BPM SYSTEM AND ITS DEVELOPMENT FOR THE STORAGE RING OF NSRRC

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Abstract

About 60 BPMs were installed in the storage ring of an NSSRC. High precision closed orbits were measured by Bergoz's MX-BPMs. Data were acquired by multi-channel 16-bit ADC modules. The orbit data was sampled every millisecond. Fast orbit data were shared by reflective memory network to support fast orbit feedback. The Averaged data were updated to control database at a rate of 10 Hz. Turn-by-turn beam position signals were processed by several Bergoz's log-ratio BPMs and recorded by a transient digitizer to support various beam physics study. Digital BPMs were installed at the storage ring to improve the BPM system functionality at the storage ring, supporting routine operation and study of beam physics. A preliminary test of Instrumentation Technologies' Libera digital BPM is ongoing. The system structure, software environment and performance of the BPM system are summarized in this report.

INRODUCTION

The storage ring of an NSRRC is a 1.5 GeV synchrotron light source. Orbit stability and multi-bunch stability are both very important for user service. The storage ring consists of six super-period triple-bent achromatic lattices. Multi-bunch instability was eliminated using the SRF cavity and multibunch feedback systems. Eight BPMs one wiggler, two conventional undulators (U5 and U9), one elliptical polarised undulator (EPU5.6), one superconducting wavelength shifter and one superconducting multi-pole wiggler were installed in each section. Extra BPMs were installed at the upstream and downstream the insertion devices to guarantee micro-level stability, except thermal, water flow measure. A BPM and orbit feedback system is essential to guarantee good orbit performance, especially when operating the undulator gap change and the EPU phase during an experimental scenario.

MULTIPLEXING BPM SYSTEM

A total of 58 button-type BPMs were installed. The orbit signal was process with Bergoz's MX-BPM [1]. The measured performance was around one micron for a 10 Hz orbit update rate. All MX-BPMs were synchronized externally with a common clock source to avoid the alias effect resulting from synchrotron sideband. To achieve μm level stability, the ambient environment of the BPM electronics was also monitored. The control system interface of the MX-BPM system and its relationship with corrector control and orbit feedback is illustrated in Fig. 1. The BPM server VME crate acquired orbit data every 1 msec. These fast orbit data were shared with an orbit feedback VME crate and a corrector control VME crate with a dedicated reflective memory network. The average slow orbit was updated to control the database every 100 msec. The orbit feedback node read the fast orbit data and compared them with the reference orbit data to execute the control rule, locking the orbit into in-loop BPMs. A typical orbit in a user shift is illustrated in Fig. 2. The beam position can be maintained at the μm level by an orbit feedback system even when undulator parameters are changed.

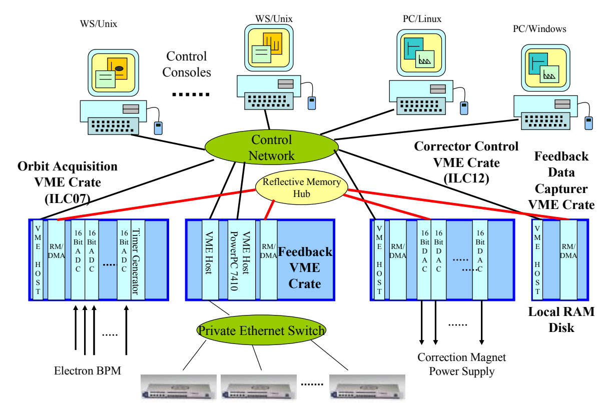

Figure 1: Software environment for BPM data access.

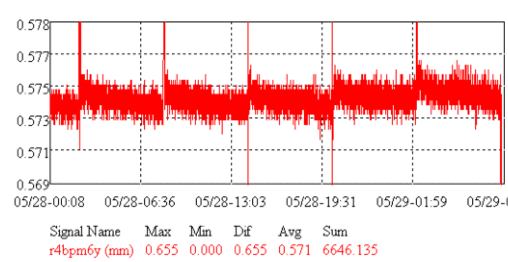

Figure 2: Typical long term beam position measured by in-loop MX-BPM, root mean square is less than 1 μm by the help of orbit feedback loop.

LOG-RATIO BPM

To measure the turn-by-turn beam position, several Bergoz's log-ratio BPM processors [1] were installed at the storage ring accompany with a digitizer to capture the turn-by-turn beam position data. The digitizer was clocked by the machine revolution clock, and triggered by the timing system to synchronize with the external excitation source. The system support mechanism has been widely studied during last several years [2, 3]. Resolutions better than 100 µm have been achieved.

DIGITAL BPM DEVELOPMENT

A digital BPM test-bed was set up at the storage ring to improve the functionality of the BPM system and support routine operation and various beam physics study [4]. The purpose of this test-bed is to measure and explore the potential and performance of the new technology for storage ring beam diagnostics.

Commercial DBPM2 products [5] were used for the first test. The experimental system comprised a multi-channel coherent down-converter and VME64x crate equipped with multi quad-digital receivers boards (QDR). Preliminary experimental results show that the system achieved micron resolution in the closed-orbit mode and high resolution in the turn-by-turn mode. Promising results were obtained from the test bed. To meet various operation conditions and measure the functionality and performance, the integrated system includes multi-channel access, channel calibration, gain control, and parameter control. The DBPM system must be programmable to calculate the multi-mode high precision beam position, turn-by-turn beam position, tune and other diagnostic measurements. A control system interface was implemented to support the DBPM system operation. A new architecture was designed to improve the integration and functionality of the digital BPM system. Libera products [5] were chosen as the DBPM integration candidates. Since the TLS is the operation user's facility, all functionality is in the operation. Providing seamless integration is necessary for the light source already in operation. Since the existing BPM system needs support routine operation and orbit feedback system, the integration and software environment emphasizes compatibility. The control system interface is separated into two layers. The front-end layer is a VME64x created with a PowerPC module running the real time operation system LynxOS. The user interface layer is located at a workstation/Unix and PC/Linux control console, supporting commercial software programs Matlab and LabVIEW. The VME host receives control parameters from the user interface via Ethernet. The user interface displays the DBPM data are transmitted on after receive a software trigger is received from the Ethernet. Fig. 3 shows the software environment. The DBPM test-bed is seamlessly integrated with the existing system. The preliminary operation environment for Libera is illustrated in Fig. 4. One VME crate is connected to a private network to acquire a low-precision orbit. The embedded server program running in Libera is interfaced with the firmware by a Control system programming interface (CSPI). Data in a slow orbit are updated at 10 Hz. Data from Libera in the turn-by-turn or post-mortem modes are accessed from the Linux server to simplify the programming effort. The fast orbit is connected to the VME crate directly via the fibre link with SFP interface in future. The fast data are then shared with existing BPM system using reflective memory.

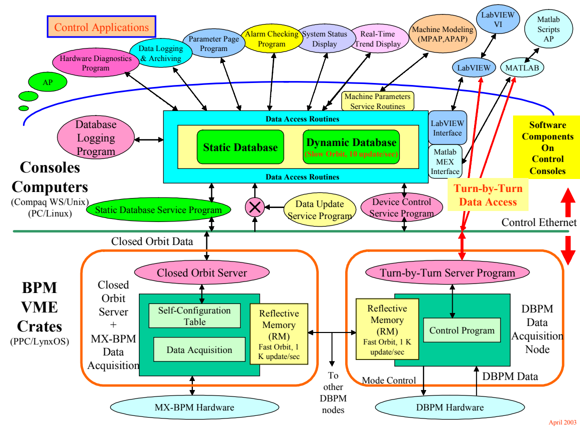

Figure 3: Software environment for DBPM data access.

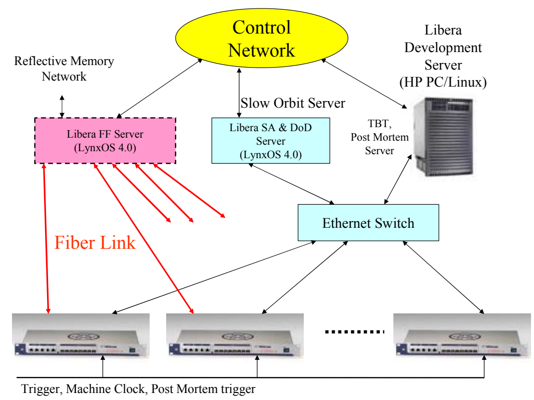

Figure 4: Block diagram of Libera data access.

PRILIMINARY TEST OF LIBERA BPM PROCESSOR

Preliminary tests were performed on the Liberal BPM processor. Most preliminary tests were performed on the integration environment and the functionality evaluation. A Libera processor is a multi-mode device which supports turn-by-turn, sub-micron precision beam position and tune monitoring. The control system need to various software packages to support the digital BPM operation. The features of the new BPM system include analog multiplexing BPM and user-transparent digital BPM. Seamless integration of these features is the most difficult task. Fig. 5 shows the typical response of the beam position when a kicker magnet is fired (K1 @ 3 KV, ~ 1.5 mrad kick). The top diagram in Fig. 5 illustrates the damped horizontal betatron oscillation. A small regular synchrotron oscillation signal rides on the envelope of the damped oscillation, because of residue longitudinal instability probably from the vacuum component of the storage ring. Vertical signal excitation was also observed; and may be due to the imperfection of the field distribution in injection kicker or machine coupling. Fig. 6 illustrates the horizontal phase space portrait of two BPM separated about π/2 phase advanced near fourth order resonance.

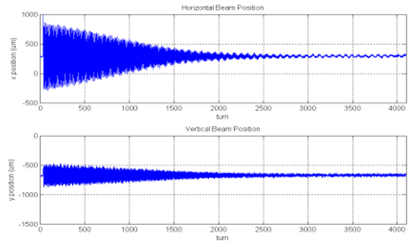

Figure 5: Turn-by-turn beam position measured by new digital BPM; upper is the horizontal beam position, and the lower figure is the vertical beam position.

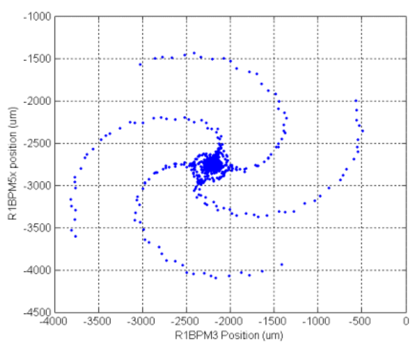

Figure 6: Horizontal phase space portrait of two BPM separated about π/2 phase advanced near 4th order resonance.

TUNE MONITOR

A dedicated tune monitor was implemented by using Libera. The proposed monitor is based on the Fourier analysis of the turn-by-turn data from the Liberas based on various beam excitation levels. Fig. 7 shows the system block diagram. The stored beam was excited by a narrow-band white noise or kicker. The excitation level was controlled by the software. The tune was extracted by Fourier analysis of the turn-by-turn beam position data. Very small beam sizes were magnified under adequate pink noise excitation. It may be compatible with a user not checking the beam condition.

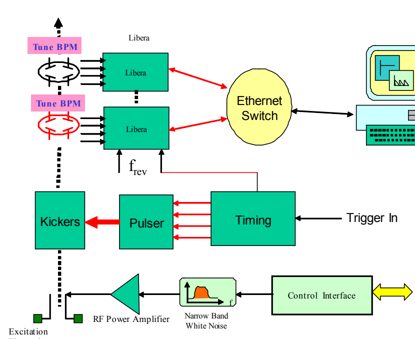

Figure 7: The block diagram of the tune monitor.

The clean tune spectrum is easy to obtain as shown in Fig. 8. The upper part of Fig. 9 displays the 128K-turn data captured by the Libera device on its large internal memory. The data show some beam instabilities in the vertical direction. An instantaneous tune extracted by the numerical analysis of fundamental frequency (NAFF) method is illustrated in the lower part of Fig. 9, showing no evidence of power line cycle tune variation. These findings demonstrate that the main storage ring power supplies ring have acceptable ripple values.

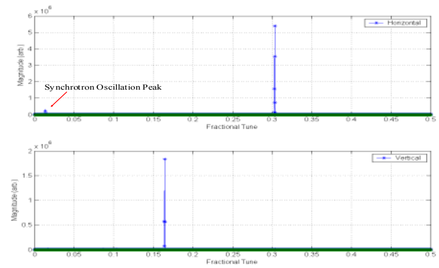

Figure 8: Tune spectrum obtained by Fourier analysis of data set in Figure 7.

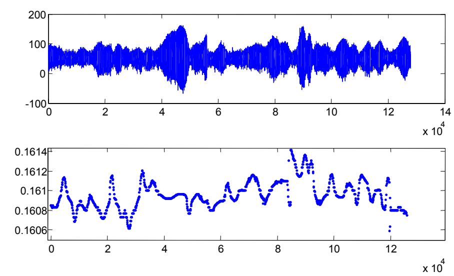

Figure 9: 50 msec turn-by-turn beam position measured data in y direction and its instantaneous tune extracted by NAFF method.

SUMMARY

This report summarizes the status and development of the beam position monitoring system at NSRRC. The short-term goals of this study were to improve the performance and reliability of the existing BPM system. New BPM electronics are being integrated with the monitoring system to improve its functionality. More testing is needed to verify the performance and the operation environment or the hybrid BPM system. Existing BPM and Libera systems are currently being combined to improve their performance and functionality.

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