PRELIMINARY BEAM TEST FOR TPS FAST ORBIT FEEDBACK SYSTEM

P. C. Chiu, K. H. Hu, C.H. Huang,C. Y. Liao, K. T. Hsu
NSRRC, Hsinchu 30076, Taiwan

Abstract

TPS (Taiwan Photon Source) is a 3 GeV synchrotron light source which had be successfully commissioning with SRF up to 500 Amp in 2015 and scheduled to open user operation in 2016. As most of the 3rd generation light source, the fast orbit feedback system would be adopted to eliminate various disturbances and improve orbit stability. Due to the vacuum chamber material made of aluminium with higher conductivity and lower bandwidth, extra fast correctors mounted on bellows will be used for FOFB correction loop and DC correction of fast correctors would be transferred to slow ones and avoid fast corrector saturation. This report summarizes the infrastructure of the FOFB and the preliminary beam test is also presented.

INTRODUCTION

The TPS is a state-of-the-art synchrotron radiation facility featuring ultra-high photon brightness with extremely low emittance [1]. This synchrotron machine requires beam position stability less than 1/10 beam size therefore the FOFB is also required to achieve sub-micron orbit stability. The FOFB is mainly implemented by three parts: BPM, feedback computation unit and corrector power supply control interface. The TPS BPM electronics will be adopted the latest I-tech product: Brilliance+ [2]. It also offers a large playground for custom- written applications with Virtex$^{\text{TM}}$ 5, Virtex 6 in the gigabit data exchange module (GDX) to be used as orbit feedback computation. The corrector power-supply controller (CPSC) is designed for FOFB corrector control interface. This module is embedded with Intel XScale IOP and Xilinx Spartan-6 FPGA which will interface the fast setting from feedback engines. It was contracted to D-TACQ [3].

FOFB INFRASTRUCTURE

The design of the TPS storage ring has 24 cells, each cell is equipped with 7 BPMs and 7 horizontal/vertical correctors winding on the sexupoles. These kinds of slow correctors could provide about 500 µrad kick while their bandwidth could be limited only several tens of Hertz due to the eddy effect of the alumina vacuum chamber. This bandwidth is not sufficient to eliminate perturbation with frequency above several hundreds of hertz. Therefore, extra four horizontal/vertical correctors per cell will be installed on the bellows site as shown in Fig. 1 to obtain higher correction bandwidth. These horizontal/vertical correctors have fast response but smaller kick strength around 100/50 µrad. Thus the orbit feedback system plans to use two kinds of correctors simultaneously. The DC component of the fast correctors will transfer from fast to slow correctors smoothly and avoid saturation of the fast correctors as well as provide capability to suppress orbit drift. The overall infrastructure of FOFB is as Fig. 2.

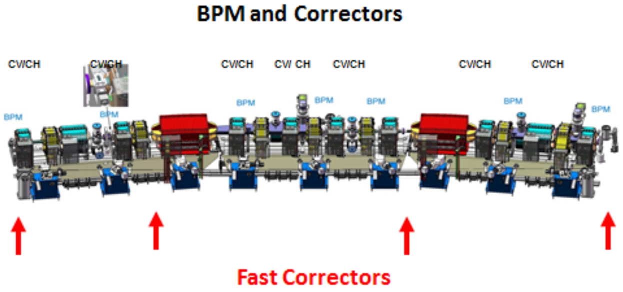


Figure 1: The slow (winding on sextupoles) and fast correctors layout in one cell of TPS storage ring.

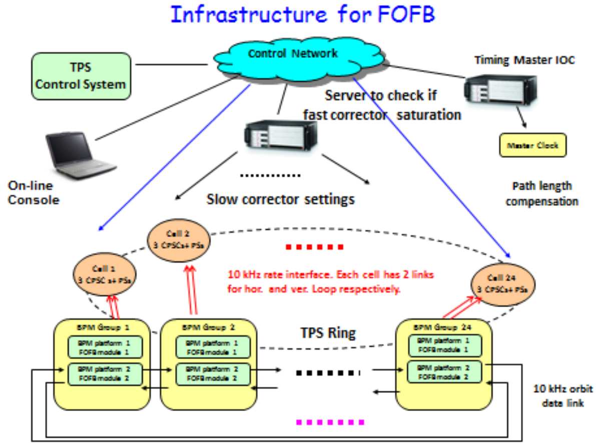


Figure 2: FOFB infrastructure.

BPM and GDX Interface

The TPS BPM electronics had commission with TPS beam commissioning in 2014 [4,5]. It consists of four kinds of modules: The timing module for clock locking and trigger; up to four BPM modules for receiving button pick-ups and signal processing, the inter-connection board (ICB) module for SW and HW interface; the GDX (Gigabit data exchange) module for FA data grouping and FOFB computation. GDX module supports SVD (singular value decomposition) calculation and provides at most 256 BPMs and 128 correctors feedback computation. Each eigenmode could be applied by individual PI coefficients for optimization. The magnet correction output is transmitted to CPSC (corrector power supply controller) based on AURORA protocol of Xilinx.

It also provides 10 kHz BPM grouping data through Gigabit Ethernet to support the angle interlock functionalities of TPS. The functional block of FOFB is shown as Fig. 3.

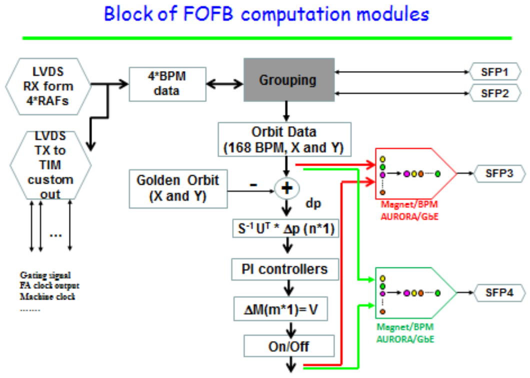
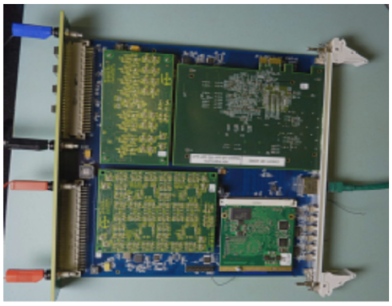


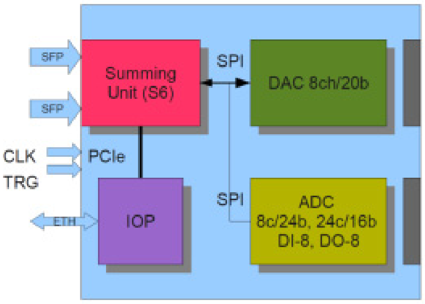
Figure 3: Functional block of FOFB computation module

Corrector Power Supply Controller Interface

CPSC is adopted for all kinds of TPS corrector power supply controls [6] incduling booster, transportline and storage correctors as well as skew quadruples. It was contracted to D-TACQ and consists of four mouldes of boards: IOP, ADC unit, DAC unit and FPGA for summing of FOFB fast setting and EPICS slow setting as Fig. 4. The CPSC will be installed at center slot of the power supply sub-rack [6]. It is embedded with EPICS IOC for slow access of the EPICS clients and its FPGA supports fast settings from GDX modules via fibre link based on Aurora protocol.



(a) CPSC boards



(b) Functional block diagram of CPSC

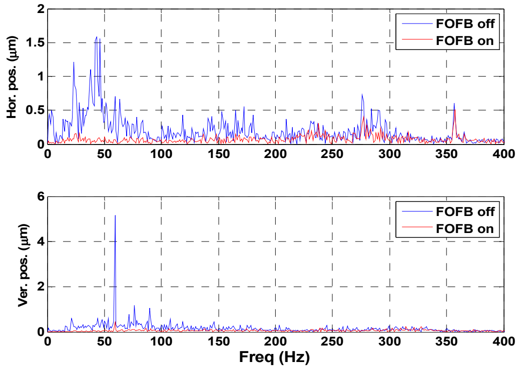
Figure 4: Functional block diagram of the corrector power supply controller module.

PRELIMINAY BEAM TEST

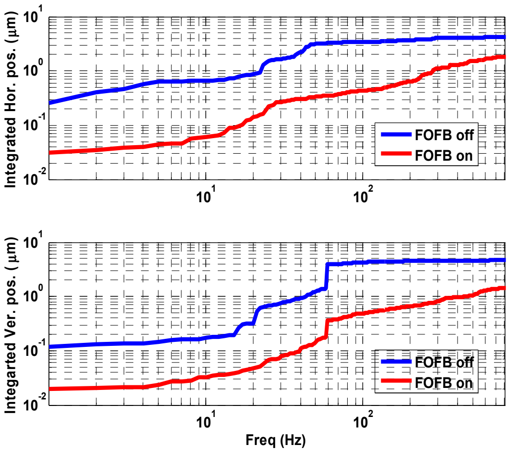
FOFB has continuous tested and operated with beamline commissioning since this February both for horizontal and vertical planes. It has suppressed the noise from DC to 200 Hz effectively. The preliminary beam test will be presented in this section.

For beam position stability of the raw TPS machine without FOFB, as Fig. 5(a) shown, most of horizontal position disturbance (blue line) is contributed from mechanical vibration which is excited by cooling water majorly [7], distributed below 80 Hz. There is also strong 3 Hz up to tens of micron meter from field leakage during booster power supply ramping. For the vertical position plane, there are very strong 60 Hz powerline noises.

With FOFB applied, it could be observed that beam stabilities of horizontal and vertical planes are both much improved. The integrated displacement of the straight line BPM from DC to 200 Hz could achieve 0.5 um for both of horizontal and vertical planes and it is satisfied the one tens of beam size stability as Fig 5(b) shown. Besides, the overall BPM 10 Hz data RMS comparison of FOFB on and off is also presented as Fig. 6. The overall orbit stability is improved one order of magnitude.



(a) Beam Spectrum (no booster power supply ramping)



(b) Integrated BPM position displacement

Figure 5: Horizontal and vertical Beam stability (nearby BPM of BL05) comparison for FOFB on and off. (a) BPM spectrum. (b) Integrated beam position displacement.

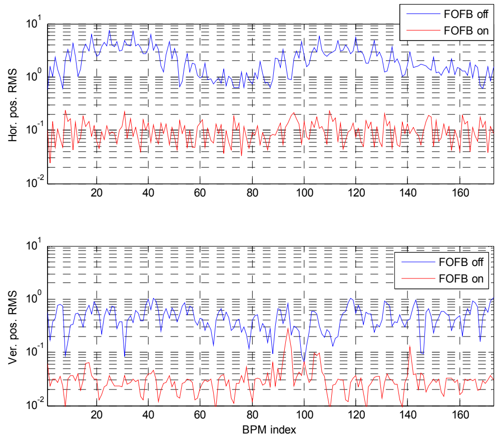


Figure 6: BPM 10 Hz data RMS comparison. The orbit stability is improved over ten times when FOFB on.

The estimated bandwidth of FOFB is around 250 Hz for horizontal plane and 300 Hz for vertical plane as Fig. 7 shown. It could suppress ten times of noise around 50 Hz which is the major noise source of TPS. FOFB would also amplify noise around 400~700Hz while the beamline experiments would not be concerned about these frequency range.

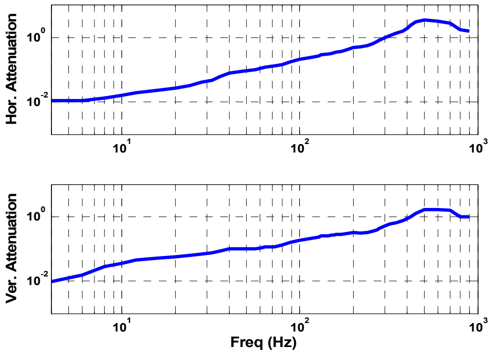


Figure 7: The measured bandwidth of FOFB. Horizontal is around 250Hz and vertical around 300 Hz.

FAST ORBIT FEEDBACK WITH SLOW CORRECTOR COMPENSATION

Since the slow correctors' bandwidth would be limited much less than 100 Hz due to the TPS alumni vacuum chamber, the fast corrector would be used only for feedback correction to suppress various disturbance form DC to 300 Hz [8,9]. A process which flow chart is shown as Fig. 8 would check the fast corrector output current periodically and transfer DC part correction to the nearby slow correctors when accumulating greater than acceptable value to avoid saturation. According the experience, FOFB operation would cause maximum 2~3 Amp accumulating value of the fast correctors since beam current injection from 30 mA to 500 mA. And after thermal equilibrium reached at top-up mode, the drift could be controlled below 0.5 Amp.

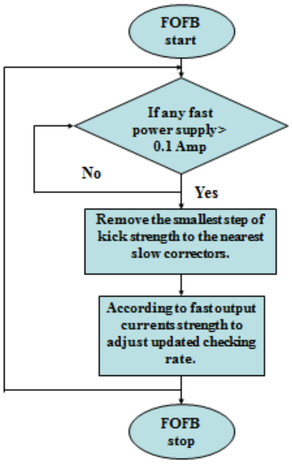


Figure 8: FOFB with slow corrector compensation to avoid fast corrector saturation.

CONCLUSION

BPM electronics and integrated orbit feedback system combined with slow and fast correctors of the TPS are summarized. All major components were tested and verified its functionalities. Testing is on-going and long-term reliability would be continuously improved. There are 170 BPMs and 96 fast correctors used in FOFB loop. The proper BPM selected would be adjusted according to the beamline experiments and the optimization would be the next efforts.

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