Global Orbit Feedback System Upgrade At The Canadian Light Source

Song Hu, Chris Payne, Daron Chabot, Dylan Maxwell, Les Dallin
Canadian Light Source, 101 Perimeter Road, Saskatoon, SK, S7N 0X4, Canada
E-mail: song.hu@lightsource.ca

Abstract. The Canadian Light Source has been using a Matlab application called CLSORB to perform slow orbit correction in the storage ring. A fast global orbit feedback system is recently deployed to replace the old system. The correction rate is about 45 Hz and all the corrections are calculated and applied by an RTEMS IOC. This upgrade has resulted in increased beam stability and reduced perturbations caused by the ramping of superconducting wigglers. This paper will discuss the implementation and performance of the fast orbit correction system.

1. Introduction
The Canadian Light Source has been using a high level Matlab application called CLSORB [1, 2] to perform slow orbit correction in the storage ring. It is based on the Matlab channel access library to connect to the underlying EPICS control system [3, 4]. Orbit corrections are applied about every 1.5 s, alternating between the horizontal and vertical planes. Corrections applied through CLSORB have very poor synchronization, which can cause undesirable orbit perturbations and prevent us from using all the singular values in the corrections. As a result, a maximum corrector change in each iteration was introduced to CLSORB to prevent large disruptive corrections being applied. Although this slow orbit feedback system has been serving well to maintain the orbit in the storage ring, the growing number of beamlines and increasing sensitivities of the experiments require a fast orbit feedback system to improve beam stability and reproducibility. A fast orbit feedback system has been implemented and operational during CLS user shifts since January 2012. The system is designed to apply corrections at 45 Hz and orbit perturbations are reduced to less than 1 μm RMS in both planes.

2. Fast Orbit Feedback System Overview
Figure 1 shows the hardware architecture of the new CLS global orbit feedback system [5, 6]. The system consists of a computer running Matlab, a Real-time Executive for Multiprocessor System (RTEMS) Input Output Controller (IOC) and four Versa Module Eurocard (VME) crates. Bergoz BPM modules sample the signals from BPM buttons to produce analog X and Y positions. These signals are digitized by ICS-110BL Analog to Digital Converter (ADC) VME modules at 10 kHz. Data is then processed by the RTEMS IOC. Corrector magnet power supply setpoints are distributed via digital I/O VME modules. All corrector magnet power supply feedbacks are on RS-232.

The RTEMS IOC serves as the control centre of the system. It is responsible for BPM data acquisition, corrector setpoints calculation and distribution. BPM data acquisition on the IOC
Figure 1. Global orbit feedback system architecture

is either interrupt driven or timer driven and data on all channels is acquired simultaneously. The computer running Matlab communicates with the RTEMS IOC through EPICS PVs to provide response matrix measurement, Singular Value Decomposition (SVD) calculation, orbit display, BPM/corrector disabling functionality. In such a configuration, 45 Hz update rate has been achieved. To make the migration from the slow feedback system to fast feedback system easier, the system also provides an operating mode called assisted mode which emulates the slow feedback system. In this mode, the corrector setpoints are calculated and distributed by Matlab and the RTEMS IOC provides beam position data through EPICS PVs at 2 Hz. This mode proved to be very useful during commissioning. After commissioning, it also serves as a diagnostics tool when manual or slow correction is required.

The slow feedback system applies corrections in a sequential manner which can cause undesired orbit perturbations and prevented us using all singular values. As a result, the maximum corrector change has to be limited in each iteration. In the fast feedback system, corrector setpoints are simultaneously applied around the ring. It is not necessary to limit the maximum change. However, we choose to keep this option in the fast feedback system because this limiting factor can provide one more parameter to optimize the performance and diagnose faulty corrector/BPM of the fast feedback system. Operators can also choose to bypass this limiting factor.

The slow feedback system applies an RF correction in every iteration to compensate for circumference changes, which is about every 3 s. Since the storage ring path length change is dominated by thermal effects which tend to be slowly drifting, there is no need to apply the RF correction in each iteration in the fast feedback system. The RF correction algorithm has been modified to accommodate a faster update rate [7]. The general algorithm is to calculate the difference orbit, calculate and subtract RF component in the difference orbit, calculate corrector increment, calculate and subtract RF component in the corrector pattern and apply correction in
Figure 2. Orbit stability with HXMA wiggler ramping up/down during injection

each iteration. After 45 such iterations, the RF correction is applied if the calculated frequency change is greater than 0.5 Hz. With this modified algorithm, the RF correction is applied about every 1 s and undesired beam perturbations which can be caused by BPM noise and numerical instability are avoided.

3. Performance
Until recently, operators needed to ramp down the Hard X-ray MicroAnalysis (HXMA) wiggler before injection and ramp it up after injection to maintain booster to storage ring injection efficiency during the injection cycle. Figure 2 shows the beam position reading comparison between the slow orbit feedback system and the fast orbit feedback system at BPM(10,1) during injection. With the slow orbit feedback system, the maximum orbit shift caused by wiggler ramp in the horizontal plane is about 100 µm. As a comparison, the maximum orbit shift is only 4 µm in the horizontal plane when the fast feedback system is in operation. When the machine is in static state, beam motion has been reduced from 1.5 µm RMS to 0.2 µm RMS in the horizontal plane and from 0.7 µm RMS to 0.2 µm RMS in the vertical plane. In the past, wiggler field change was not allowed during users’ beam time since it could cause large orbit perturbations with the slow feedback system. With the fast feedback system, the orbit shift caused by wiggler field change is much smaller and we expect it will be transparent after further software and hardware upgrades.

4. User Operation
The fast orbit feedback system has been operational since January 2012. The major focus was the software reliability at the beginning. However, we found that the fast orbit feedback system could cause problem in the spectrum of Fourier transform infrared spectroscopy on the FAR-IR beamline. Whenever the fast feedback system was in operation, harmonics of 45 Hz showed up in the spectrum of FAR-IR beamline. We observed the same effect on the beam motion spectrum acquired by a Libera Brilliance, which has the capability of acquiring 10 kHz beam position. As a result, we had to switch back to the slow orbit feedback system whenever FAR-IR beamline was in operation. To solve this problem, further efforts were made to introduce a random delay in each correction cycle to flatten out 45 Hz harmonics in the spectrum. With this randomization
Figure 3. Beam motion spectrum comparison between 45 Hz update rate and 18 Hz update rate

method, 45 Hz harmonics are much suppressed in the spectrum. However, they were still not completely eliminated from the spectrum. As a temporary solution, we reduced update rate from 45 Hz to 18 Hz to eliminate the harmonics of the update rate from the spectrum. Figure 3 shows the beam motion spectrum comparison between 45 Hz update rate and 18 Hz update rate. Currently, work is being done to fine tune the bandwidth of the corrector magnet power supplies to accommodate a higher update rate.

5. Future Work
Although the fast orbit feedback system has been operational, we had to limit the update rate to 18 Hz. Future work will include fine tuning the bandwidth of power supplies to accommodate the update rate of 45 Hz. Further effort will be made to increase the update rate up to 100 Hz. Other work include removing current dependence from the BPM data, investigating new BPM data processing algorithms instead of simple average and moving all functionalities currently carried out by Matlab to EPICS to improve reliability and optimize performance of the system.

6. Summary
The fast orbit feedback system has been deployed to the CLS storage ring and operational since January 2012. It has resulted in increased beam stability. Further software upgrade and fine tuning of the corrector magnet power supplies are underway.

7. References
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