ARCHIVE SYSTEM FOR INJECTION CURRENT AT SuperKEKB

H. Kaji*[A)], Y. Iitsuka[B)], M. Hirose[C)]
[A)]KEK, Ibaraki, Japan
[B)]East Japan Institute of Technology Co., Ltd., Ibaraki, Japan
[C)]Kanto Information Service Co., Ltd., Ibaraki, Japan

Abstract

The archive system for the injection information is developed for the SuperKEKB collider. The information is archived in pulse by pulse so that the detailed studies of injection condition become possible. It is necessary to keep high efficiency of injection. The system consists of database server and the module of Event Timing System. The fluctuation and significant loss of injected current are observed. The archive is implemented in the entire phase-2 operation of SuperKEKB.

INTRODUCTION

SuperKEKB [1,2] is an electron-positron collider with the center-of-mass energy of 10.58 GeV. This is an luminosity frontier machine aiming the world largest luminosity of $8 \times 10^{35}\,\mathrm{cm}^{-2}\mathrm{s}^{-1}$.

The top-up filling operation is required for both the electron ring (HER) and positron ring (LER). The beam currents become quite large like 3.6 A (HER) and 2.6 A (LER) in such a large luminosity. The beam lifetime is short and to be $\sim$5 minutes in case of LER.

We develop the archive system which archives the injection related information in pulse-by-pulse. It can be utilized for understanding the injection condition. This is necessary to keep efficient injection for the entire run period.

The system is designed and developed during the shutdown period between phase-1 and phase-2. It is commissioned in the early stage of phase-2 operation, and then becomes fully functional since April 2018. The data have been archived until the end of phase-2.

This report introduces the specification of archive system and its data acquisition scheme. Then some results from archiver are discussed.

ARCHIVE SYSTEM

Overview

Figure 1 is the schematic view of archive system. The system consists of database server and the module of Event Timing System [3]. In addition, there is software which associates individual archived data as one injection information.

All archived data are collected from EPICS Process Variables (PVs) [4] with their issued time. The issued time is quoted from the CPU time of each EPICS IOC. Therefore the variables belonging to different IOCs use the different timestamps as the issued time.

* hiroshi.kaji@kek.jp

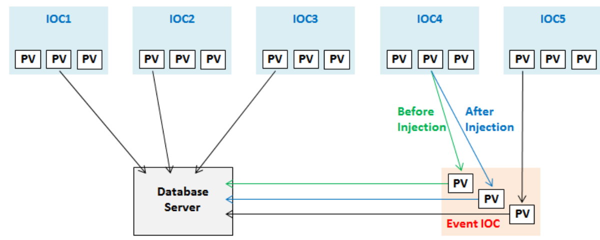

Figure 1: Schematic view of archive system: the database server collects and archives the information related with the injection via the accelerator network. The archived variables which need to unified their issued time are once stored into the Event IOC. Then, they are sent to the database server with the timestamp of Event IOC.

There is one IOC which the Event Receiver (EVR) is installed. The archived variables which need to use the unified timestamp as the issued time are once stored on this IOC. Its detailed specification and usage are described later.

Database Server

The database server is based on the Control System Studio (CSS) archiver and the postgreSQL as the database management system. It is originally developed for monitoring the QCS and Belle2 solenoid magnets [5].

The standalone PC with Linux OS is employed for the database server. It collects information from the remote EPICS PVs via the accelerator network.

Event IOC

The Event IOC consists of the CPU and EVR modules and is configured on the VME form factor. This is utilized for unifying the timestamps of individual archived variables.

There is the advantage to use the CPU time of Event IOC as the unified timestamp. The CPU time of all Event IOCs and IOCs for Abort Trigger System are synchronized [6]. Therefore the issued time of archived data can be compared with the timing of activities of above mentioned IOCs.

The other motivation to use the Event IOC is the data buffer information. This IOC receives the several kinds of information related with the injection pulse. They are the shot ID, the RF-bucket to be injected the next injector pulse (injection-bucket), and so on.

We archive the bunch currents of only injection-buckets and some neighboring RF-buckets which are affected with the injection kicker pulse. The injection-bucket information from data buffer is utilized for this process. We can save the disk space and the computing resource by avoiding the archive of all bunch current monitor (BCM) information.

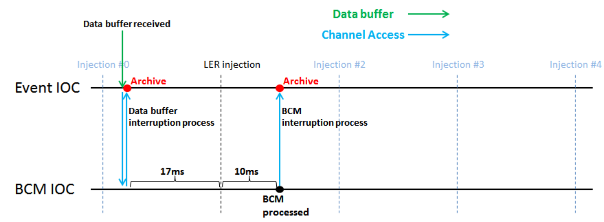

Figure 2: Time chart of data acquisition: the Event IOC receives the bunch current before injection when it receives the data buffer. That after injection is received when the BCM is processed.

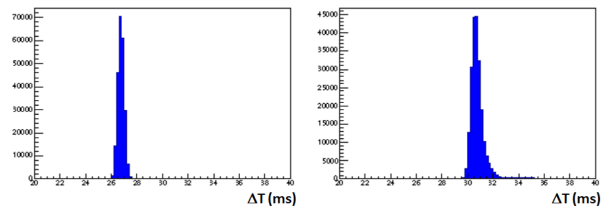

Figure 3: An example of issued time difference of BCM data between before and after injection: the left plot shows the time difference of BCM. It is typically ∼27 ms. The right plot shows time difference between BCM data before injection and BPM data at beam transport. It is typically ∼31 ms. The resultant time differences are consistent with the processed time difference of EPICS PVs.

Client for Monitoring and Offline Analysis

The two kinds of software are available to access the injection database. One is the CSS monitoring client. This has already utilized since the phase-1 operation. The several components at the interaction point are monitored [5]. Of course, we can utilize also for the injection information monitoring.

The other is ROOT [7]. It is the C++ base software which is developed at CERN for the high energy physics experiments. The ROOT includes the PostgreSQL library so that we can access our database.

The ROOT enables the detailed offline analysis as well as the simple monitoring. We can easily program the complicated arithmetic-operation of archived data with the C++ code. For example, the individual variables archived in parallel are associated as the each injection pulse data in the offline analysis with ROOT.

DATA ACQUISITION SCHEME

Figure 2 is the time chart of data acquisition. The Event IOC collects the BCM information twice in every injection pulse.

The first process is launched when the EVR receives the data buffer. The data buffer is delivered 17 ms before injection process. The bunch current at the injection-bucket is collected from BCM IOC via the Channel Access protocol of EPICS and stored into the PV on the Event IOC. This process is finished before injection in a enough time margin.

The second process is triggered when the objective IOCs are processed. The BCM IOC is processed every time when the injection is carried out. Therefore the collected bunch current becomes the one after injection. Typically, the BCM IOC is processed 10 ms after the injection.

The issued time of BCM data are changed to be the one determined from the CPU time of Event IOC. It is important for the reconstruction of injection data performed on the ROOT program.

The same thing is carried out for the last BPM at beam transport line between the injector and main ring. The charge of beam pulse is archived in every injection.

Note, the entire process need more than 20 ms. However the injection frequency is limited to be less than or equal to 25 Hz in the phase-2 operation of SuperKEKB. Therefore we have enough time for data acquisition.

RESULTS IN THE PHASE-2 OPERATION

In this section, we introduce some results from our archiver. We develop the new method to monitor the injected beam current by using the data acquisition described in the previous section and the offline analysis.

The injected current is defined as the bunch current difference of injection-bucket between before and after injection. The bunch current data after injection is associated with those before injection when their issued time difference is less than 40 ms. The charge of beam pulse at beam transport line also is associated in the same criterion.

Figure 3 shows the issued time difference of associated bunch current data. The time difference is ∼27 ms and consistent with the processed time difference of EPICS PVs. That of charge at beam transport is ∼31 ms.

An example of operation current and injected current at LER are shown in Fig. 4. The injection current from our archiver shows some interesting features.

There is the fluctuation for injected current which are caused by the instable operations of injection components, like the kicker and septum magnets. Besides, the significant beam loss is observed in many pulses. They can be observed since the injected current is archived in pulse by pulse. Note, traditionally, we monitor the injected current from DCCT in average of 1 second. The fluctuation and beam loss are disappear in this way.

The other advantage of new injected current is it avoids the influence of beam lifetime. There is no degradation of injected current even though the operation current becomes large to be 340 mA in this run. The obvious degradation is observed in the DCCT measurement. It is because the DCCT measures the beam current of all operation bunches so that the natural beam loss of those bunches affects the current measurement.

There are the data of bunch currents which are affected with the injection kicker pulse. Those bunches may be the source of beam background. Therefore the analysis of those

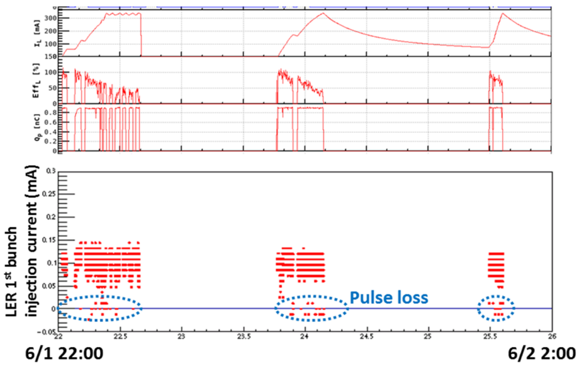

Figure 4: An example of operation current and injected current at LER: the upper three plots show the operation current, injection efficiency at LER, and charge at beam transport line. The injection efficiency is the kind of injected current and determined as the injected current divided by charge at beam transport. The lowest plot is the injected current determined and archived in the new method.

bunch currents are important to understand the beam background events in the physics analysis. It is planned to be reported separately in future.

CONCLUSION

The archive system for injection information is developed for the SuperKEKB collider. The database server is based on the CSS archiver and the postgreSQL. The Event IOC is utilized for unifying the timestamp of injection related variables.

The injected current is archived in pulse by pulse. The fluctuation and significant loss of injected current are observed with this new method. The archive is implemented in the entire phase-2 operation.

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