Orbit Feedback Development In SRRC

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Abstract

A project of global and local orbit feedback system had been launched in the Synchrotron Radiation Research Center (SRRC). In this paper, we will discuss the suppressant results of orbit feedback experiments with various vibrations and orbit drift that lead to distortions in the closed orbit and result in a larger effective emittance. Together with the brightness reduction, beam motion induced incident light position and angle variation 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. Feedback system is used to eliminate these undesired effects. From control points of view, orbit feedback is an typical multiple input multiple output (MIMO) problems. Technically, it is difficult to implement an analog matrix operation consisting of large amount of beam position monitors (BPMs) and correctors. On the other hand, the flexibility of system development is considered. Consequently, digital processing was used here to implement feedback system.

1 Introduction

The insertion devices are essential to produce high brilliance synchrotron radiation. However it influences the electron orbit and the lattice of storage ring. Orbit feedback system is used to eliminate these undesirable effects. Work to improve beam stability had been carried out during 1997 with improvement of the orbit feedback system. New BPM, photon BPM and data acquisition system were installed in the storage ring. The 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 with the insertion devices operation, such as U5 undulator and adjustable phase undulator (APU). Eliminate orbit drift and low frequency oscillation is to continue effort. In this paper, we will discuss this new structure and the results of beam position feedback experiments conducted on new insertion device.

2 Control structure

A digital orbit feedback system (DOFB) [1, 2] 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 correctors are individually perturbed. Then, this response matrix is used to design a local orbit bump. The feedback controller is based on PID algorithm [3]. Digital filtering [4] techniques were used to remove 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 orbit feedback system is composed of orbit acquisition system, gigabit fiber links, digital signal processing hardware and software, high precision digital-to-analog converters. The model of storage ring is acquired by measured method. It is transferred to control model for feedback that is based on singular value decomposition. The control loop structure is shown in figure 1.

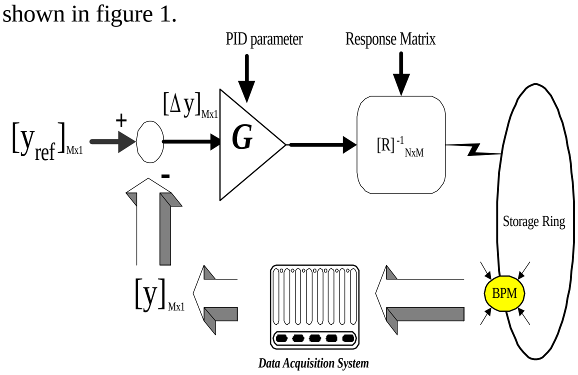

Figure 1. Control block diagram.

There are two orbit feedback systems in this control loop. One is local feedback, and other is global feedback. In order to integrate these two feedback loops for better tune-up, bandwidth of 10 - 100 Hz is necessary. These feedback systems are 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 orbit 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.

2.1 Hardware structure

The hardware configuration of the corrector control system in SRRC is shown in figure 2. The low layer is a VME crate system includes a PowerPC 604e CPU board and I/O interface cards. The CPU board consists of a PowerPC microprocessor, 32 megabytes on-board memory, RS-232, PMC sites and Ethernet ports. The front-end devices are connected to this system via interfaces for analog I/O, digital I/O etc. A PowerPC based server system is used as the TFTP file server for downloads 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 kernels are embedded in a single board computer of the VME bus. 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 handles 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.

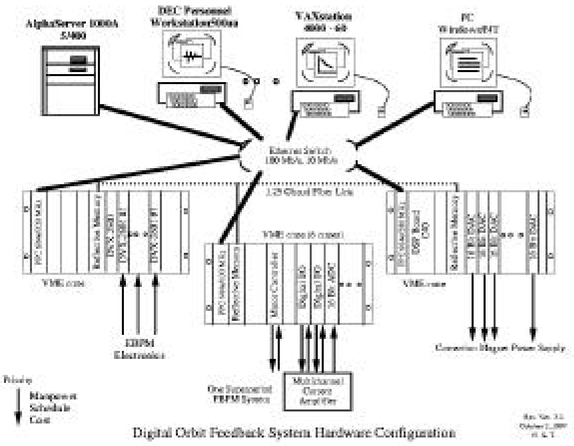

Figure 2. Hardware structure of system

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. It takes 1 ms to complete feedback processes including operation of PID, digital low pass filtering, matrix operation, BPMs data reading from reflective memory (RM), and corrector settings. The corrector setting had been upgrade to 16 bit DAC to achieve sub-*u*rad steering resolution. All parameters can be remotely adjusted from graphical users interface of control system.

2.2 Photon beam position monitor data acquisition

Intrinsically, the performance of feedback system is limited by BPM and PBPM resolution. The PBPM processing electronics are based on electrometer, which is commercial product. The PBPM data is directly acquired from pre-amplifier of electrometer by A/D channel of VME crate with 7 slot, which are distributed in beam line. These crates are used as PBPM server node. It contains that PowerPC 604, reflective memory and 16 bit A/D card in each crate. The upper plate and low plate signals of PBPM are sent to PowerPC with VME bus. The vertical signals are sent to RM with PMC bus after transformation processing of two plates. This loop is synchronized with 1 ms PMC interrupt that is requested by server crate with RM and fiber link. There is 133 Mbyte per second data communication in PMC bus, to provide large amount and fast PBPM data transfer. All data are collected to BPM server node. 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.

2.3 Software structure of system

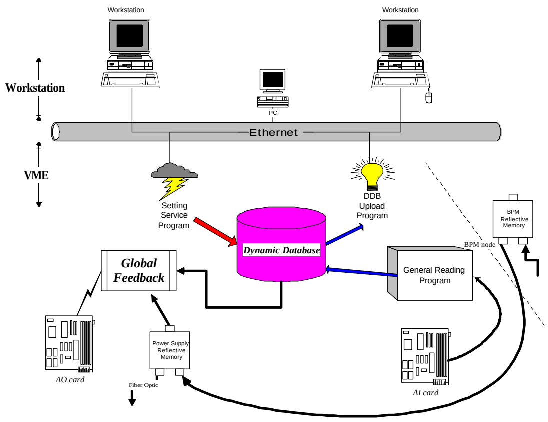

Figure 3: Software diagram of system

The corrector node is supplied to corrector control with PowerPC, 16 bits D/A card and DSP card. The structure of application software is described in Fig 3. There are some process tasks in PowerPC. The setting process handles corrector setting when setting command arrives from database. It spawns child tasks to process all setting requests corresponding tasks to each incoming UPD facility setting packet. The reading process is triggered by the external 10 Hz clock from the network when receives the broadcasted upload message from Ethernet, and sends an event to wake up the data acquisition process. The increased I/O card is easily updated by modified configuration table file. All acquired data are broadcasted to Ethernet in every 0.1 s. The server of shared memory is supplied by DDB process that is to communicate between reading process and setting process. It also provides the data access to extra process.

3 Performance of digital orbit feedback loop

Performance of the orbit feedback system has been tested with changing the gap of insertion devices and externally applied perturbation. The results are shown in figure 4, 5 and 6. The cutoff frequency of LPF is 60 Hz, and the combination of PID parameters are chosen to fulfill control goals to minimize orbit changes due to various type of perturbation. The PID parameters were not optimized yet. It will be modified together with promoting the bandwidth of feedback. The test results shown below were based on the parameters $K_p = 0.8$, $K_i = 0.03$ and $K_d = 0$.

3.1 Perturbation with U5 gap change

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

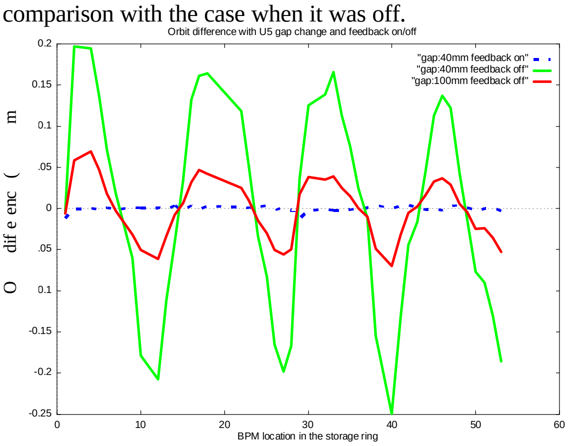

Figure 4: Orbit difference with U5 gap change and feedback on/off.

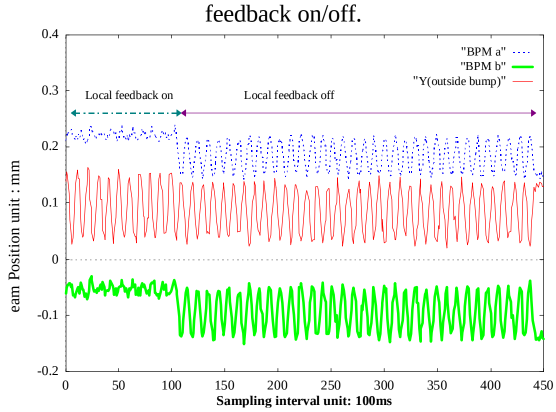

Figure 5: Difference orbit between feedback on and off with perturbation source: EPBM.

3.2 Perturbation from EPBM

It was notices that the orbit will be changed due to the bump leakage of elliptical polarization from bending magnet (EPBM) [5]. The orbit changed without and with DOFB, while EPBM is working, is indicated in figure 5. The displacement of orbit is much smaller when the digital local feedback is turned on in comparison with the case when it was off.

3.3 The PBPM of U10 beam line

The observed PBPM prototype signal of U10 beam line was drifting during the experiment, as shown in figure 6. The reading of PBPM can be come back reference position when DOFB was applied onto the associated feedback loop, the photon beam position was locked to the reference orbit. The orbit drift will be continued after feedback is off. The spike from feedback off to on can be cleared if adjusted PID parameters properly, in the cost of a reduced bandwidth.

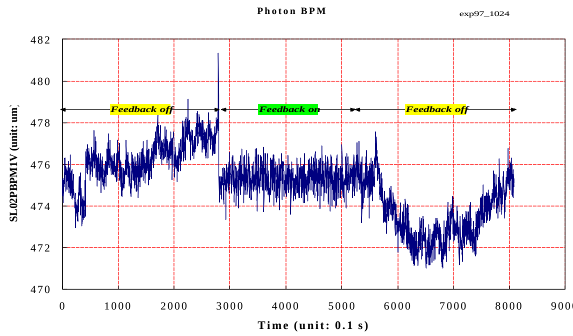

Figure 6: Photon BPM with feedback on/off.

4 Conclusion

A digital orbit 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 experiences.

Acknowledgements

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