signals, feed-forward control loops were required to provide the steady state control desired. In this project, Allied Signal did all of the work through integration and test and would only turn over the system for maintenance.

The time was not measured in any way to give us accurate numbers. Estimates given were that 12 months were used to gather requirements. Allied used 9 months to develop the database and screens, six of which were used to train a new engineer. Industry Pac drivers were needed and 3 months was spent developing them. Finally, four months was used to install and test the system and tune the loops with a RF into the RFQ. Los Alamos offered only peripheral support, probably less than a week overall. System integration was completed by putting the path for their displays into our operator account.

The engineers at Allied Signal thought that they would have accomplished the job of defining the database in about 3 months had they used PLCs instead of EPICS. This is a saving of 6 months. It would have required a database be written for integration into EPICS by someone at LANL, which took about 2.5 months for the similarly sized vacuum controls potential savings of about .5 month. A real loss in savings shows up in the 3 months to write drivers. Similar drivers were written for the RFQ vacuum and could have been provided directly for a saving of three person-months. The lack of regular communication between the groups could be a reason that this opportunity was missed.

5 LESSONS LEARNED

Before we decide that there is any great insight gained, it is important to know that all time is estimated. In spite of this fact, the circumstances do allow us to make several claims. Developing the requirements for subsystem control at the place where the subsystem is being developed is most efficient. The people producing the subsystem control are going to be most efficient using tools that are familiar to them. Then integration with the facility needs to be considered. Costs will increase when the facility must train people in new technology to maintain a subsystem. Integration requirements must be considered from the design phase through completion. It is clear that the subsystem requirements are only a subset of the requirements for an integrated control system. In the research physics community, it also seems clear that these requirements do no always show up in a timely fashion.

6 SUGGESTIONS TO AID IN SUCCESSFFULLY ACQUIRING SUBSYSTEM CONTROLS

When selecting an approach to control a simple subsystem, it is easiest to use adequate tools that are familiar to the engineer performing the work. Control engineers that are working on these subsystems should be in contact with the control engineers that are responsible for integration, as problems are best solved when a complete understanding of local and global control issues are represented. Always be prepared for requirements to change. If a simple problem suddenly becomes complex because of a new requirement, it is important to be able to recognize and resolve the situation promptly. Complex systems are easiest to build and maintain by using a system that is inherently capable of controlling complex systems. Stately simply, it is easier to have too much capability then not enough, as new requirements often convert a simple problem into a difficult one.

REFERENCES

[1] J. Meyer, “Redesigning a Radio Frequency Control System with TACO Why and How?” ICALEPCS ’99, Beijing, China, November 1997. http://www.aps.anl.gov/icalepcs97/paper97/p002.pdf