STATUS OF SSRF FAST ORBIT FEEDBACK SYSTEM

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Abstract

As the 3rd generation light source, Shanghai Synchrotron Radiation Facility (SSRF) are pushing the requirement of beam stability to sub-micron in the range of DC to 100Hz. To satisfy this requirement, fast orbit feedback system is introduced into SSRF, which consists of 40 eBPMs and 60 correctors (horizontal and vertical). In this paper, the system structure, the structures of its hardware & software and system performance are presented. At last, the design of mixed orbit feedback system (slow & fast orbit feedback system) is discussed.

INTRODUCTION

SSRF fast orbit feedback system (FOFB) consists of 40 eBPMs and 60 correctors (horizontal and vertical), which layout is shown in Fig. 1. The sampling rate of FOFB system is about 10kHz, and the analogue bandwidth of fast corrector and BPM system for FOFB system is up to 1kHz. [1] [2]
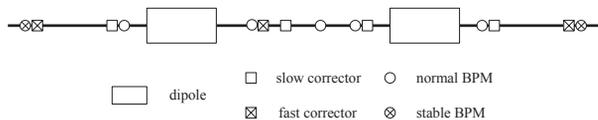
Figure 1: FOFB system devices layout in one cell.

SYSTEM STRUCTURE

SSRF FOFB system is the distributed control system, which electronics are installed in 10 stations. In each station, there are 2 VME SBC computers, 4 BPM electronics, 12 power supply controllers (for 6 correctors), 1 reflective memory and 1 timing module (EVR).

System Structure

In FOFB system, the distributed computing is implemented. The orbit data could be shared in all 10 stations by the reflective memory networks, and the corrector settings could be calculated in the individual stations.

The global orbit feedback algorithm is introduced, in which the pseudo inverse matrix, generated by SVD method, is used for calculating the correctors setting.

PID controller is used in FOFB feedback system, but P coefficient (proportion) and I coefficient (integrate) are mostly used in our system. The FOFB system performance of orbit noise suppression bandwidth is largely dependant with PID controller parameters.

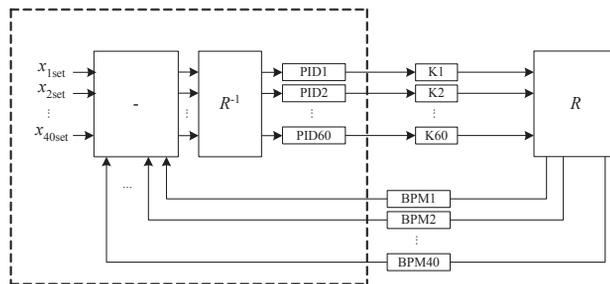The whole FOFB system structure is shown in Fig. 2.

Figure 2: The FOFB system structure.

Hardware Structure

The dedicated gigabit Ethernet port in Libera, as BPM electronics, is implemented in FOFB system, which the data rate is about 10kHz and bandwidth is about 1kHz. To reduce the latency of frame decoding, the universal gigabit Ethernet module (PMC module) is used to receive beam orbit data from Libera, and raw frame decoding (no UDP/IP protocol) is used to extract orbit data from Libera data frame.

In order to achieve the 10kHz sampling rate of FOFB system, two VME SBC computers are implemented, which one computer is used to receive orbit data from Libera, and another is used to calculate correctors setting. The detailed feedback operation sequence is described in next section.

The timing module is used to synchronize the operation sequence of all 10 stations by VME interrupt mechanism. The dedicate event code, which is generated by FOFB clock in SSRF timing system (about 10kHz), is mapped into VME interrupt in EVR setting of each station. By this design, FOFB task in each station could be triggered by VME interrupt in the same time.
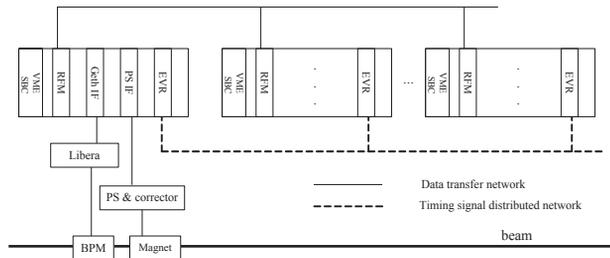
The hardware structure is shown in Fig. 3.

Figure 3: Hardware structure of SSRF FOFB system.

Software Structure

SSRF FOFB system runs at vxWorks 5.5.1/EPICS base-3.14.8.2 platform. The software structure is shown in Fig. 4.
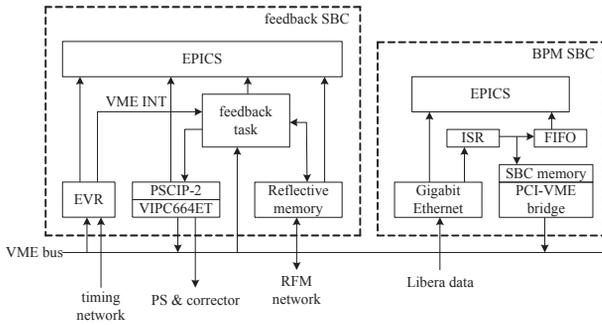
Figure 4: Software structure of SSRF FOFB system.

There are two VME SBC computers in each station, so two IOCs run in each station. One IOC (BPM SBC) is used to receive orbit data, and triggered by Ethernet data frame. When an orbit data frame arrived, BPM SBC IOC is triggered and extracts orbit from Ethernet frame, then stores orbit in SBC memory. Another IOC (feedback SBC) attains orbit data through VME bus, and pushes orbit of this station into reflective memory network. Feedback SBC IOC is triggered by EVR and gets all eBPMs orbit from reflective memory network, then calculates corrector settings and downloads these settings to power supply.

The whole operation sequence of SSRF FOFB system is shown in Fig. 5. The total latency is about 700us, 7 periods of FOFB system feedback.
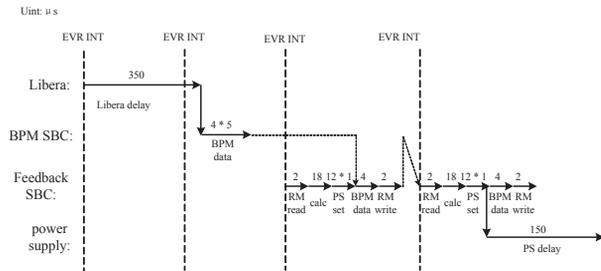

Figure 5: Operation sequence of SSRF FOFB system.
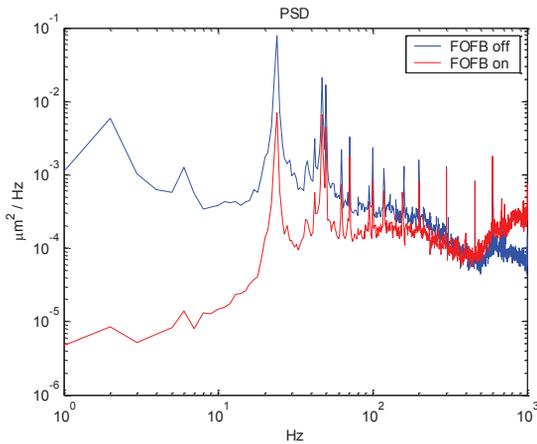
SYSTEM PERFORMANCE
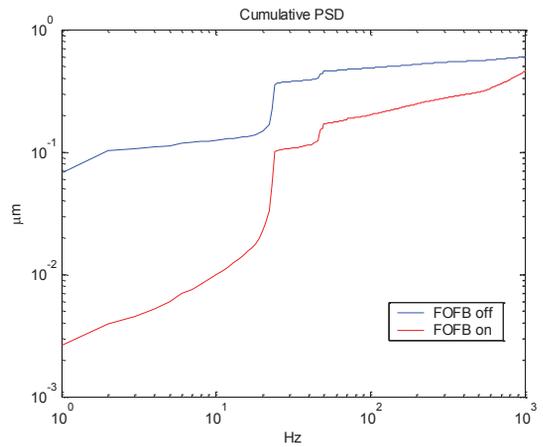

Figure 6: Orbit PSD in horizontal plane.

Figure 7: Cumulative orbit PSD in horizontal plane.

Orbit PSD and cumulative PSD in each plane (Horizontal and vertical) are shown in Fig. 6 – 9. Orbit PSD is calculated from Libera orbit data (10kHz sampling rate and 1kHz analogue bandwidth). From these figures, the orbit noise suppression bandwidth in each plane could reach to 100Hz or above.
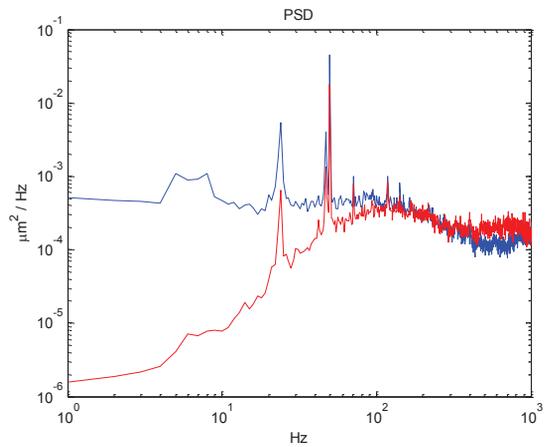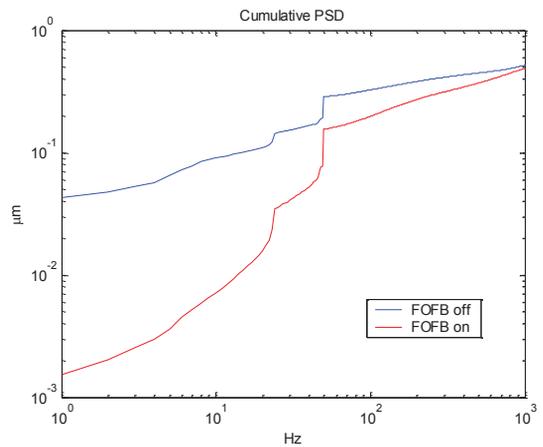

Figure 8: Orbit PSD in vertical plane.

Figure 9: Cumulative orbit PSD in vertical plane.

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When the FOFB system turns on, the orbit stability in long term (horizontal and vertical plane) are shown in Fig. 10 and Fig. 11. The orbit data is acquired by Libera SA channel (sampling rate is 10Hz), and the machine is run at top-up mode. In top-up mode, when injecting into storage ring, the FOFB system does not turn off. The orbit disturbance, caused by injection, is shown in Fig. 10.
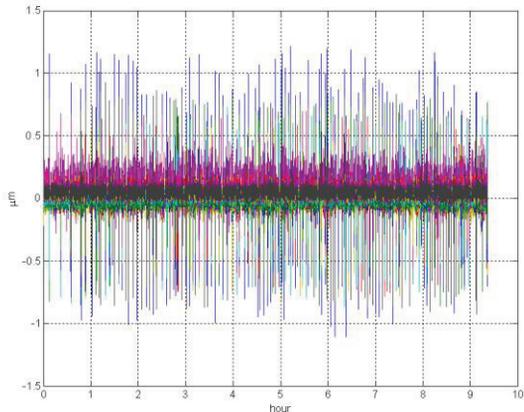

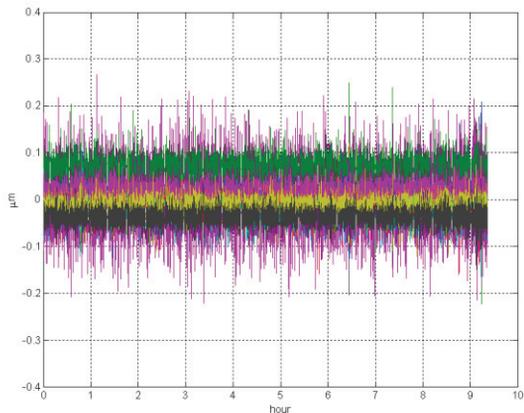Figure 10: Orbit stability (horizontal plane) in long term.

Figure 11: Orbit stability (vertical plane) in long term.

CONCLUSION

The PID controller parameters and eigenvalue selection in pseudo inverse matrix calculation is largely related with the FOFB system performance and stability. The more eigenvalue truncates, the more FOFB system stable, but the more additional orbit drift out of FOFB loop is caused. For the PID controller parameters, the more strength of the parameters, the lease of system stability. So, after careful selection of eigenvalue in pseudo inverse matrix calculation and PID parameters, the orbit noise suppression bandwidth and FOFB system stability could be satisfied simultaneous. The additional orbit distortion, caused by the FOFB system could be compensated by SOFB system. So, the mixed system (FOFB+SOFB) will be turned into SSRF normal operation after this summer.

REFERENCES

[1] B.C. Jiang, J. Hou, C.X. Yin, Z.T. Zhao, Proc. of IPAC2012 2855-2857.

[2] ChongXian Yin, Ph.D. thesis, SINAP.CAS (2007).