UPGRADE OF THE BOOSTER BEAM POSITION MONITORS AT THE AUSTRALIAN SYNCHROTRON

E. van Garderen, A. Starritt, Y.-R. E. Tan, K. Zingre
Australian Synchrotron, Melbourne, Australia

Abstract

Thirty two Bergoz Beam Position Monitors are located in the Australian Synchrotron booster ring. They suffered from a poor signal-to-noise ratio and a low sample rate data acquisition (DAQ) system, provided by a portable DAQ device. This architecture has been upgraded to offer better performance. Phase matched low attenuation cables have been pulled and readout electronics have been located in two sites to reduce cable length. Data acquisition has been upgraded using a high accuracy PCI board. The board's trigger, originally delivered by a Delay Generator, is now generated by an Event Receiver output following our recent upgrade of the timing system [1]. The new Linux driver is EPICS-based, for consistency with our control system.

INTRODUCTION

The Australian Synchrotron (AS) booster ring has a circumference of 130.2 m and a harmonic number of 217. It accelerates the 100 MeV beam from the linac to 3 GeV before injection into the storage ring within 600 ms. AS currently operates in decay mode with two daily injections to 200 mA. AS plans to implement top-up operations within two years. To reduce the operating costs, only one of the two linac klystrons will be used. The beam from the linac will no longer be injected at 100 MeV but at the highest energy that can be achieved with one klystron. Monitoring of the orbit at the extraction point to optimise the transfer to the storage ring will also be necessary. The booster will therefore need to be recommissioned, which will require the diagnostics equipment in the booster to operate reliably. The thirty-two beam position monitors (BPMs) that were not practically usable have been upgraded.

ORIGINAL DESIGN

The 32 beam position monitors are of the button type with four electrodes assembled diagonally at 30 degrees to the horizontal plane [2]. The signals were all brought into a single rack using standard RG58 cables and processed by Bergoz MX-BPM modules. The output voltages, proportional to the horizontal and vertical positions, were then fed into four NI-DAQPad 6015 (USB) modules that digitized each of the 64 signals at 12.5 kSamples/second/channel (single ended). These analogue-to-digital convertors (ADCs) were triggered at 1 Hz, which corresponds to the injection frequency of the machine. The timing signal was delivered through DG535 delay-generators [1]. The interface to the digitizer was through a laptop via a custom Labview program on Windows that would read a single sample at the trigger and update an EPICS process variable (PV) using the Labview Shared Memory Interface developed by the Spallation Neutron Source (SNS) diagnostic group.

NEW SYSTEM

As a result of using RG58 cables and large differences in lengths, there was a spread of 37 dB (-8 to -45 dB attenuation) in the signal strength across the BPMs. Although the dynamic range of the MX-BPMs (75 dB) is sufficient to cope with this spread it was observed that at any time half of the BPMs would be either saturated or too noisy due to the low signal strength. The acquisition system also needed a solution that is better integrated into the existing control system.

Cables have been replaced with LMR240 coaxial cables and have been cut to equalize electrical length and attenuation between the four signal cables of each BPM to $<$ 0.5 dB. The location of the electronics has also been split into two sites to reduce cable lengths. The final measurement of the attenuations of the cables showed a maximum spread of 25.6 dB and an RMS spread of 0.15 dB between buttons without BPMs 12 and 22 which are faulty (Fig. 1).

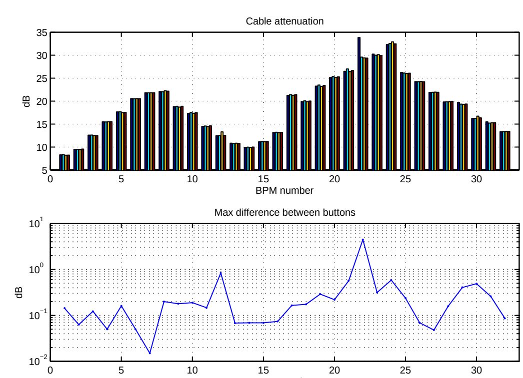

Figure 1: New attenuation values around the ring showing the variation across buttons (top). The bottom plot shows the peak to peak difference in the attenuation between button on a single BPM.

Two IOCs have been purchased, one for each site, and run CentOs 5.3 Linux. For reliability, the portable ADCs have been replaced by four National Instruments PCI cards (PCI-6289), with an increased sampling rate of 31.2 kSamples/second/channel (differential mode), and a resolution of 18-bits. These PCI cards were chosen as existing in-house developed Linux EPICS drivers (along with the Linux version of the NIDAQmx) had previously been developed for beamlines using base 3.14.9 and asyn-4.12.

The ADCs are clocked internally, but the low sampling rate of the Bergoz (2 kHz per BPM) does not require their internal clocks to be synchronized together. They are triggered by the 1 Hz injection trigger event from the timing system, delivered by two outputs of two event receivers (EVRs) [1], one for each site. The signals from the EVRs are daisy-chained so that all four PCI cards are fed with a trigger. A schematic of the setup is shown in Fig. 2.

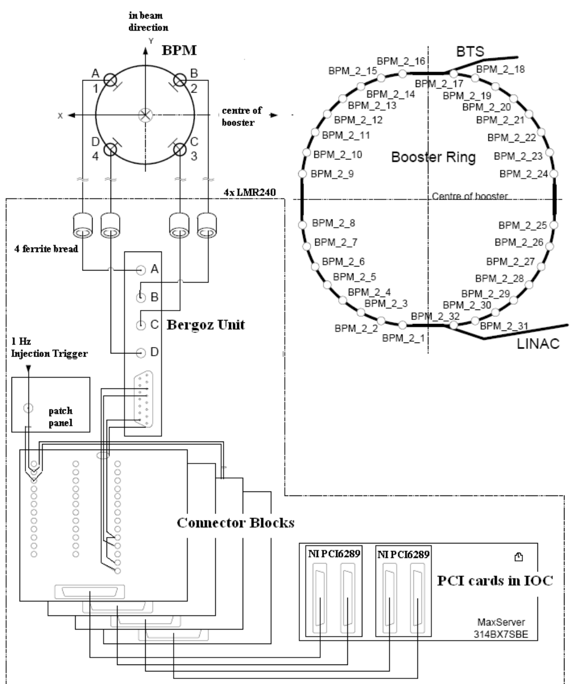

Figure 2: Setup of the booster BPM system showing a button monitor connected to a Bergoz unit and a PCI card.

The data acquisition can run in "trigger" or "single shot" mode. In "Trigger" mode, the system is primed to acquire data for a period of up to 800 ms, at a nominal rate of 10 kHz. The trigger occurs continuously at the rate of the injection trigger event (1 Hz), and requires the gun to be turned on. The IOC must transfer the data from the NI card to the appropriate PV and re-prime the card for the next pulse within 200 ms. This is a consequence of the booster ramping time being 600 ms. When the data acquisition is complete, the low level NI kernel notifies the EPICS driver that data is available and the 64 waveform records are updated. The horizontal and vertical mean positions are then generated as well as the standard deviations from the averaged positions.

In "Single Shot" mode the operator can start and stop the acquisition on demand. The trigger output from the EVR is inactive by default (tied-low). When the "single shot" button is pressed, the trigger becomes active until data are collected after the following injection trigger pulse. The trigger is then set back to "tied low".

A graphical user interface (GUI) based on the Borland-Delphi framework has been designed to display the BPM readings and the requirements listed above. See Fig. 3. The GUI allows for the choice of the acquisition mode (trigger or one shot) and for the selection of the offset and length of the acquisition points (up to 800 ms). The X and Y positions, resulting from the averaging over the "length" period of the raw data, are displayed as a function of the BPM number. Raw data of selectable BPMs can be plotted as a function of time.

MEASUREMENTS WITH THE NEW SYSTEM

With the new BPM system tightly integrated into the control system it is now possible to use the tools from Matlab Middle Layer (MML) [3] to optimise the injection system. The booster was left in a static state to capture and store 100 MeV electrons for one second for each injection at 1 Hz. By varying a single corrector a difference orbit was measured and compared against the ideal model. It was discovered that two of the four ADC cards were swapped around and the sign of the read back was inverted on the BPMs. Using MML one of the first booster response matrices was measured at 100 MeV, shown in Fig. 4. It immediately showed that horizontal corrector magnet (HCM) 15 was not affecting the beam (later found to be electrically shorted) and that there was a problem with BPM 14 (faulty Bergoz unit). Some of the noisy BPMs were the result of loose ground connections.

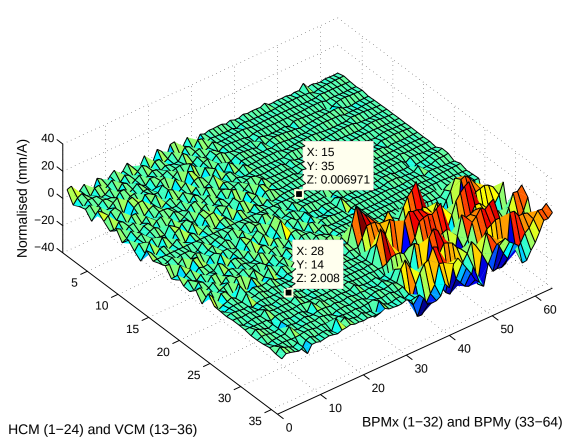

Figure 4: Response matrix for the booster at 100 MeV showing an unresponsive HCM 15 and a problem with BPM 14.

After solving the above issues another response matrix was measured and LOCO [4] was used to calibrate the BPMs and correctors. Not having a dispersion measurement (not yet measured) in LOCO lead to an ambiguity between the corrector and BPM gains when both were fitted at the same time and resulted in predicted kicks that were half

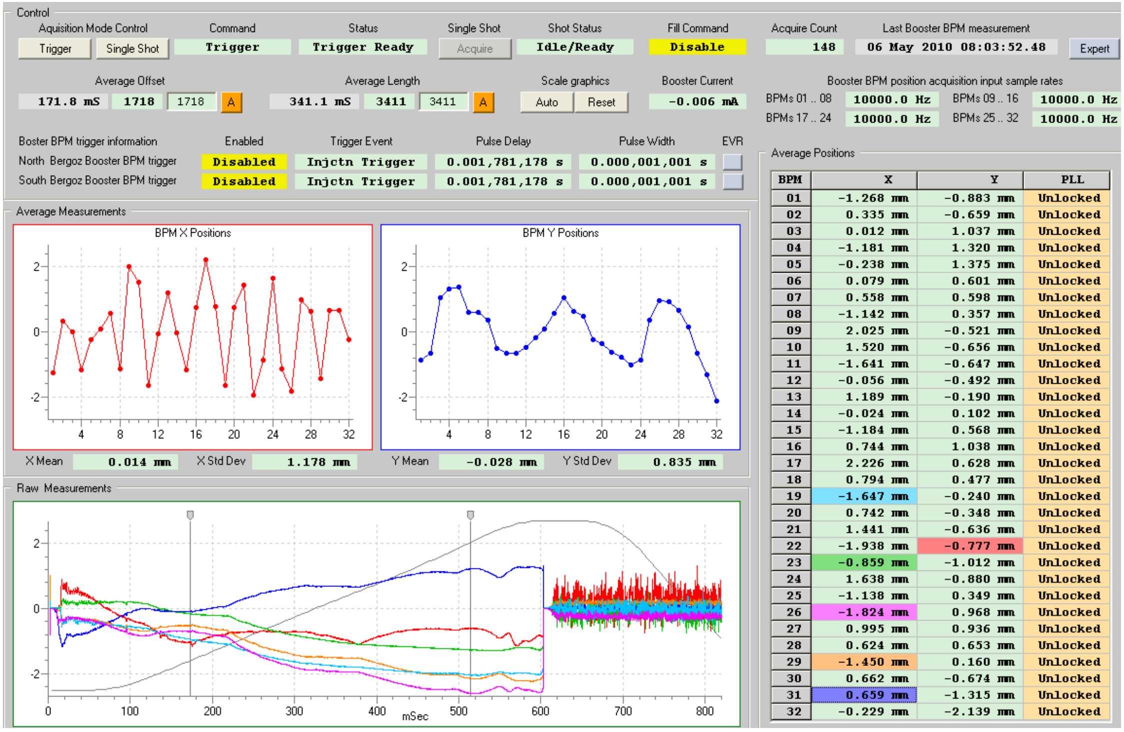

Figure 3: Graphical User Interface. See text.

of expected values. Fitting the BPM gains and coupling first before adding the correctors to the fit gave consistent corrector kicks averaging -0.63 mrad (H) and -0.23 mrad (V) where the expected was -0.60 mrad and -0.21 mrad respectively (Fig. 5). It also correctly picked out the half strength VCM 6 and also identified HCM 12 which was not in the correct location in the model.

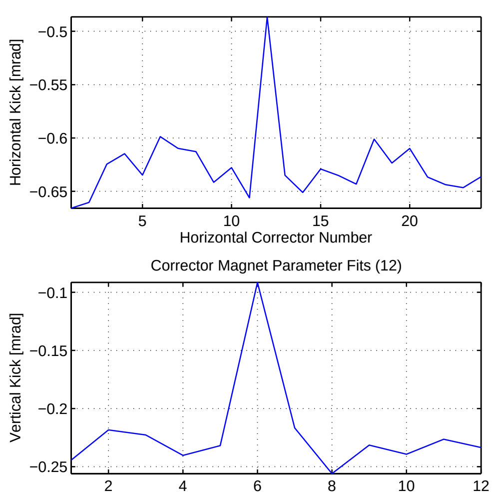

Figure 5: Corrector magnet fits in LOCO.

LOCO also reported an average gain on all the BPMs of around 0.35 which seemed strange at first as it was initially assumed that the BPMs had a total gain of 1 V/mm. Referring to Ref. [2], numerical simulations had showed a chamber geometry sensitivity of $S_x = 8.75\%/mm$ and $S_y = 5.25\%/mm$ which coupled with the gain on the Bergoz ($G_x = 0.0455V/\%$ and $G_y = 0.0763V/\%$) gives the predicted total gain of 0.400 V/mm in both planes. So the corrector and BPM gains were shown to be consistent.

CONCLUSION

The upgrade of the booster BPMs is almost complete. Hardware has been replaced and software has been developed to improve the performance of the system. This will allow better understanding of the behavior of the beam in the booster and help improve the injection efficiency. This will also be necessary for recommissioning the booster using only one klystron, as planed for the up-coming implementation of top-up.

ACKNOWLEDGEMENTS

Thanks for the extensive work done by Michel Ten Have and the electrical group at the AS.

REFERENCES

[1] E. van Garderen et Al., "Upgrade of the Timing System at the Australian Synchrotron", DIPAC'09, Basel, TUPD27, p. 357.

[2] S. V. Weber, "Booster for Synchrotrons - Exemplified by the Australian Synchrotron Booster", PhD Thesis, 2007.

[3] J. Corbett et. Al., "Accelerator Control Middle Layer", PAC, 2003.

[4] J. Safranek et. Al., "Matlab-based LOCO", EPAC, 2002.