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INJECTION CONTROL OF THE TPS

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Abstract

Injection control application served for Taiwan Photon Source (TPS) to help commissioning and operation of the machine. Top-up injection functionality is available from machine commissioning stage to accelerate vacuum conditioning. During last two years, several updates have been done to enhance flexibility for the injection control. The injection control includes foreground and background processes to coordinate the operation of e-gun, linear accelerator, booster synchrotron, storage ring by the help of event based timing system. Lifetime calculation of the storage ring is also synchronized with the injection process. Detail of the implementation will be presented in this report.

INTRODUCTION

The Taiwan Photon Source TPS [1] is a latest generation of high brightness synchrotron light source which is located at the National Synchrotron Radiation Research Center (NSRRC) in Taiwan. TPS consists of a 150 MeV electron linear accelerator (linac), a 3 GeV booster synchrotron, a 3 GeV storage ring, and experimental beamlines. Ground breaking for civil construction was held on February 2010. The civil construction completed in April 2013. Accelerator system's installation and integration started in later 2013. The control system environment readied in mid-2014 to support subsystem integration and test. After 4 months of hardware/software testing and improving, the commissioning of booster and storage ring was started in December 2014. First synchrotron light shines in the last day of 2014 [2].

Injection control application with top-up functionality was deploy at early period of commissioning phase to release loading of operator and increase beam dosage accumulation to accelerate vacuum conditioning. Constant current with lower and upper limit top-up injection was used for user service since September 2016. However, time interval between injections vary slightly which caused by beam lifetime variation affected by machine conditions such as coupling, nonlinear beam dynamics, insertion device parameters (gap and phase) changed, etc. User could hardly predict the timing of injection even hardware gating signal provided. The experimental data deteriorated by the injection transient. Some beamlines could use hardware gating signal to exclude the transient but most of the instruments and data acquisition systems which cannot gated by hardware gating signal were sensitive to the injection transient. The top-up injection control had been revised to fixed time interval between injections in early 2018. The time of next injection is predictable to suspend data acquisition during the injection window. Maximum stored beam current is set to 405 mA at the moment. The storage ring is refilled every 4 minutes. Beam current drops around 4 mA during this period, it takes about a few seconds (< 5 sec) to refill the stored beam current back to 405 mA.

INJECTION SUPPORT SYSTEM

The injection process need coordinate various subsystem such as electron gun, buncher, RF system of linear accelerator, injection and extraction pulse magnets of the booster synchrotron, and injection septa and injection kickers of the storage ring.

Linac and Booster Synchrotron

The TPS injector consists of a 150 MeV linac and a 3 GeV booster synchrotron. The 150 MeV linac was available for booster injection in the 2nd quarter of 2014. Measured linac beam parameters are well accepted with its specifications. The LTB transfer line has been successfully commissioned with beam and the magnet settings agree with designed expectation [3].

The booster synchrotron was commissioning in the third quarter of 2014 successful. Optimization were done in performance for routine operation. These optimizations consist of system upgrade to improve its weakness and the improvement of the ramping procedure to increase the capture and ramping efficiency of the beam charge, optics characterization [4].

Pulse Magnets and Pulsers

The pulse magnets of TPS consist of one booster injection septum and one booster injection kicker, two booster extraction septa and two booster extraction kickers, two storage ring injection septa and four storage ring injection kickers, and two storage ring pingers for diagnostic purpose [5]. Coordinate operation of these pulse magnets except pingers are necessary for storage ring injection.

Event Based Timing System

Event based timing system was adopted to coordinate operation of TPS include injection. The event system consists of event generator (EVG), event receivers (EVRs) and timing distribution fiber network [6]. Machine clocks (repetition rate, revolution clock of BR and SR, synch clock, etc.) are distributed by distributed bus. While trigger events for the injection are management by the sequence RAM inside of the EVG which installed the timing mater node which is the sources of major timing events. The 125 MHz event rate will deliver 8 nsec coarse timing resolution.

A control page for the EVG configure and testing as shown in Fig. 1, The interface provides a tool to configure event generator such as clock rate, sequence RAM, DBUS,

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signal mapping, etc. To operate the accelerator efficiency, the injection control sequence was coded by state notation language (SNL) and execute by the EPICS sequencer running at the timing master as shown in Fig. 2. An injection interface page was implemented to provide a convenient interface to do beam injection for the storage ring. The injection sequence program running at the timing master EPICS IOC which communicate with the injection interface via process variables. Injection program is a state machine to help users to control the injection is shown in Fig. 3.

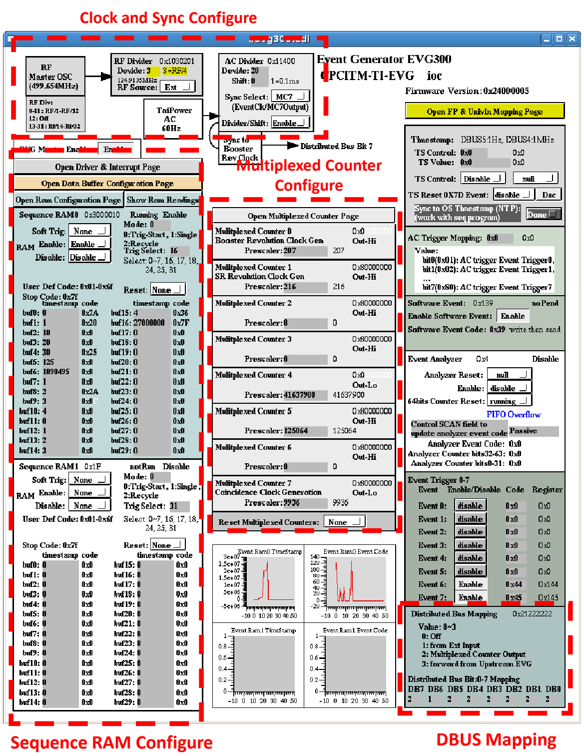

Figure 1: Event generator configuration graphical user interface.

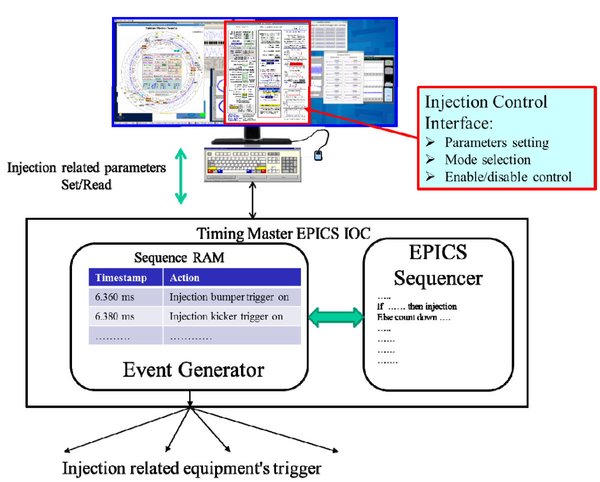

Figure 2: Injection control page communicate with the injection sequence program running in timing master EPICS IOC.

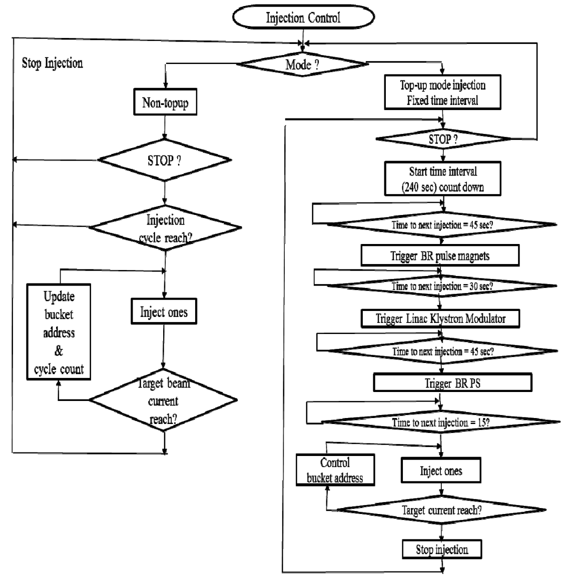

Figure 3: Sequence for injection control.

Filling Pattern Measurement

Filling pattern is an important factor which will affect storage ring operation performance such as lifetime, instability, etc. Keep the desired filling pattern are important during user operation which continue eleven-days operation every two weeks of current shift plans. Filling pattern should be monitor continuously. The acquired waveform from button signal by a dedicated oscilloscope with 40 GS/sec effective sampling rate trigger by revolution clock are used to extract bunch current with high resolution. The filling pattern analysis code extract bunch relative intensity accompany with total beam current measured by DCCT to calculate bunch current of individual bunch.

INJECTION INTERFACE

An injection control EDM page was implemented to support parameters configuration and operation of the injection as shown in Fig. 4. All of injection modes and sequences are managed by the content of sequence RAM which updated by the injection control EPICS sequencer program every injection cycle (0.333 second).

The left side of the page provide electron gun mode control, trigger enable, and dump beam setting. Timestamp stored in the sequence RAM is also listed.

Middle part of the injection control page consists of injection parameter setting, such as bucker address, injection cycle, target current setting, top-up control current range and time interval. The Top-up mode can select either multi-bunch mode or hybrid mode. If hybrid mode selected. it need specify the bucket address of isolated bunch. The injection process will be multiplexing the injection for multi-bunch and isolated bunch in hybrid mode as shown in Fig. 5.

Right parts provide synoptic display of beam current, filling pattern, beam lifetime, front-end status, and booster beam information.

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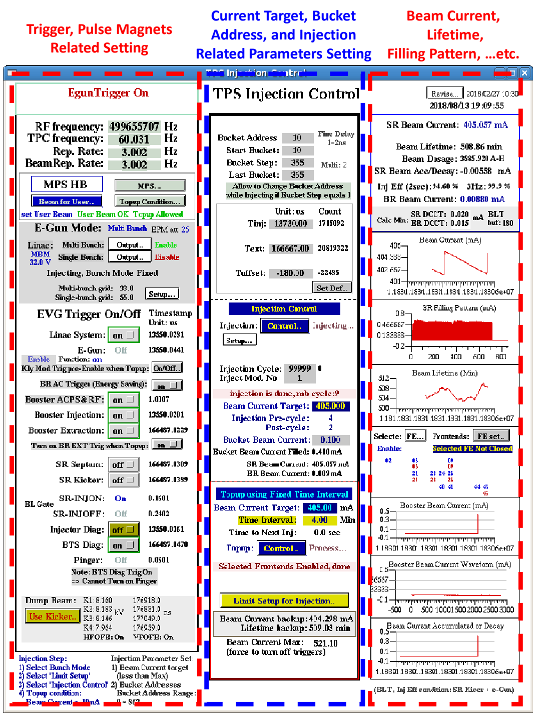

Figure 4: Injection control page.

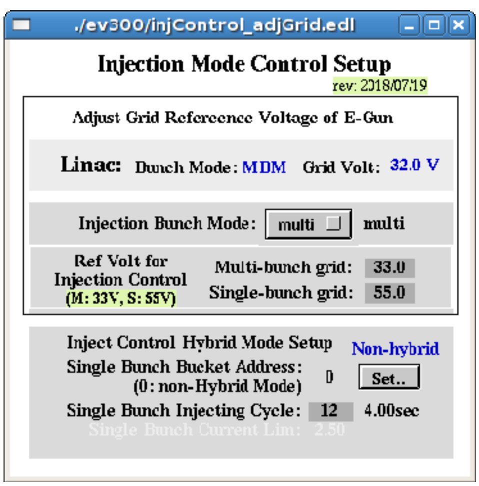

Figure 5: Top-up mode selection page.

Typical beam current and lifetime history, and filling pattern are shown in Fig. 6. Since the booster synchrotron can provide bunch-train near 1 µsec, current injection the electron gun and booster bunch train length as 700 nsec (350 bunches) in multi-bunch injection. The storage ring injection is only switch back and forth between two specific bucket location for bunch train injection until desired current accumulated. The gap of the lifetime data is due to lifetime calculation is stop during beam current accumulation. It need time to acquire sufficient data for regression before the first lifetime data available. So, the lifetime during this period is no updated.

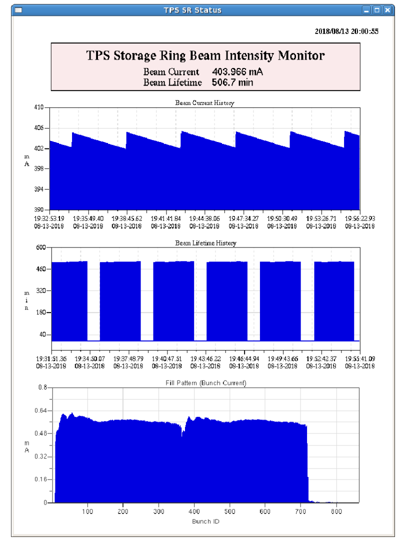

Figure 6: Beam current, lifetime, and filling pattern in typical user service shifts.

SUMMARY

Injection control for the TPS was implemented and revised several times since machine commissioning in late 2014. Event based timing system support synchronized action of various injection/extraction elements. Sequence RAM in event generator is used to configure the sequence of injection/extraction processes. Constant current mode was adopted from beginning of commissioning in late 2014 and user service started in September 2016. However, to help synchronize of experiment data acquisition with the injection process, constant time interval injection was chosen in early of 2018. The injection control functionality for TPS is working well and continue functionality revision will be performed to satisfy various requirements in future.

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