FAST ORBIT FEEDBACK SYSTEM COMMISSIONING OF THE TAIWAN LIGHT SOURCE

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Abstract

The global orbit feedback system of the TLS has been deployed for a decade to stabilize electron closed orbit. Its loop bandwidth is limited by various hardware to less than 5 Hz. Along with the upgrades of digital BPM electronics and corrector power supplies, the infrastructure of orbit feedback system has also been modified and rebuilt. The major tasks for the upgrade plan have been done including installation of new BPM electronics, corrector power supplies and modification of the infrastructure of the orbit feedback system. The system will evolve to a new fast orbit feedback system. Orbit stability is expected to achieve a submicron level of the electron beam at a higher bandwidth. This is useful to eliminate various fast orbit perturbations, such as mechanical vibration, residue field change due to insertion devices gap/phase change, etc.

INTRODUCTION

Orbit stability is an extremely important for a modern synchrotron light source. Generally, beam motion should be less than 10 % of its beamsize or even smaller. There are many efforts make to improve orbit stability of Taiwan Light Source (TLS) such as control of the ambient environment, removing various mechanical vibration passively, feed-forward compensation of insertion devices, locate faulty power supply and etc. Nevertheless, the limited loop bandwidth led incapability to suppress fast orbit excursion above 5 Hz. The fast orbit feedback system was thus proposed. The commissioning of the new fast orbit feedback system will come to an end soon. In this report, progress of the upgrade project will be presented, various tests and measurements for system performance, effects of the control parameters and noise attenuation are also demonstrated.

NEW FAST ORBIT FEEDBACK SYSTEM INFRASTRUCTURE

The Libera Brilliance [1] is employed to replace the existed BPM electronics for the TLS. It integration started from 2007 until finish in August 2008. It was gradually deployed and performed without interfere routine operation. There are 59 Libera Brilliances online operation for more than 8 months in the present. Adequate long-term reliability has been achieved. All of Libera Brilliances in the storage ring are grouped together to produce a single packed GbE UDP packet to reduce the number of IP packets and improve GbE jitters [2, 3]. The infrastructure of the new orbit feedback system is shown

in Fig. 1. The orbit controls for the horizontal and vertical plane are separated form the old version to increase available computation power. The reflective memory is employed to shares fast orbit data without consuming extra CPU resource and support data acquisition for other subsystems. The correctors are carefully chosen to have faster bandwidth.
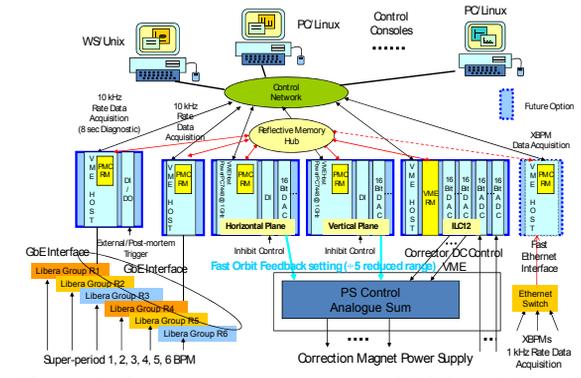

Figure 1: Infrastructure of the new FOFB and the related subsystems.

SYSTEM RESPONSE AND LATENCY MEASUREMENTS

There are several kinds of corrector magnets installed in the TLS due to historical reasons. They have different response. Aluminium vacuum chamber is in elliptical shape with 80 mm and 38 mm in major and minor axis respectively. Thickness of the vacuum chamber is 4 mm. There are cooling channel at the both side of the vacuum chamber in horizontal plane. Measurements of all components response at the laboratory are difficult due to no sufficient spare part available. To understand the compound response of the power supplies, correctors, vacuum chamber and the stored beam, pseudo-random binary sequence (PRBS) excitation is employed. This kind of signal is easy to generate by a simple recursion loop program, having only two levels of limited amplitude and its spectral amplitude dose not decrease with frequency as the step signal. Fig. 2 shows one section of PRBS generating by 12 bits linear feedback shift register (LFSR) and its power spectral density. The PSD curve is almost at flat level from DC to a corner frequency around 500 Hz with sinc function sampling system, which depends on the feedback system sampling clock 1.25 kHz. This 1.25 kHz is the sampling frequency of the old system and still used for the new system. It might increase the sampling frequency after the successful migration to FOFB system in the near future.

The transfer function can be easily obtained by the ratio of power spectra data from BPM fast access (FA) 10 KHz data and the power spectra of PRBS sequence. Adopt orthogonal binary sequence is possible to measure response of several power supplies and correctors is possible in future.
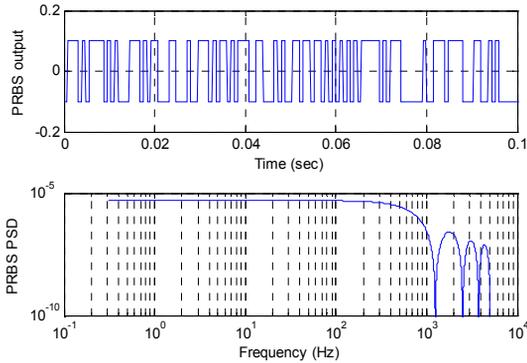

Figure 2: A part of a pseudo-random binary sequence (top) and its power spectral density (below).

Open Loop System Response

Different kinds of correctors installed in the storage ring of the TLS at different periods. Elliptical shape of the vacuum chamber contributed to 20 and 80 Hz in horizontal and vertical plane respectively. Figure 3 shows the measured overall response of the three vertical correctors in section R6 used for orbit feedback system by means of PRBS. It includes power supply, corrector, vacuum chamber, correctors to BPM readings. The dynamics of these three correctors differ from each other. Through measurements around the whole storage ring, it can be concluded that some vertical correctors' bandwidth can achieve 80 Hz while others may below 30 Hz. Choosing proper correctors for FOFB is thus necessary.
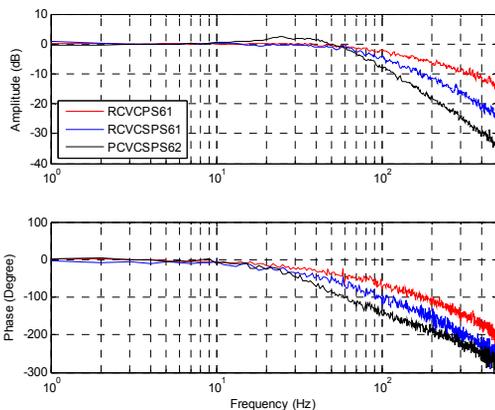

Figure 3: Three vertical correctors' (RCVCPS61, RCVCSPS61, RCVCSPS62) response functions.

Latency Time Evaluation

Latency time will affect the performance of the feedback system. The PRBS excitation can help to estimate the latency form the DAC output to the BPM reading. The data of one BPM reading to the PRBS sequence is shown on Fig. 4. The estimated latency time

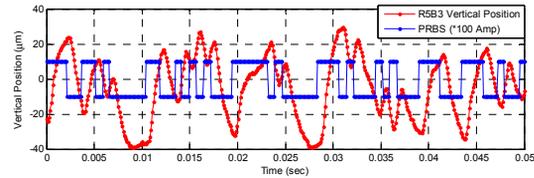is 500 µsec of which is at peak location of the cross-correlation function as shown in Fig. 5.

Figure 4: A section a BPM displacement and PRBS to cause orbit movement.
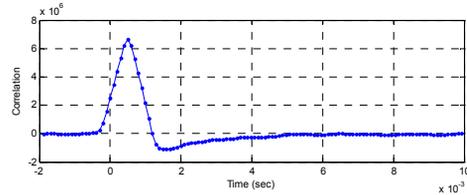

Figure 5: Cross-correlation function of PRBS sequence and BPM reading, the peak location corresponding to the overall latency from the DAC output the BPM reading.

System latency of the data acquisition and computation are also detailed evaluated as Fig. 6. Transfer BPM data to feedback node takes around 40 µsec; $S^{-1}U^{T}$ matrix (response matrix $R=USV^{T}$) and PID computation around 60 µsec; V matrix computation and DAC settings 20 µsec. The time for whole feedback loop takes about 120 µsec. It infers that we can push feedback sampling frequency from the current 1.25 kHz to higher frequency under constrains of the current orbit feedback infrastructure which is implemented in economic way.
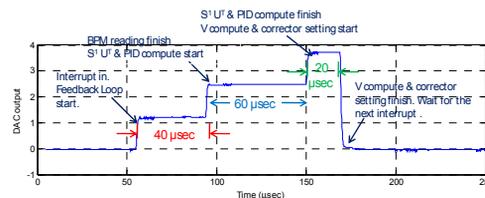

Figure 6: When each compute step finished, DAC output level is changed. The interval between two adjacent levels stands for the respective latency for each computation.

This computation latency plus the prior measured latency from DAC setting, beam response to the Libera Brilliance and latency to acquire data form Libera grouping, we can estimate that the total latency in one loop is around 620 µsec.

SINGULAR VALUE DECOMPOSITION AND TIKHONOV REGULARIZATION

Orbit response matrix R relates the orbit shifts to the steering magnet changes as a linear mapping. Singular value decomposition, as a most commonly used correction algorithm [4,5], is employed to invert the mapping. Furthermore, to obtain a stable solution, Tikhonov regularization is adopted. This regularization is one of the most used methods to solve ill-conditioned problems and prevent too large solutions of the systems. By means of it, the system can adjust correction speed

automatically according the respective eigenmodes and it has been adopted by the Diamond Light Sources for its FOFB system [5] and shown a satisfactory results. Fig. 7 shows the scaling singular value versus different regularization parameter α of the TLS. Determine an appropriate α requires practical experience and is studied continuously.
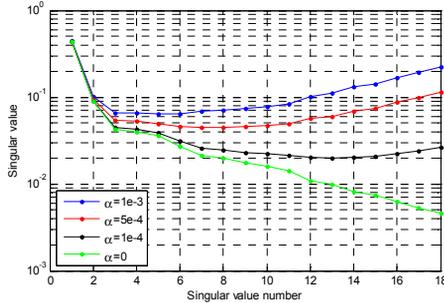

Figure 7: Singular values and Tikhonove regularization for different regularization parameter α

PRELIMINARY PERFORMANCE TEST

The feedback system can improve beam stability as shown in Fig. 8 and Fig. 9. One of BPM readings is shown in Fig. 8. Beam motion can be reduced less than 0.5 μm p-p compared to the 4 μm p-p with and without orbit feedback. The standard deviation of all BPM reading is shown in Fig. 9 where feedback loop can reduce the BPM reading deviation to about 0.2 μm.
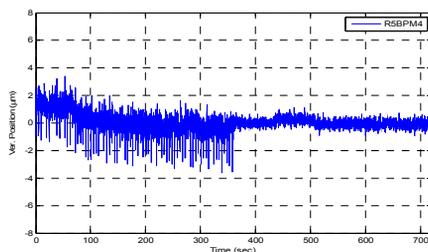

Figure 8: R5BPM4 vertical displacement comparison with/without FOFB. FOFB off before 360 secs ; on after 360 sec.
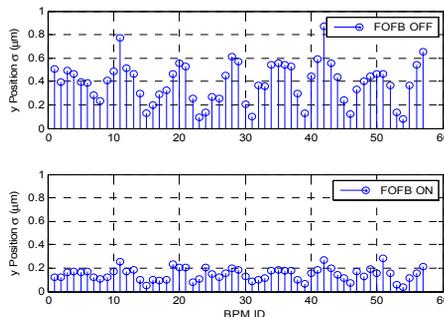

Figure 9: The standard deviation of vertical orbit displacement between FOFB on/off.

Fast operations of gap and phase of the warm insertion devices are highly desirable. However, the old global feedback loop cannot effectively suppress the orbit excursion when insertion devices parameters change too fast due to the limited bandwidth. It can only be operated at quite time-consuming motion. The wider bandwidth of the new orbit feedback loop can promote the motion speed. Fig. 10(a) shows the 1 mm/sec phase move of the EPU5.6. The orbit displacement is shown in Fig. 10(b). It is clearly observed that the feedback loop can eliminate the orbit excursion.
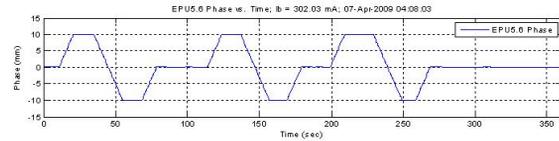
(a) History of the EPU5.6 phase motion at speed of 1 mm/sec.
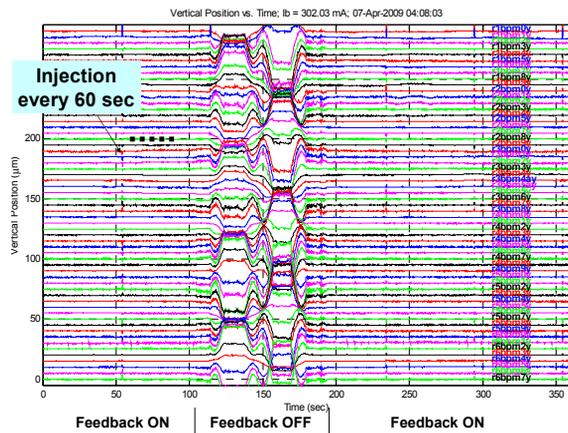
(b) Beam position reading of all BPMs

Figure 10: Effectiveness of the new orbit feedback system to suppress orbit excursion of 1 mm/sec phase change of EPU5.6.

SUMMARY

Infrastructure of the FOFB for TLS has been revisited. Commissioning of the FOFB system is on going. Various R&D including modelling, measurement, control rules, and etc. are in proceed. Preliminary results and many exercises confirmed that the FOFB system will be useful for the TLS and will be valuable for the future TPS projects.

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