ISBN: 978-3-95450-168-7 doi:10.18429/JACoW-IPAC2015-TUPHA007

NSLS II BOOSTER EXTENDED INTEGRATION TEST*

G.M. Wang#, T. Shaftan, B. Bacha, A. Blednykh, E. Blum, W.X. Cheng, J. Choi, M. Davidsaver, J. De Long, L. Dalesio, R. Fliller, G. Ganetis, W. Guo, K. Ha, Y. Hu, W. Louie, G. Shen, O. Singh, V. Smaluk, Y. Tian, L. Yang, X. Yang, F. Willeke
BNL, Upton, NY, 11973, U.S.A
P. Cheblakov, A. Derbenev, A. Erokhin, S. Karnaev, S. Sinyatkin
BINP, Novosibirsk, Russia

Abstract

The National Synchrotron Light Source II (NSLS-II) is a state of the art 3 GeV third generation light source at Brookhaven National Laboratory. While the installation activities in the booster-synchrotron are nearly completed and waiting for the authorization to start the booster commissioning, the injector and accelerator physics group have engaged into the Integrated Testing phase. We did the booster commissioning with simulated beam signals, called extended integrated testing (EIT) to prepare for the booster ring commissioning. It is to make sure the device function along with utilities, timing system and control system, to calibrate diagnostics system, debug High Level Applications, test and optimize all the operation screens to reduce the potential problems during booster commissioning with beam.

INTRODUCTION

The NSLS-II [1] is a state of the art 3 GeV third generation synchrotron light source at Brookhaven National Laboratory. The injection system consists of a 200 MeV linac, a booster ring 3 GeV, transport lines and the storage ring injection straight. The linac commissioning was in April 2012. The booster commissioning [2] includes Linac to Booster transport line, Booster and Booster to dump transport line. But the start of the booster commissioning was moved towards later in the project schedule due to increase in the scope of the booster ARR review and uncertainty.

To make the beam commissioning smooth and efficient, a new phase of booster commissioning was introduced, Extended Integration Test (EIT) [3]. In this phase we will model the beam-induced signals through the EPICS controls and test and optimize all engineering screens and High-Level applications and safety systems with the actual hardware controls and operating subsystems but only with simulated beam signals without the real beam present in the machines. This phase is likely to 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.

In this paper, we report our experience with booster extended integrated testing.

*This manuscript has been authored by Brookhaven Science Associates, LLC under Contract No. DE-AC02-98CH10886 with the U.S. Department of Energy.
#gwang@bnl.gov

EXTENDED INTEGRATION TEST

Extended Integrated Testing is carried out to exercise the beam commissioning without beam.

The EIT objectives are following through the commissioning sequence:

1) Passing the beam through transport lines.
2) Matching the beam emittance with the accelerator acceptance.
3) Observation and correction of the beam trajectory at the first turn closing.
4) Beam optimization during injection and RF capture.
5) Accelerating beam along the energy ramp.
6) Extracting beam.
7) Measuring the extracted beam parameters in the diagnostics transport line.

It provided the environment to test applications for routine beam parameters measurement and correction. Meanwhile, real time alarms and interlock signals was also engaged in the operation system and this trained operators on commissioning and operations of the live machine safely.

The hardware operates as in the actual commissioning, including power supplies, vacuum, diagnostics and RF systems. Equipment Protect System and Personal Protection System will be tested during the unit and integrated testing stages.

The beam signals for the non-existing beam are simulated and generated by a computer program, ELEGANT [4]. Then they are transported by the same data channel as the real beam signal would travel. In this process, we test and optimize all the operation screens, high level applications by subsystem with the actual hardware controls. This function is realized by setting the diagnostics related PVs to the simulation mode. These diagnostic devices require reconfiguration of the EPICS records: Booster beam diagnostics (36 BPMs, 1 DCCT, 1 FCT, 6 Beam flags, 2 SR monitors, 1 Tune measurement system), LTB part II diagnostics (3 BPMs, 4 Beam flags, 1 FCT), BSR TL part I diagnostics (4 Beam flags, 4 BPMs, 1 ICT, 1 FCT and 1 Faraday cup). 'Beam' signals include closed orbit readings, turn by turn data from BPMs system, beam intensity signals, beam image signals and so on. The unknown imperfections of the booster alignment are included in the model as well. The hardware real readback including power supplies, RF and timing systems, are feed into Elegant Model and controlled by high level applications.

ISBN: 978-3-95450-168-7 doi:10.18429/JACoW-IPAC2015-TUPHA007

DATA STRUCTURE

Figure 1 shows communication of the ELEGANT kernel with the panels/HLAs at high level and EPICS [5] structure at low level. As the actual beam commissioning, the CSS [6] GUI and related high level applications communicate with hardwares' setpoint and readback PVs through the network. The CSS or HLA application will either monitor or set hardware new values through PVs as normal operation. The PV input value is either from actual hardware (power supply signal) or from the Elegant simulation result (beam related signal).

The 'Tasks' to generate beam simulation result is an independent application. It is a python program to read the hardware actual signal, convert them into physics unit through unit conversion server, and set it as an Elegant input file. Depending on the study purpose, different elegant input file was set, such as close orbit calculation, or betatron oscillation signal. Elegant application will generate the new 'beam' signal, such as orbit, twiss parameters, beam size or BPMs turn by turn data. 'Tasks' will read these data and set them into diagnostics simulation PVs as the beam status based on the hardware setting.

The 'Tasks' application is parallel run with the high level applications and set the hardware new value based on 'beam' response. Realistic noise was added and the signals will be displayed and processed by operator panels and HLAs. As the 'beam' signal is known well from Elegant model, the solution or response from high level application is also expected well. This provides a self-consistent environment for high level application debug.

Comparing with virtual accelerator, it is one more step forward closer to beam commissioning, as all the hardware are in actual operation. All the operation panels and high level applications for commissioning and operation are in the real PVs communication. The support environment setting, such as unit conversion server are also built and tested in the process.

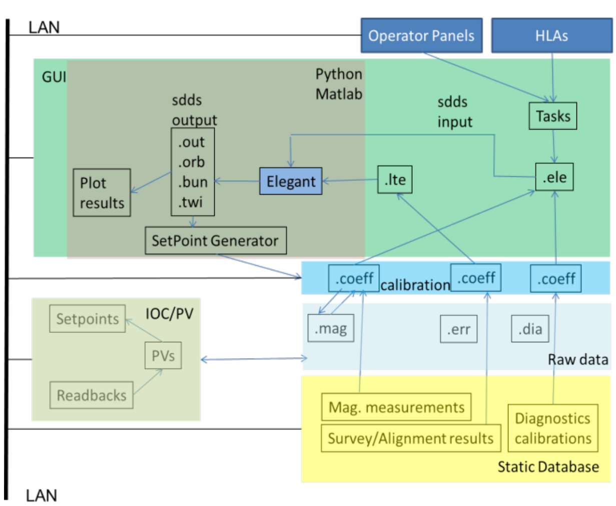

Figure 1: EIT control system data flow structure.

EIT TEST RESULTS

During the EIT, we developed shift schedule, daily shift plans and shifts summaries, closely corresponding to the actual beam commissioning. The EIT activities consist of 4 hour shifts per day with shift team from BNL and BINP and took ~ two months.

We tested BR all the power supplies and diagnostics. Besides the hardware function test, the operation screen and related tools were optimized with operation experience. Most hardware work well as expected. Some problems, such as injection kicker 1 and 4, QD and QG top ripple, correctors fault signal, DC septum, BPMs signal couple was found and fixed. For the operation screen and related tools, such as orbit display and correction, tune measurement, beam extraction control, and beam measurement in the diagnostics beam line, they followed the commissioning sequence, tested with simulation signal and debugged based on the operators' using experience.

BPMs Test

For BPMs test, we use Pilot Tone source and CW RF source to simulate the beam signal and check the beam position change when RF attenuator changes. During the test, we found the four button signal mismatch and 'beat', as shown in Fig. 2 and the beam positon dependence on the RF attenuation. The mismatch was due to cable loss connection. The 'beat' was diagnosed due to the signal coupled with embedded EVR oscillator. This is solved by modifying the oscillator and installing a microwave absorber. The BPM position noise level is now improved down to 1 μm. The position dependence on the RF attenuator was fixed by internal gain calibration.

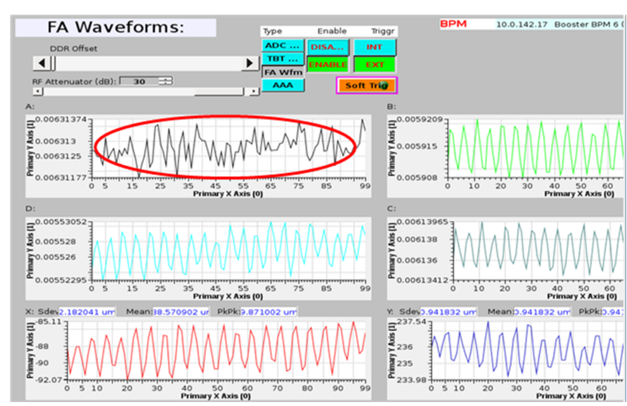

Figure 2: BPMs button signal from External signal input.

PS Test

During PS test, QG and QD ramping top curve shows ripple. Figure 3 shows the QG test result. The top curve local relative error is about 1%, comparing with the PS specification 0.1%. The spectrum shows 240 Hz signal from power supply. This problem was solved by modifying all Quad power supply and charger by adding more bypass capacitors, rerouting signal cables and optimizing the power supply feedback and aharger PID loops to eliminate 240 Hz signal.

ISBN: 978-3-95450-168-7 doi:10.18429/JACoW-IPAC2015-TUPHA007

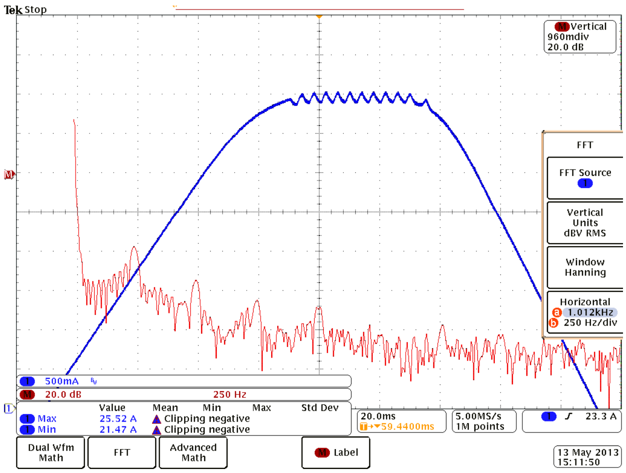

Figure 3: QG PS flat top ripple waveform from scope.

Ramping Manager

Booster magnetic field and RF voltage are ramped to accelerate the beam from 200 MeV to 3 GeV. Ramp manager is the interface to control the main PS and RF system. Figure 4 showed the example of RF voltage and phase control from ramp manager, which can be either points or polynomial. Besides the curve, ramp manager also include the function of the RF voltage limit (50 kV-1700 kV), implement the RF sequence and control the Gun trigger during the RF change to avoid wrong operation.

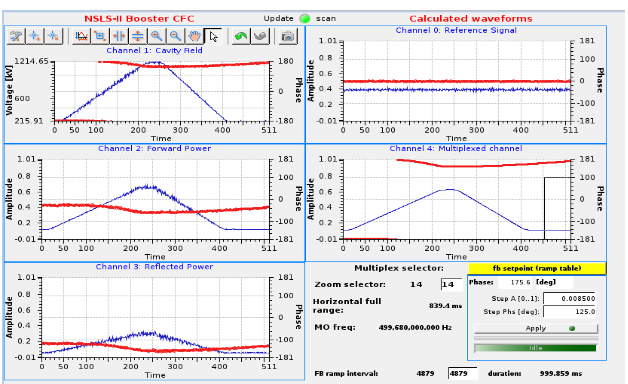

Figure 4: Booster RF ramping control.

1st Turn Trajectory Display and Correction

Figure 5 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 with alignment errors and 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. With assigned misalignment error and injection position and angle error, the 1st turn beam trajectory is a few mm. After 3 steps correction, the beam trajectory is reduced down to ~1mm.

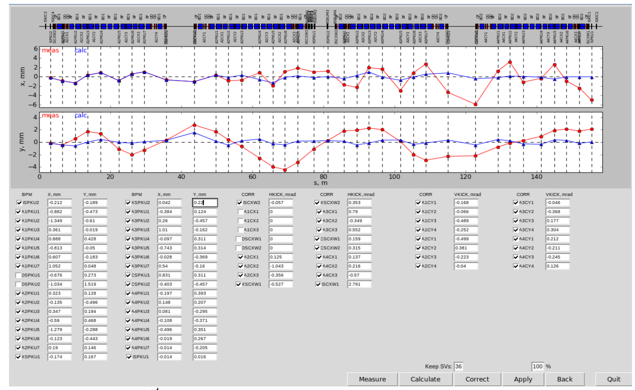

Figure 5: 1st turn beam trajectory measurement and correction.

CONCLUSION

The extended integration test 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 and the injector commissioning team build up the operation experience.

ACKNOWLEDGEMENTS

All of this work would not have been possible without constant support of all the NSLS II teams and the close collaboration with the BINP team.

REFERENCES

[1] F. Willeke, Commissioning Results of NSLS-II, IPAC15, 2015.
[2] T. Shaftan et al., Status of the NSLS-II injector, MOPEA080, IPAC13.
[3] G.M. Wang, et. Al, NSLS II Injector Integrated Testing, THPEA063, IPAC13.
[4] M. Borland, ‘Elegant: A Flexible SDDS-Compliant Code for Accelerator Simulation’, Advanced Photon Source LS-287, Sep, 2000.
[5] L. R. Dalesio, et. al., “EPICS Architecture,” Proc. of ICALEPCS‘91, KEK Proceedings 92-15, pp 278-282 (1992).
[6] http://cs-studio.sourceforge.net/