OPERATION STATUS OF BUNCH-BY-BUNCH FEEDBACK SYSTEM FOR THE TLS

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Abstract

Bunch-by-bunch feedback systems play crucial roles to delivery stable beam to users in the operation Taiwan Light Source. The feedback system is FPGA based feedback loops that were deployed in since 2005. The systems are indispensable to suppress beam instability. Feedback based on SPring-8 designed feedback processors is delivery in 2005 highly successfully. Dimtel feedback solution was selected as hot spare units and further development also successful commissioning in 2010 for both planes of transverse feedback as well as longitudinal feedback. The new system provides seamless control system integration to the EPICS environment. Rich functionality includes excitation of individual bunch or specifies bunches, averaged spectrum, tune measurement by the feedback dip in the averaged spectrum. Operation status of the new system summarised in this report.

INTRODUCTION

Digital bunch-by-bunch feedback systems by using Spring-8 feedback processors for the TLS were deployed in 2005 to combat transverse and longitudinal coupled-bunched instability highly successful. In the TLS, these feedback loops are indispensable to deliver high quality photon beam. To explore functionality of the new generation bunch-by-bunch feedback solutions, provide a better diagnostics and evaluate functionality for TPS usage, a general feedback signal processor solution, called iGp (Integrated Gigasample Processor) was selected for the upgrade. The iGp provides real-time baseband signal processing at an RF frequency of 500 MHz for 200 bunches at the TLS. The major reason is that the system supports EPICS control environment and provides good control system integration for future machine upgrade. Rich functionalities are supported, such as feedback, bunch train excitation; selective bunches excitation, tune measurement, bunch cleaning, precision timing adjustment and etc. This new system accompany with the existed system as hot spare purpose. Explore the bunch-by-bunch feedback functionality for the future 3 GeV Taiwan Photon Source (TPS) which being under construction is another driven force of this test.

BUNCH-BY-BUNCH FEEDBACK SYSTEMS

Both transverse and longitudinal bunch-by-bunch feedback system adopt iGp/iGP12 are summary in the report [1]. It accompany with the existing SPring-8 processor as hot spare units [2, 3]. Both units can switch easily.

Current transverse feedback used a pairs of 150 mm diagonal striplines in skew position as feedback kicker. Direct RF sampling is used for current signal sampling. Two peaks of 16-tap filter was used for current configuration. Separate of the horizontal and vertical feedback loop is planned. Separate feedback loop of both plans will provide flexibility for operation and beam physics study.

The longitudinal feedback system used the I-Tech bunch-by-bunch feedback front-end to detect bunch phase oscillation [4]. The bunch oscillation is processing by the iGP12 to fulfil feedback functionality.

Two versions of iGp processors were used for the bunch-by-bunch feedback system upgrade due to historical reason. The iGp processor is implemented with a high-speed processing channel with 8 bits ADC and 12 bits DAC. The iGp12 is the latest version of iGp with 12 bits ADC and DAC. Functionalities and software environment of both models are the same. The processor unit is primarily designed for bunch-by-bunch applications in storage rings. However, wideband low-noise ADC input and integrated diagnostic features make the feedback processor to be a valuable bunch-by-bunch diagnostic tools. The feedback processor is configured to individually process for all bunches in the ring. Signal for each bunch passes through a 16-taps or 32-taps FIR filter for transverse feedback and longitudinal feedback respectectly before being sent to the one-turn delay from there, to the high-speed DAC. The main signal processing chain consists of a high-speed ADC, an FPGA, and a high-speed DAC and is driven by the RF clock. In addition to performing real-time control computations, the FPGA interfaces to the on-board devices, such as high-speed data acquisition memory (SRAM), low-speed analog and digital I/O, as well as temperature and supply voltage monitors. The FPGA uses an internal USB interface to communicate to an embedded EPICS IOC computer and is housed in the same chassis. The IOC runs the Linux operating system and is connected to the overall control system via the Ethernet. System control and diagnostics are performed via EPICS. All control and diagnostic features are accessible through the supplied EDM panels. Acquired diagnostic data can be exported for off-line analysis.

A simple GUI was deployed for the control room operator usage as shown in Fig. 1. Several waveforms accompany this interface to ensure the operator wheatear the bunch-by-bunch system working properly or not.

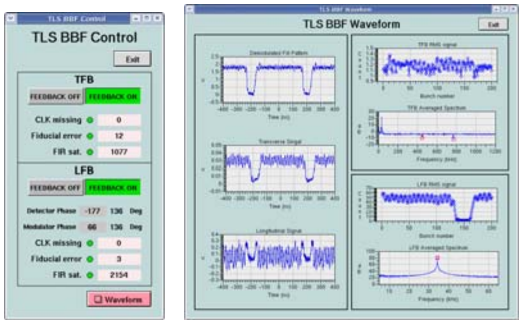

Figure 1: Operator interface to operate the bunch-by-bunch feedback system includes of transverse as well as longitudinal feedback system. Various waveforms include of filling pattern, beam oscillation amplitude in RMS and bunch phase oscillation in RMS, are shown on the integrated with front-end and iGp control page. Corresponding spectrum are shown also, it is easily used as a tune monitor.

USAGE OF THE FEEDACK SYSTEMS

The bunch-by-bunch feedback system major function is to suppress the instabilities in transverse as well as longitudinal planes. Beside its basic feedback mission, many another functionality are useful for various diagnostic purposes.

Feedback Functionality

Feedback functionality of the transverse and longitudinal feedback loops are working well. There are no big problem since deploy of Spring-8 digital feedback system since 2005. The iGp/iGp12 system deploy in 2010 are the same. Various feedback parameters can be optimized according to the beam conditions to achieve best performance.

Tune Measurement Functionality

There are two possibilities to measure tune supported by the feedback system in user transparency way. The first method is performed peak identification of the bunch spectrum of the single excited bunch data. Figure 2 shows the rms value of bunch #66 with excitation. Fourier analysis of the turn-by-turn data for this excited bunch shows a clear betatron oscillation peak.

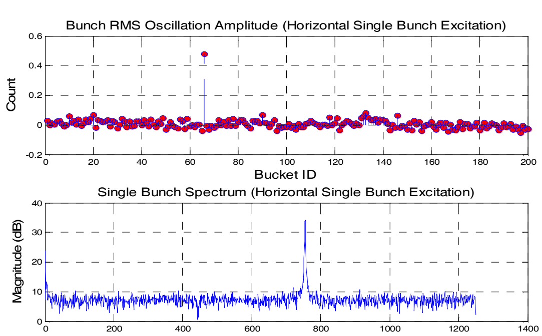

Figure 2: Single bunch excitation and single bunch spectrum for tune identification.

The second approach identifies the notches position in the turn-by-turn averaged bunch spectrum as shown in the Fig. 3, these notches in the averaged bunch spectrum are due to the noise suppression of negative feedback. The beam response has a single narrow band resonance in the horizontal and vertical betatron frequency. Even the noise can be suppressed to lower than the noise floor always the resonance position. This feature is nature of the negative feedback, it needs not to do anything to the beam for tune measurement. These notched appeared when the feedback loops are activated. It is clear that the notch depth is enhanced when the loop gain is increased.

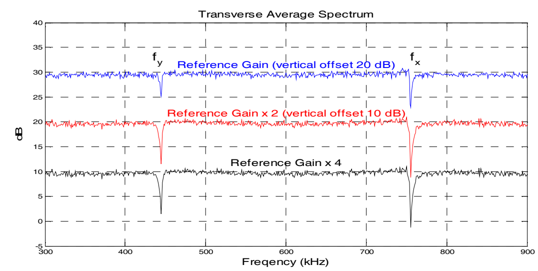

Figure 3: Tune measurement by extract the notch position in the bunch averaged spectrum when feedback loop is activated.

Arbitrary Pattern Excitation

The bunch excitation pattern can be in arbitrary way with feedback system for some beam experiments. For example we can excite the beam motion of specific bunches encoded by the Morse code pattern of "TFB" and "LFB" corresponding on excitation on horizontal betatron oscillation and phase oscillation as shown in Fig. 4. The excitation level can be adjusted as desire.

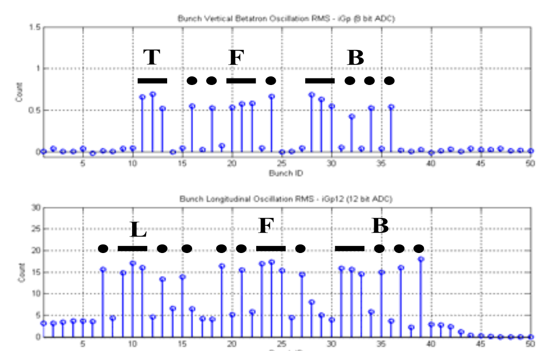

Figure 4: Bunch oscillation amplitude due to selective bunches excitation. The excite pattern of "TFB" and "LFB" are encoded by Morse code.

Growth-Damp Experiment

The iGp/iGp12 can capture bunch data either by software or hardware trigger. There are two feedback filters can be switched upon trigger. It is easy to do growth/damp experiments and capture data for further analysis for model predictions, and optimized the feedback system to acheve better damping rate for the instability modes. This is another study topic and will not conver in this report. Figure 5 shows the longitudinal feedback loop, there are two prominate modes with growth rate about 100 msec^{-1}. The feedback loop will provide less than 1 msec^{-1} damping rate to ensure the stored beam is longitudinally stable.

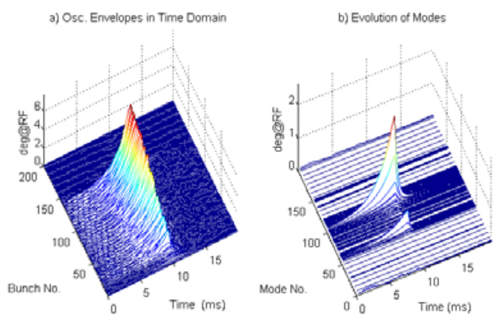

Figure 5: Typical growth-damp data in longitudinal feedback loop..

Stored Beam Perturbation Due to Kickers in Injection

If the data capture trigger of iGp/iGp12 is injection trigger, it can capture transverse or longitudinal motion of the stored beam or injected beam. If injected beam will study, it need located in the empty bucket or without stored beam. Figure 6 shows that the transverse oscillation during a top-up injection of TLS, the motion are contributed by the stored beam rather than the injected beam, due to the stored beam intensity are much large than the injected beam. Figure 7 show that perturbation is a low order mode beam motion (coherent), it contributed by the mismatch of the kickers. Using this tool, we can study the matching characteristic of the injection kickers.

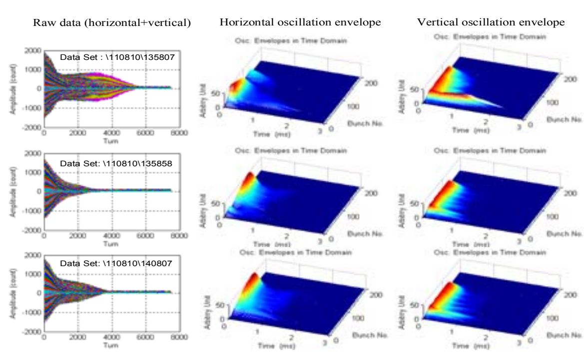

Figure 6: Stored beam perturbation due to kickers at injection instance.

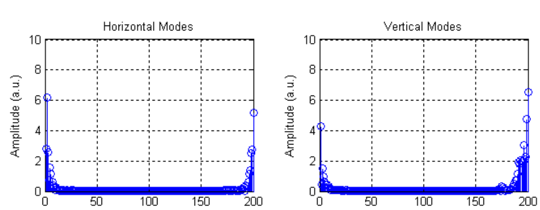

Figure 7: Typical mode pattern of the stored beam excited by the injection kickers. .

Filling Pattern

The rms value of bunch oscillation of each individual bunch provides a reliable way for filling pattern measurement as Fig. 8.

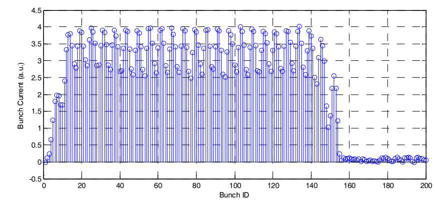

Figure 8: Averaged longitudinal bunch phase filling pattern.

ISSUES IN STUDY

There are several issues are study on-going, include growth/damp property of various stored beam conditions. Systematic study of the injection transient, try to find a possible mitigation solution to minimize the transient problem. Try to unveil some mysterious beam losses.

SUMMARY

Adopt iGp/iGP12 for the complementary units for the bunch-by-bunch feedback system at TLS, are successfully deployed in 2010. Functionality was explored. Enhancement functionalities include: tune measurement, fill pattern measurement, abort trigger, injection study, etc are in process. Separate horizontal and vertical feedback loops will provide flexibility for machine physics study and to test various issues for the operation, it will be next step when spare units available in future. Specifying the requirements of bunch-by-bunch feedback and bunch-by-bunch diagnostic for future 3 GeV TPS synchrotron light source is also on going.

ACKNOWLEDGEMENT

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