NEW BOOSTER TUNE MEASUREMENT SYSTEM FOR TLS AND TPS PROTOTYPE

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Abstract

Taiwan Light Source (TLS) is a 1.5 GeV synchrotron based light source and its booster synchrotron was delivered in 1992. Initial booster tune measurement which adopted extraction kicker as beam excitation and use digital oscillator to extract tune was obsolete. Recently, the beam excitation device has been modified to provide more effective excitation strength and new BPM electronics is adopted to acquire tune for routine booster tune measurement. It also provides a chance to experience for the TPS project booster prototype with the similar infrastructure. Efforts will be summarized in the report.

INTRODUCTION

The TLS booster synchrotron was commissioned in 1992 [1]. Initial booster tune measurement adopt extraction kicker as beam excitation and strength adjusted according to different energy and use digital oscilloscope to capture demodulated signal to extract tune [1, 2]. However, these diagnostics devices of the TLS booster are obsolete and discarded after twenty years operation. Recently, there are the latest BPM electronics delivered for the new TPS project which is a 3-GeV synchrotron machine scheduled to commissioning in 2014. During the construction period of the TPS, the available BPM electronics is temporarily borrowed for the TLS booster measurement. There are two advantages for these revised efforts: as test bed for the TPS project to practice hardware, software, and application development; to provide better understanding of characteristics of the TLS booster synchrotron.

There are two tune measurement schemes proposed. One solution is using X-Y diagnostic kicker over the ceramic chamber [3]. This kicker have can provide horizontal and vertical kick simultaneously and powered by a pulse amplifier. Beam loss will occasionally occurs but does not affect the measurement. However, the solution can only capture single tune value at specific energy therefore it will take multiples booster cycles to construct full cycle tune during the ramping. The reproducibility of power supply for different ramping cycle will affect tune variation and thus it was used to study tracking performance of White circuits [4].

Continuous tune measurement in one ramping cycle would be preferred [5, 6, 7]. The other solution is therefore proposed. It utilizes the magnetic shakers with multi-turn coils mounted on the ceramic chamber. These two coils in horizontal and vertical planes driven by amplifier could provide horizontal and vertical kick respectively. It takes one booster cycles for measurement to construct full cycle tune variation during the ramping. However, the beam loss is frequently observed due to the third resonance crossing when beam is excited [8].

These two solutions will be used as booster tune measurement prototype for TPS project: a new 3 GeV synchrotron machine to provide more x-ray users. The excitation scheme for booster tune measurement of TPS was not yet determined while the beam loss problem due to beam excitation is expected lessened than TLS because more advanced power supply will result in smaller tracking error. The two solutions still be both provided.

TUNE MONITOR SETUP AND MEASUREMENT

Early efforts adopt extraction kicker as beam excitation with shift timing and strength adjustment setting at different energy and use digital oscilloscope to capture demodulated signal and perform FFT analysis to extract tune. The associated turn-by-turn information picked up from stripline BPM was recorded with a transient digitizer. The raw data was then saved to the control console where the FFT analysis and peak identification were performed. The process is a little time consuming. Now new generation BPM electronics will provide turn-by-turn data flow to extract tune value.

Button electrodes of the beam position monitor (BPM) in the TLS booster synchrotron was mounted 45 degrees on the chamber between the dipole and the quadrupole. The lattice of the booster synchrotron is FODO type with periods of 12. There are 23 BPMs used around the synchrotron because one is used for a synchrotron radiation monitor photon port. The BPM cabling and electronics were completely modified during shutdown in August 2012. BPM electronics [9] has been borrowed from the TPS project and would be available before 2014. It would provide turn-by-turn data to extract tune value. Two BPMs with large response locations would be chosen dependent on phase advanced from the magnetic shaker to measure horizontal and vertical tune respectively.

Scheme 1

There are two stripline electrodes used on the TLS booster synchrotron to measure tune. However, small shut impedance cause ineffective beam excitation in higher energy. The existed X-Y diagnostic kicker over the ceramic chamber is used to provide horizontal and

ISBN 978-3-95450-127-4

vertical kick simultaneously and powered by a pulse amplifier. The single tune could be extracted at the specific energy by adjusting the pulse magnet trigger delay. Beam loss could be occurred while the single tune value could be acquired before beam loss and it would not affect the next tune measure in the next cycle. However, it will take multiple booster cycles to construct full cycle tune during the energy ramping. Fig. 1 shows the horizontal and vertical beam position and the measured tune extracted from the spectrum peak at 20 msec (~690 MeV energy). Fig. 2 shows the 14 single tune measurements at different specific energy for 14 ramping cycles. The tune variation is larger during the lower beam energy therefore the measure points are also denser at lower energy. The high voltage of the pulse amplifier would be increased as the energy increased. The beam loss was observed at several measurement cycles especially at low energy but it did not affect the measurements.

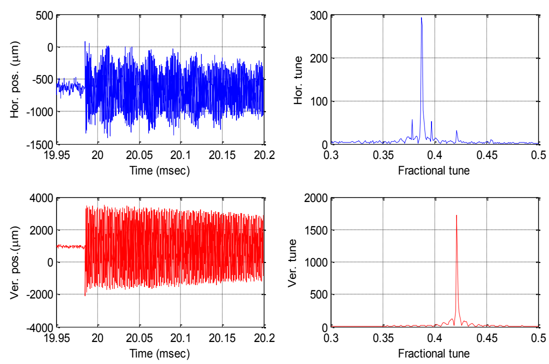

Figure 1: The horizontal and vertical beam position and extracted tune at 20 msec (~690 MeV).

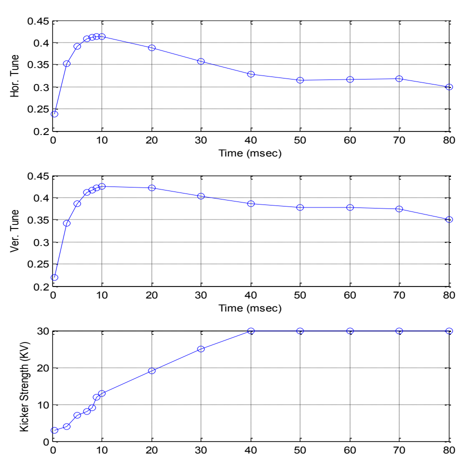

Figure 2: The upper two figures are single tune extracted for different specific energy at 14 ramping cycle for horizontal and vertical plane respectively. The lower figure is the high voltage settings of pulsed amplifier for different measurement cycle. The settings would be increased as the energy increased.

Disadvantage of this scheme is that it requires multiple cycles to attract tune along ramping. The power supply system should be stable enough and have good reproducibility to obtain repeatedly and precise measurement during different cycles. Tune measurement in one ramping cycle could be better and therefore the other scheme is also considered.

Scheme 2

To explore continue beam excitation for single ramping cycle measurement, the diagnostic X-Y kickers are modified as magnetic shaker as Fig. 3. Multi-turn coils are mounted on the existed ceramic chamber of the diagnostic kicker. There are two coils in each plane enclosed surrounding ferrite box with ceramic chamber surrounding them. The kickers with 50Ω terminated load have calibration factor of 3 mG/A. The kickers are driven by a 50W amplifier in each plane. The turn-by-turn beam oscillation data is observed by the Libera Brilliance+ [9] BPM electronics. Agilent arbitrary signal generator would provide band-limited, strength-adjustable excite signal. The functional block diagram of this new tune monitor system is shown in Fig. 4.

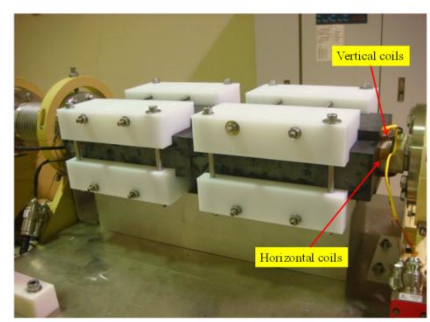

Figure 3: Magnetic shaker.

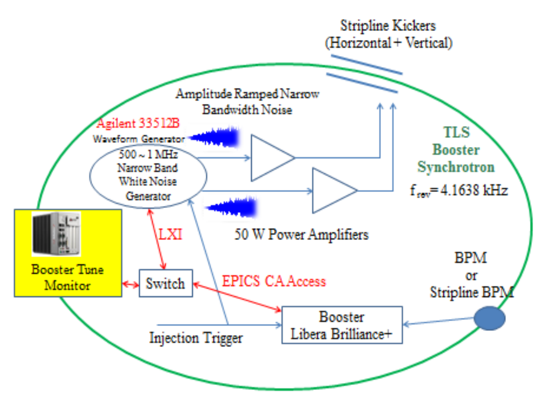

Figure 4: Functional block diagram of the new tune monitor for TLS booster.

Preliminary tests show that the beam can be excited effectively during the whole ramping cycle. The BPM can observed betatron sideband with acceptable signal to noise ratio as Fig. 5. The spectrogram of the horizontal and vertical of BPM turn-by-turn data could identify tune variation clearly. Peak identification from the

ISBN 978-3-95450-127-4

spectrogram could extract the varying tunes during one ramping cycle.

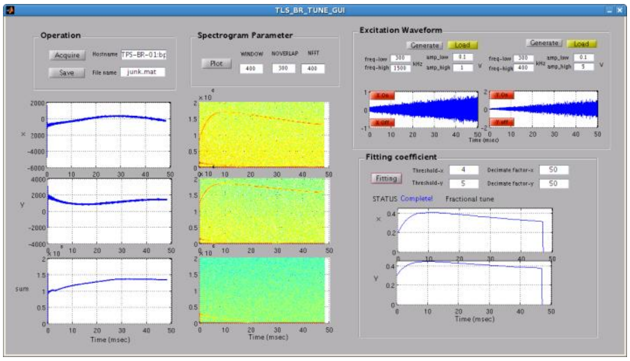

Figure 5: Tune monitor GUI.

Tune variation during ramping was observed in current routine operation. The fractional tune drift can be as large as 0.2. It is related to the tracking errors between focusing/defocusing quadrupoles and dipole as Fig 6. In cooperating with the monitoring system of FQ and DQ to dipole magnet strength, optimization of the booster working point can be achievable. Compared to TLS booster power supply which adopt white circuit scheme to implement ramping waveform during energy ramping, the racking error in TPS booster power supply would be expected to much smaller for it would utilize more advanced power electronics technique to allow any arbitrary waveform download and play.

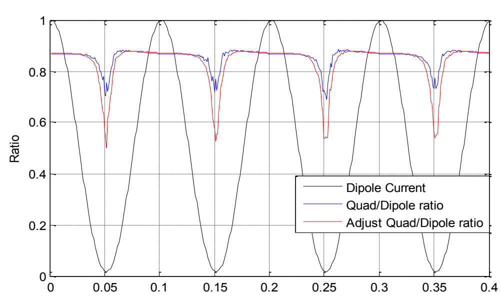

Figure 6: Tracking errors among quadrupole and dipole.

Since the magnet system for the TLS booster synchrotron is excited by 10 Hz White circuits, It is hard to adjust the tracking at lower energy part just after injection (low current) due to hysteresis effect of magnetic cores and power supply performance. Current operation across third order resonance in vertical plane without beam loss due to its strength is weak enough at low energy side. The beam loss was observed sometimes if the third resonance crossing when apply white noise is applied. Decreasing beam excitation could be lessen beam loss but could results in the measured tune blurred. There are two solutions: one is adjusting quadrupole to avoid the resonant. Fig. 7 shows the quadrupole is adjusted to avoid the vertical third order resonance and it does lower beam loss rate. The other solution is to put a notch filter with adequate bandwidth center at 1/3 resonance frequency to exclude beam excitation at that region. This kind of excitation signal can be implemented by an arbitrary waveform generator easily.

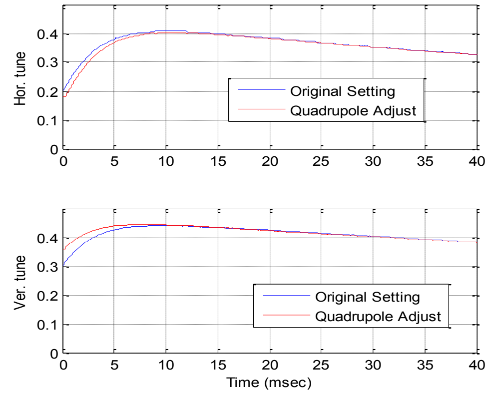

Figure 7: Quadrupole adjustment to avoid vertical 1/3 fractional tune resonant. It could lower beam loss rate during low beam energy period.

Tune Stability

Tune stability is normally depended on power supplies stability and could be its indicator. It can monitor the tracking stability of dipole and quadrupole power supplies, when tune variation data of each booster cycle available. The measurements show the 5 continuous tunes measured in an interval of 100 booster cycles (10 seconds). There is no sensible tune variation. The difference of these measured tunes is shown that the repeatability of tune is good for 5 times measurement. The fractional tune difference is less than 0.005. The difference looks like from the data fluctuation rather than from the contribution of power supplies' fluctuation.

Chromaticity Measurement

The chromaticity of booster was also calculated as RF frequency and measured tune change during the ramping. For a small variations, the chromaticity should be a linear function of the tune shift, $\xi_{x,y} = -\alpha_x f_{RF} \Delta\nu_{x,y}/\Delta f_{RF}$. The momentum compaction factor is normally a constant depending on the lattice. The measurement result is shown in Fig. 8.

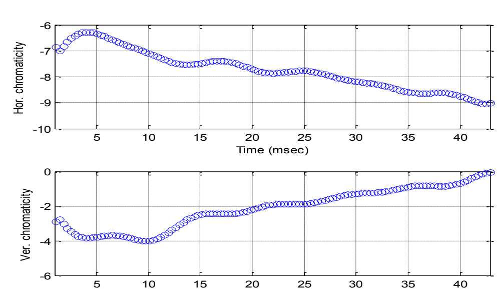

Figure 8: The measured uncompensated chromaticity during booster ramping.

ISBN 978-3-95450-127-4

TUNE MONITOR FOR THE TPS BOOSTER SYNCHROTRON

The booster synchrotron of the TPS booster synchrotron is in installation now as Fig. 8. The TPS will be equipped with the similar system described in this reports except that the magnetic shaker will be a replaced by stripline electrodes. Vertical and horizontal pairs of 300 mm long stripline electrodes will be installed at the boster synchrotron. Single and continuous measurement will be available during 150 msec ramping periods.

Beam excitation by extraction kickers can also apply as another complementary option. However, it can only be used for single point measurement per cycle. It needs multiple cycles to obtain tune during ramping. The trigger time and strength of the kicker need adjustment according to different energy. The kicker cannot shake vertical motion while residue coupling between horizontal and vertical plane might be still large sufficiently to observe for vertical tune measurement.

Figure 8: TPS installation. The left arc of upper figure is storage ring; the right arc is booster synchrotron. The lower figure shows the booster magnets which are fastened on the wall.

SUMMARY

In this report, we performed some minor modification of the TLS booster synchrotron to modernize tune measurement. Two schemes are proposed and adopted. The systems can be used as test bed for the similar system for the TPS booster synchrotron tune monitor development. The schedule of TPS is still for one year, a plan to test hardware and software supporting are in proceeding.

ACKNOWLEDGEMENT

The authors thank injection group for their supports on X-Y kicker of this study. Help from J. M. Kock of ESRF are very useful for the magnetic shacker implementation. Help from the staffs of the operation group to operate the booster synchrotron for experiments are highly appreciated.

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ISBN 978-3-95450-127-4