CONCEPTUAL DESIGN OF THE CONTROL SYSTEM FOR SPring-8-II

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Abstract

The SPring-8 storage ring was inaugurated 17 years ago in 1997. The storage ring is an 8-GeV synchrotron that functions as a third-generation light source, providing brilliant X-ray beams to a large number of experimental users from all over the world. In recent years, discussions have been held on the necessity of upgrading the current ring to create a diffraction-limited storage ring at the same location. Now, a plan to upgrade the storage ring, called SPring-8-II, has been launched. First, new beam optics capable of storing beams of 6 GeV was designed using a five-bend magnet system to obtain smaller electron beam emittance that would produce coherent X-rays that are brighter than those produced by the current ring. The design of a control system that would meet the performance requirements of the new ring has also started. Equipment control devices are based on factory automation technologies such as PLC and VME, whereas digital data handling with high bandwidths is realized using telecommunication technologies such as xTCA. In this paper, we report on the conceptual design of the control system for SPring-8-II on the basis of the conceptual design report proposed by RIKEN.

INTRODUCTION

SPring-8, which is a third-generation light source, has been in service for more than 17 years. Out of the 140,000 users in the SPring-8 community, approximately 4,500 users come to the site for synchrotron radiation experiments every year. In the past, productive scientific results have been obtained and shared with the community. Recently, an XFEL facility, SACLA, was constructed at the same site as SPring-8 and inaugurated for public use in 2012. The SPring-8 site is now unique in the sense that it is the only location to have both the SR light source and XFEL.

Experiments at SPring-8 provide good measurements of static phenomena with crystal samples because of incoherent X-ray beams. On the other hand, SACLA can measure fast-moving dynamical phenomena even for non-crystal samples such as thin-film proteins, with 10-fs pulses destroying the samples. This difference represents the characteristic features of the two light sources. On the basis of the proposed conceptual design report (CDR) [1], we can infer that a wide gap exists between the two machines.

To narrow the present gap, a new project involving a new storage ring is planned; that is, the current storage ring will be replaced by a new storage ring at the same location. In the proposed project, a 1-GeV linac, which currently serves as the injector for SPring-8, will be replaced with an 8-GeV SACLA linac. The CDR says, "*We know how it happens but we do not know why it happens. We should provide a tool to offer answers to the question, why*". This is the motivation of the SPring-8-II project.

The control system plays an essential role in the working of large accelerator facilities currently operational in the world. The controllability and operability of the facility strongly depend on the architecture and implementation of the control system; hence, the current control system of SPring-8 will be upgraded suitably to fulfil the performance requirements of the SPring-8-II storage ring, as described in this paper.

SPring-8-II Project

The CDR of the SPring-8-II project is available on the Web [1]. The basic idea is to replace the current 8-GeV storage ring with a low-emittance 6-GeV storage ring at the same location by reusing the present machine tunnel. The C-band linac of SACLA will be used as a full-energy injector for the new ring. To transport electron beams to the new ring, a beam transport line, XSBT, is constructed, as shown in Fig. 1. The X-ray beamlines for the present undulators will be retained. The blackout period (construction period) is expected to be one year or less.

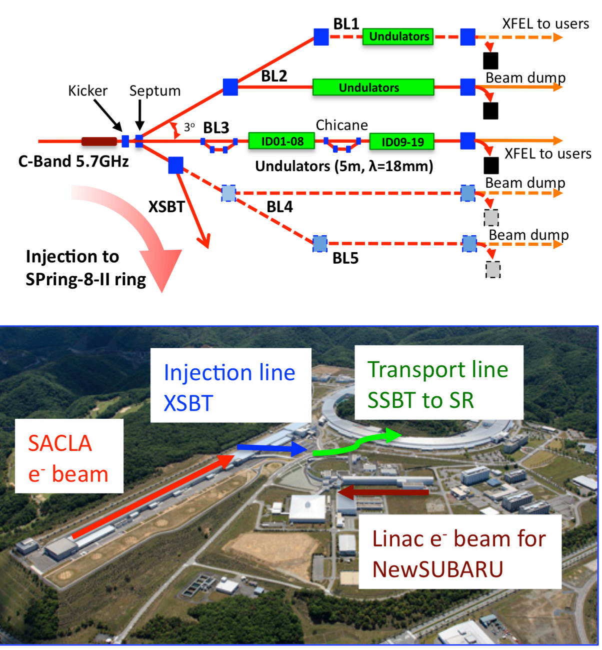

Figure 1: Injection line to SPring-8-II by XSBT at SACLA (upper), and beam transport route (lower).

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CONTROL DESIGN OVERVIEW

The control system for SPring-8-II is based on the concept of "*right platform in the right place.*" The system will be constructed by using heterogeneous platforms. While beginning the construction of the current storage ring, the control system design group chose the VME and PLC platforms so that the system could be developed efficiently within a short construction schedule by a small number of group members. Considering this scenario, we now have a rich history in developing equipment control devices. Therefore, we can choose the *best-fit devices* out of a variety of device options, while considering the device availability/sustainability in the future.

Implementation Concept

Control processing performance is usually classified as fast control and slow control. The features necessary for slow control are reliability, simplicity, and cost effectiveness; therefore, we can use PLC and VME platforms and reuse well-established software developed previously. However, how fast processing capabilities beyond the bandwidth supported by the VME backplane can be developed is a question that needs to be answered soon.

Today, great progress has been made in the electrical and information technology fields. Some of the emerging platforms can be applied to accelerator control, such as xTCA (ATCA, MTCA), which is a family of platforms proposed by the Telecommunications Carriers Association. The higher processing capability of digital data/signals is important for accelerator control, especially low-level RF (LLRF) control.

Accelerator Control System

An example of RF control that consists of a composite platform is shown in Fig. 2. The LLRF controls the phase and amplitude modulation of the low-power RF through feedback loops; therefore, we use xTCA for digital processing after the analog-to-digital signal conversion. High-power parts such as the klystron power supply will be controlled by a PLC interconnected by FL-net to a VME, or by a PLC directly connected to the Ethernet.

At this moment, we have not decided which xTCA platform will be used: ATCA or MTCA. A decision will be made after the R&D phase, which will start soon.

The beam operation of the new storage ring will be difficult because of the narrow dynamical beam aperture and the sensitivity of the circulating beam to residual error sources such as misalignment and magnetic field leakage. Combination control involving the beam position monitor (BPM) and St-magnet power supply (PS) should have sufficient feedback performance for the global beam feedback and COD correction to achieve stable beam operation. A shared memory network is used for fast data sharing and message communication without software interconnection, as shown in Fig. 3.

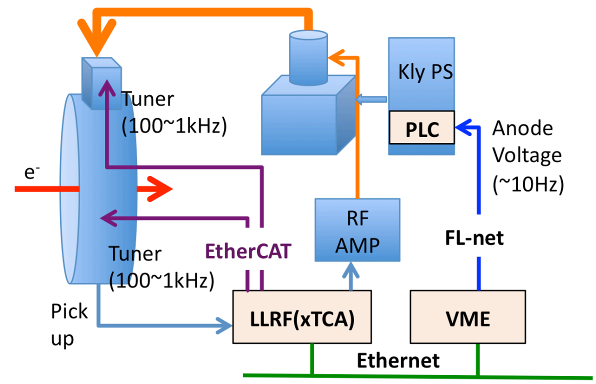

Figure 2: Control scheme of RF control system. The system consists of a PLC, VME, and xTCA designed on the basis of the "right platform in the right place" concept.

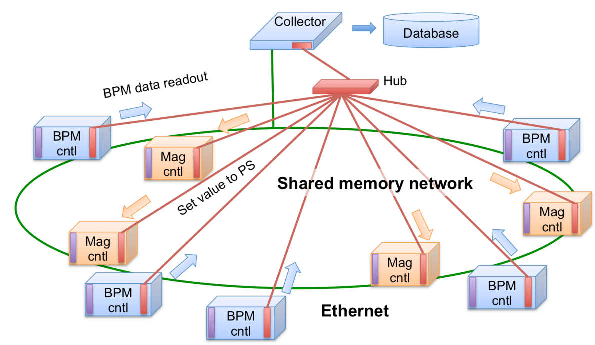

Figure 3: Schematic view of BPM readout and St-magnet PS control using shared memory network.

Beamline Control

The current beamline control consists of three parts: (1) insertion device control, (2) optics component control (frontend, transport channel), and (3) experimental station control (monochromator), as shown in Fig. 4a. The controllers consist of VMEbus systems and a PC. A separated control subsystem provides an independent construction/tuning schedule and efficient maintenance, which serves as a degree of freedom; however, as a trade-off, there will be communication overhead between controllers. Such a trade-off somewhat disturbs the synchronized operation of the insertion device and beamline components during fast experiments. In this sense, it is better to connect the controllers using a single line (loop) for communication. Currently, EtherCAT is a promising candidate that can provide real-time performance; its performance is sufficiently good for providing undisturbed synchronized operation of beamline components and a monochromator, including an insertion device (ID).

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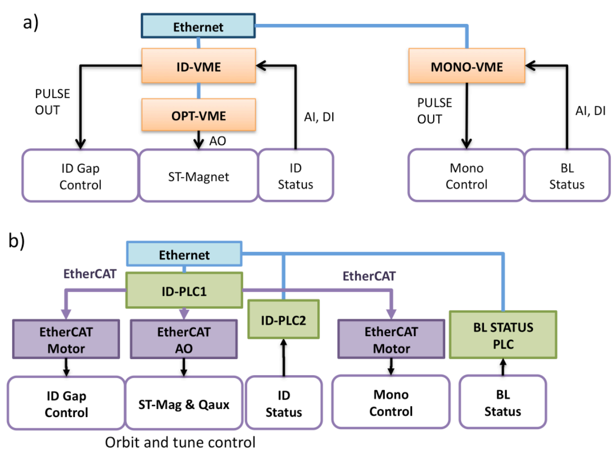

Figure 4: Schematic view of current beamline control (a), and proposed control for SPring-8-II (b).

An auxiliary PS of a Q-magnet and the St-magnet PS are controlled by the same controller that belongs to the ID section to correct the electron beam orbit and tune at the ID region.

Control Framework

The SPring-8 storage ring has been controlled successfully by using the MADOCA framework since 1997 [2]. Now, MADOCA is widely used not only for the accelerator and beamline but also for the data acquisition (DAQ) system for SACLA experiments. Owing to the wide application and long history of MADOCA, there are requests for upgrading the functions of the framework. Therefore, we launched an upgrade project for the framework, named MADOCA-DX (Daq eXtension). The project was completed successfully in 2013, and the upgraded framework product is called MADOCA II [3]. The MADOCA II middleware is implemented using ZeroMQ and MessagePack. The MADOCA II software scheme is shown in Fig. 5.

MADOCA II supports the following features:
1) A variable-length message with no length limitation
2) Handling of binary data such as image data
3) Windows OS and LabVIEW interface to MADOCA
4) Better message transaction (~1 ms for a round trip)
5) Logging data management by NoSQL database

Database

In MADOCA II, machine status data (logging data) are managed by NoSQL database engines that consist of a combination of Redis and Cassandra [4]. The key-value-store (KVS) database is suitable for handling chronologically ordered row-type data In fact, the data transaction performance is one order of magnitude better than that of a relational database we are currently using. The Redis database manages the machine status data in the online memory. The "Writer" processes that run on relay server machines transfer the status data to the Redis and the Cassandra simultaneously as shown in Fig. 5. The computing system for the Cassandra database consists of cost-effective PCs, which provide operation redundancy.

We still expect to use the relational database management system for the configuration and alarm databases. The database management system for SPring-8-II will be a hybrid system consisting of SQL and NoSQL database engines.

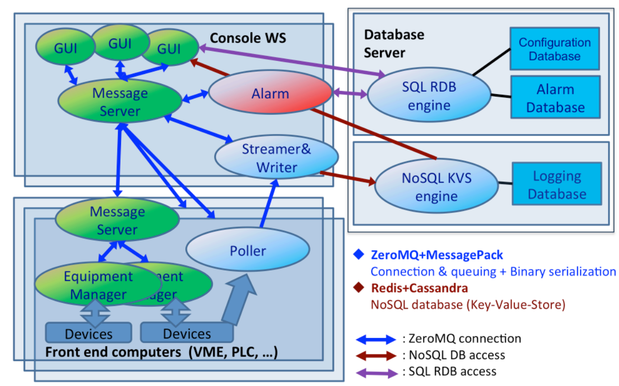

Figure 5: Software structure of MADOCA II that uses ZeroMQ and MessagePack for the message transaction. The NoSQL database engines receive machine status data from the Writer processes.

FUTURE WORK

The accelerator control system of SPring-8 has been functioning well under the MADOCA framework since 1997. Now, we have improved the framework and named it as MADOCA II.

We plan to start R&D on new technology such as xTCA. In addition, we plan to move one step ahead from the current conceptual design to a technical design, as we move toward the commissioning of SPring-8-II in the early 2020s.

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