INSTALLING A FAST ORBIT FEEDBACK AT BESSY

Roland Müller*, Benjamin Franksen, Rainer Görgen, Ralph Lange,
Peter Kuske, Ingo Müller, Joachim Rahn, Tobias Schneegans
Helmholtz-Zentrum Berlin für Materialien und Energie GmbH, BESSYII, Berlin, Germany

Abstract

In view of increased processing bandwidth at demanding experiments and the need for rapid compensation of noise spikes and new, yet unknown excitations, a fast orbit feedback aiming at noise suppression in the 1Hz-50Hz range has become mandatory for the 3rd generation light source BESSY II. The fast set point transmission plus the replacement of all corrector power supplies is scheduled as a first step. Later – in combination with top-up operation – orbit stability can be further improved by replacing today's multiplexed analog beam position monitors by state-of-the-art fast digital units. This paper describes how the pilot installation of a small subset of fast corrector power supplies allows to tune performance and study the benefits for today's most sensitive experiments.

INTRODUCTION

The level of photon beam stability needed by experimental signal conditions or resolution goals varies from experiment to experiment. At 3^{rd} generation light sources, sensitivity of measurements to electron beam motion typically requires micron and sub-microradian electron orbit stability, time scales range from hours to microseconds.

Many experiments today typically average data for as short as 100ms. Perturbations in the frequency range 1Hz to 50Hz have to be kept as low as possible to ensure that limits for high resolution experiments are not set by the broad-band noise floor. Any irregular transients and noise spikes generated by experimental activities at multi-user facilities have to be suppressed as fast as possible. Consequently, modern light sources put much effort into the design of all components crucial for the orbit stability and provide a sophisticated fast orbit feedback (FOFB) in addition.

THE BESSY SETUP: FEATURES, LIMITATIONS

Hunting and eliminating the sources of smallest beam motions has a long tradition at BESSY: the smaller the perturbations to correct, the less noise is introduced by imperfections of a feedback loop running at high gain.

To achieve these goals, power supplies have been additionally stabilized by ripple suppression circuits. Ultra-high precision, thermally stabilized I/O boards have been directly plugged into the power supplies, enabling short analog cable length and preventing signal cross talk. Set points and commands are transmitted to the I/O boards in digital form via ethernet and CAN bus network links. This setup results in a competitive high intrinsic stability of the light source.

Initial focus on the beam position monitor (BPM) data acquisition was precision and high dynamic range, achieved by integration and averaging of the BPM signals for 1s. Data collection from the 16 front end computers (IOCs) is done unhurried by a master node via software handshake over the standard network link every 2s.

This slow orbit feedback (SOFB) setup allows for a precise global orbit drift control with an excellent basic electron beam position and energy stability [1, 2]. The installed orbit correction scheme, running at a cycle of 0.2Hz, corrects orbit drifts as well as imperfect compensations of slowly moving insertion devices and guarantees good experimental conditions with respect to run-to-run and fill-to-fill reproducibility and uniformity.

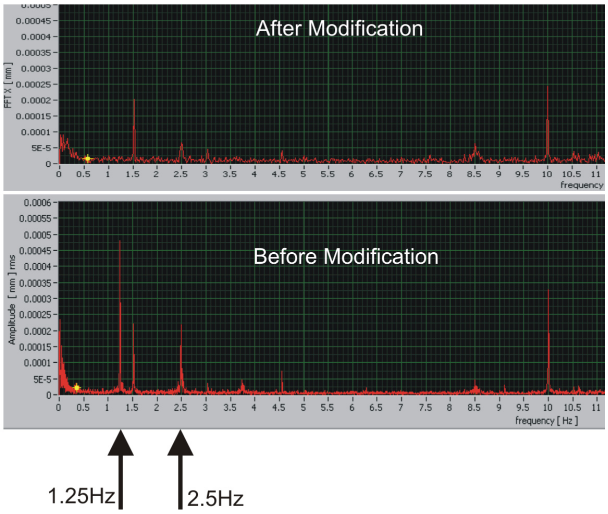


Figure 1: Recent example of successful noise elimination at the source. Analyzing the fast BPM data, the central bending magnet of the femtosecond slicing chicane could be identified as the origin of horizontal beam motions at 1.25Hz and 2.5Hz. Appropriate countermeasures have been taken with obvious success.

The major bottlenecks that have to be overcome for a FOFB at BESSY are corrector power supplies and set point transmission. Possible solutions differ from those available for new installations (Diamond, Soleil, ALBA) [3, 4], where the complete chain from BPM data acquisition to corrector actions has been tailored to the requirements of a FOFB at an early design stage.

---

* Roland.Mueller@helmholtz-berlin.de

UPGRADE OF COMPONENTS

A system typical for a first generation FOFB setup [3, 4] can be obtained by pushing the existing installation to the limits achievable with moderate investments.

Beam Position Data Acquisition

Parallel to the initial slow reference BPM data acquisition system, the fast BPM data collection with a sampling rate of maximal 2.4kHz and a 300Hz low pass filter has been in place since several years for diagnostic use in the 0.1Hz to the several 100Hz region.

The initial BPM data end station has now been augmented by dedicated compute and control workstations. A high throughput reflective memory network connects workstations and all corrector IOCs. During one cycle, all BPM readouts are available at the central computing node(s), where operation modes are controlled, set point changes calculated and distributed to the power supplies IOCs. This architecture allows for feedback correction loops tailored to specific mode space characteristics [5].

After these modifications, BPM data access is simplified and flexible. Fig. 1 shows the result of a beam motion analysis and the success of the attempted countermeasures: Doubling the switching frequency of the readback ADC on the I/O board, combined with an experimentally optimized pairing of a selected I/O-board and a specific power supply unit removed this perturbation (compare lower curve with upper trace in Fig. 1) and pushed this setup one order of magnitude beyond its specifications.

Fast Power Supplies

The new system places highly demanding requirements on new fast power converters:

An output current of up to +/-8A at 40V is needed to allow for 3mrad kicks[1]. The new power supplies have to have the same characteristics with respect to stability, precision, ripple, and thermal drift (typically +/- 25ppm) as the existing units, since they have to be replaced sequentially group by group without any noticeable effect on the storage ring performance.

Multiple options for set point inputs have to allow for future developments: if the CAN bus input to the present I/O board turns out to be insufficient, the slow control part via CAN bus could be disentangled from the FOFB system via the analog modulation input (Fig. 2). Even if component obsolescence or technical improvements require or advise the replacement of the whole power supply controller [8], no major modification should be needed.

The transfer functions measuring the effect of fast corrector magnet changes on the beam show the limits of the chosen WME PA4008\11 converters appear at 200Hz.

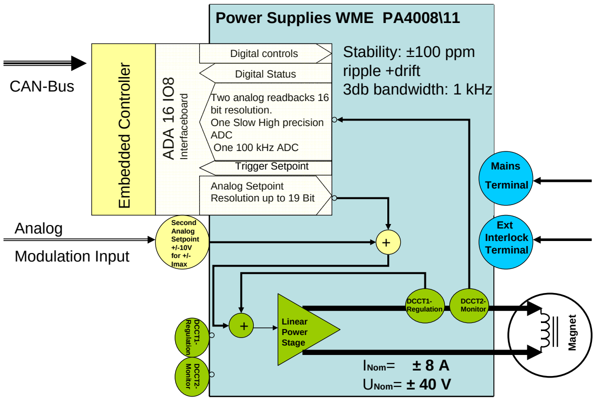
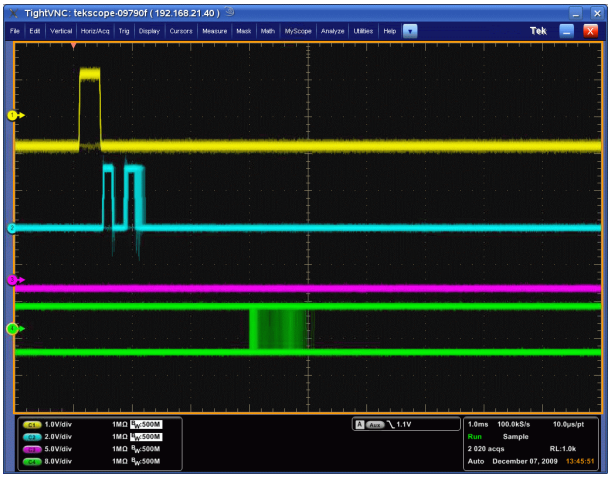


Figure 2: Power supply control flexibility is given by two symmetrical input interfaces: digital and analog set points are internally added (or optionally multiplied).

Set Point Transmission

Since the power supply I/O boards allow for set point changes at rates up to 200Hz, only the link between the central computing node and the power supply I/O boards had to be significantly modified and upgraded. This has been achieved by linking the 8 power supply IOCs and the FOFB computing nodes via reflective memory and by modifying the CAN based distribution from the IOC to the power supplies (see [6] for details).



C1 1.0V/div 1MΩ B_W:500M
C2 2.0V/div 1MΩ B_W:500M
C3 5.0V/div 1MΩ B_W:500M
C4 8.0V/div 1MΩ B_W:500M
A Aux ╲ 1.1V
1.0ms 100.0kS/s 10.0μs/pt
Run Sample
2 020 acqs RL:1.0k
Auto December 07, 2009 13:45:51

Figure 3: Measured data transmission time and jitter: 1ms after the clock trigger (upper, yellow line) all set points are delivered via reflective memory to the IOCs (middle, cyan line, 1ms/div). Without a sync event, 3ms later, with a jitter of 1ms, the last CAN object provides the set point to the power converter (bottom, green line).

The measurement depicted in Fig. 3 shows that set points are available at all power converters within 4ms. On the sync trigger, all power supplies reach their new values with a jitter of 0.1ms. Orbit data are delivered to the central VME crate with a scan rate of 600Hz (up to 2.4kHz). The central computing nodes can be chosen powerful enough

---

[1] The diagnostic value of this capability has recently been used to locate a beam destructive obstacle in the beam pipe with meter precision thus allowing for repair and resume of user operation withing about one week.

to complete the computation task for one cycle well within 2ms. Thus the known time budget of the present installation seems to allow for a closed FOFB loop running at a frequency around 100Hz.

Feedback Algorithm

The orbit correction capability of the Matlab Middle Layer (MML) toolkit [7] turned out to be a flexible and instructive supplement to the operational SOFB. It is also used on the RT-linux computing node of the FOFB as a rapid prototyping development environment and will be replaced by a custom program as soon as experiments have determined the optimal algorithm.

FOFB PHASE I

Pilot Installation

A small subset of 8 power supplies has been installed to be able to gain experience with the proposed system. Their position and orientation have been chosen to address the dominant components of known residual perturbations originating from the superconducting wavelength shifters, the femtosecond slicing chicane, fast polarization switching elliptical undulators, etc.

Global FOFB

Once extended to all corrector power supplies, we expect the full scale FOFB to eliminate most noise spikes or infrequent jumps harmful for difference measurement methods. We also expect a significant reduction of broad-band noise, which will improve intensity and contrast conditions for certain sophisticated experiments.

Maintenance/Upgrade Options

Dependent on the progress of recent developments [8] or maintenance requirements of components at BESSY II, a possible replacement of the power supply controllers might give room for further improvements. The deterministic and reliable data distribution investigated at NSLS-II seems to be a very promising approach [9].

FOFB PHASE II

In a second phase we intend to replace the BESSY BPMs by state-of-the-art, parallel processing, fast digital units to further increase correction precision: In combination with top-up operation, the large dynamic range (especially for high single bunch currents in decaying beam mode) is no longer necessary, and the precision of the beam orbit measurement could become better by nearly an order of magnitude.

By the time a final decision has to be made on which system to use, there will be sufficient experience available from other FOFB installations to be able to assess the advantages of the different solutions developed for the most recent facilities (e.g. NSLS-II). In addition, novel ingredients like the jitter minimized data distribution system [9] will be better understood.

SUMMARY

A fast acquisition of BPM data and a correspondingly fast distribution of these data via reflective memory to the nodes involved has been achieved, all in a reliable and easily configurable way. 8 out of 112 corrector power supplies have been seamlessly replaced by fast units, without any adverse effect on routine operation. The fast data distribution needed to close the feedback loop for any subset of FOFB phase I is installed and performs to specifications.

The pilot installation is expected to already provide worthwhile suppression of certain frequency components and will provide valuable information on possible shortcomings of the envisaged setup. The running-in process features identical data representation on all relevant intermediate levels of the SOFB and FOFB systems (BPM data, power supply set points, correction algorithm, and control parameters). Thus, slowing down the new fast system to the Hz level, the FOFB system has to show behavior that is identical to the well known SOFB system. This consistency check has been successfully completed. Now, machine development time is needed to tune the fast feedback performance for the subset already available.

REFERENCES

[1] Orbit Stability at BESSY, J. Feikes, K. Holldack, P. Kuske, R. Müller, `RPAE035`, PAC'2005, Knoxville, USA (2005)

[2] Orbit Stability in the 'Low Alpha' Optics of the BESSY Light Source, J. Feikes, P. Kuske, R. Müller, G. Wüstefeld, `THPLS017`, EPAC'2006, Edinburgh, UK (2006)

[3] Global Fast Orbit Feedback System Down to DC using Fast and Slow Correctors, N. Hubert, L. Cassinari, J. Denard, A. Nadji, L.S. Nadolski, `MOOC01`, DIPAC'2009, Basel, Switzerland (2009)

[4] Overview of Fast Beam Position Feedback Systems, D. Bulfone, `TUZM02`, EPAC'2008, Genoa, Italy (2008)

[5] Introducing Fast Orbit Feedback at BESSY, R. Müller, R. Görgen, R. Lange, I. Müller, J. Rahn, `THP059`, ICALEPCS'2009, Kobe, Japan (2009)

[6] Preparing Slow Controls at BESSY for Fast Orbit Feedback, R. Lange, R. Görgen, I. Müller, R. Müller, J. Rahn, `THP063`, ICALEPCS'2009, Kobe, Japan (2009)

[7] Optic calibration at the MLS and BESSY II, P. Schmid, D. Engel, J. Feikes, P. Kuske, R. Müller, G. Wüstefeld, `WEPEA014`, IPAC'2010, Kyoto, Japan (2010)

[8] Control Architecture of a New Power Supply Controller for Diamond Light Source, M. Heron, M. Abbott, J. Dobbing, A. Rose, J. Rowland, I. Uzun, `TUP062`, ICALEPCS'2009, Kobe, Japan (2009)

[9] Power Supply Control at NSLS-II, Y. Tian, EPICS Collaboration Meeting, Vancouver, Canada (2009) `http://isacwserv.triumf.ca/...` `...epics09html/FR1/PS_control_EPICS09.ppt`