UPGRADE OF THE GLOBAL FEEDBACK OF THE ESRF STORAGE RING

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Abstract

We have recently upgraded the fast orbit correction system of the ESRF storage ring. We are now operating a global feedback system using 32 BPMs and 24 correctors in the horizontal and vertical planes to compute and apply corrections at a rate of 4.4 KHz from .1 to 150Hz. This new system has greatly improved the damping of the orbit distortion up to 100Hz. It also provides new diagnostics tools thanks to its new data logging capabilities. We report the performance of this new system and some of its applications as a diagnostic.

INTRODUCTION

Until the end of 2004, the damping of the fast beam orbit distortions of the ESRF was done in the vertical plane by a global feedback system using 16 BPM and 16 correctors; in the horizontal plane we were using a set of 4 local feedback systems to stabilize the beam in the 4 most sensitive ID straight sections [1]. This fast orbit correction is working in parallel with a slower correction system using 224 BPM and 96 correctors to perform 2 corrections per minutes with a very good accuracy and long term reproducibility. The goal at ESRF is to keep the amplitude of the fast beam movement time $\beta^{1/2}$ below 2µm inside the insertion devices straight sections (integrated over the frequency span going from .1 to 200Hz). Since the implementation of vibration damping pads on the girders supporting the storage ring magnets in 2001 [2], the beneficial effect of the vertical feedback had become a bit marginal; in the horizontal plane, there was no way to increase the number of local systems, due to the imperfect closure of the local correction bumps at high frequency: with more than 4 systems in operation, the cross talks between the local feedbacks resulted in instabilities. In order to overcome these limitations, we decided in 2001 to upgrade our fast correction scheme and to implement a fast global correction system active in both horizontal and vertical planes. One of the constraint for this upgrade, was to use as much as possible of the components of the old system: BPM, correctors, front end electronics and data links, in order to reduce the cost of the project and to avoid leaving the ring without fast orbit correction during the implementation of the new system. We kept the same approach of separating the slow and fast orbit correction in 2 systems so this new system do not perform any orbit correction below.1Hz.

UPGRADE LAYOUT

The constraint was to achieve an efficient correction in both planes, given the value of the tunes of our storage ring (ν_H=36.44 and ν_V=14.39), the number of BPM and correctors that could be easily integrated in our upgraded system and the frequency range needed for an efficient damping of the orbit distortion.

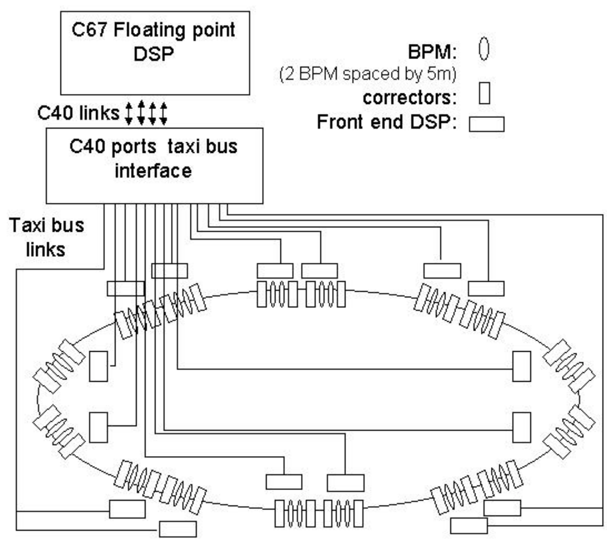

Figure 1: Layout of the global feedback system.

Static correction: BPM and correctors number

The layout of the upgraded global feedback is shown on figure1. The upgrade had to be compatible with some limitation put by the existing hardware. A front end DSP has 8 ADC inputs and 3 DAC outputs so it can handle the data of the 8 electrodes of 2 BPM blocks and drive 3 correctors amplifiers inputs. At the other end of the data link the most convenient interface available for data transmission between a commercially available central DSP board and our data links was the TI C40 port. The central DSP board that we chose can handle four C40 ports and we can concentrate on one C40 port the data stream of four front end DSP; so the size of our system is limited to 32 BPM for both planes and 48 correctors. Presently the correctors output are shared equally by the 2 planes: 24 vertical and 24 horizontal correctors (but this may not be the most efficient repartition). A rule of thumb is that it takes a number of BPM and correctors roughly equal to the tune value to obtain a significant fast global correction (i.e. leaving less than 30% of residual distortion).

According to simulations the global effect of the correction is efficient enough with 32 BPM, 24 correctors and 16 eigen values for the SVD correction computation, even in the horizontal plane, where the tune value is the highest (36.44). As shown on figure 2 the amplitude of a random static orbit distortion can be reduced by a factor of 5 all over the ring and more than 10 at the feedback BPM location, assuming perfectly accurate horizontal position measurements (simulation plot).

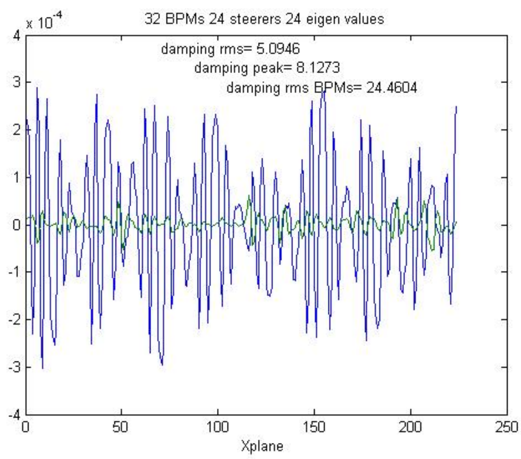

Figure2: initial (blue) and corrected (green) orbit

Dynamic correction: processing power

In order to operate a feedback with a bandwidth of 150Hz without instability or noise increase in the vicinity of the cut off frequency we need, as for the initial vertical feedback, to run the loop at a high enough rate and to achieve a low delay of the signal propagation between the BPM and the correctors, together with a low noise contribution of the BPM. So we aimed at keeping the same figure for the loop rate (4.437 KHz) and loop delay figure (<.6ms) as on the previous systems). This was achieved by using the same type of air cored magnets for the new system, and by replacing the TI C40DSP of the old system by a more powerful DSP.

Choice of the DSP

The choice of the processor board was driven by the need for a sufficient processing power and the possibility to interface this board with the data link already used in the previous system; given these constraints we went for a *TI C6701 DSP* implemented on a *Sundance SMT327* board. Signal processing cannot realistically be coded on such a processor without an adequate programming environment. We used the *3L* real time OS for this project.

BPM resolution

The BPM of our system are dedicated use dedicated BPM pick ups located at both ends of the insertion device straight sections where $ß_x$=36m and $ß_z$=4m; the disadvantage of the low $ß_z$ value is compensated by the possibility to have BPM vacuum chamber with a small 18mm vertical aperture which improves the BPM resolution. The capacitive electrodes are RF matched to the impedance of the cables using resonant RF transformers, which improves the noise figure of the BPM electronics. The BPM electronics is the one used for our previous fast feedback systems and based on a RF multiplexing scheme. They are not designed to achieve any DC position measurement performance since our system does not perform any DC correction but are aimed only at achieving a high frequency resolution. They are definitely a bit outdated, but they still achieve a $10nm/Hz^{1/2}$ resolution, or .5µm per sample at our sampling rate. This good resolution, combined with the number of BPM available on the upgraded system keeps the contribution of the BPM noise to the beam motion below 200nm when the feedback loop is closed.

Correctors magnets

The correction kicks are produced by air coil steerer dipoles. $ß_z$ value at the steerers location is 35 m and $ß_x$ value is 5m. The stainless steel vacuum chamber at the steerers location is 2mm thick giving 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. With their amplifiers, they contribute for .3 ms to the loop delay.

CORRECTION ALGORITHM

The flow chart of the feedback loop is shown on figure3

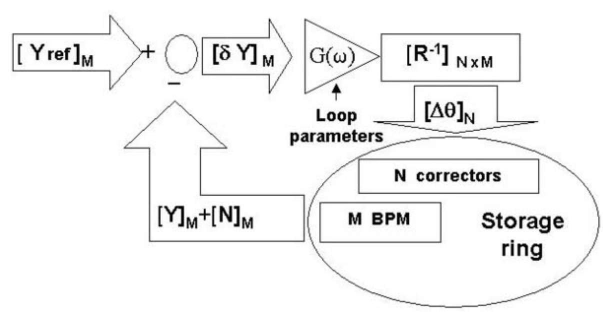

Figure3: flow chart of a global orbit feedback loop

With the 32 positions we calculate a correction vector using a correction matrix. To obtain this correction matrix we invert during a calibration phase, the matrix of the response of the feedback BPMs to each steerer, using the SVD method

PID correction

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 f_c must be at least two times higher than the highest frequency (60 Hz) that we want to damp significantly.
- On the other hand, the propagation delay of the signals in the loop is .6ms; this delay results in a significant amplification of the input signals around the cut off frequency, when this frequency is set above 150Hz.

We found that a cut off frequency of 150Hz was the best compromise between these two requirements

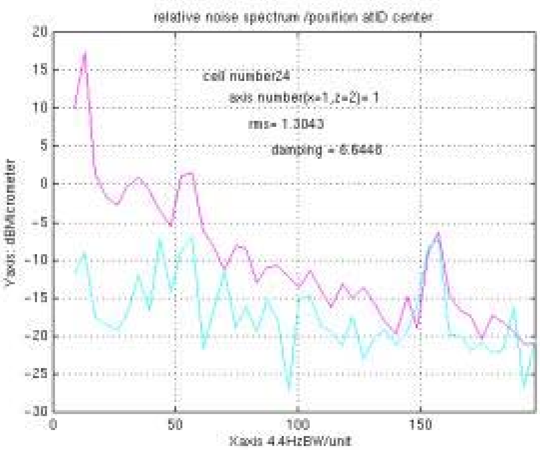

Figure4: spectrum of the horizontal beam motion with PID correction OFF (red) and ON (blue)

50Hz notch filter

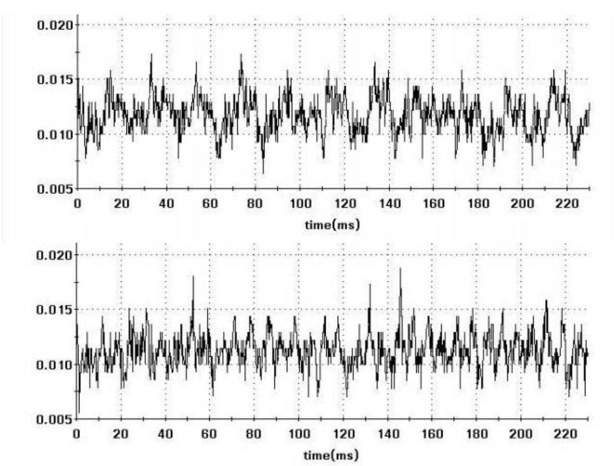

Figure5a and b: time plot of the vertical beam motion with a PID correction only (up) and an additional 50Hz notch correction (down), vertical scale: mm.

In addition to the PID loop, we have added a narrow bandwidth notch filter tuned at 50 Hz to the transfer function of the loop. It further reduces the amplitude of this AC main line by a factor 3. The effect of this notch filter is shown on figure 5. We have implemented it as a recursive filter, with the same high Q second order low pass response as is used at NSLS [3].

ADDITIONAL DIAGNOSTIC FUNCTION

The new feedback allows the data logging of the position measured and corrections computed.by the system. This data logging can be triggered by an external signal, by an alarm in the system (measured position or computed correction exceeding a threshold) or by a request coming from the storage ring control system. 1024 samples of the positions and corrections can be recorded after a trig. A very useful application of this data logging is the possibility to locate the origin of a transient fault on a storage ring component. For instance, in the case of a transient fault of the power supply of one of the 96 slow orbit correction magnets, we compare the data logging triggered by the orbit distortion to the pre recorded responses of the BPM of the global feedback to each of the 96 correctors to locate easily the origin of the problem.

SYSTEM PERFORMANCE

Following the implementation of our new system, we have measured in all the storage ring straight section (equipped with BPM used in the loop or not) a very significant reduction of the fast beam motion as summed up on the table below:

	β at the BPM location	rms motion (.1to200Hz) no feedback	rms motion (.1to200Hz) feedback ON	motion/ beam size
H	36m	5 μm	1.5 μm	<.006
V	6.5m	1.5 to 2 μm	.7 μm	<.1

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REFERENCES

[1] E. Plouviez, Fast positional global feedback for storage rings, DIPAC1999, Chester, May 1999

[2] L. Zhang, L. Farvacque, J.M. Filhol, E. Plouviez, “E-Beam Stability Enhancement by Use of Damping Links for Magnet Girder Assemblies at the ESRF”, PAC2001, Chicago, USA, June 2001

[3] B. Podobedov ``Operation with fast digital orbit Feedback Systems at NSLS", 2nd workshop on beam orbit stabilisation, SPRING8, Japan, December 2002.