ISBN: 978-3-95450-208-0 doi:10.18429/JACoW-IPAC2019-WEPGW029

THE DESIGN OF THE CONTROL SYSTEM FOR THE SACLA/SPring-8 ACCELERATOR COMPLEX TO USE THE LINAC OF SACLA FOR A FULL-ENERGY INJECTOR OF SPring-8

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Abstract

At the SPring-8 site, the X-ray free electron laser facility, SACLA, and the third-generation light source, SPring-8 storage ring, have been operated. On the SPring-8 upgrade project we have a plan to use the linac of SACLA as a full-energy injector of the storage ring. To achieve the SACLA's user operation and the beam injection to the storage ring in parallel, it is necessary to control the beam energy and the peak current on a pulse by pulse. The demand for an injection occurs anytime during the top-up operation of the storage ring. For this purpose, two accelerators should be controlled seamlessly and the SACLA has to provide the low emittance electron beam to generate X-ray laser and to be an injector of the storage ring simultaneously. Because SACLA has to control the beam energy and peak current on a pulse by pulse, we are designing a system to meet these requirements. A master controller stores a pattern of parameters required for the low-level RF controllers. Each pattern consists of 60 rows which correspond to the parameters for one second with a beam repetition rate of the SACLA, 60Hz. The master sends the parameters to the controllers with reflective memory. We can select the pattern every second on demand and it is flexible enough for the top-up operation of the storage ring. Also the data of low-level RF and beam position monitor are stored into the database with a beam repetition rate. In this paper, we report the design of control system for SACLA/SPring-8 to control the beam energy and the peak current on a pulse by pulse.

INTRODUCTION

In the last twenty years, SPring-8 has been a large-scale third-generation synchrotron radiation facility with the highest electron energy in the world. The SACLA project started in 2006 with a five-year construction schedule and it has been in operation for user experiments since 2012. We designed the SACLA linear accelerator to be used as a full-energy injector for the SPring-8 storage ring. An ultralow emittance electron beam delivered from SACLA should be compatible with the future upgraded SPring-8 facility. [1]

SACLA delivers pulsed X-ray laser beams whose pulse duration is as short as a few femtoseconds. The peak brilliance of SACLA is extremely high. The complementary use of the storage-ring light sources and pulsed X-ray laser is essential for opening new frontiers in science and technology.

In SPring-8-II the dynamic aperture will be markedly narrower than that in the current SPring-8. We cannot use the existing injector system in SPring-8 without large-scale modification. In addition, because of the long injection interval during top-up operation it is necessary to keep the injector system in a standby condition, which will increase the operation cost. On the other hand, the linac of SACLA is always running for user experiments independently from SPring-8. Therefore, if the injection beam is delivered from SACLA, the operation cost will be minimized. To enable operation by SACLA users experiments and beam injection to SPring-8-II in parallel, it is necessary to control the beam energy and peak current on a pulse by pulse.

DESIGN OF CONTROL FRAMEWORK

In the SPring-8 upgrade project we are going to use the linac of SACLA as a full-energy injector. For this purpose, two accelerators should be controlled seamlessly and SACLA has to be operated for user experiments and as the injector of SPring-8 simultaneously. The former control framework, call the MADOCA [2], could not satisfy the requirements and we have started to design a control system to meet these requirements. The basic idea of the control system is the following concepts;

1. A messaging service must be unified into one service. Because a GUI of operation needs to handle the both accelerators.
2. A relational database management system for a parameter must be merged to the same system. Because the parameters for the injection are spread in the both accelerators.
3. A data acquisition must be synchronized with the injection beam to achieve the control on a shot by shot.
4. A demon process, such as a feedback or a beam route control, should be easy to manage and maintain.

Figure 1 shows a schematic of the new control framework. We are redesigning the following components.

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Database System

The database system is composed of three parts [3]. The first is an online database for instantaneously logging the machine status. The second is an archive database for the machine status permanently logging. The last is a parameter database to store the machine control parameters such as the calibration constants and the current settings of the magnet power supply. We use Cassandra [4] for the online database. This kind of architecture has good performance at the writing speed, but it is not suitable for search and retrieve tasks which are required for analysis of the archived data. Therefore, we selected a relational database management system for the archive database. The parameter database requires flexible data manipulation and a relational database is more suitable for this purpose. We selected MariaDB [5] for the archive and parameter database. Because of the different architectures between Cassandra and MariaDB, We have designed the table structure with one element of the point data in one table. The synchronized data are stored into the online database with an event number counting up by the beam repetition rate. For the archive, the data are stored at each second dividing the event number by 60.

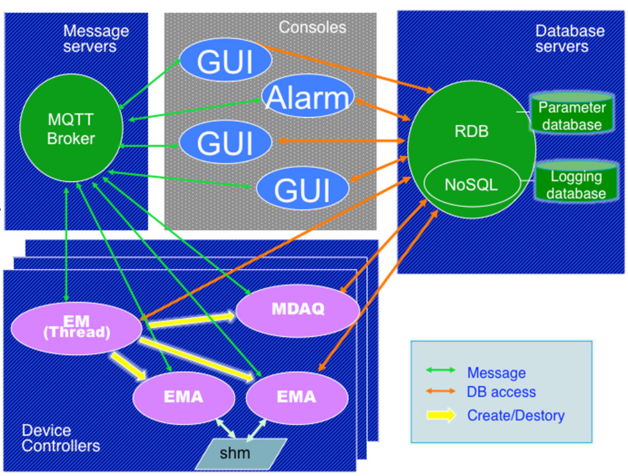

Figure 1: Schematic of the control framework for the SPring-8 accelerator complex.

Message Server

We use MQTT [6] as the messaging protocol to communicate between the operator console and the equipment control device. MQTT is an open industry standard and the de facto standard for Internet of Things applications. Therefor, there are many products to use MQTT on the market.

Equipment Manager

The messaging scheme is the MQTT and each topic is sent or received without queuing. The equipment manager (EM), which controls devices, has to be implemented with multiple threads to receive multiple messages. We decided that the EM is the only process at boot-up. Other processes such as data acquisition or feedback control will be forked from the EM. This makes it easy to manage processes and resources.

Data Acquisition

The data acquisition scheme is based on a daemon process, called MDAQ, which is forked from the EM. We are preparing four types of process.

- The acquisition process of point data with a fixed interval by polling. This is used for slowly varying data such as a voltage, current, temperature and water flow.
- The acquisition process of point data by triggered event, such as a beam position monitor of the SACLA. This has to be work with 60Hz and to be synchronized with beam to achieve the control on a shot by shot.
- The acquisition process of one-dimensional array data such as a waveform.
- The acquisition process of two-dimensional array da-ta such as a picture of a beam profile monitor.

The configuration parameters of MDAQ are loaded from the parameter database and acquired data are written to the online database. The state of the MDAQ is controlled using messages such as create, start, stop and destroy. The MDAQ process has a keep-alive function to report the up status of MDAQ such as stand-by, pause, running and stop to the database.

DESIGN OF CONTROL SYSTEM WITH PULSE BY PULSE

Because SACLA has to control the beam energy and peak current on a pulse by pulse, we are designing and developing a system with reflective memory real-time network. We selected the reflective memory card with the PMC form factor. It is possible to use for the VME and the MTCA.4 [7, 8]. Each reflective memory is connected to the reflective memory hub. It can automatically bypass ports when it detects a loss of signal, allowing the other nodes in the network to remain operational. The process which control the parameters, is implemented as the demon process called EMA-SW. The EMA-SW communicates with the feedback process via the shared memory and sends or receives a pattern data from the reflective memory. To keep timing jitter less than 1 mill-second we use the Solaris real-time class with the HiRes tick for the VME and low-latency kernel for MTCA.4.

A master controller stores all patterns of parameters required for the low-level RF controllers. Each pattern consists of 60 rows correspond to the parameters for 1 second with a beam repetition rate of 60Hz. We can select the pattern every second on demand. The system will be introduced to the all RF units. Also, it is installed in the kicker magnet power supply.

Figure 2 shows a schematic view of this system. Although, the control modules in SACLA's RF system are VME based, the master controller is an MTCA.4 module because this module is also used for injection timing con-

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trol of SACLA and SPring-8 [8]. The master sends the parameters to the VME with past, present and future beam parameter. Regarding the data acquisition timing of the pulsed machine linac, we need to wait for data conversion of the digitizer after trigger. This means the data obtained just after the trigger is related to the previous shot. For the timing of the parameter setting of the RF system, we need the settling time for a DAC. We must set the data prior to the target bunch. From these conditions, the master system has to send, and the VME system has to receive past, present and future parameters to control the operation with pulse by pulse.

We are modifying the parameter database to store all patterns for the management of the beam injection from SACLA to SPring-8. The pattern data have to be retrieved from the database and sent to the master controller on demanding the SPring-8 operation. Also we need to modify the archiving process. An archived data is required to store associated with a certain beam route. For the process, we deploy the route-pattern as one of the signals, which defines 60 sets of routing. We can select whether to keep or not in the archive by comparing a route-pattern.

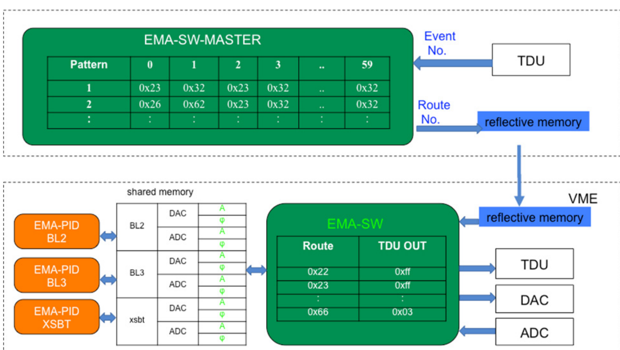

Figure 2: Schematic of parameter control with pulse by pulse.

STATUS OF THE PROJECT

As part of the SPring-8 upgrade project we started to design the brand-new control system in 2016. First we replaced a few VMEs of the test stand to develop and debug the system. The next step is to replace the dedicated accelerator for BL1 [9]. Before the replacement we made a feasibility study during the shutdown in spring 2017. From this study, we found the necessity for a small modification of the control system. We replaced the control system of the dedicated accelerator for BL1 during the summer shutdown in 2017. The control system has been working well since the replacement.

We have been replaced the control system of SPring-8 at the end of FY2017 and that of SACLA during the shutdown in summer 2018. A feasibility study of the injection from the SACLA to the SPring-8 is started at the beginning of 2019.

CONCLUSION

We are designing the control system to meet the requirement that the two accelerators, SACLA and SPring-8, must be controlled seamlessly. Also this system must simultaneously cope with the operation of SACLA for user experiments and the injector for the SPring-8 while controlling beam energy and peak current on a shot by shot. The master controller sends the parameters to all of the low-level RF controllers and the kicker magnet power supply via a reflective memory network. We can select the pattern every second on demand and it is flexible enough for the top-up operation of the storage ring. We are redesigning the control framework such as the Database, Messaging System and Equipment Control to include a NoSQL database, a relational database and MQTT for messaging.

We successfully replaced the control system of the dedicated accelerator for BL1 during summer shutdown in 2017. We replaced the control system of SPring-8 and SACLA during summer shutdown in 2018 to enabling seamless control of the two accelerators. We use this control system for the injection from the SACLA to the SPring-8.

ACKNOWLEDGEMENTS

The authors would like to thank all of contributors to the project, including members of RIKEN/SPring-8 and JASRI/SPring-8. Also, we thanks to SACLA/SPring-8 operators and RIKEN engineering team gratefully.

REFERENCES

[1] SPring-8-II Conceptual Design Report (2014); http://rsc.riken.jp/pdf/SPring-8-II.pdf

[2] R. Tanaka et al., “The first operation of control system at the SPring-8 storage ring”, Proc. of *Icalepcs'97*, Beijing, China, 1997, p. 1.

[3] K. Okada *et al.*, “Database Scheme for Unified Operation of SACLA / SPring-8”, in *Proc. 16th Int. Conf. on Accelerator and Large Experimental Control Systems (ICALEPCS'17)*, Barcelona, Spain, Oct. 2017, pp. 201-205. doi:10.18429/JACoW-ICALEPCS2017-TUBPA03

[4] http://cassandra.apache.org

[5] https://mariadb.com

[6] http://mqtt.org

[7] H. Maesaka et al., “On-Demand Beam Route and RF Parameter Switching System for Multi-Beamline Operation at SACLA”, *IPAC2019*, Melbourne, May 2019.

[8] T.Ohshima et al., “Timing Synchronization System for Beam Injection from the SACLA Linac to the SPring-8 Storage Ring”, *IPAC2019*, Melbourne, May 2019.

[9] N. Hosoda, T. Fukui, M. Ishii, T. Ohshima, T. Sakurai, and H. Takebe, “Control System for a Dedicated Accelerator for SACLA Wide-Band Beam Line”, in *Proc. 15th Int. Conf. on Accelerator and Large Experimental Control Systems (ICALEPCS'15)*, Melbourne, Australia, Oct. 2015, pp. 74-78. doi:10.18429/JACoW-ICALEPCS2015-MOM305