FIRST OPERATION OF THE SACLA CONTROL SYSTEM IN SPRING-8

R. Tanaka, T. Fukui, Y. Furukawa, T. Hatsui, T. Hirono, N. Hosoda, M. Ishii, M. Kago, A. Kiyomichi, H. Maesaka, T. Masuda, T. Matsumoto, T. Matsushita, T. Ohata, T. Ohshima, T. Otake, Y. Otake, C. Saji, T. Sugimoto, T. Takebe, M. Yamaga, A. Yamashita, RIKEN-JASRI Joint Project for SPring-8 XFEL, Hyogo, Japan

Abstract

The control system design for the X-ray free electron laser facility (SACLA, SPring-8 Angstrom Compact free electron LAser) in SPring-8 has started in 2006. The facility construction started in 2006 and has completed to begin the electron beam commissioning in March 2011. The electron beams were successfully accelerated up to 8GeV and the first SASE X-ray was observed at the beginning of June. The control system is built by using MADOCA control framework that was developed in SPring-8. The upper control layer consists of Linux PCs for operator consoles, Sybase RDBMS for data management and NAS for NFS. The lower layer consists of VMEbus systems with off-the-shelf I/O boards and specially developed boards for RF waveform processing with high precision. Solaris OS is adopted to operate VMEbus CPU. The PLC is used for slow control and connected to the VME systems via FL-net. The Device-net is adopted for the frontend device control to reduce the number of signal cables. The control system started operation in advance to support beam tuning. The reliability of the control system was enough during the commissioning but small system tuning and adjustment was necessary to achieve more stability.

STATUS

The X-ray Free Electron Laser project in SPring-8, now called SACLA, has started in 2006 with the success of SCSS prototype accelerator [1]. The facility construction has completed in March 2011, and the electron beam commissioning has started right after the completion. The electron beams were successfully accelerated up to 8GeV and the first SASE X-ray was observed at the beginning of June as can be seen in Figure 1. The SASE laser signal has homogeneous round shape with the X-ray wavelength of 0.16nm~0.08nm, and the maximum laser power is ~4GW. The laser beam intensity is quite stable for coherent X-ray experiments as shown in the Figure 1.

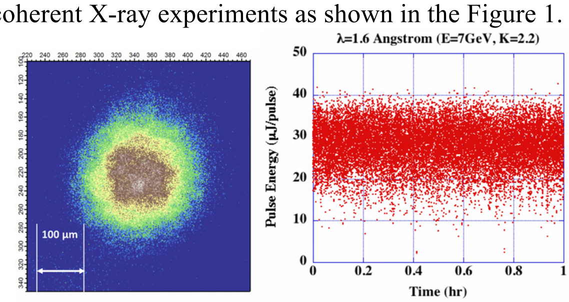

Figure 1: The observed profile of the SASE laser signal at 10keV (left) and the laser intensity stability (~18% fluctuation) during one-hour operation (right).

The SACLA control system stated smoothly at the early stage of the electron beam commissioning. The control system was tuned suitably, and its reliability was achieved along with the progress of the commissioning.

CONCEPT

The design of the control system for SACLA is based on that of for SCSS test accelerator [2] as can be seen in Figure 2. SCSS was constructed for the principle study of the free electron laser mechanism by using the linac and technology assurance towards the coming 8GeV XFEL machine, SACLA. The electron beam energy of SCSS is 250MeV, on the other hand SACLA is 8GeV. The basic system elements for the SACLA control system can be shared commonly with those of SCSS. The energy difference results the difference of the number of elements of the control system to build. Equipment control is optimized to use simple devices such as programmable logic controller (PLC) and common control devices for each subsystem as much as possible [3]. This comes from the short construction period for the fast start up and less human resources coming from the joint project management sharing with SPring-8 operation.

SACLA has an electron beam transport line to inject the electron beams to the SPring-8 storage ring as shown in Figure 3. At present, the injection is not scheduled yet, but SACLA works independently by using its own beamlines for X-ray FEL experiments. In order to avoid unexpected interference to the SPring-8 duty operation and establish independent operation, the control network zone between SACLA and SPring-8 is loosely coupled, and also the server computers such as a database machine and a NAS-based NFS file server are installed separately.

EQUIPMENT CONTROL

VMEbus systems and PLC stations are main base components of the SACLA accelerator control [3]. A linear accelerator consists of mainly accelerating structures with RF systems, and also magnets and vacuum systems are basic components. We made one RF control unit and repeated its production as much as needed. Additionally, fine timing system and beam monitoring system is necessary for the beam tune. Interlock systems are installed for the machine protection system (MPS) and personnel protection system (PPS), as shown in Figure 2.

As described in somewhere [3], the PLC system is used for RF high power (A, V) device control and the interlock systems. The PLC systems are simple and suitable for the slow control with high robustness and reliability. On the other hand, the VMEbus systems are suitable for the fast device control such as beam steering magnets and large data handling, especially for the DAC/ADC wave data that is taken by the low-level RF control. A complicated application for example the LLRF system IQ modulation/demodulation runs on the VME systems.

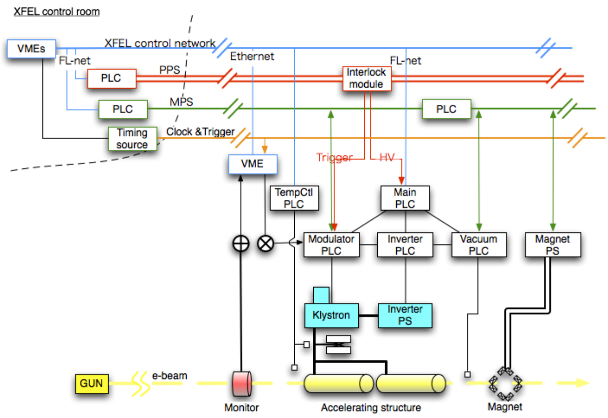

Figure 2: A schematic view of the SACLA control system.

Implementation

The VMEbus systems are connected to the backbone Ethernet switches with metal cables. A VMEbus system consists of a CPU board with a chassis and several I/O boards stuck into the chassis. The CPU board, SVA041 already used in SPring-8, was selected for the SACLA control even though single core processor. The well-established CPU is good for smooth start-up of the control system. At the beam commissioning stage, the accelerator repetition rate is 1~ 10Hz but will go up to 60Hz later. So far, signal processing power of the VMEbus CPU is enough but it will be marginal soon, especially for the large data processing in on-line. A multi-core CPU with low power consumption is now available. A multi-core CPU (Core i7) may replace a current CPU if computing power is tight. The DMA and block transfer scheme is another solution to meet the large data handling.

The FL-net is a FA-link that interconnects VME systems and PLC stations. The FL-net shares the same Ethernet switches by using the virtual LAN topology. The FL-net link is divided into several links to keep independency of the device groups. The multiple links on a VME system is handled by using the virtual machine technology, Solaris10 Container. The I/O board configuration of a VMEbus is adjusted not to share one bus together with the large-data handling boards and the slow control FL-net links. A monitoring and notify mechanism for FL-net unexpected link-down is necessary.

SIGNALS AND DATABASE

The number of equipment signals of SACLA is much larger than that of the SPring-8 accelerator complex on the contrary to the initial estimation of the SACLA data size. The number is the initial information to select a database computer. The comparison of the data size is listed in Table 1.

The large number of SACLA data originates in the number of the RF acceleration structures. We used the Open Office spread sheet to manage the database signal registration and the equipment configuration tables, in order to eliminate inconsistency between the device configuration data.

Figure 3: A bird eyes view of the SACLA facility. The electron beams are generated and accelerated from the right hand side to the left inside of the linac yard. The pictures of SPring-8 site and SACLA inside views are imposed.

Database and Servers

The SPring-8 database system can process many data as we expected, however SACLA database system used almost full CPU power. The heavy load sometimes caused unexpected delayed responses to the accelerator operation GUI. Actually, the number of data was about factor two more than we estimated at the beginning of the database design phase. We adjusted the Sybase RDBMS configuration such as the procedure cache size, data cache size, the size of data log area and table lock mechanism. And we, also, optimized the periodic machine data-taking cycle to ease the database load. The alarm surveillance and monitoring programs handle many watching points as well. Especially at the alarm process start-up time, the heavy accesses from the alarm programs to the database deteriorated operation response.

Table 1: The Number of Equipment Signals

Accelerator	Analogue points	Digital points
SACLA	19,500	225,000
SPring-8 (Li,Sy,SR)	22,000	90,500

We will add a 3GHz 12core FT-server with 48GB memory together with the current database machine of a 2GHz 8core CPU with 16GB memory. We don't change NAS-based disk system because it has no problem. We will tune the alarm software algorithm for much efficient surveillance and easier database access.

The program development environment for SACLA shares with SPring-8, but the dedicated NAS machine was installed as the NFS server for SACLA. This configuration is good for the common software development and timely program installation to the SACLA server without interference to the SPring-8 user-mode operation.

FACILITY CONTROL

The facility utility control of SACLA has unique features [4]. The accelerator beam tuning to achieve the stable laser state imposes sever stability to the RF cooling water and electric power for example. The facility control has a gateway to the accelerator control to receive "put" command from the machine control. If the observed temperature deviated from the monitoring point, the water set point would be actively adjusted from the machine control side.

The precision of the monitoring sensors for the cooling water temperature was 0.01C, however the precision has to be improved to 0.001C resolution because the RF phase of the C-band shifted according to the water temperature drift.

The room temperature data of the accelerator house and the set-up space for the control racks of the LLRF systems have been monitored and kept into the machine database right after the completion of the facility building. The long accumulated temperature data during almost one year is useful to understand the stability and drift of the room temperature before the beam commissioning.

BEAMLINE CONTROL

SACLA will have five beamlines for the experiments finally. Now, one beamline (BL3) is ready for the experiment. The user interface software of the SACLA beamline control has the same look&feel as that of developed for SPring-8 because of smooth migration of the current users from SPring-8 to SACLA. The beamline control uses the VMEbus system as well. The beamline components consist of slits, screen monitors, beam position monitors, a monochrometer, mirrors and so on, those are same equipment used in the SPring-8 beamlines. Additionally, the synchronized data-taking scheme (DAQ) is introduced to the beamline control [5]. In SACLA, the DAQ takes the set value of optical devices and pulse motor positions, and sends the data to the beam-synchronized data-acquisition system for the accelerator. The data will be used for the experimental analysis together with the accelerator status. The beamline control started smoothly and has been working well.

SUMMARY

The SACLA control system has stated smoothly since the early stage of the electron beam commissioning. The VMEbus systems and PLC stations worked well to support the beam tuning. The control framework MADOCA showed the potential of adaptation to the higher repetition rate of the large linear accelerator operation. The interconnection between the utility control and accelerator control is useful to monitor the temperature for the long time with fine resolution to understand the facility environment. The accelerator data handling by using the database management system was tight due to the large number of device data that we underestimated at the beginning. The database computing system has to be strengthened by adding new server with more computing power and memory.

REFERENCES

[1] T. Shintake et al., "Status of SPring-8 compact SASE source FEL project", NIM A21188, Nuclear Instrum. And Meth. In Phys. Resea. A507(2003)382-397.

[2] T. Fukui et al., "STATUS OF THE SCSS CONTROL SYSTEM, ICALEPCS2005, Geneva, Switzerland, MO3.2-10 (2005)

[3] T. Fukui et al., "STATUS OF THE X-RAY FEL CONTROL SYSTEM AT SPRING-8, ICALEPCS2007, Knoxville, USA, TOAA03 (2007)

[4] T. Masuda et al., "FACILITY UTILITY CONTROL SYSTEM OF XFEL/SPRING-8", ICALEPCS2009, Kobe, Japan, TUP095 (2009)

[5] T. Ohata et al., "DESIGN OF AN XFEL BEAMLINE DAQ SYSTEM", ICALEPCS2009, Kobe, Japan, TUP095 (2009)