DATA ACQUISITION AND ANALYSIS IN SSRF BPM SYSTEM*

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Abstract

The beam position monitor (BPM) system in Shanghai Synchrotron Radiation Facility (SSRF) is fully (Linac, transfer lines, booster and storage ring) equipped with Libera Electron BPM Processors. Primary data acquisition and position calculation has been done in Libera FPGA. EPICS support package developed by Diamond Light Source has been adapted to link BPM system with accelerator control system. Two dedicated soft IOCs are introduced to collect beam position data from all Libera IOCs and calculate RMS noise, histogram, spectrum and phase space, etc. online. Other BPM based analysis is completed via MATLAB scripts. The initial results during the booster and storage ring commissioning will be described in this paper.

INTRODUCTION

Shanghai Synchrotron Radiation Facility (SSRF) is a third generation light source located at the Zhangjiang Hi-Tek Park, Shanghai, P.R.China. Its small emittance requires a high resolution Beam Position Monitor (BPM) system in order to achieve beam stability at the micron level [1]. The same BPM system can also measure the turn-by-turn beam position for various machine physics studies.

According to the experiences from Diamond and SOLEIL, SSRF BPM system is based on the Libera electron beam position processor, which is produced by Instrumentation Technologies. A total of 181 Libera Electrons (3 in the Linac, 8 in the transfer lines, 30 in the booster and 140 in the storage ring) are used for BPM signal processing and orbit feedback system. Two extra Libera IOCs are dedicated to tune measurement for the booster and storage ring. Two HP workstations running as soft IOCs are added into the booster and storage ring respectively, which collect turn-by-turn beam position data from all Libera IOCs and calculate RMS noise, histogram, spectrum, phase space and etc online. Other BPM based analysis is completed via MATLAB scripts. Some examples of data acquired and measurements performed during the booster and storage ring commissioning are reported.

LIBERA IOC

The Libera Electron is based on the typical software radio prototype. The RF signals from four button pickups are processed in four RF channels performing anti-alias filtering and gain control, then under-sampled at 117.28 MHz directly. The following digitized IF signals processing, position data calculation and delivery are finished by FPGA and DSP software.

The Libera EPICS support package is based on Diamond Light Source, which talks to hardware through Control System Programming Interface (CSPI) layer and linux device drivers. Some function modules (Automatic Gain Control (AGC) module, beam lifetime calculation module for storage ring and 24-hour buffers for slow data sources) are added into it according to our specific needs. All data path including ADC raw data, first turn, turn by turn and slow acquisition can be access via EPICS CA. Most of the data sources are triggered synchronously with the injector, which is running at 2 Hz. The system fulfils several important tasks [2-3]:

- FT (First Turn): It provides the beam position and intensity at the first turn.
- TT (Turn by Turn): It is used to analyze the beam position and intensity on a longer scale for machine physics applications (machine model, non-linear beam dynamic studies) and tune measurements.
- SA (Slow Acquisition): The closed orbit is measured at about 10 Hz acquisition rate. It gives the mean position for a stored beam and provides a good accuracy and resolution for the closed orbit drift correction. In SSRF BPM system 24-hour buffers are available for SA data.
- Interlock: When the beam goes outside a predefined position range at any selected BPM, the BPM electronics gives an interlock signal which is used to prevent possible damage to the machine.
- FA (Fast Acquisition): The closed orbit is measured at a high acquisition rate (10 kHz). We make this data source available through an industrial personal computer with two Ethernet adapters (One is used to capture the FA data streaming from the specified Libera Electron, and another is connected to the Ethernet for EPICS channel access). This part of the support package is completed by SSRF. In the future it will be directly connected to the FOFB network through a communication controller implemented on FPGA.
- PM (Post Mortem): It records the last few thousand turns of beam position data in case of a sudden beam loss. It is not currently used in SSRF.

SOFT IOC

During the system debugging, evaluation or diagnostics, the statistical analysis and data processing are frequently used to get some system performance parameters. Generally there are two methods. One is to acquire data with shell scripts and then finish offline analysis using MATLAB or other mathematical tools. This method is proved to be time-consuming and always unavailable to capture some random events. The other

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method is developing a particular support module to perform real-time analysis and processing. This requires the developers understanding some system low level details. At the same time, the support package for specified channel is hard to migrate. Therefore we designed and developed a unified common online data analysis software package based on EPICS soft IOC and run-time database template.

Based on the demand analysis, we designed and implemented the IOC running database, as shown in Figure 1. It mainly includes: calculation of the average, maximum value, minimum value, and standard deviation; drawing distribution histogram; Fast Fourier transform (FFT); Correlation, convolution and de-convolution of two signals; digital filtering and etc.

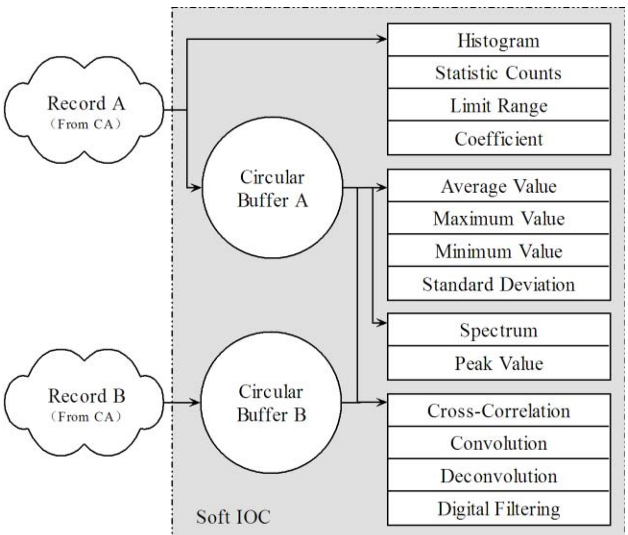

Figure 1: Diagram of soft IOC running database

The soft IOC periodically gets the value of record A (as shown in Figure 1, which needs to be analyzed) via Channel Access protocol, and then divided into two paths. One is used to draw the distribution histogram, whose range will be calculated by the statistical module below. The other is a circular buffer which is used to perform the statistical analysis, spectrum analysis, and 2-way signal processing. Another circular buffer is introduced for the operations of the two signals.

Many macros are used in this package. After the source code complied on Linux platform, the users only need to load the specified database files with corresponding macro replacements in the start-up scripts.

This online data analysis software package described above has been used in the BPM system, running as soft IOCs. The soft IOCs collect SA and TT beam position data from all Libera IOCs of the booster and storage ring and provide RMS noise, histogram, spectrum and phase space, etc. online. Figure 2 shows an example of the SA data analysis in the storage ring. We store 2048 points in the circular buffer and update the result at 2 Hz. All these analysis and processing parameters such as buffer size and update rate can be configured in the start-up scripts.

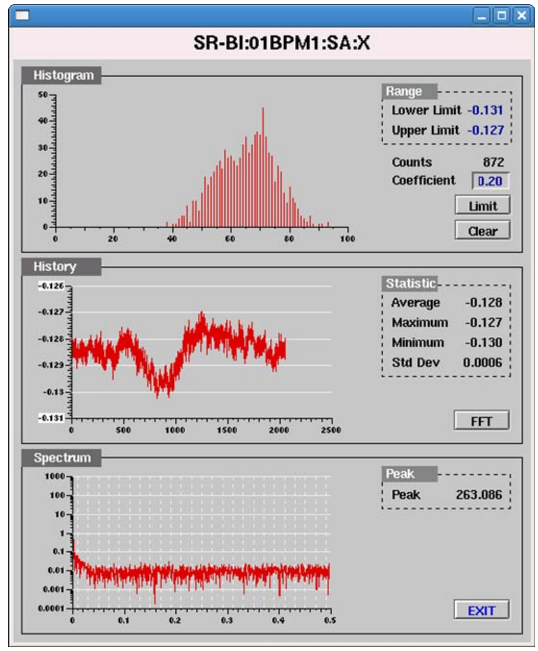

Figure 2: SA raw data and derived results

MATLAB PROCESSING

In SSRF most of the high level applications have been built in the MATLAB environment and using MATLAB computational and graphical capabilities. All the data in the Libera IOCs and soft IOCs are available as EPICS PVs and transferred into MATLAB via LabCA. Several applications have been written in MATLAB to perform routine tasks during the booster and the storage ring commissioning, such as drawing the closed orbit, displaying the turn-by-turn data, measure the betatron tunes at injection and tracking them during the ramp. These complete the post-processing of BPM data, while the data acquisition and per-processing are completed in the Libera IOCs and soft IOCs.

COMMISSIONING RESULTS

Resolution

The preliminary resolution measurement result is shown in Table 1. We can observe that the RMS deviations are small and achieve beam stability at the micron level.

Table 1: Resolution Measurements of Storage Ring

Type	Rate	BW	RMS X	RMS Y
SA	10 Hz	4 Hz	100 nm	100 nm
FA	10 kHz	2 kHz	< 2 μm	< 2 μm
TT	694 kHz	347 kHz	< 5 μm	< 5 μm

Beam Current Dependence

The position reading of a BPM should ideally be independent of the beam current. With parallel processing channels, unequal nonlinear response or unequal attenuator steps of the individual channels lead to a position offset as a function of beam current [4]. Figure 3 shows the statistics of beam current dependence from 140 units of the storage ring.

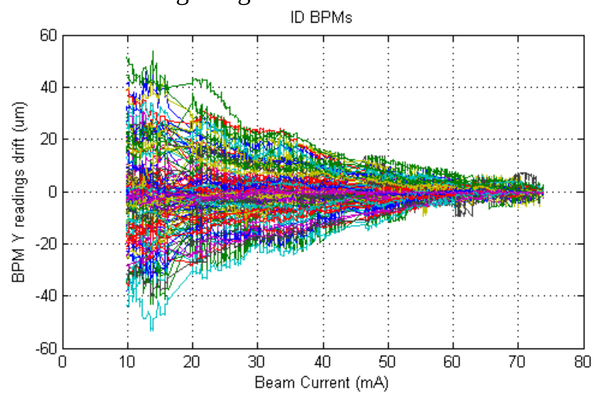

Figure 3: Beam Current Dependence measurement

Tune Measurement

Tune measurement is an important application of the Turn-by-Turn data. Since it is planned to install a bunch by bunch feedback system in the storage ring including kickers as well as power amplifiers, we use these to excite the beam motion. The fractional tune is obtained through the FFT performed on Libera turn-by-turn data. As shown in Figure 4, they are 0.2896 (Horizontal direction) and 0.2997 (Vertical direction). It seems to be better than 10-4.

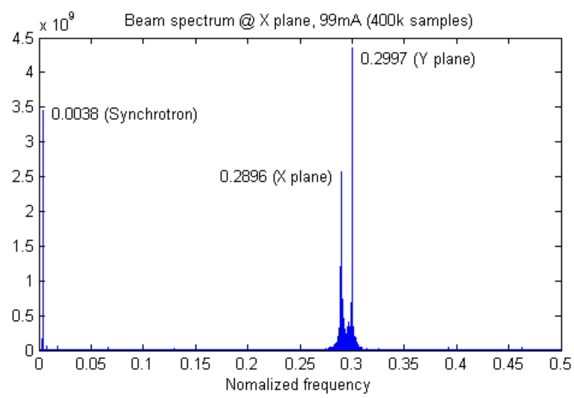

Figure 4: Tune measurement of the storage ring

Using the turn-by-turn data available from a BPM the tunes are tracked dynamically during the booster ramping cycle. The results are shown in Figure 5.

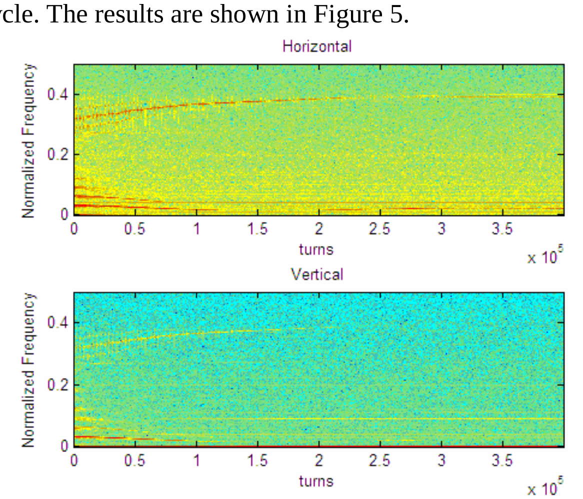

Figure 5: Tune drift of the booster

Beam Lifetime Measurement

The beam current measurement has been implemented in the Libera EPICS support package and the lifetime can be calculated from it. The average lifetime of all 140 units of the storage ring and the lifetime from DCCT current are shown in Figure 6.

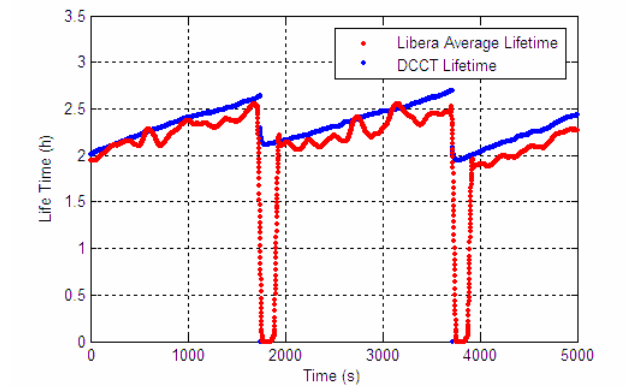

Figure 6: Beam lifetime measurement using Libera

SUMMARY

Since the booster and storage ring commissioning started last year, the BPM system has been working well and offered great support to the commissioning. A few problems were identified and corrected. In the future more processing and analysis of the turn-by-turn data will be done using some professional tools, such as LOCO.

ACKNOWLEDGEMENTS

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