DIGITAL GLOBAL ORBIT FEEDBACK SYSTEM DEVELOPING IN SRRC

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Abstract

The digital global orbit feedback system for the storage ring of SRRC has been upgraded in terms of its feedback bandwidth extension by increasing its data acquisition sampling rate and compensating eddy current effect of vacuum chamber with filter. This orbit feedback system has been applied incorporate with the insertion devices operation, such as U5 undulator and engineering model adjustable phase undulator. Eliminate orbit drift and low frequency oscillation is to continue effort.

1 INTRODUCTION

Work to improve beam stability continues during 1996 with improvement of the orbit feedback system. New BPM and data acquisition system is installed in the storage ring. In this paper , we will discuss the results of global beam position feedback experiments conducted on new insertion device in Synchrotron Radiation Research Center. Any vibrations and orbit drift that lead to distortions in the closed orbit will result in a larger effective emittance. Together with the brightness reduction, beam motion induced incident light position and angle varying can degrade the advantages of using synchrotron light. Insertion devices are essential to produce high brilliance synchrotron radiation, however it influences the electron orbit and the lattice of storage ring. Global feedback system is used to eliminate these undesirable effects. From control points of view, global feedback is an typical multiple input multiple output (MIMO) problems. Technical, it is difficult to implement an analog matrix operation consisting of large amount of BPMs and correctors. Consequently, digital processing was used here to implement global feedback system.

BPM resolution has to be better than 3 um, decoupling the interference between global and local feedback loops [7], integrating these two feedback loops for better tunability, bandwidth of 10 - 100 Hz is necessary to suppress vibration and power supply ripple related beam motion, etc. The global feedback system is integrated with the existed control system. BPMs data and correctors readback are updated into control system dynamic database in the period of 100 msec. Digital global feedback system is bounded on I/O as well as computation. It is important to arrange the real time task and to arbitrate computer bus properly in order to optimize system performance.

2 CONTROL ALGORITHM

The global orbit feedback system includes 19 BPMs and 18 correctors in the vertical plane for this study. The response matrix of the system was measured by vertical beam displacement while sequentially varying the corrector strengths, and then is inverted by SVD [1, 2] skill. This method is part of the extension of local feedback technique. The advantage of the method used in this system is that it isn sensitive to the beam instability while measuring the response matrix.

A schematic diagram of the feedback system is shown in figure 1. The position error vector $[\Delta y]$ is filtered by a LPF [4] in order to compensate the system response dominated by eddy current effect of vacuum chamber. Filters are also used to extend close loop bandwidth and to eliminate processing noise.

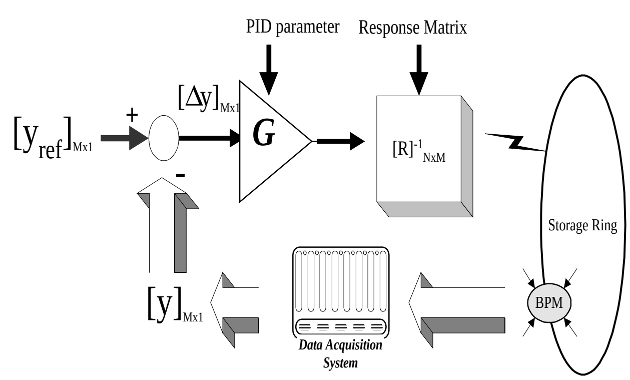

Figure 1: Block diagram of digital global feedback.

Then control algorithm is applied to position error vector. Control algorithm of the digital global feedback is executed in corrector and computation VME crate. 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

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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 global feedback system is close to zero when the open loop DC gain is large enough. Therefore long-term drift can be completely corrected. Output vector from PID controller is multiplied with the inverse-model matrix (R^{-1}) and is sent to correctors for mend orbit.

3 SYSTEM STRUCTURE

The hardware configuration of the corrector control system in SRRC is described in figure 2. The low layer is a VME system based single board computer which includes a PowerPC 603 CPU board and I/O interface cards. The CPU board consists of a PowerPC microprocessor, 32 megabyte on-board memory, RS-232, PMC and Ethernet ports. The frontend devices are connected to this system via interfaces for analog I/O, digital I/O etc. An power PC based server system is used as the TFTP file server for download OS and mounted disk of network file server (NFS). All application programs are put on server disk. These programs are developed and debugged on client node to relief loading of server. The real-time multi-tasking kernel on the VME bus single board computer. It provided a satisfactory performance, reliability, and a rich set of system services. New device is easy to be created by that only modify device table file as if on line editing. The system can automatically boot and execute different applications in each VME node with the same operation system environments. The upload process will be removed when global feedback is on. This process handle device (analog input) and send acquisition data to database when receives the broadcast upload message from the Ethernet in each 0.1 second. The system timing had been improved to 1 ms by VME interrupt.

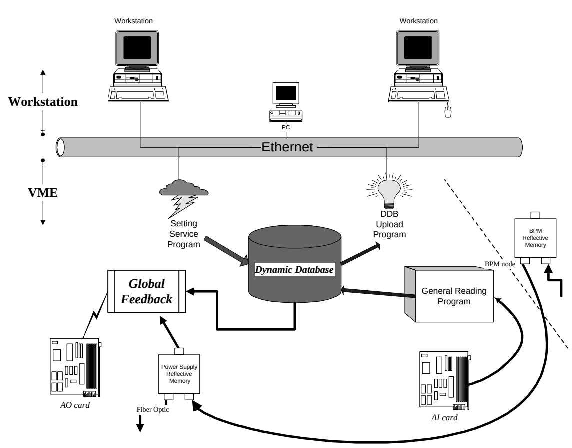


Figure 2: System diagram of corrector node.

Intrinsically, the performance of feedback system is limited by BPM resolution. The BPM processing electronics are based switched electrodes design, which is widely used around synchrotron radiation facilities. The BPM data is acquired by 16 bit A/D cards which are installed at one VME crate. The crate is used as orbit server. The orbit server provides fast beam position information to be used for feedback loop. It also provides slow orbit information for centralized database. The fast orbit information is sent via gigabit fiber linked reflective memory to corrector and computation needs in the VME crates.

Present system consists of two VME crates, i.e. orbit server VME crate, and corrector and computation VME crate. Within corrector and computation server, a VME bus to ISA bus adapter is used to provide PC and VME crate communication. The bus adapter is fit onto slot 1 of VME crate as system controller. All programs were developed and debugged on PC and downloaded to DSP board. The DSP board carrying TMS320C40 module handles all signal processing, including a digital low pass filter (LPF) and PID controller [5]. It takes 1 ms to complete feedback processes including operation of PID, digital low pass filtering, matrix operation, BPMs data reading from reflective memory, and corrector settings. The corrector setting had been upgrade to 16 bit DAC to achieve sub-μrad steering resolution. All parameters can be remotely adjusted from graphical users interface of control system.

4 ERFORMANCE OF DIGITAL GLOBAL FEEDBACK LOOP

Test results of the global feedback system has been done with changing the gap of insertion devices and externally applied perturbation. The results are shown in figure 3, 4 . The cutoff frequency of LPF is 60 Hz, and the combination of PID parameters are chosen to fulfill control goals to minimize 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 was based on the parameters $K_p = 0.8$, $K_i = 0.03$ and $K_d = 0$.

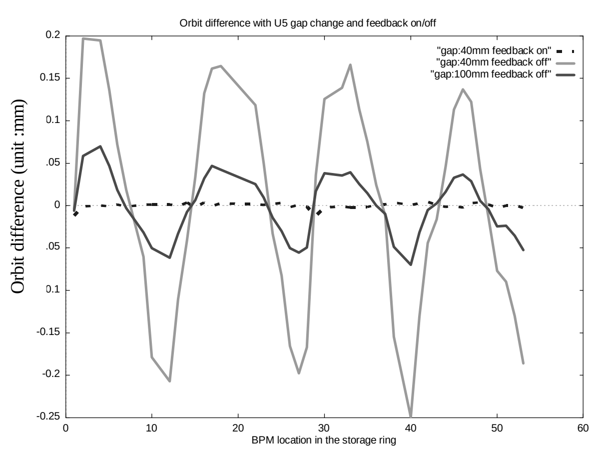
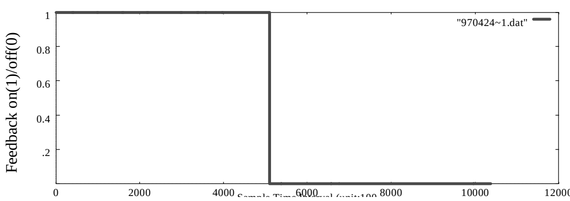
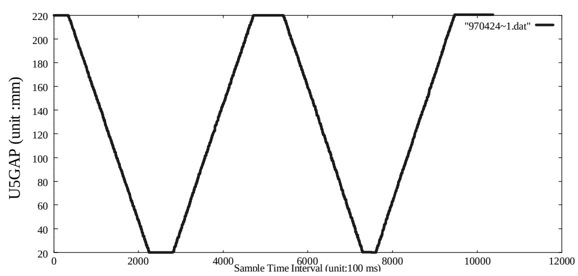


Figure 3: Orbit difference with U5 gap change and feedback on/off.

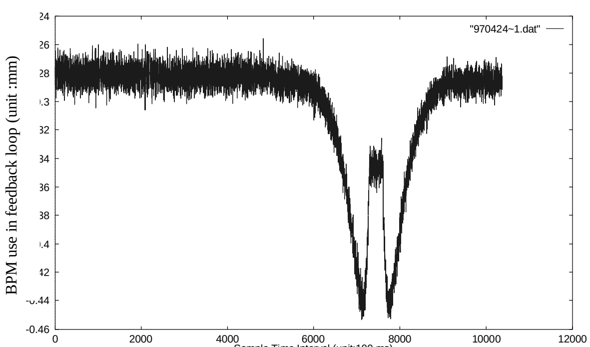
There is a new installed insertion device at the storage ring. One is a 4-meters long prototype undulator with 5 cm period (U5). Orbit will be changed due to beta beating and field error of the insertion device. The orbit changed without and with DGFB while adjusting the U5 gap as indicated in figure 3. The difference orbit is defined to be the orbit changed at 100 mm and 40mm from 219mm of U5 gap. The displacement of orbit was much smaller when the digital global feedback was turned on in comparison with the case when it was off.



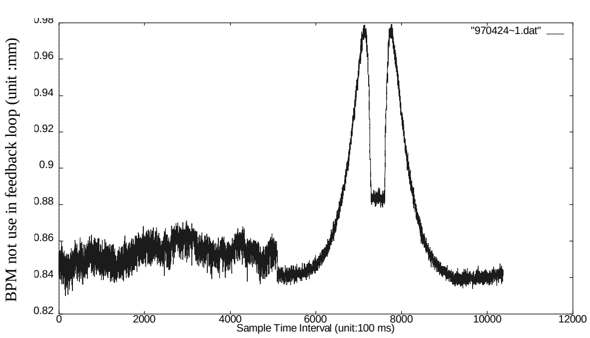
(a)



(b)



(c)



(d)

Figure 4: Difference beam position between undulator open and close with feedback on/off.

At present, only 19 out of 53 BPMs and 18 correctors were used in the vertical feedback system. It was noticed that at some of the BPM locations when gap change from 219 mm to 20 mm, as indicated in figure 4., the beam orbit difference were relatively larger than others. These BPMs were found to be those which were not included in the feedback loop. Orbit difference is showed in figure 4(c) when BPMs is in feedback loop. Conversely, is showed in figure 4(d). Further study is needed in order to improve the performance of the feedback system. However, its seems that feedback loop will deteriorate beam quality. This isn a general case, this is cause by feedback loop parameters mistune. Increase robustness of the feedback system by various techniques is under way.

5 CONCLUSION

Performance of the DGFB system will be improved as we gain operation experience and hardware upgraded. Furthermore, horizontal DGFB will be implemented in analog with the vertical DGFB. The configuration of feedback system will be distributed in three VME crates for operational version. Every crate will play its own role as beam position server, computation server, and corrector server. This arrangement is convenient for routine machine operation and DGFB system development.

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