

## ORBIT FEEDBACK SYSTEM FOR THE STORAGE RING OF SRRC

C. H. Kuo, Jenny Chen, C. J. Wang, K. H. Hu, C. S. Chen, K. T. Hsu, SRRC, Hsinchu, Taiwan

### Abstract

The orbit feedback system plays crucial roles for the operation of the 3<sup>rd</sup> generation light source. There are various issues in the orbit feedback system that should be addressed to achieve ultimate performance. The orbit feedback system in SRRC was upgraded recently to satisfy the requirement of demanding users. Based upon operational experiences of the last few years, the new system was designed with more robustness and flexibility. Performance analysis tools are also developed to monitor system performance. Algorithms for feedback control, data acquisition and analysis are described and measurement is also presented.

### 1 INTRODUCTION

The orbit feedback system is used to eliminate orbit excursion due to various perturbation sources. Work to improve orbit stability started to form in 1995 with the orbit feedback system. This orbit feedback system has been incorporated with the insertion devices operation, include undulator (U5 and U9) and elliptical polarized undulator (EPU5.6). Suppressed orbit drift and low frequency oscillation was also achieved. The orbit feedback system for the storage ring of SRRC is being upgraded to improve its performance. The effort includes increased feedback bandwidth, increasing sampling rate, compensating eddy current effect of vacuum chamber with filter, and enhance performance and robustness of the control rules. In this report, we will summarize the status of the orbit feedback development in SRRC.

### 2 EXISTING ORBIT FEEDBACK SYSTEM

A digital orbit feedback system [1,2] had been developed to suppress orbit disturbances caused by long-term drift, low-frequency oscillation and perturbation from insertion device operation. First, a linear response matrix is measured by taking electron beam position monitor (BPM) readings when the corrector is individually perturbed. Then, this response matrix is used to design a local orbit bump. The feedback controller is based on a PID algorithm. Digital filtering techniques were used to remove noise from the electron beam position reading, to compensate the eddy current effect of the vacuum chamber, and to increase the bandwidth of the orbit feedback loop. The infrastructure of the digital orbit feedback system is composed of the orbit acquisition system, gigabit fiber links, digital signal processing hardware and software, and high precision digital-to-analog converters. From a controls point of

view, the orbit feedback is a typical multiple input multiple output problem. The basic concept of the orbit feedback system is shown in the Figure 1. Technically, it is difficult to implement an analog matrix operation consisting of large amounts of BPMs and correctors. Consequently, a digital based feedback system is a natural way to implement orbit feedback system.

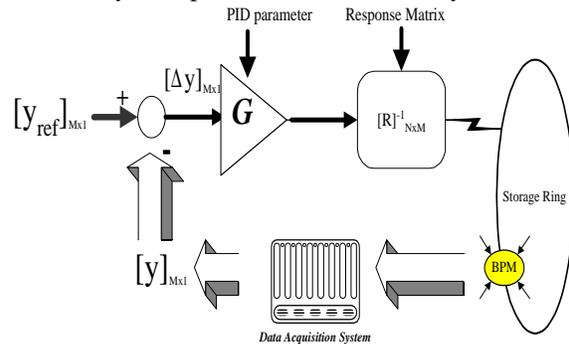


Figure 1. Basic concept of the orbit feedback system

There are two orbit feedback system in this control loop. One is local feedback, and another is global feedback. Integrating these two feedback loops yield better coordination. A system bandwidth of 10 - 100 Hz is necessary to suppress vibration and power supply ripple related beam motion, etc. The feedback system is integrated with the existing control system. BPM data and corrector readbacks are updated into the control system dynamic database in the period of 100 msec. The digital feedback system is bounded on I/O as well as computation. It is important to arrange the real time task and to arbitrate the 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 including a PowerPC 604e CPU board and I/O interface cards. The front-end devices are connected to this system via analog and digital I/Os. A PowerPC based server system is used as the TFTP file server for OS downloads and mounted disk for the network file server (NFS). All application programs are put on the server disk. These programs are developed and debugged on client nodes to relief loading of server. The real-time multi-tasking kernel on the VME bus single board computer provided satisfactory performance, reliability, and a rich set of system services. A new device is easy to create by modifying the device table file

as if editing on line. The system can automatically boot and execute different applications in every VME node with the same operation system environments. The upload process handles device (analog input) and sends acquisition data to the database when it receives the broadcast upload message from the Ethernet every 0.1 second. The sampling rate of the feedback loop is 1 kHz by VME interrupt.

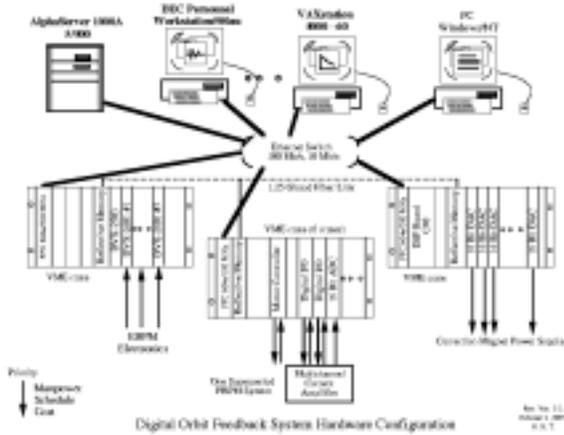


Figure 2. Hardware architecture of the orbit feedback system.

The present system consists of two VME crates, orbit server VME crate, corrector and DSP VME crate. The orbit server acquires BPM data every 1 msec and transfers the BPM data to the corrector node by the aid of reflective memory. The host processor also provides average BPM readings and updates to the control database every 100 msec, the average number is programmable. A JTAG emulator is used for the development of the DSP program. The bus adapter is fit in slot 1 of the VME crate as system controller. Feedback software was developed and debugged on a PC and downloaded to DSP board via a front panel JTAG port. The DSP board, carrying two TMS320C40 TIM modules, handles all signal processing, including a digital low pass filter and PID controller. It takes 1 ms to complete feedback processes including data input, operation of PID, digital low pass filtering, matrix operation, BPMs data reading and corrector settings. The corrector setting has been applied to multi-channel 16 bit DACs with sub-micrad steering resolution. It is allowed remote adjustment when the corrector setting from the graphical users interface feedback loop is turn on.

Intrinsically, the performance of the feedback system is limited by BPM and PBPM resolution. The PBPM data is directly acquired from a multi-channel electrometer by the A/D channel of the VME crate, which are distributed to the beam line. These crates are used as PBPM server nodes. It contains a PowerPC 604, reflective memory and a 16 bit A/D card in each crate. The upper plate and low plate signals of PBPM are sent to the PowerPC with the VME bus. The vertical signals are sent to RM with the

PMC bus after transformation processing of two plates. This loop is synchronized with a 1 ms PMC interrupt that is requested by the server crate with RM and fiber link. There is 133 Mbytes per second data communication in the PMC bus, so it is provided for PBPM data transfer quickly and largely. All data is collected at the BPM server node. The orbit server provides fast beam position information to be used for the feedback loop. It also provides slow orbit information for the centralized database. The fast orbit information is sent to the corrector via gigabit fiber linked reflective memory and computation needs in the VME crates.

## 2.2 Software structure of system

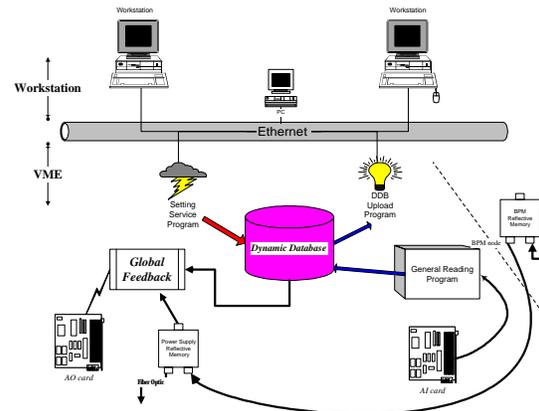


Figure 3: Software structure of the orbit feedback system.

The corrector node is supplied to corrector control with a PowerPC, 16 bit D/A card and DSP card. The structure of the application software is described in Figure 3. There are some service tasks in the PowerPC. The setting task handles corrector settings when the setting command arrives from the database. It spawns child tasks to process all setting requests corresponding to each incoming UPD facility setting packet. The reading process is triggered by the external 10 Hz clock from the network when it receives the broadcast upload message from Ethernet. And sends an event to wake up the data acquisition process. The data acquisition process is directly controller by remote login. The increased I/O card is easily updated by modifying the configure table file. All acquired data is broadcast to Ethernet every 100 ms. The DDB process is the server of shared memory that coordinates the communication between the reading process and setting process. It also provides the data access from another process.

## 3 AN EXAMPLE APPLICATION OF THE ORBIT FEEDBACK SYSTEM

Changing gap and phase parameters of insertion devices is essential in the operation scenario of a modern light source. Residue fields from the insertion devices are the major perturbation source leading to orbit excursion. It is hard to eliminate with lookup table compensation

schemes. In routine operation of the storage ring, look-up table scheme is used to reduce orbit excursion and orbit feedback system is used to keep the orbit change within micron level. During the gap change of U5 (4-meters undulator with 5 cm period), the orbit changes due to field error. The orbit changed without and with global orbit feedback while adjusting the U5 gap as indicated in Figure 4. The difference orbit is defined to be the orbit changed at 100  $\mu\text{m}$  and 40mm from 219mm of U5 gap. The displacement of the orbit was much smaller when the digital global feedback was turned on in comparison with the case when it was off.

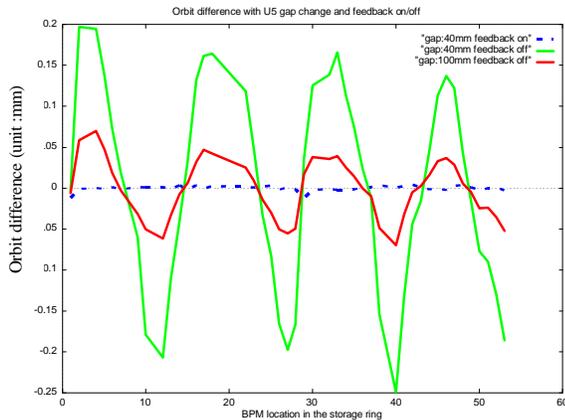


Figure 4: Orbit difference with U5 gap change and feedback on/off.

#### 4 ORBIT FEEDBACK SYSTEM UPGRADE

Upgrading of the orbit feedback system is underway. It is planned that the new system will put into operation in early 2002. There are several reasons for the upgrade: Firstly, to improve system maintainability and stability. The DSP board of the original feedback system is embedded in the corrector control VME crate. It is inconvenient for the development of the feedback system, interference between machine operation and feedback loop R&D is a troublesome problem. Secondly, the system was implemented in 1995 with a slow DSP board; the functionality of the feedback loop is limited. There is not enough computing power to handle the increase demand of the number of BPMs and correctors. The selection of control algorithms is also limited. In the new implementation, the DSP board is located in a separate VME crate. An Ethernet based DSP development system was selected to provide remote access capability. The corrector node is loosely coupled to the DSP VME crate. There are three VME crates in the upgraded system: BPM node, corrector node and DSP node. These three nodes are connected by reflective memory. Several of the fiber link reflective memory cards are tied together by one dedicated reflective hub that simplifies the wiring of

the fiber link. The corrector node handles power-supply control. The DSP node handles graphic interface connection of feedback control, calculation of control algorithm and signal conversion from orbit information to correction of corrector. The correction value results are sent to the corrector node and notice the host processor of corrector node by interrupt. The functional block diagram is shown in Figure 5. The planed photon BPM information is sent to the DSP node by a private fast Ethernet network. Local data acquisition for PBPMs are planned to use a compact PCI crate system. In the meantime, this data is sent to the database of console level with the control network.

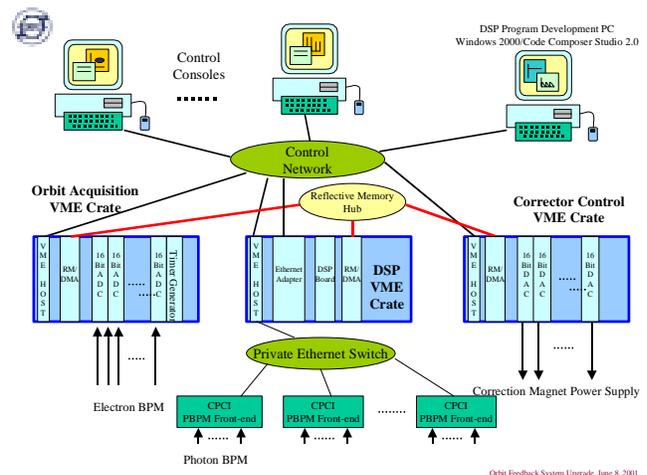


Figure 5: Functional block diagram of the upgrading orbit feedback system.

#### 5 CONCLUSION

An orbit feedback system was developed at SRRC in 1995. To satisfy the requirement of demanding users, the system is being upgraded now. The new system will provide sufficient computing power to execute various control rules and improve the system maintainability at the same time. The performance of this system will be improved as the hardware and software is upgraded and eliminated in any shortage of the existing system.

#### REFERENCES

- [1] C. H. Kuo, et al., "Local Feedback Experiment in the Taiwan Light Source", Proceedings of 1997 IEEE Particle Accelerator Conference, Vancouver, 1997.
- [2] C. H. Kuo, et al., "Digital Global Orbit Feedback System Developing in SRRC", Proceedings of 1997 IEEE Particle Accelerator Conference, Vancouver, 1997.