THE DIAMOND LIGHT SOURCE CONTROL SYSTEM

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Abstract

Diamond is a new 3rd generation synchrotron light source currently being commissioned in the UK. The control system for Diamond is a site-wide monitoring and control system for the accelerators, beamlines and conventional facilities. This paper presents the design and implementation of the Diamond control system, which is based on the EPICS control system toolkit. It describes the detailed choice of hardware and software, the solutions realised for interfacing and control of the major technical systems of Diamond, and progress on installation and commissioning.

INTRODUCTION

The Control System for the Diamond synchrotron light source[1] uses the EPICS toolkit to provide a high degree of integration of the underlying technical systems. These include all power converters, most diagnostics, vacuum systems, the machine protection system, insertion devices, RF amplifiers, girder alignment, front-ends, and photon beamlines. Further work is ongoing in integration of building information, control of some experimental stations, instrumentation and detectors.

DEVELOPMENT FRAMEWORK

Application Development Environment

The development process for all VME systems is based on EPICS 3.13.9. Whilst it had been planned to standardise on one version of EPICS, this has not proved possible and EPICS base 3.14.8 is being used for the Libera eBPMs and for simulation systems, most notably a virtual accelerator with an EPICS interface. The development and operational client platforms are PCs running RedHat Enterprise Linux 4.

Version Control

Version control has been managed through CVS, but initial work is now being undertaken to move to Subversion, front-ended with scripts to provide a controlled interface to the repository and an automated build mechanism, whereby all operational software is checked out of the repository and built in a known environment to give consistency and stability of build.

Virtual Accelerator and Physics Applications

To enable early testing of physics tools through the control system, a virtual accelerator has been implemented to give simulation of the accelerators though the intended PV interface. This was developed by providing EPICS device support to interface to the model using the TRACY II libraries [2]. For physics tools the Accelerator Toolkit [3] for Matlab is used.

Applications

For each technical system, synoptic-based views have been realised using the EDM display manager. This implementation has necessitated deployment of several new EDM widgets, including a thumb wheel control and a display for video images. The ControlDesk [4] application is being used to provide tabular displays of the control parameters.

Development Model

The development model adopted has been to take requirements, and based on these, to develop any required device driver support, communication protocol and a template representing each type of physical device. The template is then instantiated as many times as necessary, with the required addresses and process variable (PV) names. From each physical template a soft template, which replaces the hardware reference by a simulation, is created. The soft templates are then used to build a model of the technical system, which is then used to build higher level tools.

HARDWARE

Programmable Logic Controllers(PLCs)

Omron CJ1 PLCs are used for low-end units, which provides interlocking and control, e.g. for vacuum valves. For high-end process control applications, such as the Linac, RF cavity and cryoplant controls, the Siemens S7 series of PLCs are used. The low-end units interface to IOCs using a serial protocol over an RS232 connection and the high-end units use Industrial Ethernet. Standard solutions have been developed by encapsulating the low-end PLCs in crates, for control of four vacuum valves, six vacuum valves, thermal protection and water flows for machine protection.

Physical Structure

The control system interfaces to the technical systems at 37 control and instrumentation areas (CIAs) covering the accelerator and beamlines. For the SR there is one CIA per cell. The CIAs are air-conditioned rooms which maintain a clean and temperature-stabilised environment for the instrumentation.

Generic IO

Most equipment is interfaced through a range of generic VME IO from Hytec Electronics Ltd [5] based on VME IP carriers, IP modules, transition cards and plant interface modules. The system is very modular and allows a high flexibility and density of IO. The IP module types include 16 bit ADC and DAC, digital IO, serial RS232 and RS4222/485, an incremental encoder, and a high resolution ADC for direct PT100 and thermocouple connection. For motion control the OMS VME58 has been used for straightforward applications; however beamline requirements for synchronous control on monochromators necessitated greater controller functionality, for which the Delta Tau PMAC controller is used.

Network

A fibre optic infrastructure is installed from each of the CIAs back to the Control System Computer Room and from there to the Control Room. It consists of a mixture of single-mode and multi-mode fibres using a blown fibre structure. The fibres provide two computer networks, a control system network and a secondary computer network. Each network uses a central switch in the Control System Computer Room and a further layer of switches at each CIA. The fibres are also used for event distribution, for the Machine Protection System and for the beam position feedback system.

TECHNICAL SYSTEMS

Linac

The control of the modulators and electron gun for the Linac RF is performed by a number of Siemens S7 PLCs. All other hardware associated with the Linac, including PSUs, Vacuum, Timing etc, is managed using the standard VME interfaces.

Diagnostics

The Libera [6] electron beam position monitor (eBPM) uses an ARM processor running the Linux OS and version 3.14.8 of EPICS to provide multiple data paths trading BW and resolution. For optical diagnostics, CCD cameras with the IEEE1394 Firewire bus have been adopted as a standard. Firewire device driver support has been developed for both Linux and VxWorks and an EDM widget has been developed to display the images.

PSUs

The 1300 PSUs used on Diamond are controlled using the PSI PSU controller [7]. The interface from the controller is a 5MHz Manchester-encoded point-to-point serial interface over a fibre optic link which connects to the IOC using a VME IP carrier and IP module.

Vacuum

All vacuum gauge controllers and ion pump supplies are interfaced though serial connections in a point-to-point configuration. Vacuum valves are controlled and protected by standard valve control units, each encapsulating a PLC, and interfaced to the IOC using a serial connection. RGA units, which are capable of being operated in a stand-alone or network mode, are also interfaced to the control system, to allow a number of predefined mass scans to be viewed and archived.

Personnel Safety System

The Personnel Safety System (PSS) on Diamond is based on the Daresbury-designed PSS [8] which is a hard-wired, dual guard line, relay based system. Whilst the protection logic is all realised though the hard-wired relay logic, the inputs and intermediate states are all monitored by the control system. The PSS logic is realised in a crate with a G64 bus to read out module data. A VME processor running EPICS accesses the module data over a VME-to-G64 bridge module.

Machine Protection System

The Machine Protection System (MPS) manages global equipment protection for vacuum vessels and series-connected magnets (SR dipoles, Booster dipoles and Booster quadrupoles). Water and temperature are monitored on each cell using a standard PLC-based solution, which is supervised over a serial link by the IOC. The PLC does not meet the speed requirements for some of the interlock inputs, notably on mis-steered beam, and these interlocks, together with an output from the PLC are then managed by the local MPS module. Each local MPS module generates a pulse stream to the global MPS module which, subject to all local modules being good, generates a pulse stream to the source of the energy, RF amplifiers or PSUs. The local and global MPS modules are realised as VME64x transition cards and are monitored by a VME DIO board; they use principles defined in the CEBAF Fast Shutdown System [9]. The VME IO board and EPICS software are not part of the protection process, but serve to manage the process.

Timing System

The timing system [10] uses new versions of event generator and receiver modules, based on the principles of the APS and SLS event systems, which have been developed by Micro-Research. The new versions have increased functionality and exist as VME 64x modules for both generator and receiver, and also as a PMC module for the event receiver. The EPICS support for these has been developed to support the improved functionality of the VME modules and to add support for the PMC variant. This development has introduced a new scheme to distribute and increment time across the Event System.

Fast Orbit Feedback

The choice of the Libera eBPMs has influenced the design of the Fast Orbit Feedback System to stabilise the electron beam in the SR. The data from the 168 eBPMs is required to be moved into the 24 VME processor cards, which carry out the feedback processing to update the corrector PSUs. This requires a low-latency high-bandwidth data path which is being realised by connecting the Libera units and the computation nodes using the high-speed serial interconnects available on the Xilinx FPGAs. The interconnection is being realised over a fibre optic link and a custom communication controller designed and implemented in VHDL [11].

RF and Other Systems

The Booster RF amplifier is a commercial unit using a proprietary amplifier controller and interfacing into the IOC over a serial link. Control of each of the SR amplifiers is performed by an associated IOC, which interfaces to the amplifier through generic VME IO. Booster and SR low level RF use analogue signal processing and are controlled using DACs, ADCs and digital IO.

The 72 girders which make up the SR each have 5 degrees of freedom driven by motorised cams which are controlled by OMS VME58 controllers. Other hardware associated with the girder positions is managed through the standard VME IO.

Each of the first seven permanent magnet IDs is controlled by OMS VME58 motion controllers, together with a PLC subsystem to define a safe operating window and hence protection of the structure. Other instrumentation associated with the IDs is managed though the standard solutions.

EPICS is also being applied to the control of all instrumentation for the photon beamlines. Consideration is now being given to integrating detectors and other experimental components with EPICS.

TURNKEY SYSTEMS

Diamond has procured a number of turnkey systems complete with EPICS-based controls. These include the Linac, Booster and SR RF amplifiers, SR low level RF, , a superconducting multipole wiggler, monochromators and other beamline components. The SR girder alignment motion controls and insertion device control systems were contracted out as design and build packages. In each case, the supplier was free-issued with standard components in order to maintain consistency of hardware, together with an EPICS development environment and documentation on the Diamond application development process and PV naming conventions. This has resulted in systems being delivered that have taken the minimum amount of work to integrate back into the in-house development process, and enabled effective in-house support and maintenance.

INSTALLATION AND COMMISSIONING

The commissioning of technical systems for the Linac took place during August and early Sept 2005. This went very smoothly with the commissioning of nine VME IOCs for the RF modulators, diagnostics, PSUs, vacuum, PSS and timing, and six Libera eBPMs, together with a temporary control room.

The Booster commissioning of 27 VME IOCs and 22 Libera eBPMs took place during Nov and Dec 2005, with first coasting beam in the Booster in Dec 2005 and accelerated and extracted beam in April 2006. Storage Ring technical systems, 197 VME IOCs and 168 Libera eBPMs, were commissioned in the 4-month period from Jan to April 2006. This was followed by first beam into the Storage Ring in May 2006 and accumulated beam on 30th May. At the present time the full Machine Protection System, Girder Alignment, position measurement of the location of the eBPMs, insertion devices and front-ends remain to be commissioned.

CONCLUSION

An extensive control system has been realised for the Diamond Light Source. In doing so, considerable benefits have been realised from the stable nature of the core components of EPICS, IOC processing and communications, enabling resources to be concentrated on the task in hand. The use of simulation systems to test configurations and applications early has enabled more mature applications to be available before first commissioning with real hardware. As a result the commissioning of the Diamond Control System went very smoothly with a high level of functionality available for day one commissioning with beam.

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