THE CONTROL AND DATA ACQUISITION SYSTEM OF THE SWISS LIGHT SOURCE

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Abstract

The Swiss Light Source (SLS) is a third generation synchrotron light source under construction at the Paul Scherrer Institute (PSI) in Villigen, Switzerland. The high performance and aggressive time schedule of the machine and experiments put some particularly high demands on the accelerator and beam line control systems. An integrated system based on the Epics toolkit and Cdev has been built to provide machine and beam-line control as well as experimental data-acquisition. The control and data acquisition system consists of 28,000 signals, with requirements spanning from sub mili-second response times to multi-mega bytes per second throughput. Sub-systems including the complete Linac and the RF systems are being delivered as turnkey units. The contractor for these systems will deliver a working control system, built using the standard SLS control system hardware and software components. This will simplify integration, maintenance and operation of these sub-systems. To reduce development time, tools have been produced to allow system configuration and state machines to be built graphically. Extensive use is made of Personal Computers, as well as VME systems and IO cards making use of new features such as 'hot-swap' technology.

INTRODUCTION

The SLS has been designed to provide experimenters in the fields such as protein crystallography, micro tomography, material science, X-ray diffraction, and nano structures with capabilities and performance meeting or exceeding those available at existing facilities. SLS will provide very high brightness photon beams over a wide energy range of 10eV to 40KeV. High brightness, coupled with advanced detectors such as the protein crystallography beamline pixel detector, and material science beamline silicon strip detector, will dramatically increase the speed of data taking, allowing more precise results and increased numbers of users per beam line.

Machine parameters

The SLS consists of a 100MeV 3Hz electron Linac, a 100Mev-2.4 GeV booster synchrotron and 2.4 GeV 400 mA storage ring. Initially three undulator, one wiggler and one bending magnet beam line will be installed The 270m circumference booster and the 288m circumference storage ring are located in the same tunnel. This large booster circumference will provide a low emmitance, and allow the use of compact magnets. The storage ring will have a triple bend acromat lattice with twelve sectors. Fill time will be three minutes, and is designed to achieve a long lifetime, even with a small (4mm) insertion device gap. A Top up injection mode is foreseen in which a small number of electrons are injected every few seconds to replace losses, with the insertion device gaps staying closed This will keep beam current constant over very long periods.

Time Schedule

Following approval of the project in June 1997, a very aggressive time schedule was established to produce first data from experiments in August 2001. This schedule called for building to start one year after project approval, in June 1998, building to be complete and equipment installation to start in Augut 1999, Linac commissioning in March 2000, Booster commissioning in July 2000, storage ring commissioning in January 2001 and beam line commissioning in March 2001. Progress is so far on or ahead of schedule, with the building complete, and Linac commissioning now expected to start in December of this year.

Data Storage

Data storage requirements for both machine and experimental data are high with an initial on-line capacity of 1 TB. This will be using a distributed data storage system [1] of high performance file servers using RAID technology. Access to the data from SLS offices and outside the facility is provided via a Web interface.

Physics Applications

Machine physics applications use a dedicated modeling server [2], to calculate new machine parameters. The model server is accessed by a Corba, while actual values of the machine are read via the control system Cdev interface. Machine physics applications have been developed with simulated SLS machine control points using epics soft channels. This allows applications to be developed before controls hardware can be installed.

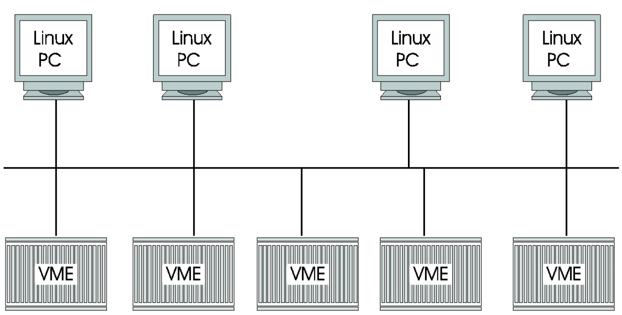
Operator Interface Level

The operator interface level makes use of standard personal computer hardware running the Linux operating system. Personal computers provide the best price performance ratio, and allow regular upgrades for be affordable by ‘recycling’ machines for office use. Linux makes maximum use of available performance, while providing a robust environment for program development and operation. Familiar Unix tools are used for system and network administration.

Java, C++, Tcl and IDL are the standard languages for writing application and access to the control system is provided by a Cdev layer. Cdev provides a standardized device oriented view of the control system, allowing standard operations to be carried out on individual or groups of devices, for example to return the currents in all quadrupole magnets. Standard Epics tools such as the alarm handler, channel archiver, save-restore tool and DM2K operator screen package are also used.

Network level

Network hardware consists of standard 100 Mbit/sec switched Ethernet. Each VME crate and Console is connected via a dedicated 100 Mbit connection to one of 40 local Ethernet switches, which are in turn connected to a ‘backbone’ switch with 100 Mbit (in future 1 Gbit) fiber optic up-links. The SLS network is arranged as a single class C IP network without direct connection to the PSI public network. Dedicated servers (File server, Database server, and Archive server) have two network interfaces, on the SLS controls net and the PSI public network to allow SLS data to be accessed from offices without increasing network usage on the SLS controls net.



Equipment access is via Epics Channel Access protocol which runs over TCP/IP. Data updates are arranged by setting monitors on devices properties, such that a message is only sent when a property changes by a value greater than a set amount. In this way network traffic, and client processor load is minimized. The network performance has been tested, and provides up to 5 M Bytes per second throughput and < 1 ms response time to each VME crate.

Equipment Interface Level

Equipment to be controlled and monitored connects to the control system via VME crates located close to the equipment. In total 145 VME crates will be installed, dedicated by machine (Linac, Booster, Ring, Beam line), function (Diagnostic, RF, Magnets, Vacuum,…) and location (Sector 1,2,3,…). For instance one crate will be used to control ring vacuum in storage ring sector 4. Dedicating crates to one purpose improves the reliability and maintainability of the system.

With such a large number of systems, crates must have a high reliability and low down time when adding or replacing a module. For this reason VME-64 Extensions (VME64-X) standard crates have been chosen which support hot swap of I/O modules. In our system it is possible to replace or add an I/O card designed to support hot swap without shutting down the crate. The crates are also equipped with fan failure warning to detect when a fan is operating below normal speed (an indication of imminent failure), and the fan units can be replaced without powering down the crates. VME64X crates also support slot keying, geographical addressing, better EMC performance, more ground pins, and more user defined IO pins. VME64-X Industry pack carrier boards are being used which support these features allowing the choice of hundreds of IP modules[3], and Epics drivers have been written for some standard IP modules that support this functionality.

Timing

All VME crates are equipped with timing modules to synchronize hardware and software processes. Using a design which is an upgraded version of the APS event system[4] messages are broadcast to all crates, with a resolution of 20nS and a jitter of 100pS. The VME receiver module decodes those events which it has been programmed to accept, and provides hardware signals (programmable level and duration) and/or software synchronization events to trigger Epics record processing.

Even higher resolution hardware synchronization is available for those systems needing it (such as the Linac Gun) by using VME modules, designed at KEK[5]. These provide 2nS resolution with 5pS jitter. Phase compensated fiber optic cable is not needed for this system as the distances are never greater than 100m.

Database

An Oracle database is used to hold all static and dynamic system configuration information. This information includes all devices, their properties, and their characteristics. This information is used to generate Epics configuration data for each VME crate, information for the Cdev directory service, and also hold information directly used by physics application programs, such as the distance between a magnet and a BPM or the magnetic length of a magnet. Equipment specialists can manipulate the oracle database via a web interface to update operational parameters (such as operational limits for a power supply).

Diagnostics

The main diagnostic tools for the SLS include: beam position monitors; beam current transformers; beam loss monitors; and beam profile monitors. Beam position monitors use a VME digital mixer and a commercial VME DSP card to provide either first turn capability or closed orbit information from the same pickups. This system can provide the required one micron resolution from full beam current (400mA) down to single bunch (5mA) in the storage ring. Beam current monitor electronics are interfaced to standard VME analogue input cards. Beam profile monitors (Optical transition radiation monitors and fluorescent screens) use CCD cameras, the signal from which are directly digitized using a VME frame grabber. Critical parameters (beam center, size,…) as well as the raw image is then made available to application programs via Cdev/Epics.

Linac and RF

Both the SLS Linac and RF system are being delivered as a turnkey system complete with controls. These control systems are being built following SLS standards, using hardware supplied by us. Controls specialists from the contractors have received training on Epics at PSI. This approach minimizes problems integrating a turnkey system into the control system, and reduces future maintenance load, and eliminates the need to learn two systems.

Magnet Power Supplies

In order to achieve maximum performance, and to facilitate machine commissioning, all quadrupole power supplies are individually powered. This contributes to a relatively high total number of power supplies to be controlled (450). Each power supply is controlled by a dedicated digital power supply controller, incorporating a Sharc DSP. The power supply controller is connected via a low cost fiber point to point link to an industry pack mezzanine board mounted on a VME carrier. Each industry pack board can control two power supply links, so a single width IP carrier board can control eight power supplies.

Vacuum

Vacuum components (gauges, valves and pumps) are controlled directly from VME using standard analogue and digital I/O cards. In parallel, the interlock system built using a Siemens S7 PLC, monitors the system, and if necessary closes the valves in a vacuum section. Further information on vacuum performance is gained from monitoring the power consumption of each pump, which gives an indication of the vacuum at that point.

Alignment

Because of the tight tolerances of the SLS, computer monitoring and control of alignment is needed to compensate for ground motion. The system consists of three parts: A magnet mover system with three degrees of freedom, which can position any of the 48 magnet girders with an accuracy of <10 micro meter; a Hydrostatic leveling system which monitors the height of the four corners of each girder; and a horizontal positioning system which monitors the relative movement in the horizontal plane of two girders. Each of these sub-systems will be integrated into Epics.

Insertion devices

The insertion device control will be directly carried out in VME with Epics. This involves the synchronized movement of many motors. This is accomplished using VME motor controllers (Oregon Micro Systems), absolute encoders interfaced using SSI bus, and other standard VME I/O cards.

SLS beam lines

Both the control and the data acquisition for SLS beam lines will use the same technology (hardware and software) as the machine controls. Initially at SLS two low energy beam lines will be built, a Spectroscopy Beamline and a Microscopy beamline. The spectroscopy beamline will have a electromagnetic undulator, with swichable circular or linear polarization, and two experimental end stations. The micropscopy beamline will have a permanent magnet undulator, a plane grating monochromator, and a photo emission electron microscope experimental station. The SLS will also have high energy beam lines: A materials science beamline using a minigap wiggler, a double crystal (Si 111) monochromator, and three end stations (non monochromated, power diffraction, and glancing incidence surface diffraction); and a protein crystallography beamline using an in vacuum minigap undulator, a Si 111 monochromator, and an end station that can use a single axis high precision diffractometer or a Kappa diffractometer; Both the high energy beamlines will use advanced detector technology, which will produce high data rates. In the case of the protein crystalography beamline the initial data rate will be 5 Mbytes per second, which can be handled by our standard architecture, but later the data rate may be up to 80 M bytes per second which may require local storage.. A micro and nano structures beamline is also planed as part of the initial construction.

Conclusion

The control and data acquisition system of the Swiss Light Source is a conservative design, making best use of commercial components (PCs, Ethernet, and VME crates), and software sharing (Epics and Cdev). It places a high emphasis on maintainability (hot swap VME), and support of modern software tools (Java). Database technology is used as a central part of the control system.

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