A TUNE FEED FORWARD SYSTEM FOR THE BESSY II STORAGE RING*

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Abstract

The gaps of the BESSY insertion devices (ID) are driven independently under control of the corresponding beamline user. Changing an ID gap creates a tune shift of the electron beam that has to be compensated by correcting the settings of quadrupole magnets. The Tune Feed Forward System collects the gap information of all IDs and evaluates the resulting correction values for the quadrupole magnets. These values will be applied as offsets to the quadrupole power supplies.

This paper describes the design and implementation of the Tune Feed Forward System, which allows for a rapid prototyping process as well as a reliable and stable operation mode.

INTRODUCTION

The insertion devices (IDs) of the third generation light source BESSY II are operated independently under user control. Changing the ID gaps has an important impact on the lifetime of the electron beam due to the resulting tune shifts and distortions of the optical functions. A typical lifetime for a current of 250 mA is 5-8 h, this decreases by 30-40 % when specific IDs are changing their gaps to small values. Decreased lifetime results in more frequent injections, which is not tolerable.

It has been shown that this type of lifetime reduction can be cured by introducing a feed forward scheme that adds correcting offsets to the fields of the involved quadrupole magnets. [1]

REQUIREMENTS

A static preset of the magnets is a prerequisite for a stable storage ring operation. To be able to separate the static preset from correction values resulting from certain correction algorithms the control system has to provide an appropriate interface to the magnet power supplies.

A further requirement for implementing correction schemes is the availability of a prototyping tool. The intended correction algorithms have to be tested before they are activated in the production system. These tools are typically supporting the expert in testing out different approaches to correct the machine.

In contrast to the prototyping period, where fast and comfortable tests and iteration cycles are needed, day-to-day operation requires a stable, reliable implementation of the correction scheme. To operate the storage ring using automatic correction algorithms it is essential to implement these schemes in a transparent way. The operator should be enabled to easily identify problems resulting from the correction algorithm as quick as possible.

POWER SUPPLY SOFTWARE INTERFACE

In the BESSY II control system all quadrupole power supplies are represented by a structure which dedicates one main input to the setpoint associated with the static preset required for the storage ring optics. Additionally the structure provides variable offset inputs that can be written to. (Fig. 1 shows the graphical representation on the operator screen.) These offset inputs are typically used by application programs to apply results of correction algorithms. All offsets are added to the main setpoint and the result will be written as the raw setpoint to the power supply hardware.

18.25 223.68 365.00

MEM: 223.99

223.41 setpoint with offsets

setpoint	223.68	offset G	0.00
offset B	-0.27	offset H	0.00
offset C	0.00	offset I	0.00
offset D	0.00	offset J	0.00
offset E	0.00	offset K	0.00
offset F	0.00	offset L	0.00

Figure 1: Quadrupole Control Panel

PROTOTYPING

As a first step the computed offsets for the quadrupoles have to be tested on the running machine.

The BESSY II control system is based on the EPICS software package [3]. In this context the SDDS-compliant EPICS toolkit [2] provides a large number of useful applications which can be run on the operator console. These tools can acquire data from the control system, process it, and write back computation results.

The sddsfeedforward application made it possible to conveniently test out the intended feed forward algorithm. Simple text files with sensor / actuator value sets were used to define feed forward tables for the corrector values. In this case the gap readback of a certain ID is the sensor value and the resulting quadrupole setting the actuator value. Because sddsfeedforward is an external application program,

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there is no need to implement an EPICS database for prototyping the algorithm. The results of the prototyping process are tested feed forward tables. These tables are breakpoint tables with ID gap / quadrupole offset value pairs. For ID gap values between breakpoints a linear interpolation between the neighbouring values is sufficient.

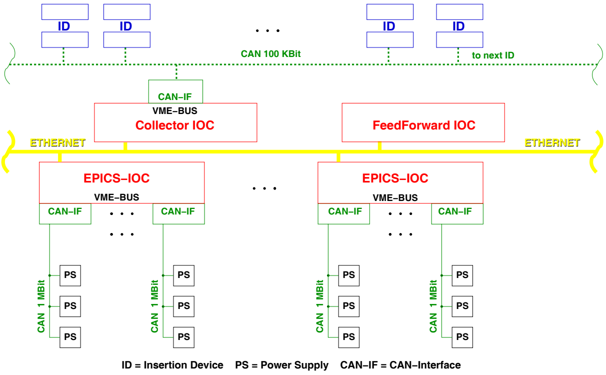

Figure 2: Tune Feed Forward Setup

FEED FORWARD IMPLEMENTATION

The BESSY II control system is a so-called standard model control system with Unix operator consoles, Ethernet as communication path, and VME front end computers. The CAN field bus is extensively used to interface all power supplies and many other devices [4].

All insertion devices are connected to a 100 kBit CAN field bus segment. This circular CAN bus segment serves as a highly available real time data path between the control system and the IDs. A dedicated VME computer (collector IOC) is the only connection from this CAN circle line to the control system. Whenever relevant information like gap, shift, or status changes are available, the IDs send this data to the collector IOC via the CAN bus. This data path is also used to send commands from the control system to the insertion devices (Fig. 2).

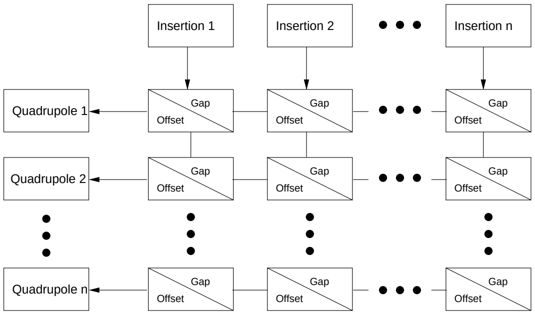

Figure 3: Feed Forward – EPICS Database Scheme

The feed forward tables derived from the prototyping process are transformed into EPICS breakpoint tables. These breakpoint tables are stored on a dedicated feed forward IOC and translate the gap information to quadrupole offsets. An EPICS database (Fig. 3) running on the feed forward IOC reads the ID gaps values from the collector IOC every 0.1 seconds and calculates the quadrupole offsets using the breakpoint tables. With the same 10 Hz repetition rate the feed forward IOC sends the offset values to the distributed IOCs that are controlling the affected quadrupole power supplies. On these IOCs the offsets will be added to the presets as described in Section .

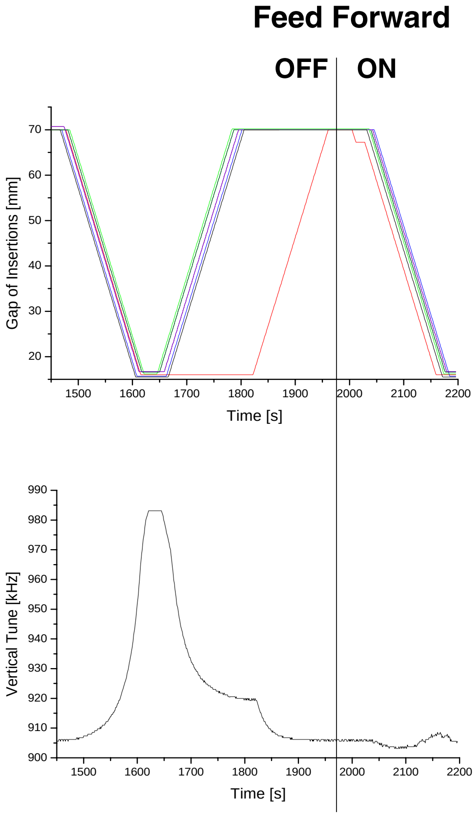

Figure 4: ID Gaps and Tune with Feed Forward OFF / ON

PERFORMANCE

Figure 4 shows the performance of the implemented feed forward scheme.

The gaps of the IDs are shown in the upper part and the corresponding tunes of the machine in the lower part. In the left part of the charts the feed forward is OFF while the ID gaps are changing from 70 mm to 15 mm. This results in a tune shift of 80 kHz (from 905 kHz to 985 kHz). In the right section of the charts the feed forward is ON – it reduces the tune shift to 5 kHz (from 905 kHz to 910 kHz).

CONCLUSION

In an EPICS based environment the sddsfeedforward application is a convenient prototyping tool for testing calculated feed forward tables.

The CAN field bus has proven to be a ruggedized, reliable real time data path between control system and insertion devices.

A transparent and stable implementation for the production system was easily created as an EPICS database.

For standard insertion devices a feed forward scheme based on breakpoint tables with ID gap / quadrupole offset value pairs is sufficient.

OUTLOOK

After operating the described feed forward scheme for several months it turned out that the utilized correction algorithm works well as long as the tune shift of the machine depends only on the gap of a certain insertion device.

For elliptical undulators not only the ID gap but also the shift parameter produces a tune shift of the machine (Fig. 5). An improvement would be the implementation of a feed forward scheme based on two-dimensional breakpoint tables. The correction offset for a certain quadrupole should be a value in the correction value space spanned by the gap and shift parameters.

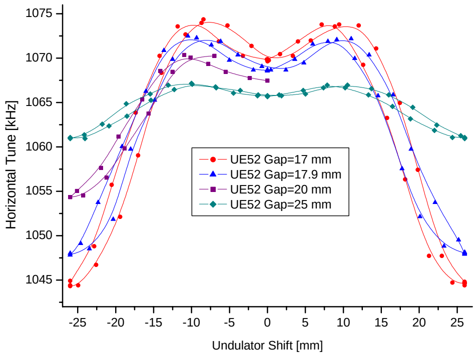

Figure 5: Tune Shift Due to Shifts of Elliptical Undulator

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