A FAST GLOBAL FEEDBACK SYSTEM TO CORRECT THE BEAM POSITION DEVIATION IN THE ESRF STORAGE RING

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Abstract

We have installed a fast global orbit correction system in order to reduce in the vertical plane the fast distortions of the closed orbit due to the mechanical vibrations of the girders supporting the quadrupole magnets of the storage ring of the ESRF. The main parameters of this system are:

-bandwidth of the correction: 10^{-2} to 200 Hz

-number of BPMs and correctors :16

The correction is based on the SVD analysis of the machine response to individual correctors. The fast corrections are computed by a floating point DSP connected to the BPMs and correctors with a fast digital data link. We present the implementation of the system (BPMs RF and digital electronics).We present datas on the efficiency of the orbit correction measured after the commissioning of the system.

1 INTRODUCTION

The ESRF storage ring is a high brilliance source with low emittance values (ε_x=4.10 $^{-9}$ m.rad and ε_z=4.10^{-11} m.rad) and generates Xray from insertion devices installed on 5 m long straight sections. With β_x=36m and β_z=2.5m in the center of the high beta straight sections, the rms beam sizes at the BPM locations on both ends of the straight sections are σ_x= 380µm and σ_z= 14µm.

The parasitic motion of the beam due to slow drifts or high frequency vibrations of the quadrupoles support girders must be kept at low enough values to avoid spoiling this emittance figure. We observe two kinds of motions: very slow drifts and vibrations at 7Hz, 30 Hz and 60 Hz. The amplitude of these vibrations at the ends of the straight sections is 10 µm rms horizontally and 3µm rms vertically. The slow drifts are corrected every 30 seconds by a global correction method using the measurements made over the whole machine by the 224 BPMs of the closed orbit measurement system [1]. We are adding another correction system to damp these vibrations in the vertical plane. These vertical vibrations are smaller compared to the horizontal vibrations, but not negligible compared to the incoherent motion due to the vertical emittance.

2 SYSTEM CONFIGURATION

This system uses 16 BPMs and 16 correctors to correct the orbit at a 4.4 KHz rate in order to provide an extra damping in the 10^{-2} to 200 Hz frequency range. The layout of the system is shown on figure 1.

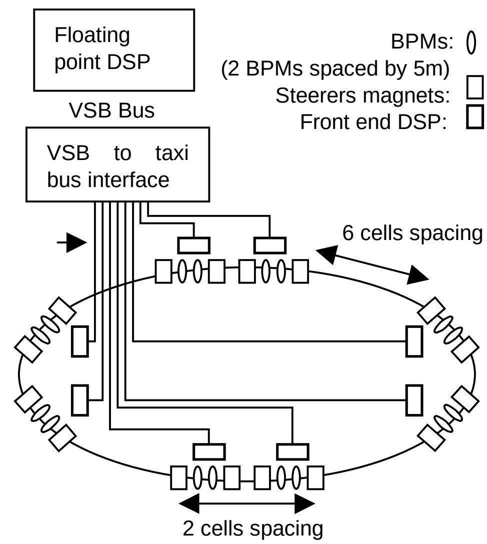

Figure 1: Layout of the global feedback system.

2-1 Beam position measurement

The beam positions are measured using capacitive electrodes installed at both ends of the straight section. The BPMs of eight straight sections are used as shown in figure 1. This location is not the best in terms of ßz value, since the ßz is only 5 m there, but it enables electrodes to be closer to the beam in the narrow 18 mm gaps ID vessels, giving a better sensitivity to the BPMs; the large phase advance value along the straight section (˜100°) is also convenient.

The electrode signals are detected with the now classical RF multiplexing system [2]. The beam positions in both planes are computed by the front-end feedback digital signal processors after acquisition of the sampled electrode voltages by an ADC module.

Special attention has been paid to the noise of the electronics in order to achieve a resolution of 20 nm/√Hz over the full operation intensity range from 5mA (in single bunch) to 200 mA . Special features of our BPMs are: impedance matching of the electrodes by resonant RF transformers, 4.4 KHz multiplexing synchronized with the beam, low noise amplifiers and gain control [2].

2-2 Orbit corrections

The correction kicks are produced by sixteen air coil steerer dipoles. These steerers are located near the ends of the eight straight sections equipped with BPMs, between the adjacent quadrupole triplets and the dipoles.

ßz value at the steerers location is 35 m and the phase advance between two steerers in a cell is 120°. The stainless steel vacuum chamber at the steerers location is 2mm thick giving the beam a flat frequency response to the magnet field up to 1 KHz. The steerers are powered by wide band power amplifiers and are able to produce up to 40 µradian kicks in a 1 KHz bandwidth . They contribute for .4 ms to the loop delay.

4 SIGNAL PROCESSING

4.1 Correction algorithm

With the 16 positions we calculate a correction vector using the matrix of the response of the feedback BPMs to each steerer, inverted using the SVD method. In the vertical plane, due to the lower value of the vertical tune (14.39), 16 position measurements are sufficient to calculate a correction reducing usually the orbit distortion by a factor of 3. The best efficiency is achieved with 8 eigen vectors for the correction calculation.

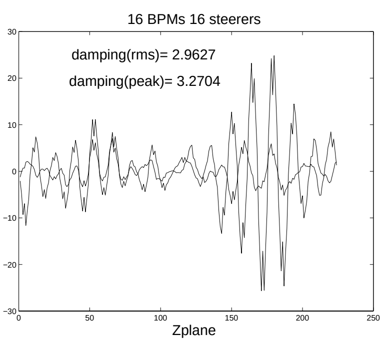

Figure 2: Example of static orbit correction obtained with our 16 BPMs/16 steerers system

4.2 Dynamic correction parameters

This correction vector is used to compute the actual correction applied to the beam using the previous correction values and a proportional integral iterative algorithm (PID type). In addition, the correction is cancelled at very low frequency (10^{-2} Hz) to decouple the fast orbit correction from the slow orbit correction.

These dynamic parameters have been chosen in order to meet the following requirements:

- The cut-off frequency fc must be at least two time higher than the highest frequency (60 Hz) that we want to damp significantly.
- The sampling rate also affects the signal delay in the loop since a new correction is applied one sampling period after the corresponding position measurement; the total loop delay must be less than 1/(10. fc) in order to have a stable loop and if we do not want to amplify the input signals above the cut-off frequency as shown in figure 3.
- In addition, we need to sample correctly some spurious signals related to the energy fluctuation of the beam at the synchrotron frequency fs = 1.9 KHz: The dispersion is not null at the BPMs location, causing a significant horizontal position fluctuation and adding 1.9 KHz parasitic signals on the BPMs electrode signals. This requires a minimum sampling rate of 2 x fs and 4.4 KHz is the most convenient sub harmonic of the revolution frequency close to 2x fs.

4.3 Digital signal processing hardware

The digital signal processing is implemented as shown on Figure 1. The corrections are computed at a 4.4 KHz rate by a VME board equipped with a TI C40 floating point DSP and an extra VSB bus [3]. The data transfer (beam positions and correctors settings) are made through this VSB bus. The data transferred through the VSB bus are transmitted on eight optical data links to eight front-end VME crates close to the location of the eight groups of BPMs and steerer magnets through two interface boards. The data transfer at both ends of the optical fibres is done with "taxi bus" drivers implemented on IP modules developed at ESRF [3]. These "taxi bus" IP modules are implemented on VME boards developed at ESRF, equipped with a AD2171 fixed point DSPs; two DSP boards, each equipped with four taxi bus drivers and a VSB bus interface, manages the data transfer between the eight optical fibres and the main DSP board. At the other ends of the fibres, eight of these fixed point DSP boards, also equipped with ADC and DAC IP modules, manage, in addition to the data transfer on the taxi bus, the data acquisition from the BPMs and the programming of the steerers current. A clock signal at 4.4 KHz , a subharmonic of the 355 KHz revolution frequency, is distributed all around the machine and synchronizes these processes as well as the multiplexing/demultiplexing of the BPM signals. The data acquisition and transfer to and from the main DSP takes 100 µs leaving 125 µs for the main algorithm execution.

5 TESTS OF THE SYSTEM

The measured damping efficiency obtained is shown on the transfer function in figure1. The signals delay in the loop is .78 ms (including the contribution of the BPMs electronics, steerers amplifiers, eddy currents, processing time); it induce some unwanted signal amplification above the loop cut off frequency for the larger values of the feedback bandwidth as shown in figure 3. Eventually, the optimum value of the bandwidth of our feedback, giving a good damping of 7 Hz to 60 Hz lines and a moderate amplification of high frequency signals is 150 Hz. Without feedback, the main perturbation is a 7 Hz line due to the mechanical resonance of the quadrupole girders as pointed out in 1. With the feedback on, as shown in figures 4 to 6, the amplitude of this line is reduced by 10 dB, as measured during the static tests and the 150 Hz AC line remains the main perturbation.

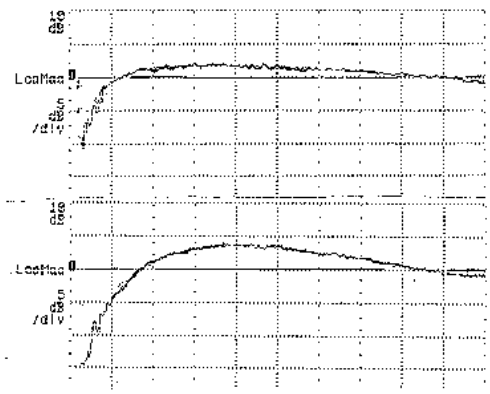

Figure 3: recording of the transfer function of the loop (BW= 100 Hz and 200Hz, 10 dB/div, span 0 to 1KHz)

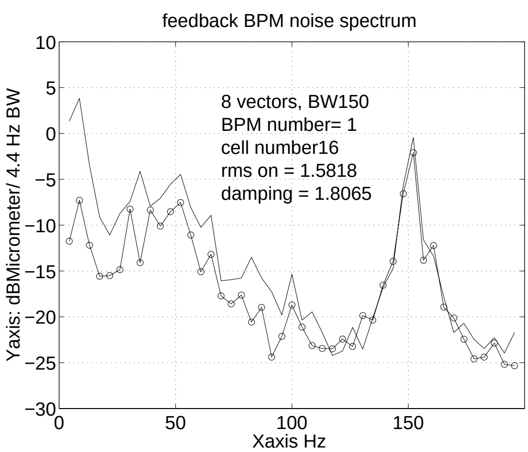

Figure 4: Spectrum of the beam position motion signal of a feedback BPM with feedback off and on

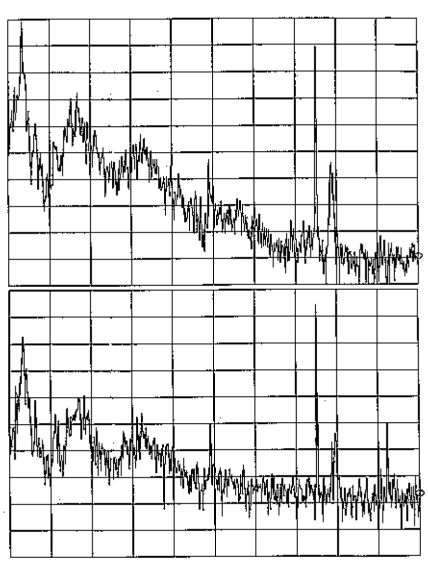

Figure 5: Spectrum of a dipole X ray beam position 25 m away from the source with feedback off and on (5dB/div, 200 Hz span).

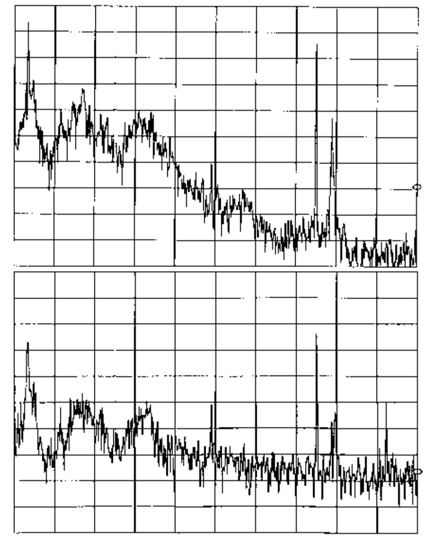

Figure 6 : Spectrum of an undulator X ray beam position 25 m away from the source with feedback off and on (5dB/div, 200 Hz span).

7 CONCLUSION

The system works. It is mostly efficient on the lowest frequency orbit distortions which are the most harmful for the users. The drawback is a slight increase of the beam motion at higher frequencies (200 to 600 Hz) due to an excessive signal delay in the amplifiers of the steerers. The principle of the correction is not original but the efficiency of this scheme at high frequency and on very small orbit distortion required a careful optimisation of the performances of its different components performances. The key parameters in such a system according to our experience are the noise of the BPMs, the bandwidth of the correctors, the number and location of the BPMs and steerers, the delay in the loop.

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