ORBIT CORRECTION UPGRADE AT THE CANADIAN LIGHT SOURCE

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Abstract

The Canadian Light Source is a 3rd generation synchrotron that began user operations in 2005 and now supports 22 operational beamlines. The previous orbit correction system was experiencing an increasing number of failures associated with obsolete hardware. This system was upgraded to improve machine reliability and performance, as well as to support new diagnostic capabilities.

OVERVIEW

The orbit correction system is responsible for maintaining the orbit of the stored electron beam. It reads the beam positions at various points around the storage ring, computes the deviation of the beam from its ideal location, and then calculates and distributes new setpoints to the orbit corrector magnets. As the complexity of the machine increases with the addition of insertion devices, the speed and accuracy of this setpoint distribution becomes even more critical to quickly damp down perturbations in the stored beam so that a stable orbit is maintained.

OLD SYSTEM

The previous system used versa mezzanine eurocard (VME) based hardware to read beam positions and to distribute orbit correction magnet setpoints. The VME cards were obsolete and showing increasing signs of failure. The beam position readings were averaged onboard, which restricted the diagnostic capabilities, and the setpoints were not distributed in parallel, which limited the correction rate.

The software used to support this system had multiple layers, hosted on a variety of machines, in a number of different languages. Furthermore, the computer that hosted communication with the orbit correction hardware was running an obsolete operating system with a customized compile environment, on hardware that was becoming increasingly difficult to service or replace. As a result, implementing changes or diagnosing problems was challenging.

NEW SYSTEM

The upgrade eliminated all of the obsolete hardware and dramatically increased the diagnostic capabilities. The new orbit correction system exposes all of the raw data which is now used to analyze performance and identify potential issues.

Hardware

The new orbit correction system, shown in Fig. 1, incorporates D-tAcq analog to digital converters (ADC) [1,2] to read beam position monitor (BPM) positions and custom built nuclear instrument modules (NIM) that use PoLabs single board controllers (SBC) [3] to support parallel distribution of magnet power supply setpoints.

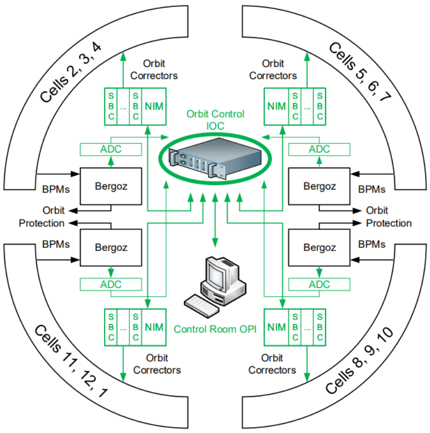

Figure 1: New orbit correction system architecture.

Software

The new software is running on more robust hardware, using a Scientific Linux 7 operating system, as shown in Fig. 2. This allows cores to be dedicated to specific tasks to ensure fast and predictable response times. In addition to simplifying the architecture, the new software is both dynamically configurable and easily extensible.

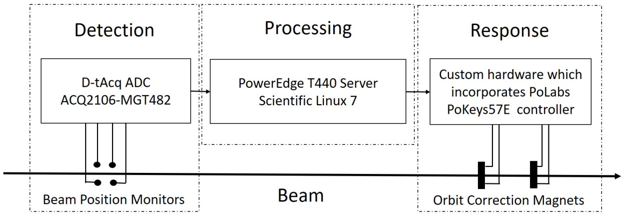

Figure 2: Orbit correction block diagram.

ENHANCEMENTS

The new diagnostic capabilities include:

Extensible Architecture

The architecture of the new software makes maintenance, support, and enhancement efforts more efficient. It supports dynamic saving and reloading of configuration and machine parameters for easy adjustment and machine recovery in the case of a hardware failure or a power outage.

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Real-Time Logging

The beam position values and orbit corrector setpoints are exposed at a rate of up to 1000 Hz which allows correlation of this information with other machine parameters.

Figure 3 shows the effect of ramping the Biomedical Imaging and Therapy (BMIT) superconducting 4.3 Tesla wiggler from zero, and the associated response as the orbit correction system works to damp out this disturbance. The perturbations caused by this wiggler when ramping from 0 T, mean that this can only be done when the current in the ring is below the bad orbit threshold. The perturbation is not as significant at higher fields, however during normal operation additional compensation does occur to allow this wiggler to change field strength.

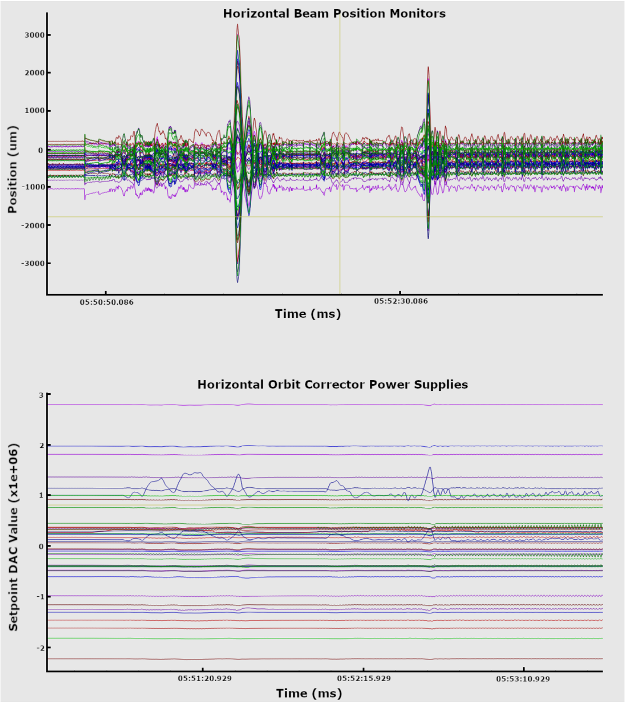

Figure 3: Logger showing horizontal beam position and orbit corrector setpoints during ramping of the BMIT super conducting wiggler.

Real-Time Analysis

Real-time root mean square and standard deviation values are calculated for individual and global beam position readings to support detection of noisy electronics.

Power spectral density and cumulative power spectral density data is calculated for all BPMs. This information quantifies noise in the stored beam as a function of frequency. The graphical user interface allows any combination of BPMs to be selected simultaneously. Figure 4 shows an example of this data from all of the horizontal beam position monitors.

Waveform Generation

Waveform signals can be sent to any combination of orbit correctors. This functionality has proven to be beneficial for both commissioning and as a diagnostic tool for analyzing noise issues. By introducing a sine or square wave with selectable frequency, amplitude and offset, the orbit correction system performance can be analyzed as it damps out the injected signal. This supports measurement of the closed loop bandwidth.

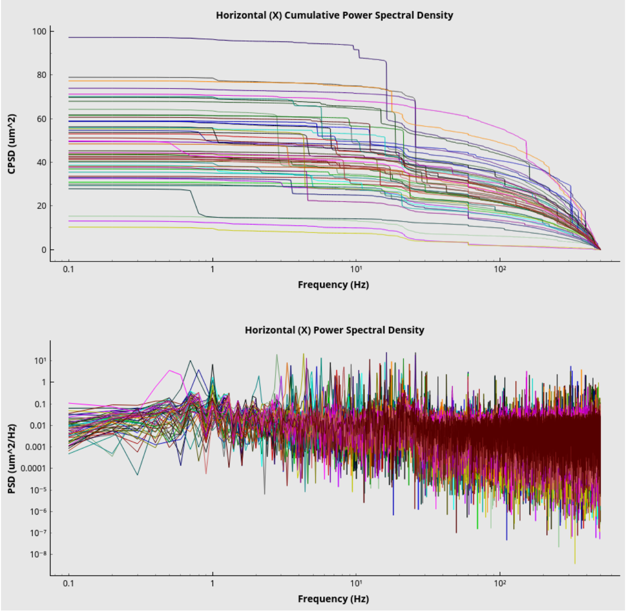

Figure 4: Horizontal beam position power spectral density and cumulative power spectral density.

The sine wave generation, shown in Fig. 5, has also been used to diagnose noise issues reported by beamlines. This is done by moving the electron beam to determine whether the noise seen by the beamline is introduced by this beam motion.

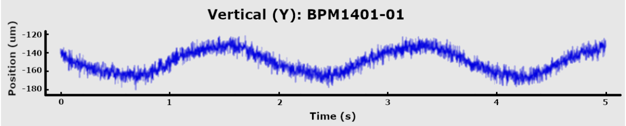

Figure 5: Beam motion resulting from a sine wave introduced on an orbit corrector.

The generation of a square wave, shown in Fig. 6, has been used to determine the step response of the system.

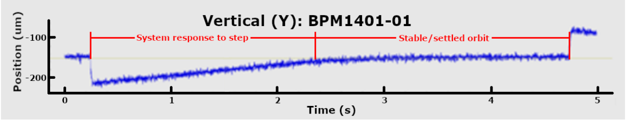

Figure 6: Introduction of a square wave to measure the response of the system.

Digital Filtering

Digital filtering is available on both beam position inputs and orbit corrector setpoints for future performance enhancements.

System Monitoring

A significant increase in the error handling ensures that a loss of communication with orbit correction hardware or a related external system is reported in real-time.

Hardware Verification

Verification of power supply components is automated. This automated testing is used to verify an individual, a subset of, or all orbit corrector power supplies. This allows quick and efficient testing and supports easy identification of issues.

PERFORMANCE LIMITATIONS

Magnet Bandwidth

It was initially believed that the bandwidth of the orbit correction magnets was on the order of 50 Hz. However, using the waveform generation functionality it has been determined that the bandwidths are between 15 and 30 Hz depending on the axis and type of magnet.

Noise on Beam Position Signals

There is noise on the beam position signals after the Bergoz electronics, used to convert the button signals to vertical and horizontal beam positions. To reduce this noise some averaging has had to be introduced, which impacts the bandwidth.

CONCLUSION

The new orbit correction system was commissioned in November 2021. This upgrade has improved reliability and maintainability, and has dramatically increased the diagnostic capabilities. The architecture supports easy integration of new functionality, providing the foundation for future enhancements.

ACKNOWLEDGEMENTS

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REFERENCES

[1] D-tAcq ACQ435ELF 32 Channel Simultaneous Sampling Digitizer, `https://www.d-tacq.com/acq435elf.shtml`

[2] D-tAcq ACQ2106 6 Site ELF Carrier, `https://www.d-tacq.com/acq2106.shtml`

[3] PoLabs PoKeys57E Ethernet Computer Numerically Controlled Controller, `https://www.poscope.com/product/pokeys57e/`.