FAST ORBIT CORRECTION AT THE ESRF

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Orbit stability requirement

1. ESRF is a 3rd generation light source:
   Energy: 6GeV
   Circumference: 844.39m / 32cells
   Horizontal and vertical emittance: 4nm and 30pm

1. Position stability must match this emittance figure

1. Stability criterion
   Less than 20% emittance growth or:
   <10% beam size increase
   <10% beam divergence increase

More stringent demands at high frequency from some beamlines
Beam stability at ESRF (until Nov. 2004)

Beam motion on straight sections BPMs:
- $\beta_x = 35.4 \text{m}$, $\beta_z = 6.2 \text{m}$
- $\sigma_x = 360 \mu\text{m}$, $\sigma_z = 15 \mu\text{m}$
FAST/SLOW correction management:

1. ESRF solution:
2. 2 independent systems:
3. Slow system with 224 BPMs/96 correctors from 0 to .1Hz
4. Fast systems from .2 to 100 Hz
5. Frequency separation between the slow and fast system

1. Addition of a feed forward angle corrections during ID gap change on some straight sections to improve the orbit settling time in the .2 to .02 Hz range
2. Choice due to circumstance, but it works fine

We have recently upgraded our fast global feedback to damp the horizontal and vertical orbit distortions from .1 to 200Hz
Situation before the global feedback upgrade

1 Vertical global feedback system

- Aimed at bringing back the fast vertical motion to less than 10% of the beam size
- 20 nm/Hz$^{1/2}$ BPM resolution (1 µm in 2 KHz BW)
- .1 to 150 Hz feedback bandwidth
- (separation from the slow correction in the frequency domain)
- 4.4 KHz sampling and correction rate
- Air cored magnets and 2mm thick stainless steel vessel
- Low signal latency in the loop: .6mS

1 4 horizontal local feedback systems

Installed from 1999 to 2001 on sensitive beam lines:

1 ID14: Protein crystallography
1 ID21: X-ray microscopy
1 ID8: Soft X-ray spectroscopy
1 ID24 X-ray absorption spectroscopy

Same type of BPMs and steerers as the global feedback
Global closed orbit correction principle

Corrected orbit = ( [Y]_{Mx1} - [Y_{ref}]_{Mx1}) - R \cdot [\Delta \theta]_{Nx1}

\([R^{-1}]_{N \times M}\) is obtained by a SVD method
efficiency

1. A limited number of monitors and correctors can correct all the machine => global scheme = undersampling

1. According to simulations, 16 monitors and correctors are enough in the vertical plane (Q=14.39)

1. Rule of thumb: Number of BPM corrector needed = Q
Vertical global feedback layout

- Floating point DSP
- Fast data links (taxi bus)
- 6 cells spacing
- 2 cells spacing

Vertical correction only

4.4 KHz sampling and correction rate

150 Hz feedback bandwidth

Achieved damping: 2 (.1 to 100 Hz)

Residual movement: 12% of the beam size
Local feedback layout

- 20 nm/Hz^{1/2} BPM resolution (1 µm in 2 KHz BW)
- 4.4 KHz sampling and correction rate
- 0.1 to 150 Hz feedback bandwidth
- Factor 4 damping (with our beam spectrum)
- Separation from the slow correction in the frequency domain
Si(111) or Si(311) Bragg/Laue polychromator @ 64 m

Energy range: 5 - 25 KeV

Demagnification mirror @ 32.5 m

Vertical focusing mirror @ 30 m

Tapered undulator source

Spot: $\Delta x \sim 20 \mu m$ FWHM

Flux $\sim 10^{12}$ photons/sec

CCD based Position sensitive detector @ 68 m

Beamline ID24

1. X ray Absorption Spectroscopy
2. All the absorption spectrum is recorded simultaneously thanks to a polychromator
The measurement of the absorption coefficient $\mu(E)$

\[ I_1(E) = I_0(E) e^{-\mu(E)d} \quad \Rightarrow \quad \mu(E) d = \ln \frac{I_0(E)}{I_1(E)} \]
EFFECT OF THE LOCAL FEEDBACK

No local feedback

With local feedback

I(t)-I(0)

I(0)

I(t)-I(0) (a.u.)

I(0) (%)

Dec 97

Dec 98

pixels

pixels

No local feedback

With local feedback

I(t)-I(0)

I(0)

I(t)-I(0) (a.u.)

I(0) (%)

Dec 97

Dec 98

pixels

pixels

I(t)-I(0)

I(0)

I(t)-I(0) (a.u.)

I(0) (%)

Dec 97

Dec 98

pixels

pixels
Spectrum of the motion on the sample:
Damping pads on the magnets girders

Damping link design

VEM: ViscoElastic Material
GMF: Girder Mounting Fixture
FMF: Floor Mounting Fixture
Damping pads on the magnets girders

-20dB reduction of the 7Hz

Less reduction of the 30Hz: it is due to the water flow in the quadrupoles coils
Feedforward correction: ID gap dependant
CO distortion

1. A good solution for the .03 to 3Hz span without feedback
2. Used to take care of the transient orbit distortion due to the gap change of some insertion devices:

   1. Measurement of the closed orbit distortion for every ID gap opening values during calibration sessions
   2. Calculation of a correction using 2 correction dipoles at both end of the straight section for every gap opening values
   3. Application of this additional correction as a function of the gap opening in operation (update rate of the correction: 10Hz
Limitation of our correction system

1. Vertical global feedback system

Victim of the success of the damping pads installation:
The resolution of the BPMs was now too close to the amplitude of the vertical beam motion without feedback!

1. Horizontal local feedback systems

ID24 X ray Absorption Spectroscopy beamline got the first system
Others beam lines requested horizontal correction:

Eventually crosstalk between the systems due to imperfect bump closure at high frequency started to appear, setting a limit to the number of local feedback systems, but not to the number of beam lines interested by a feedback....
Global feedback upgrade

2001 situation:

1. We want to improve the resolution of the vertical orbit distortion measurement
2. We wish to have the same low horizontal beam motion amplitude as in the straight sections corrected by the local feedback all over the machine

Solution:

1. We need a global feedback in both planes (no more local feedbacks).

=> We must increase the number of BPMs and correctors (since $Q_x=36.44$) and the DSP processing power
upgraded Global feedback

32 BPMs
24 correctors
vertical and horizontal correction
Upgraded system features

1. Same components as in the first system:
2. RF multiplexing BPMs
3. Taxi bus data links
4. New DSP: TI C67 in replacement of the TI C40

Commissioning during 2004, now in operation
Feedback efficiency measured at the end of high horizontal $\beta$ straight section

<table>
<thead>
<tr>
<th></th>
<th>$\beta$ (in m)</th>
<th>rms motion without feedback (in $\mu$m, .1 to 200Hz)</th>
<th>rms motion with feedback (in $\mu$m, .1 to 200Hz)</th>
<th>rms motion/ rms size</th>
</tr>
</thead>
<tbody>
<tr>
<td>H plane</td>
<td>36</td>
<td>5 to 12 (depending on BPM)</td>
<td>1.5 to 2.5 (depending on BPM)</td>
<td>.004 to .006</td>
</tr>
<tr>
<td>V plane</td>
<td>6.5</td>
<td>1.5 to 2.5 (depending on BPM)</td>
<td>.8 to 1.2 (depending on BPM)</td>
<td>.1</td>
</tr>
</tbody>
</table>

Feedback bandwidth: .1Hz to 150 Hz
Beam H and V emittance: 4nm and .03nm
V plane results:

Left: feedback OFF
Right: feedback ON

rms value: integrated from .1 to 200Hz
H plane results: correction better than with the local feedback at the feedback BPM locations

Local feedback ON (left), global feedback ON (right)

rms value: integrated from .1 to 200Hz
Feedback efficiency

rms stability in 2 sensitive ID straight sections:

Left: no feedback
Right: both feedback applied

red and brown:
horizontal rms position variation
blue and green:
horizontal rms position variation

Integrated from .1 to 200Hz
Next steps

1. Addition of a selective damping of the 50Hz line in the DSP algorithm
2. Addition of more diagnostics functions (triggering of the BPMs recording on external events...)

Conclusion

1 With a mix of feedforward action on the orbit perturbations, passive damping of the vibration of the magnets, and a fast orbit correction with a global feedback, we manage to still have a state of the art beam stability (even if our BPMs are now a bit outdated...).

System size for fast global correction:
All you need is:
1 4 KHz sampling for 200Hz BW
1 BPM and correctors number roughly equal to the integer of the tune value