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DATABASE SCHEME FOR ON-DEMAND BEAM ROUTE SWITCHING OPERATIONS AT SACLA/SPring-8

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Abstract

At SACLA, the X-ray free electron laser (XFEL) facility, the electron linac operates in time-sharing (equal duty) mode between beamlines. The upgrade plan of the facility includes varying the duty factor on an on-demand basis and bringing the beam into the SPring-8 storage ring. Low-emittance beams are ideal for the next generation storage ring. In every 60 Hz repetition cycle, we must deal a bunch of electrons to each beamline properly. The challenge here is we must keep the beam quality for the XFEL demands while responding occasional injection requests from the storage ring. This paper describes the database system that supports both SACLA/SPring-8 operations. The system is a combination of RDB and NoSQL databases. In the on-demand beam switching operation, the RDB maintains the parameters to define sequences, which include a set of 1-s route patterns and a bucket sequence for the injection. Data analysis is a post-process to build an event for a certain route, because not all equipment receives the route command in real time. This paper presents the preparation status toward the standard operation for beamline users.

INTRODUCTION

The upgrade plan of SPring-8 is to build a fourth-generation ring-based synchrotron radiation light source [1]. The role of SACLA will be to provide high quality electron beams as an injector. In the top-up mode, SACLA is expected to respond to requests from the storage ring while running as a source of XFEL beam lines. This route switch must be operated in a selected bunch of the accelerator's 60 Hz cycle. After the injection into the storage ring, characteristics of electron bunches must be returned back to meet the demand of XFEL emission. In addition to the kicker magnet for routing, the RF units must be tuned to set energies and bunch shapes accordingly.

Though the upgrade project is still in the planning stage, realizing SACLA as an injector to the current SPring-8 storage ring has benefits which include reductions in the electric power consumption and the maintenance cost of the current dedicated injector apparatus.

Restructuring of the accelerator control system to enable a unified operation of SACLA and SPring-8 [2] is mostly established. In this paper, we describe the scheme of database at the site with a focus on the beam route switching operation.

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DATABASE AT THE SITE

Overall Scheme

The database at SACLA/SPring-8 supplies a platform for operating the accelerators. Instead of having various independent systems, all subsystems are to follow a common rule in the data storage and this allows the simplification of the correlation analyses. A schematic view of the data stream from a viewpoint of databases at the site is presented in Figure 1. Parameter DB manages signal information that are read by each DAQ component before data logging, and DAQ components push the data to Online DB. Operations of slow feedback control often use Online DB as the data source. The data in Online DB are eventually moved to Archive DB with a size reduction process. Parameter DB also stores various operation setup parameters and calibration factors in an organized format.

The unified data format allows for the provision of a global alarm service. The alarm service monitors signals periodically and compared with a simple set point. The results are stored in Parameter DB.

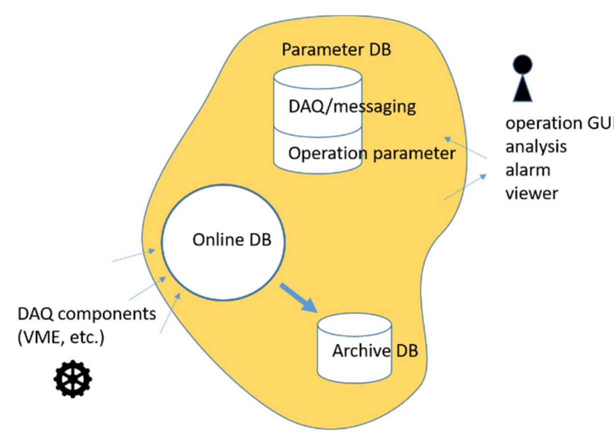

Figure 1: Data stream from the viewpoint of a database.

Parameter Database

Parameter DB is the entry point of every application that need to access data. It is so important that a limited number of librarians control updates of contents. Users who add new equipment will submit a request to register it onto the database.

DAQ/messaging: Parameter DB has a list of signals for the DAQ and messaging. The signals are for equipment and are sorted by group/subgroup categories. Each host

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may hold several DAQ processes. The signal name is normally determined to match the scheme of the SVOC format used in the control messaging protocol (i.e. "get/xfel_llrf_238_iq_cav_pickup_ave/amplitude").

The DAQ type is attached to a signal. In the "poller" type, point data are stored with a timestamp and the typical cycle is 5 s. In the "sync" type, the DAQ is synchronized with a trigger and data are stored with an event number. In SACLA, there are 60 Hz "sync" signals that match the accelerator cycle. In addition to point data, 1-dimensional and 2-dimensional data are to be implemented.

The settings of the alarm type, criteria, alarm history and the current alarm status are also stored in Parameter DB.

Operation parameters: Parameter DB also stores the operation parameters such as equipment settings, calibration parameters, and operation sequence. It used to be a place of random personal spreadsheets strongly connected to specific applications. However, by taking the opportunity of the system overhaul towards unified operation of SACLA/SPring-8, this is also under reviewed [3].

Values are stored connected to an "id" and a "key". The "id" is an identification number in an ID list (e.g. equipment list) and the "key" is a keyword that represents attribution e.g. (id, key) is (qmag_1_2, current). When a chain type relationship or categorization is needed, an ID-to-ID relationship is defined and by limiting the format, the same set of interfaces to access can be applied.

A set of values forms a group and once a series of operations or studies are completed, they are moved from the working table to the storing table with an auto-incremented version number. A tree type structure of groups enables the operation to be applied on a set of groups.

The keyword must be simple and clear, and groups must be sorted by types and by frequencies of updates as this will minimize confusion. The current groups of operation parameters are shown in Figure 2.

Figure 2: List of operation parameters management groups. There are 3 trees here, SR, SRCODBPM_ARC, and XFEL. The upper layer group can manage its family groups.

Hardware: We run 10.2.12-MariaDB [4] on Fault-Tolerant Server [5] to assure a high level of reliability for SACLA/SPring-8 Parameter DB, since every access starts from here. The messaging broker service, another important component of the control system, also runs here.

Data Logging Database

Online database: Online DB must catch up data streams from DAQ processes. We selected a noSQL database (Cassandra 2.2.11) [6] by taking writing capabilities. In the current set, each node holds a 2-TB SSD disk. The number of nodes determines the data storage ability and the reduction of workloads. SACLA and SPring-8, each have Online DB and their specifications are summarized in Table 1. In SACLA, the sync data of 60 Hz is dominant and the data can stay for about a half year. The massive 1D, 2D data are stored separately in a file format, and only the metadata is managed by Online DB.

Table 1: Online Database Specification and Data Volume as of the First Half of 2019

	SACLA	SPring-8
#Cassandra nodes	44	20
pol rate [kHz]	18.4	13.9
sync rate [kHz]	114.5	2.5

Archive database: The final destination of the data is Archive DB, and data are skimmed and packed in tables of 10.2.12-MariaDB [4]. The reduction factor depends on signals, for example, the 60 Hz sync data are reduced to between 1 and 2 Hz.

READING FROM THE DATABASE

Interfaces

Users are not allowed to connect to the databases directly to avoid accidental mistakes. They access the database through standardized interfaces prepared by the control group.

C-library database functions: Operational graphical user interface software (GUIs) are built on the C-library of access functions. One may read the conditions of accelerator from the database and use them for slow feedback controls. These operational set points can be labelled and stored in Parameter DB.

Python interface: A set of Python scripts is not open to general users and access is only limited to the managers. It builds a viewer service on the web described later sections of this paper. Management tasks such as adding new signals or setting operation parameter tables are conducted using the set of python scripts.

Rest-API interface: The script-based interface is not open with a fear of mishandling because of its flexibility. Hence analyzers have requested for convenient access to the database especially from the offline side.

A limited set of access functions are provided with the rest API interfaces as a trial run. The access log will be analyzed to judge what types of safety nets are needed to make this service to be open to general users.

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Web Viewer Service

A web-cgi service is provided to allow users to check trends of signals. Figure 3 and Figure 4 show examples of this data viewer. Correlation analysis is also possible by adding multiple data on one panel. It also serves as a portal for viewing the contents of Parameter DB.

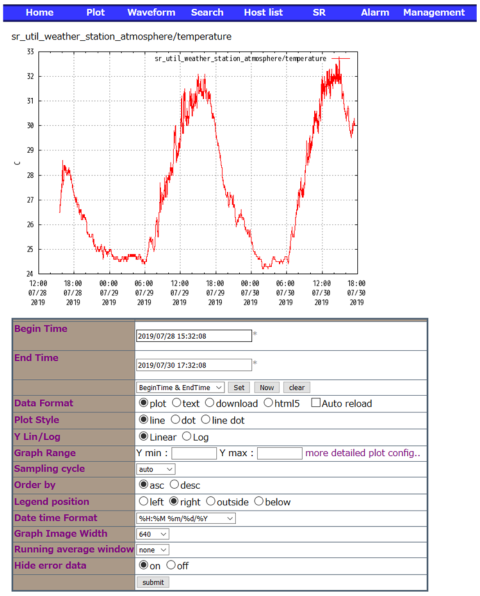

Figure 3: Viewer for “poller” data.

Figure 4: Viewer for “sync” data. Selections can be set by either the time or the event-tag range. This example shows the 60 Hz alternate outputs for an equal duty two-beamline switching operation.

Alarm Service

This is an example of C-library applications and is illustrated in Figure 5. The application has a loop of a typical cycle of 5 s to check signals. The judgements are recorded in the tables in Parameter DB which other display and voice application responses. The alarm status and related history is also viewed on the web page.

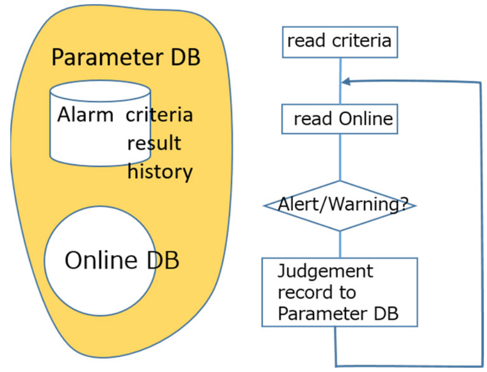

Figure 5: Alarm service.

OPERATION STATUS

The restructuring of the control system to the current style was started in 2018 [3]. Several problems with the hardware that affects the operation of the accelerator have been encountered, and are listed in Table 2. All the problems were related to one Cassandra node except for one network problem. The network problem could have been avoided if the link aggregation had been correctly set. The Cassandra cluster has a redundancy to down nodes, however, it turned out the DAQ application connected to that particular node was vulnerable depending on the type of problem. This was overcome by setting up a detection scheme and an easy recovery procedure.

Table 2: Database Hardware Problem Since 2018

Date	Problem
5/12/2018	Parameter DB: TRX down + LAG setting error
12/5/2018	SACLA Cassandra node #17 hung-up
3/1/2019	SACLA Cassandra node #36 hung-up
4/30/2019	SACLA Cassandra node #40 hung-up

ON-DEMAND BEAM ROUTE SWITCHING OPERATION

Abstract of the Project

As an injector to the storage ring, SACLA needs to respond to the injection requests while serving the XFEL beamlines. On a request for the injection which comes approximately 60 s intervals, the kicker magnet and all the RF components must fire correctly in one of the 60 Hz shots.

This route switch command is shared through a reflective memory network [7]. Here we decided to handle them by pre-determined sets of 60 routes (= 1 s pack), instead of random shots of 60 Hz. The details is in elsewhere [8].

Database for On-demand Beam Route Switching

Considering the latency of the TCP/IP network connection and furthermore the eventual consistency policy in Cassandra used for Online DB, the role of the database system is limited to a repository and a post-process.

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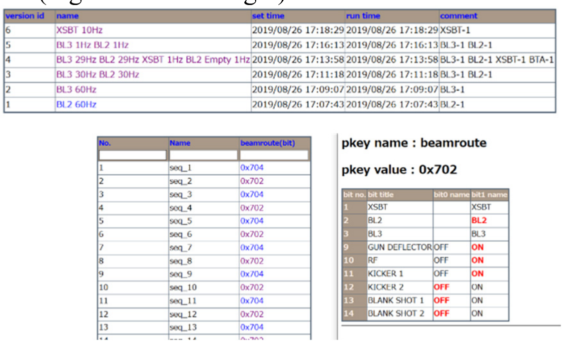
Parameter sets: A new parameter set group for the route pattern was prepared. Each set of beam routes of 60 (= 1 s pack) had a name and a version number (Figure 6 top). The beam route was stored according to the sequence number (Figure 6 bottom-left), and each bit of the value was defined (Figure 6 bottom-right).



version id	name	set time	run time	comment
6	XSBT 10Hz	2019/08/26 17:18:29	2019/08/26 17:18:29	XSBT-1
5	BL3 1Hz BL2 1Hz	2019/08/26 17:16:13	2019/08/26 17:16:13	BL3-1 BL2-1
4	BL3 29Hz BL2 29Hz XSBT 1Hz BL2 Empty 1Hz	2019/08/26 17:13:58	2019/08/26 17:13:58	BL3-1 BL2-1 XSBT-1 BTA-1
3	BL3 30Hz BL2 30Hz	2019/08/26 17:11:18	2019/08/26 17:11:18	BL3-1 BL2-1
2	BL3 60Hz	2019/08/26 17:09:07	2019/08/26 17:09:07	BL3-1
1	BL2 60Hz	2019/08/26 17:07:43	2019/08/26 17:07:43	BL2-1

No.	Name	beamroute(bit)
1	seq_1	0x704
2	seq_2	0x702
3	seq_3	0x704
4	seq_4	0x702
5	seq_5	0x704
6	seq_6	0x702
7	seq_7	0x704
8	seq_8	0x702
9	seq_9	0x704
10	seq_10	0x702
11	seq_11	0x704
12	seq_12	0x702
13	seq_13	0x704

pkey name : beamroute

pkey value : 0x702

bit no.	bit title	bit0 name	bit1 name
1	XSBT		XSBT
2	BL2		BL2
3	BL3		BL3
9	GUN DEFLECTOR	OFF	ON
10	RF	OFF	ON
11	KICKER 1	OFF	ON
12	KICKER 2	OFF	ON
13	BLANK SHOT 1	OFF	ON
14	BLANK SHOT 2	OFF	ON

Figure 6: Contents of a new operation parameter set for pre-defined 60 shots route pattern.

Concern in post process: In our data stream, building an event (a snapshot of a certain timing) is a post-process, since not all equipment is triggered and not all synchronized equipment connects to the reflective memory network that has the route information. The beam route will be stored as one of DAQ signals. Hence, for it to pick up an event of a particular beam route, it needs to refer the data that store the beam route with the event number. However, concerns have arisen as to whether this added routine degrades the performance of analyses.

Archive scheme: Online data are skimmed and prepared for the long-term storage. This is a good test for the performance, because it is the heaviest analysis task where every signal is visited.

The process was simplified by instead of processing the bare route signal, the decision whether to keep a certain 60 Hz event was conducted by the route pattern number and pre-fixed mod (event number, 60); the remainder determined by dividing (event number) by 60. This allowed for the cost of the selection routine to be kept at a minimum.

STATUS OF THE PROJECT

In the summer maintenance period of 2019, major components of the on-demand route switching operation were added and implemented. The new signals and DAQ settings were registered in Parameter DB.

Since fall, SACLA delivers beams to XFEL beamlines with the even share mode as before, however, it is now controlled by the new on-demand route switching scheme, not by a simple even/odd switching. The studies on the injection to the storage ring are in their final stages and the standard operation for beamline users is scheduled in 2020.

CONCLUSION

At SACLA/SPring-8, the control system integrates several databases in the data stream. Large-scale restructuring is currently underway, and this has allowed for the unified operation of two accelerator complexes. For the on-demand beam route switching operation, a concern in the database side is the speed of its post-process, as it needs to refer the route list stored as one of DAQ signals. A test conducted on the data archiving process which is one of the heaviest tasks as it visits every signal showed that the additional cost is tolerable.

In the 2019 summer maintenance period, major components for the on-demand beam route switching were installed and the project will be completed in the near future.

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