THE SELECTION, DEVELOPMENT AND APPLICATION OF PLC SOLUTIONS FOR THE DIAMOND LIGHT SOURCE

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Abstract

Diamond Light Source set out to address a wide range of control system requirements from process control to interlocking with a minimum number of PLC types. This resulted in standardisation of PLC's from just two manufacturers. Siemens was chosen for high end process control and Omron for a variety of other applications including interlocking and protection. These were then applied to large number of applications which have been addressed wherever possible using standard solutions. The details of this approach, and solutions managed through it, including procurement of turn key systems by industry, and how future obsolesce is being addressed are all described.

INTRODUCTION

Diamond, a third generation 3GeV synchrotron light source[1], commenced operation in January 2007. The storage ring (SR) is based on a 24-cell double bend achromatic lattice of 561m circumference. It uses a full-energy booster synchrotron and a Linac for injection. The spectral output is optimised for high brightness up to 20keV from undulators and high flux up to 100keV from multipole wigglers. The current operational state includes seven photon beamlines, with a further fifteen beamlines now under design or construction.

The design of the Diamond control system [2] is based on the EPICS control system toolkit. It uses VME and other IOCs as the primary plant interface. The VME systems undertake plant supervision and operation within defined limits but do not protect equipment from damage. Below the VME systems there is a PLC based subsystem to ensure correct operation of process based equipment e.g. cryogenic systems and protection of equipment. The requirement for the PLC system, the choice of PLC types and realization of this are presented.

PLC REQUIREMENTS

The requirements for PLC hardware on Diamond were defined to be:

- Modular
- Established supplier
- Good user base
- Product support
- Choice of input, output interface types
- Long product availability
- Minimal cost
- Accepted by industry for turn key contracts
- Capable of supporting process based applications
- Comms interface preferable Ethernet
- Good programme development environment
- Open standard of programme specification preferable IEC61131-3

In considering the requirement for a PLC on Diamond it would have been preferable to have selected one supplier and one set of hardware. However, this would have meant compromising on a number of important requirements most notably minimal cost. The solution to this was to recognise that the requirements could best be met with two platforms, a high end platform addressing process control requirements and well accepted by industry but at a cost premium and a low end solution addressing all other requirements at a reduced cost.

The other possible application for a PLC on an accelerator project is realising the logic for a Personnel Safety (PSS) system. On Diamond, while it was recognised the PSS could be designed utilising PLC hardware, the overhead in managing software for a safety critical application meant that a hardwired wired relay solution was adopted [3].

HIGH-END PLC

Choice of PLC

Early on in the Diamond project it was recognised that a number of technical subsystems would be procured as turn-key solutions from industry. For effective integration of these, they should be supplied complete with control system. Ideally the control system would comply with Diamond standards to enable future in-house support and maintenance. In considering possible turn-key systems, Linac, RF amplifier, IDs, cryogenic systems, beamline components had all been supplied to other projects with PLC controls using Siemens S7 PLC's. Also in the European market Siemens have between 30-40% of the PLC market and is well supported. Hence, the high end PLC solution was set as the S7 PLC [4] (CPU300 range).

Integration into control system

The Siemens S7 PLC EPICS integration was development using Ethernet and Siemens application level protocol. EPICS support for this had already been developed at SLS [5] and this formed the basis for integration. This provides a facility for single and block register read and write for all of the EPICS standing record types.

Application

Our initial assessment proved to be remarkably accurate. Diamond procured a 100MeV Linac, three superconducting cavities and a cryogenic refrigeration plant all with Siemens PLC's controls. The Linac used an S7 CPU314 and mix of motion control, digital and

analogue IO module and was supplied complete with EPICS integration.

Each of the RF cavities were supplied with three S7 PLC's comprising of a CPU315 and two CPU314's and a mix of digital and analogue IO module complete with an interconnecting Profibus local network. These were integrated into the EPICS control systems by the in-house team.

The cryogenic plant was supplied with an S7 CPU314 and mix of analogue and digital IO. Remote IO was linked using Profibus A commercial SCADA system called PCView was utilised for control and overview. This is now being integrated into the EPICS control system.

LOW-END PLC

Choice of PLC

In considering options for the low end PLC there were numerous possible solutions. Following a competitive tender the PLC system chosen to meet the requirement was the OMRON CJ1 series [6].This was a relatively new product to the market at the time and offered good functionality in a small modular form factor. The CPU12M and CPU43H processors were selected to meet Diamonds needs and a selection of preferred IO module types were defined, these included Ethernet, temperature, isolated relay and digital IO. This was later expanded to include 12 bit analogue.

Integration into control system

Communication to EPICS was realised over a serial connection using the Omron specific protocol. This was implemented using the ORNL communications [7] structure under EPICS and provides functions for reading and writing to single registers or blocks of register, where registers can be data memory or IO location (writing to direct IO was disabled). Again the common EPICS records are supported.

Application

The design of the Diamond control system means that the interface to the technical systems was defined by technical area and geographical location. Hence, the low-end PLC applications on the Diamond Storage ring alone would require twenty four systems for vacuum valve control and protection, and twenty four systems for protection of the storage ring vessel. This lead to the decision behind the concept of the standard modular device design.

From the various applications sited for low-end PLCs three types of products were identified. These were; the Four & Six Valve Vacuum Control Crates, the Machine Protection Marshalling Crate and the Universal Thermal Protection Crate.

Figure 1:Six Valve Vacuum Control Crate.

The two types of valve control crates functionality cover the requirements for vacuum protection within the Linac, transfer lines, booster synchrotron, storage ring, photon front-ends and photon beamlines. In total 30 Four Valve Vacuum Crates and 27 Six Valve Vacuum Crates were used. The Machine Protection Crate capabilities match the requirement for critical water flows and temperature interlocking for the booster synchrotron and storage ring. In total 28 systems were used. The Universal Thermal Protection Crate addresses the diverse needs of thermal protection requirement on photon beamlines. While the other products have well defined IO interface, this product provides a flexible way to mix the various IO modules available from the OMRON CJ1 PLC.

The philosophy for encapsulation the PLC into crates was taken to provide an element of future proofing as the PLC inside the chassis can be upgraded to keep up with advances in technology, while maintaining the same plant interface. It also helps maintain consistency of layout and simplicity of construction of control system cabinets. Using standard 3U 19" crates for the PLC encapsulation with defined IO interfaces has enabled consistent and rapid on-site commissioning.

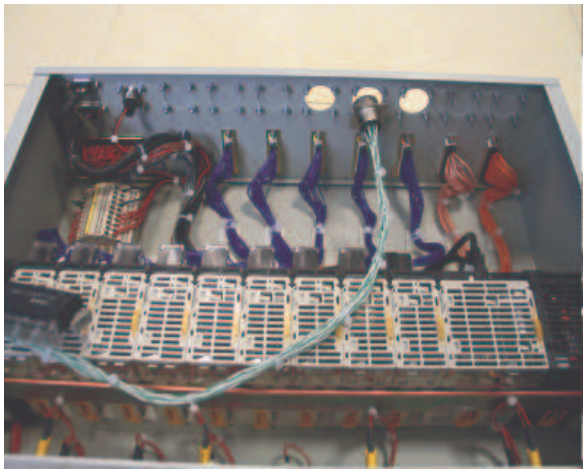

Figure 2: Top view of Thermal Protection crate showing how wiring looms can be quickly added to suit IO configuration.

Software

The Four and Six Valve Vacuum Crates, and Machine Protection Crate products had the PLC ladder logic structured in such a way as to provide a standard set of drivers for all applications that were deemed likely. The code was structured to ensure that the software engineer when integrating the unit into a system had to follow the agreed pattern regardless of where the system was being used, and what it was being used for. This approach was taken to allow easy interpretation, fault finding and additions to be made to that system by other engineers. The Universal Thermal Protection Crate was left as a more flexible solution allowing it to provide a multitude of thermal and analogue data recording and manipulation as required.

CONCLUSION

In summary the utilisation of integrated PLC's has provided Diamond with a simple and reliable way of marshalling thousands of interlocks but retain an easy and repeatable way of commissioning complex systems.

A number of turn-key systems were successfully delivered with PLC control systems complying to Diamond standards. However, each of these have supplier specific programming standards and styles, which inevitably require additional effort to support compared with the in-house standard.

By keeping to the minimum number of different PLC types it is felt that better support for the duration of the project can be guaranteed.

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