LOCAL FEEDBACK EXPERIMENT IN THE TAIWAN LIGHT SOURCE

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Abstract

A highly-effective digital global feedback system has been developed to control closed-orbit error in the Synchrotron Radiation Research Center (SRRC). However, the beam orbit in SRRC is intrinsically so stable that a digital local feedback system may be preferred for some operating conditions. Consequently, a prototype digital local feedback loop has been developed and tested for suppressing orbit disturbances at the source point of a photon beamline. This prototype consists of a local orbit bump whose strength is dynamically controlled to preserve the beam trajectory. The measured bump response is used in this feedback system, and the controller uses a PID algorithm . Digital filtering is used to reduce the noise in beam position measurements. The hardware of the local feedback system is integrated with that of the global feedback system.

1 INTRODUCTION

A digital local feedback system (DLFB) [5, 6] has been developed to suppress orbit disturbances caused by low-frequency drift and insertion devices. First, a linear response matrix is measured by taking beam position monitor (BPM)reading when the corrector are individually perturbed. Then, this response matrix is used to design a local orbit bump. The feedback controller is based on PID algorithm [4]. Digital filtering [1] techniques were used to removed noise of electron beam position reading, to compensate eddy current effect of vacuum chamber, and to increase bandwidth of orbit feedback loop. The infrastructure of digital feedback system is composed of orbit acquisition system, gigabit fiber links, digital signal processing hardware and software, high precision digital-to-analog converters. The experimental results is presented in this report.

2 BPM DATA ACQUISITION AND CORRECTOR CONTROL

The configuration of feedback system is presently distributed in two VME crates. In the future, it will be configured to three nodes for operational version. Every crate will play its own role as beam position server, corrector server, and computation server. This arrangement is convenient for routine machine operation and DLFB system development. The sampling rate of system had been improved to 1 KHz. The single board computers of BPM and corrector control node had been upgraded to PowerPC with LynxOS from 68020 with pSOS+. High precision data input and output have been upgraded to 16 bit. The sampling rate of BPM data acquisition is easy to upgrade with present hardware.

3 LOCAL BUMP DEVELOPMENT ALGORITHM

The local bump is generated based on the beam response with respect to the corrector strength change in the storage ring. The theory of measured bump is based on the relation given in Eqs. 1.

$$y_{a2} = \delta_2 \frac{\sqrt{\beta_a \beta_2}}{2\sin \pi\nu} \cos(\pi\nu - |\Phi_a - \Phi_2|) \qquad (1)$$

where β_a , β_2 are beta function and Φ_a, Φ_2 are phase advance. δ_2 is the magnitudes of the kicks.

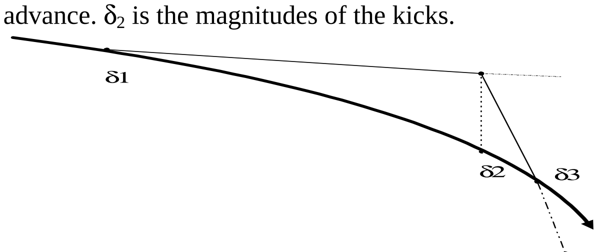


Figure 1: Three magnet bump.

A local orbit feedback system is based on a four-magnet local bump and is the major feedback mechanism to stabilized the beam trajectory in both angle and displacement. This four magnet bump is composed of two three-magnet bumps. Kicks of 3 magnet bump δ_1, δ_2 and d_3 are indicated in figure 1. The three magnet bump ratio is measured by two BPMs situated outside of the bump region.

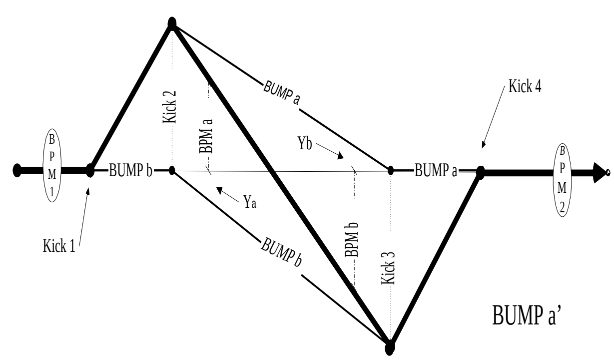


Figure 2: BUMP a’ of 4 magnet bump.

The bump ratio transformation between the bump strengths and beam positions is straightforward in the two independent three-magnet local bumps, a and b. Bump a and bump b are combined to form a four magnet bump, as shown in figure 2. The beam response with respect to the applied bump indicated in figure 2 follows the relations below:

$$[\Delta Y] = [T][\Delta K]$$

$$[T] = [\Delta Y][\Delta K]^{-1}$$

$$\delta \propto [T]^{-1}$$

where ΔK is kick deviation of strength, T is transformation between BPMs and Kicks, ΔY is BPM deviation of orbit, and matrix δ is a local bump ratio. $[T]^{-1}$ is proportional to bump ratio. Two BPMs must be selected between bump a and bump b in order to decouple these two bumps. In this way, this particular pair of 3 magnet bump is extended and become a 4 magnet bump. Contribution ratio of bump a and bump b to this four magnet bump can be subsequently determined through the following calculation.

$$\begin{bmatrix} Y_a \\ Y_b \end{bmatrix} = \begin{bmatrix} a_{11} & a_{12} \\ a_{13} & a_{14} \end{bmatrix} \cdot \begin{bmatrix} \delta_a \\ \delta_b \end{bmatrix}$$

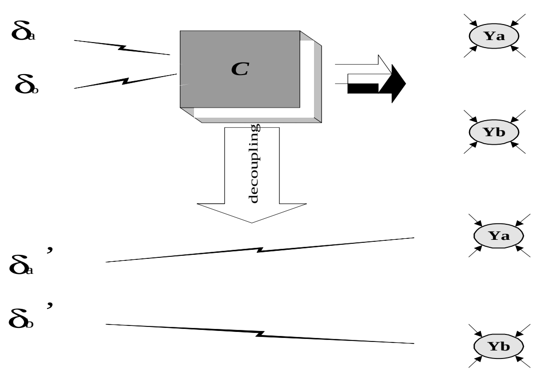


Figure 3: Decoupling of two 4-magnet bump.

$$\begin{bmatrix} b_{11} & 0 \\ 0 & b_{22} \end{bmatrix} = \begin{bmatrix} c_{11} & c_{12} \\ c_{21} & c_{22} \end{bmatrix} \cdot \begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{bmatrix}$$

Letting $c_{11} = c_{22} = 1$, we get

$$c_{12} = -\frac{a_{12}}{a_{22}} \qquad \delta'_a = \delta_a - \frac{a_{12}}{a_{22}}\delta_b$$

$$c_{21} = -\frac{a_{21}}{a_{11}} \qquad \delta'_b = -\frac{a_{21}}{a_{11}}\delta_a + \delta_b$$

4 CONTROL ALGORITHM

The control algorithm is applied to position error vector [5]. Control algorithm of the digital local feedback is executed in corrector and computation VME crates. The conventional PID controller function G(z) is given by

$$G(z) = K_p + \frac{K_i}{1 - z^{-1}} + K_d\,(1 - z^{-1})$$

where K_p, K_i, K_d are the proportional, integral, and derivative controller gains, respectively. The gain coefficients should be positive value for negative feedback. The desired response of feedback system can be adjusted by PID parameters to achieve control goals. Steady state error of local feedback system is close to zero when the open loop DC gain is large enough.

5 PERFORMANCE OF DIGITAL LOCAL FEEDBACK LOOP

The effectiveness of the local feedback system in suppressing orbit error was tested by introducing perturbation from two sources, the EPBM and U5. The results are shown in figure 4 and 5. The cutoff frequency of LPF is 60 Hz, and the combination of PID parameters are chosen to fulfill control goals in minimizing orbit change due to any type of perturbation. The PID parameters was not optimized yet. It will be modified together with promoting the bandwidth of feedback. Following description is based on the parameters $K_p = 0.3$, $K_i = 0.07$ and $K_d = 0.0$.

5.1 EPBM Perturbation

There are two recently installed devices at the storage ring. One is a elliptical polarization from bending magnet (EPBM). Orbit will be changed due to the bump leakage of EPBM [7]. The orbit changed without and with DLFB, while EPBM is working, is indicated in figure 4. The displacement of orbit is much smaller when the digital local feedback is turned on in comparison with the case when it was off.

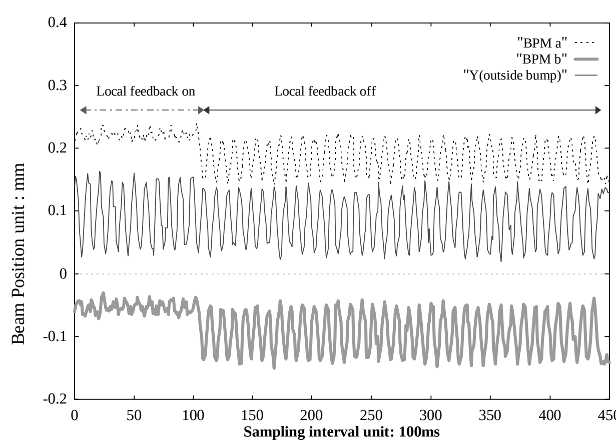
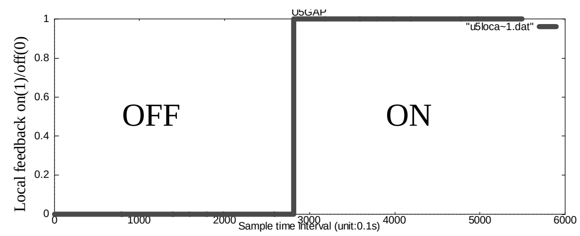


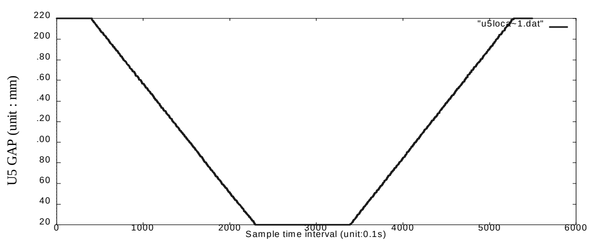
Figure 4: Difference orbit between feedback on and off with perturbation source: EPBM.

5.2 U5 Perturbation

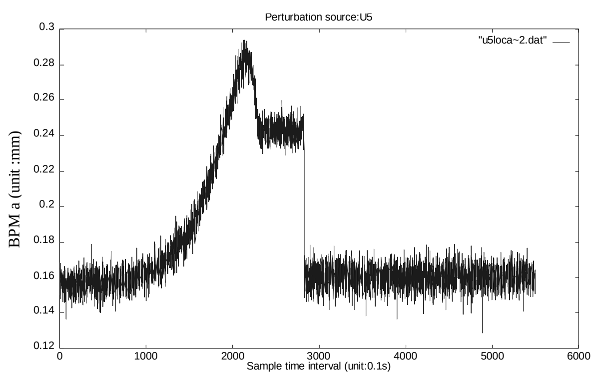
Another instrument is a 4-meters long undulator with 5 cm period (U5). Orbit will be changed due to beta beating and field errors of the insertion devices. The orbit is changed without and with DLFB while adjusting the U5 gap as indicated in figure 5. The difference orbit is defined to be the orbit changed between cases when gap is 219 mm and that of 20 mm. The displacement of orbit was much smaller when the digital local feedback was turned on in comparison with the case when it was off.



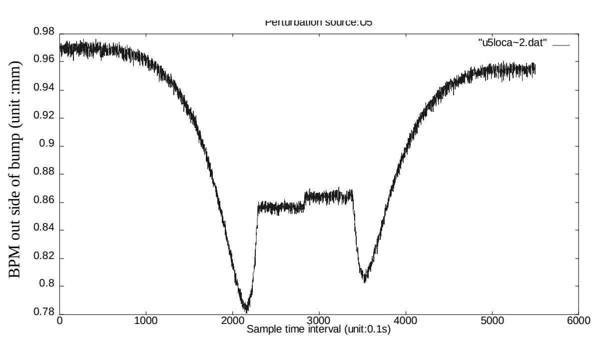
(a) Local feedback on/off



(b) U5 gap



(c) BPM a (inside bump)



(d) BPM 1 (outside bump)

Figure 5: Difference orbit between undulator open and closed with feedback on/off.

Feedback on(1)/0ff(0) is indicated in figure 5(a), and U5 gap motion is indicated in figure 5(b). BPM readings associated with the applied local bump is shown in figure 5(c). The others arbitrarily picked up BPM readings indicates that the orbit drift at that particular location is a obvious one , and the result is shown in figure 5(d).

5 CONCLUSION

A digital local feedback system has been developed at SRRC. The performance of this system will be improved as the hardware is upgraded and as we gain further operational experience.

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