USE OF INDUSTRIAL CONTROL SOLUTIONS IN THE DIAMOND PROJECT

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Abstract

Whilst the Diamond control system is based on the EPICS control system toolkit, significant use is being made of industrial controllers and control system solutions procured from industry. The choice and implementation of the industrial controllers are presented, together with the approach to procuring control systems from industry that use both industrial controllers and EPICS.

INTRODUCTION

Diamond is a 3rd generation, 3GeV synchrotron light source currently being constructed in the UK. The storage ring is based on a 24-cell double bend achromatic lattice of 561m circumference. It uses a full-energy booster synchrotron and linac for injection and will include an initial suite of seven photon beamlines.

The project is currently in a detailed design, procurement and construction phase[1]. Calls for tenders are being issued for major contracts to supply accelerator components, including the linac, RF cavities, magnets and girders.

Progress on the detailed design of the Diamond Control System[2] includes refinements in the choice of EPICS tools, the development of tools, device support and applications, and design of the control system structure, including solutions for interface options, control system networking, machine protection, wide band signals and physical implementation. This paper presents decisions in the choice and implementation of the industrial controllers, together with the approach to procuring control systems from industry that use both industrial controllers and EPICS.

CONTROL SYSTEM PROCUREMENT PHILOSOPHY

The general philosophy in procuring the technical systems for Diamond is that sufficient design work is undertaken to enable preparation of an effective specification, then tenders are invited from industry for contracts to carry out detailed design and manufacture in accordance with the specification. In some cases, the contract extends to installation and commissioning of the system to realise a turnkey solution. One advantage of this model is that it enables DLS to manage the number of in-house staff and establish a staff profile based on the long-term requirements of the operational phase. It would have been possible to have adopted this model for the whole control system, and whilst this approach is the established model for comparable control system projects in some industrial sectors and accelerator projects, notably ANKA[3], it was considered unsuitable for Diamond. The principal reasons are that industry has limited experience in delivering complete accelerator control systems, and that it would have been difficult to specify the control system requirements in sufficient detail at a suitable time, as detailed requirements from the technical systems will only become available after the design of those systems is complete. These factors represent a significant risk to the successful realisation of a control system through a turnkey procurement contract.

A safer solution, adopted by Diamond and most accelerator projects, is to manage the control system development in house and to procure components and technical systems that are then integrated by the in-house team. This enables early control system development to proceed on the basis of preliminary requirements from the technical system groups. The requirements are then iterated between the controls group and the technical system groups during the technical system design phase, to define the final specification.

An in-house development must also be cost-effective compared with a solution from industry. To achieve this Diamond has taken an established control system toolkit and is applying it. This minimises the amount of software development necessary.

An in-house development requires a staff profile in excess of that required for the long-term operational phase. This will be managed, after the development phase, by migrating the excess controls staff into groups responsible for operations, beamline control systems and experimental station data acquisition system development.

CHOICE OF CONTROL SYSTEM TOOL KIT

During 1999 four options for the control system toolkit were reviewed: TACO/TANGO from the ESRF [4,5], a development of the SRS control system[6], EPICS[7] and commercial SCADA systems. The conclusion of this was that any one of these options could deliver a working control system[8]. Whilst a number of SCADA systems had been applied to accelerators, these systems had limited accelerator-specific functionality. Following on from this a detailed analysis of control system tool kit requirements showed that EPICS offered advantages in terms of its application to other accelerator projects, a larger base of developed hardware drivers and performance/functionality.

The implementation of EPICS on Diamond follows the established model in using Unix workstations for development and as operator consoles, and VME systems as the input/output controllers (IOCs). The majority of equipment is interfaced directly to the VME systems, alleviating the requirement for a third layer. However, it was recognised that Programmable Logic Controllers (PLCs) would be used in conjunction with the IOCs.

PLCS IN THE DIAMOND CONTROL SYSTEM

Diamond PLC Requirements

Two distinct requirements for PLCs were identified in the system design for the Diamond control system. These are in the management of interlocks for the protection of equipment and the applications of continuous process control.

The management of interlocks could be achieved in the EPICS IOC, but this would necessitate the provision of a hardware watchdog timer to ensure protection in the event of the loss of the software process managing the interlocks. This would mean that an IOC with protection functionality could not be rebooted without either disabling the watchdog or shutting down the process. The ability to undertake warm reboots that do not affect the operation of the accelerator systems offers operational flexibility and improves control system up time, particularly during initial operation. This justifies the additional cost and hardware of having separate sub-systems to manage interlocks.

There are several continuous process applications which are expected to be PLC-controlled on Diamond. These are the cryogenic refrigeration plant, the distribution of cryogens to the superconducting RF cavities, the conventional services associated with the provision of cooling water and the management of the building environment. In each of these examples, it was recognised that industry would offer established solutions based on PLC technology.

Programmable Logic Controls

Despite the emergence of open programming standards for PLCs[9] and well-established open standards for buses and communications, some PLC manufacturers have continued to use proprietary standards and protocols. This can lock a project into particular family of PLCs or a particular manufacturer.

Traditionally the life cycle of a PLC family has been driven by the requirement for product stability, and the authors estimate that this life cycle has been of the order of ten to fifteen years. A number of manufacturers have continued to support product families for a period of time after the family has ceased to be current, and in some cases this period has been as long as ten years. However, the authors believe that the situation is changing as PLC manufacturers have to work with increasingly short component life cycles and market pressures towards newer solutions offering better price/performance ratios. This is resulting in shorter product life cycles, which could conceivably be as short as five years. With an estimated life of 20 years for Diamond, obsolescence is potentially a serious issue.

Choice of PLC

Whilst it would have be advantageous from a support-and-maintenance point of view to be able to standardise on one family of PLCs, it was recognised that this would not be possible because of conflicting requirements. Based on these requirements, two PLC solutions are required, one for interlocking or low-end applications and the other for process control or high-end applications.

A PLC for Low-End Applications

The functional requirements for the low-end PLCs are quite modest, in requiring small size, digital IO and logic functions together with a communication interface to the IOC. These are easily met by PLC families produced by most manufacturers. Given the relatively high number of units required, around 100, a major factor in the choice is the unit cost. Diamond has functionally evaluated a number of PLCs, in particular with regard to the communication interface to EPICS, and is currently planning a tender action to establish a preferred supplier.

It is proposed to address the issue of the PLC life cycle by building the PLCs in to 19” crates. Each crate will then provide electrical interfaces to the equipment and a communication interface to EPICS independent of its associated PLC. This effectively encapsulates the PLCs within user-defined interfaces so that the physical realisation and operation of the subsystem is independent of the PLC. Two specific requirements have been defined, one for operating and protecting vacuum valves, radiation absorbers and shutters, and the second for managing water flow interlocks associated with magnets and vessel cooling for one cell.

A PLC for High-End Applications

The choice of a PLC for high-end applications initially appeared more difficult, as such PLCs will be more closely related to the requirement of the specific application, particularly in the process control cases. However, the Siemens S7 PLC family is extensively used in Europe and is well established with a number of potential suppliers and so has been selected.

PROCURING EPICS BASED CONTROL SYSTEMS FROM INDUSTRY

Transfer of EPICS Knowledge to Industry

Early in the design phase of Diamond it was recognised that, whilst there were a number of organisations in Europe who were already offering control system design, development or support based on EPICS, EPICS was not widely taken up by companies to whom DLS would be looking for the supply of systems. To help in addressing this problem, DLS offers assistance to potential suppliers in understanding EPICS. This assistance consists of the provision of places on training courses for staff from potential suppliers and the loan of EPICS development systems to enable organisations to develop an understanding of EPICS through self training.

Procuring Turnkey EPICS Based Solutions from Industry

Whilst most of the control system will be developed by in-house staff, there are a number of subsystems which are well defined and lend themselves to delivery by industry. Diamond has already placed contracts for certain subsystems complete with EPICS-based controls and is inviting tenders for further subsystems.

The Linac tender called for a turnkey solution complete with EPICS-based controls. Six companies offered solutions which were in line with this, and a contract has now been placed with Accel GMBH. The solution being delivered by Accel, uses Siemens S7 PLCs to manage the electron source and modulators, with the PLCs connected to the IOCs using the Industrial Ethernet protocol over Ethernet. For the focusing magnet power supplies several operations are being considered, one using a Profibus interface between the power supplies and EPICS, and the second using Profibus but via an S7 PLC.

A number of solutions offered for the Storage Ring RF amplifiers offered EPICS-based control systems, but with varying levels of integration of the amplifier components. The chosen solution offers good integration, with an equipment interface based directly on the EPICS IOCs and hardware protection modules.

The Storage Ring consists of 72 girders, which are aligned using 360 motorised axes. The specification for procurement of a motor control system calls for an EPICS-based solution. In pre-tender discussions there is good interest being shown in meeting the EPICS aspect of this specification.

A number of permanent magnets insertion devices and at least one superconducting insertion device will be procured as turnkey solutions. For each of these the specification defines an EPICS-based control system as a requirement.

It is planned to procure four of the seven photon beamlines as turnkey contracts. These will call for EPICS-based controls for the beamline motion control, vacuum equipment and diagnostics components. The use of EPICS is particularly advantageous as it facilitates close synchronisation of the beamline monochromator with the insertion device located in the Storage Ring. This synchronisation is achieved by means of distributed events received by each IOC.

Further systems that will be procured with EPICS-based controls are the Booster RF amplifiers and the residual gas analyers as part of the vacuum instrumentation.

Managing Procurement from Industry

Diamond is procuring multiple systems based on EPICS, but with the open nature of EPICS this could result in as many different solutions being delivered, resulting in problems of support and life cycle management. This has been addressed by standardising the EPICS components to use, the choice of hardware and the in-house standards to follow for configuration and application software. To standardise the EPICS software components, DLS prepares and loans an EPICS-based development system containing the EPICS base, extensions, device support and other tools. To standardise the hardware, DLS provides a recommended list of hardware which it will free issue, complete with EPICS support, as part of the contract. To standardise the application configuration and software, documentation defining the naming of devices, address schemes for modules, directory structure and the design of operator interfaces is provided.

CONCLUSIONS

Diamond will standardise on two families of PLCs, for low-end and high-end applications respectively, with each providing good integration with EPICS.

Diamond has had good response to calls for tenders for turnkey solutions calling for the inclusion of EPICS-based controls. A number of companies operating in the accelerator community now see EPICS as an established, and possibly the de facto, standard for an accelerator control system, so that by offering EPICS-based controls as part of their products they gain market advantage.

REFERENCES

[1] Richard Walker," Progress with the Diamond Light Source Project", PAC 2003, Portland

[2] M.T.Heron, A.J.Duggan, B.G.Martlew, A.Oates, P.H.Owens, V.M.Smithers, P.D. Woods, "DIAMOND Control System Outline Design", ICALEPCS 2001, San Jose 2001

[3] M. Plesko et al, "The Control System for the Accelerator of ANKA", EPAC 98, Stockholm, June, 1998

[4] http://www.esrf.fr/computing/cs/taco/taco.html

[5] http://www.esrf.fr/computing/cs/tango/tango_basic /index.html

[6] M. T. Heron, B. G. Martlew, A. Oates and W. R. Rawlinson, "An analysis of the SRS Control System upgrade", PCaPAC2000, DESY Hamburg, 2000.

[7] http://www.aps.anl.gov/epics/php.php

[8] M.T. Heron, B.G. Martlew, "A Review of Options for the DIAMOND Control System", PAC'99, New York April 1999

[9] http://www.plcopen.org/pages/t_intro_IEC61131.htm