THE NEW FAST ORBIT CORRECTION SYSTEM OF THE ESRF STORAGE RING

E. Plouviez, F. Epaud, J.M. Koch, K.B. Scheidt, ESRF, Grenoble, France

Abstract

The ESRF is upgrading the orbit correction system of its storage ring. The goal of this upgrade is to damp the effect on the orbit stability of the insertion devices during the changes of their settings, as well as the effect of the environmental vibrations and AC main power spurious fields; in order to achieve this goal we aim at a correction bandwidth of 200Hz. The final system will use the data of 224 BPMs already equipped with Libera brilliance electronics. The correction will be applied by a set of 96 correctors implemented in the auxiliary legs of the sextupolar magnets, driven by newly designed fast power supplies . The power supplies are controlled using a set of 8 FPGA boards connected to the power supplies inputs with serial links; these FPGA will also compute the correctors currents using the BPMs data.

GOAL OF THE UPGRADE

Limitation of the Present Orbit Correction System

The closed orbit of the SR is affected by several kind of perturbations; some are randomly spread both over the ring in the space domain and in the time domain: slow ground settlements and environmental vibrations, AC fields at the frequency of the mains power supplies (50Hz and its harmonics); an insertion devices operated in a straight sections can also cause parasitic kicks during changes of its parameters settings (gap or phase): in this case, the perturbation occurs over a short period of time at a single location. Until now the orbit correction is performed by combining the action of two systems: a slow system applying corrections which are derived every 30 seconds from 224 position measurements using 96 correctors magnets, and a fast system applying 32 corrections at a rate of 4.4 KHz using 32 large bandwidth (1KHz) correctors magnets in the horizontal plane and only 16 correctors in the vertical plane, achieving a correction bandwidth of DC to 150Hz [1]. The weakness of this scheme is that in the case of orbit perturbation caused by the changes of the settings of an insertion device, the correction produced by the fast system will not be very effective in the interval between the two correctors surrounding the perturbation; this interval will extend over at least one cell but can be as large a three or four cells, due to the low number of fast correctors (32 horizontal and 16 vertical correctors).); last but not least, the components of the fast system are now ageing and getting difficult to maintain.

New System Features

The 224 BPM pick up sets of our storage ring are now equipped with *Libera Brilliance* electronics interconnected by the so called *Communication Controller* [2, 3] network broadcasting the position data of the 224 *Libera* at a rate of 10 KHz. In order to improve the reduction of the detrimental effect of the transient change of the insertion devices settings we have drastically increased the number of fast correctors thanks to the upgrade of the power supplies of the 96 correctors magnets of the original slow system. So in the near future, the orbit correction will be done using a single fast system and the old fast system will be decommissioned. In addition the large data stream available through the *Communication Controller* will be used to implement new diagnostics.

IMPLEMENTATION OF THE NEW SYSTEM

Upgrade of the Correctors Power Supplies

The present slow correctors are implemented by adding 3 pairs of auxiliary coils on the yoke of the sextupoles; using the proper combination of currents in these 3 coil pairs as shown in Fig. 1, we can produce any combination of vertical and horizontal kicks. The bandwidth of these correctors is affected by the eddy currents in the sextupole core and at the surface of the vacuum chamber (the vacuum chamber all over our storage ring is made of 2mm stainless steel); the inductance of these correctors is also quite large:0.6H. However, it is possible to achieve, given the small amplitude of the high frequency currents needed for the fast correction, a small signal bandwidth of 500Hz for these correctors with a proper design of the power supply. The setting of the power supply can be controlled through the main Ethernet network of our control system; an additional trim setting can be added at a rate of 10 KHz on 10% of the full dynamic range through a RS485 interface; this RS485 port is used to input the data of the fast orbit correction system.

New System Layout

The design of our new system is based on the availability of the Libera Brilliance electronics and an associated "Communication Controller" developed at DLS and using the Libera Rocket I/O ports. This allows the measurement and broadcast of the beam position with a very good resolution at a rate of 10 kHz. As indicated above, we are using the corrector magnets embedded in the sextupole cores to steer the beam. Since the power supplies feeding these magnets are installed at four locations, this particular constraint sets the architecture and topology of our system and therefore, the correction computation will be placed close to the power supplies and spread over 8 processors. For this processing, we selected a PMC board embedding a Xilinx Virtex-5 FPGA. The code embedded in this FPGA has several functions: 1) collect the data from the BPMs at 10 kHz 2) get the parameters from the PCI 3) process the corrections 4) send the set-points to the power supplies. The choice of performing the corrections inside the FPGA was driven by the fact that no real-time operating system was supported at the ESRF.

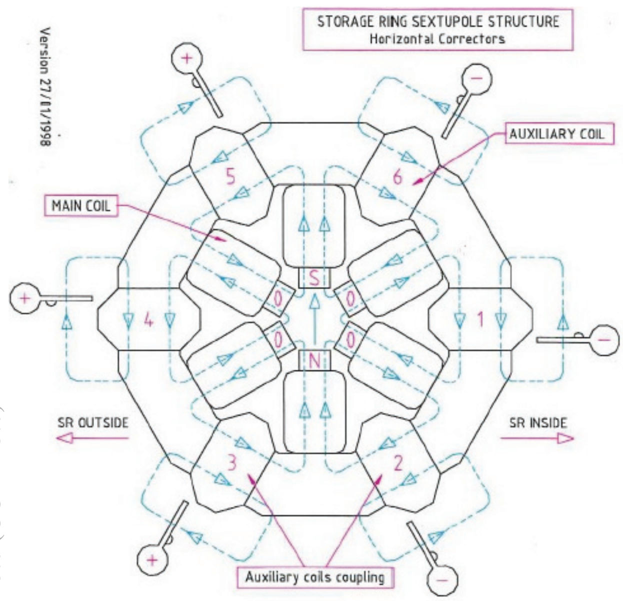

Figure 1: Layout of the auxiliary correctors in a sextupole.

Orbit Correction Algorithm

We will derive the orbit correction from the BPM data using a correction matrix obtained from the inversion of the response matrix of the BPMs to each corrector. These response matrixes are inverted using the SVD method. We will use 96 eigenvectors for the inversion of the response matrix. Before starting the 10 KHz correction loop, we will measure the average orbit and set the correctors currents in order to suppress the error measured on this average orbit; these DC values will be applied using the Ethernet input of the power supplies. We will then start the fast correction loop which will add an additionnal trim current to the DC current set initially. During the first tests of this fast loop, we have used for the 10 KHz iteration of the values of the trim correction currents a PID algorithm with an additional 50 Hz notch filter aimed to improve the damping of the perturbation at the AC main power supply frequency. Over long periods of operation, the average value of the trim currents may eventually drift up to significative values. In this case, this average current will be added to the setting of the Ethernet input of the power supply, and the average value of the fast trim currents will drop to zero. In this way, if the fast correction loop is stopped, setting the values of the trim currents to zero will only result in a very small orbit jump.

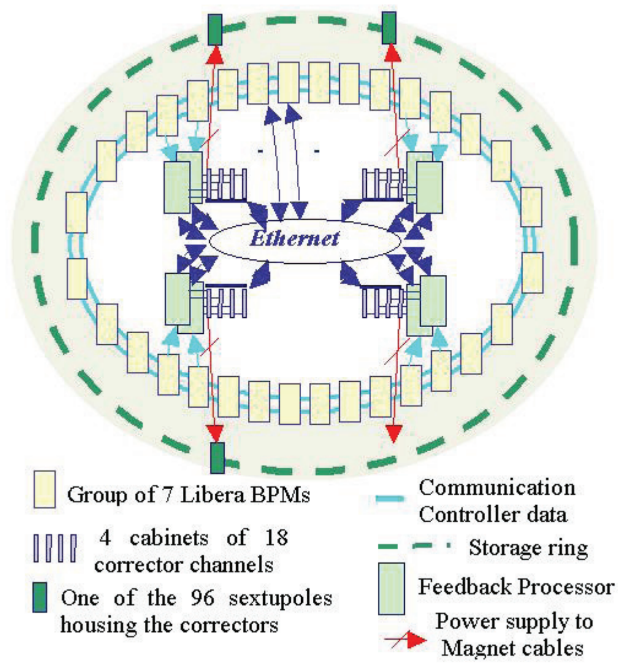

Figure 2: Layout of the future orbit correction system.

Diagnostic

In addition to the 8 feedback processor/power supply controller modules, one FPGA PMC board has been added; this board is fully dedicated to diagnostics, and is able to log up to 10s of position data; this board is a duplication of the so called "sniffer" developed for the SOLEIL and DLS orbit control systems [3].

FIRST TEST

Orbit Correction Test Set-Up

All the correctors are now equipped with their new power supplies and the BPMs FA outputs are interconnected. At the end of the year 2010, we have first implemented one power supply controller FPGA board (at this time the full batch of FPGA board was not yet available). With this single board, we were able to receive the position from all the 224 BPMs from the *Communication Controller* and to control the 6 correctors of 2 cells of the storage ring; however, given the 16 fold symmetry of the storage ring, running a local correction over these two cells is enough to assess the potential performance of the full system. The correction bandwidth was set at 150Hz, and at this stage no ponderation (Tikhonov regularization for instance [4]) was applied on the damping time of the upper order eigen vectors of the SVD decomposition. We recorded the position data with the sniffer module.

Tests Results

The plots of Figs. 2 and 3 show the reduction of the horizontal BPM signals observed at the beginning of a straight section (β_H=36m,left plots) and the reduction of the vertical BPM signals observed in the achromat (β_V=36m, right plots) .

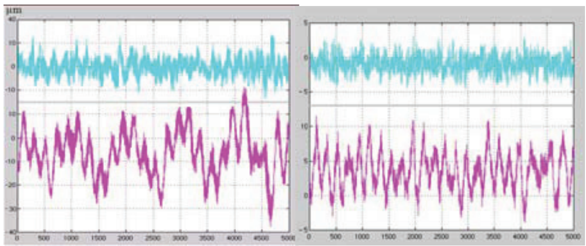

Figure 3: BPM signals with orbit correction ON (blue) and OFF (purple), H scale 50ms/div, V scale 10µm/div (left plot) and 5µm/div (right plots).

The feedback performs as expected in terms of bandwidth and damping of the 50 Hz. We have also tested that starting from an orbit already set by a slow orbit correction, turning on or stopping the fast loop was not causing any significant orbit jump. The plots of Fig. 4 show also that the noise created by the loop overshoot in the vicinity of the cut-off frequency is negligible thanks to the very low noise of the *Libera Brilliance* electronics.

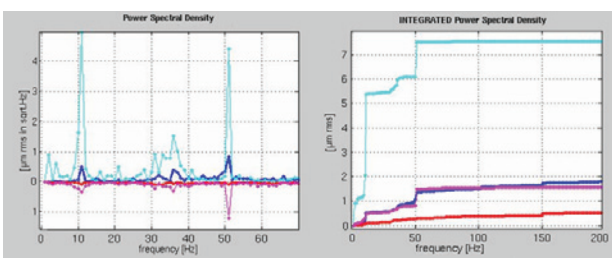

Figure 4: Power spectral density (left) and integrated power spectral density (right) averaged over the BPMs of the 2 corrected cells with and without orbit correction. Light blue, dark blue: H signals, purple, red: V signals

Other Measurements

The resolution of the 10 KHz FA output is better than 250nm for a bandwidth of 2KHz in the range of current that we store in operation. Such a resolution allows the measurement of SR parameters like the measurement of the matrix of the response of the BPMs to the correctors current, or the analysis of the SR optics coupling with a very low excitation of the beam and a short acquisition time; applying excitation signals modulated by a sine signal at a well chosen frequency, and a narrow bandwidth analysis of the beam response at this frequency, using the method tested at DLS [5], we checked that with a measurement time of 1s, a resolution of 6nm was achieved. We have used the sniffer to record over 1 second the response of the BPMs to a 40 Hz modulated 150nrad kick from an horizontal corrector. The horizontal response amplitude is 5µm (left plot of Fig. 5); the signal from the vertical response (right plot) which is due to the coupling of the horizontal and vertical optics is very clean, though its amplitude is only 150nm

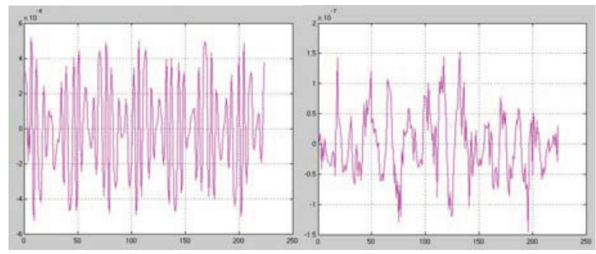

Figure 5: Horizontal (left plot) and vertical (right plot) response of the beam orbit to a horizontal kick of 150nrad.

CONCLUSION

We have have now installed and tested most of the components of our new orbit correction system; we have tested the performance of this system on a part of our storage ring covering 2 of the 32 cells and the damping of the orbit distortion that we achieved on this part of the ring fulfil our expectation.

ACKNOWLEDGEMENT

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