NSLS II INJECTOR INTEGRATED TESTING*

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Abstract

The NSLS-II is a state-of-the-art 3 GeV synchrotron light source under construction at Brookhaven National Laboratory. Since 2012, the injector system gradually moves to the commissioning stage. To make the commissioning smooth and efficient, an emphasis was put on the sub-system integration test to make sure the injector system components function along with utilities, timing system and control system, to calibrate diagnostics system and to test high level applications with simulated beam signals and required hardware. In this paper, we report our experience with the integrated testing of the NSLS-II injector.

INTRODUCTION

The NSLS-II [1] is a state of the art 3 GeV synchrotron light source under construction at Brookhaven National Laboratory. The injection system consists of a 200 MeV linac, a 3 GeV booster ring, transport lines and the storage ring injection straight.

While the installation activities in the booster-synchrotron are nearly completed and waiting for the authorization to start the commissioning, the injector- and accelerator physics group have engaged into the Integrated Testing phase of the injector development. We did sub-system integration test to make sure the device function along with utilities, timing system and control system, to calibrate diagnostics system and debug High Level Applications. We have begun the beam commissioning with simulated beam signals, called extended integrated testing (EIT) to prepare for the booster ring [2] commissioning.

During the EIT the hardware operates as during the actual commissioning with the beam. The beam signals are simulated and generated by a computer program. Then they are transported by the same data channel as the real beam signal would travel. During this process, we test and optimize all the operation screens, high level applications by subsystem by subsystem with the actual hardware controls but only with simulated beam signals and safety systems. This phase will reduce the time of the booster and transport line (TL) commissioning with the beam, train the commissioning team and reduce safety concerns related to the commissioning and operations.

INJECTOR CONTROL SYSTEM

NSLS-II uses the EPICS [4] control system to monitor and control the accelerator hardware. The high level control system includes two parts, complex accelerator physics application for beam studies and simple display/control panels. Mainly, we use cothread [5] to access the process variables (PVs) in Python script for complex accelerator physics applications and the CSS (BOY) [6] panel for simple tasks such as monitoring, displaying and setting of the machine Process Variables (PVs). Besides, MATLAB is also available for programming and EDM panels are used for Linac control system from the linac vendor Research Instruments, GmbH. All source codes including panel configurations are controlled and managed by mercurial [7] version in the control system.

The NSLS-II operation panels [8] include the user panels and the expert panels. They display the device status and parameters (setpoint and readback) and show the device performance history. A user panel shows only information that user is required, such as the magnet current setpoint and readback. The expert panel shows all the information that expert can fully control the device or diagnose devices, such as power supply operation mode and magnet temperature.

Besides the devices status and control, we also develop high level applications to realize the accelerator physics application tools. It is to translate the raw/processed data from PV to the "physics" parameters, such as from the beam size read inform beam screen to beam emittance or the beam energy measurement. The code was programmed with Python. Although we program the high level applications with Python, we implement the GUI in the CSS so that the user has a consistent interface environment. Code runs either in continuous mode or is invoked by a button. The user can input parameters and monitor the progress in GUI as regular device PV set and monitor. This process is realized through soft IOCs.

The Machine Snapshot and Retrieve service (MASAR) is an important tool used during the commissioning. It is developed by the NSLS-II Controls group for implementation of save/compare/restore function. It is implemented using EPICS V4 framework, and is a server-client based tool-set. The user creates a list of PVs that are important for the system in a configuration file and, then, MASAR saves the current configuration. Based on the configuration type, MASAR can save current machine

PVs' value, compares the current machine with the saved data and sets the machine up with the saved data by the restore function. Besides that, we also have channel finder, olog, unit conversion, and other applications, developed by the NSLS-II team.

SUB-SYSTEM INTEGRATION TEST

The purpose of the sub-system integration test is to verify the device function along with utilities, timing system and control system in control room environment. Meanwhile, we do the diagnostics system calibration and develop more functions to improve the control system features for users. The subsystem testing include all diagnostics (such as ICT, FCT, FC, Flags, BPMs) devices and power supplies. We developed the test procedure, which includes the system interface block diagram, the system physics parameters and ranges, the control parameters and procedures on mechanical/controls testing, calibration and check points. During the process, we use external "known" signal to simulate the real beam in various situations, such as 1 Hz/2 Hz/ stacking mode with low/high bunch charge at single bunch mode/long pulse mode.

Figure 1 shows an example of ICT integration test block diagram. The device hardware itself is bypassed and the signal source is 'replaced' by a pulse generator. This way, the whole system (cable connection, BCM electronics, digitizer and timing) properties are checked, except for the ICT sensor, which was tested on the bench prior to installation. By setting various known signals from pulse generator (Lecroy 9211) and comparing with the output from control system, we checked the four ICTs in LTB and BTS transport line. During the testing, we found LTB-ICT2 connection issues. We also found that four ICTs exhibit the readback difference, which is larger than 5% due to calibration, as shown in Figure 2 (the horizontal axis is the equivalent charge of pulse generator signal and the vertical axis is charge readback from digitizer). After repeating the calibration, the four ICTs readback difference came down to be less than 1% and the charge readback noise reduced below 10 pC.
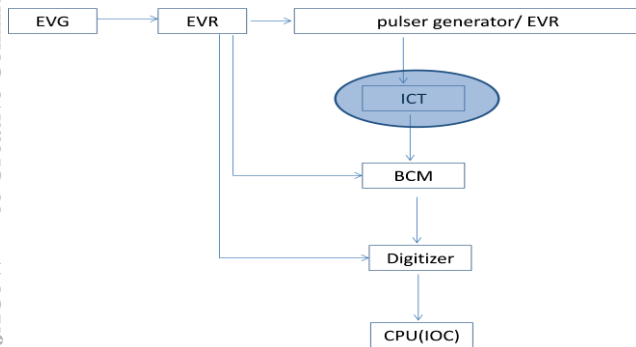

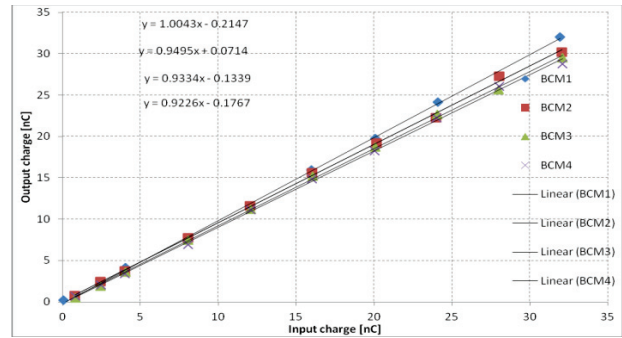Figure 1: ICT integration test block diagram

Figure 2: Four ICTs readback VS input charge before the calibration

For the flags system test, we use LED to illuminate the target. In LTB and BTS, the flag's design is the same. It has a virtual target and OTR/YAG screens. Their optics goes through different route of testing. By adjusting the camera focusing and virtual target position, both of them are focused. Figure 3 shows an image of the virtual target along with YAG screen. With both LEDs on, we can see that the camera focused on virtual target and YAG well. From the visible marker in the virtual target, we can calibrate the OTR/YAG screen.
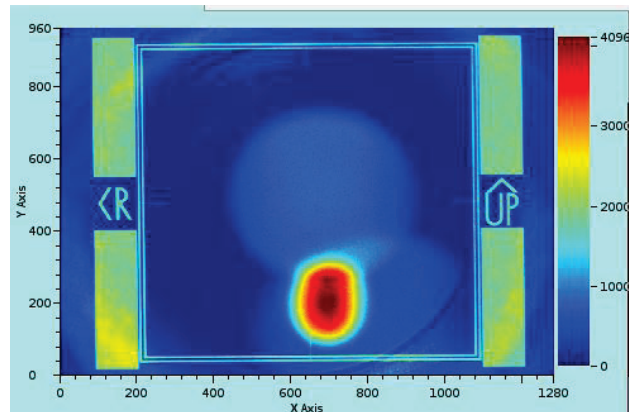

Figure 3: Image for transport lineTL flag calibration

Calibration of the BPM offsets includes two parts, the electronics and buttons separately. The beam position offsets from electronics were reduced to zero by doing the button static gain calibration. The beam position readback is within a few um range while changing RF attenuator within 31 dB range. For the button part offset calibration, we use four port analysis method and the final accuracy is about 30 um.

EXTENDED INTEGRATION TEST

As mentioned in the Introduction the Extended Integrated Testing is carried out to exercise the beam commissioning without beam. We developed shift schedule, daily shift plans and shift summaries, closely corresponding to the actual beam commissioning. Currently the EIT activities consist of 4 hour shifts per day with shift team from BNL and BINP and are expected to last two months.

The hardware operates as in the actual commissioning. The beam signals for the non-existing beam are simulated and generated by a computer program, ELEGANT [9]. Then they are transported by the same data channel as the real beam signal would travel. This function is realized by setting the diagnostics related PVs to the simulation mode. Beam signals include closed orbit readings, beam intensity signals, bunched beam signals and so on. The unknown imperfections of the booster alignment are included in the model as well. Using real readbacks from the magnet -, RF- and timing systems, commissioning activities such as injection, first turn steering, achieving circulating beam, RF capture, closed orbit, acceleration ramp optimization and extraction can be set up and optimized. This proved itself to be an efficient way of debugging the controls- and the correction systems. Many small issues and bugs, which would have us slowed down during the commissioning, have already been discovered during the test. Moreover, the testing is carried out from the control room in a way which is almost identical to the commissioning with real beam. During EIT we test also the operations procedures, the shift routines, the use of the logbook and much more. The injector commissioning team currently involved in the EIT is now well acquainted with the control system and the application programs.

Figure 4: 1st turn beam trajectory measurement and correction

Figure 4 shows one example of the EIT test, '1st turn beam trajectory measurement and correction'. The beam current trajectory (red) is from model simulation, which is built from live machine data and includes errors that consist of the alignment errors and the magnets field error. The predicted trajectory (blue) is from from high level application calculation. After applying the correction, the model loads the new corrector values and generates the new trajectory, which is very close to the predicted one.

ACKNOWLEDGEMENTS

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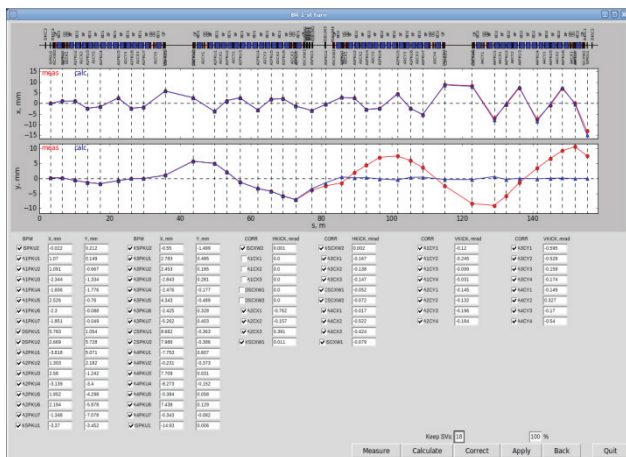
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