TEST RESULT OF SLOW GLOBAL ORBIT FEEDBACK USING MATLAB AT PLS*

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Abstract

A slow global orbit feedback using MATLAB has been tested to minimize the slow orbit movement at PLS. The feedback uses the SVD (singular value decomposition) method and MATLAB channel access to EPICS IOC of BPMs and correctors. For the orbit feedback study, 22 corrector power supplies in the vertical plane were improved to 16-bit capability by the minor change of the existing 12-bit power supply. In this paper, the test result of the MATLAB orbit feedback using the 16-bit correctors and 16-bit BPMs is described.

INTRODUCTION

The PLS lattice is a triple bend achromat with 12 superperiods and its natural emittance is 18.9 nm-rad. The operating beam energy is 2.5 GeV and the present maximum beam current is 200 mA. In the usual user-service operation the electron beam is directly injected from the 2.5-GeV electron linac twice a day. Assuming a 1%-betatron coupling, the orbit stability requirement in position for PLS is 20 μm in the horizontal plane and 3 μm in the vertical plane to get 0.1% photon intensity fluctuation at beam lines.

The number of BPMs is 9 per superperiod, and totally 108 BPMs. PLS uses 70 correctors with the maximum kick angle of 2-mrad for each plane. The power supply for corrector is 12-bit and the minimum kick angle of corrector is 1-micro-rad so that the orbit feedback was not applicable to the user-service operation. To remarkably improve the feedback performance, the upgrade of major hardware components started at the end of 2003. The replacement of 12-bit BPMs with 16-bit was completed in March 2004 and the upgrade of corrector power supplies to 20-bit capability will be finished by September 2004.

MATLAB is widely used as high-level software for accelerator physics and control in many accelerator laboratories. The PLS also adopted MATLAB, and a slow global orbit feedback using MATLAB has been tested to minimize the slow orbit movement [1]. The slow global orbit feedback system is designed to have the feedback bandwidth of below a tenth Hz. And it is based on the EPICS environment. The EPICS IOCs of BPMs and corrector power supplies are VME IOC.

ORBIT FEEDBACK SYSTEM

MATLAB Feedback Program

The orbit feedback program has several displays; the response matrix, the SVD analysis, the inverse response matrix, the calculated feedback kick, and the real time orbit [2]. The orbit feedback algorithm uses the SVD method. The BPMs and correctors used in the feedback algorithm can be selected among 108 BPMs and 70 correctors at the window menu. MATLAB Channel Access (MCA) - MATLAB interface to EPICS Channel Access (CA) client library - is the same one developed at SLAC [3]. The feedback runs every 4 seconds. It is important to select appropriate BPMs and correctors for the feedback to function well.

The present algorithm uses about 75 BPMs and 22 correctors. The available number of BPMs is changeable because some BPMs show suspicious behaviours; parasitic movement or large current dependence. The selected correctors are the ones located at the straight sections where the horizontal and vertical beta function is relatively high.

BPM

The BPM system uses the Bergoz MUX-BPM electronics module whose analog position outputs (x any y) are digitised by a VME 16-bit ADC board at 5 kSamples/s. The Bergoz MUX-BPM uses the internal clock of 8 kHz so that a very strong noise appears at 8 kHz/4. By averaging the sampled data, about two thirds of the BPMs show sub-micron reading accuracy. Other BPMs have noise bigger than 1-μm even after this averaging because of the insufficient number of averaging and low frequency noises (0.5, 6 Hz) coming from the vacuum chamber vibration due to cooling water. It is required to raise the number of averaging, but the 16-bit ADC board does not have enough buffer memory to process more sampled data, so the BPM reading refresh time is over 2 seconds.

The intensity dependence of BPM makes the BPM read a false position and the actuator in the feedback be driven with the wrong signal. Several BPMs show a very large non-linear intensity dependence which is due to TE mode in antechamber. Such BPMs are omitted from the orbit feedback. Figure 1 shows the vertical position changes of 108 BPMs (including the TE mode BPMs) caused by stored beam current change. The blue line corresponds to

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the beam current change between 110 and 140 mA, and the green line to that between 140 and 170 mA. Some BPMs have different rates of position change at the two current ranges, which means there must be a small non-linear current dependence of BPM reading. Neglecting this small non-linearity, we use the linear change rate from the beam current of 110 to 170 mA (red line). We set the allowable limit rate at 0.5 µm/mA, which corresponds to 50-µm reading error with 100-mA current change.

And we set the reference beam current for the intensity dependence table at 140 mA. The corrector-BPM response matrix essential for orbit feedback is measured at the centre of the intensity dependence table, 140 mA.

Figure 2 shows BPM reading changes just 5 minutes after the beam is stored to 170 mA in a very short time. BPMs that have reading changes bigger than 5 µm are sorted out as BAD BPM. This reading error seems to come from the chamber movement by heat load from synchrotron radiation.

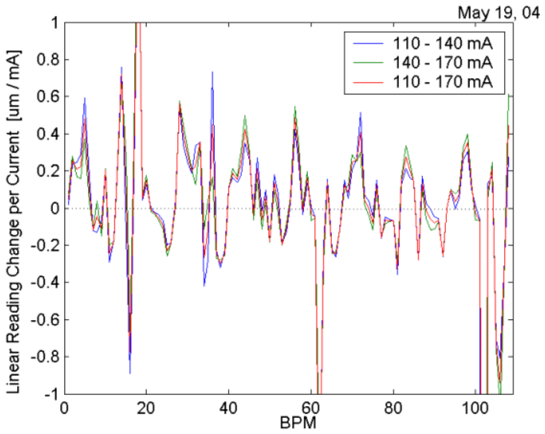

Figure 1: The vertical position changes of 108 BPMs caused by stored beam current change.

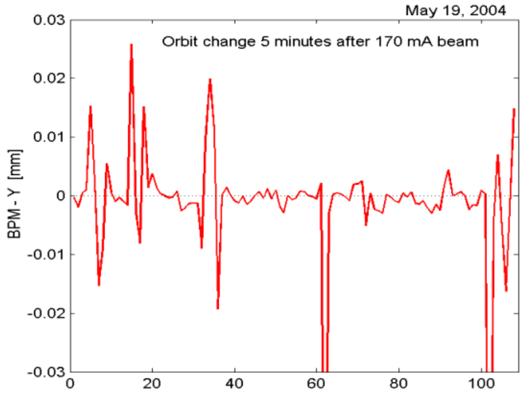

Figure 2: The BPM reading change just 5 minutes after beam is stored to 170mA in very short time.

Corrector

Correctors have the maximum kick angle of 2-mrad and the power supply for each corrector uses 12-bit DAC so that the minimum kick angle is 1 µrad. With these correctors the orbit feedback absolutely does not function well. RMS orbit motion due to the orbit feedback itself using 30 correctors with 12-bit DAC is estimated as 6.3 µm in the vertical plane. Actually we can see a very large position movement of photon beam at the photon BPM installed at beamlines.

Thus 22 correctors at the 11 straight sections, except the injection straight, will be replaced by new correctors with 20-bit capability by September 2004. With 20-bit capability the minimum kick angle is 0.0038 µrad and the vertical orbit RMS by this kick would be only 0.025 µm. In case of 20-bit capability corrector, the maximum current of the power supply is 110A, and the minimum current step is 0.2 mA, which corresponds to 2 ppm. The stability requirement of the new corrector power supply is 5 ppm.

For the orbit feedback study, 22 vertical correctors at the 11 straight sections were improved to 16-bit capability by a minor upgrade of the existing 12-bit DAC power supply. With this 16-bit capability, the minimum kick angle is 0.06 µrad and the vertical orbit RMS by this kick is only 0.38 µm.

FEEDBACK TEST WITH 16-BIT CORRECTORS

Figure 3 depicts the horizontal and vertical orbit RMS when the orbit feedback is applied to the vertical plane only. Bad BPMs are sorted out and about 86 out of 108 BPMs are used in the feedback. When the feedback is ON, the vertical orbit RMS is maintained below 2 µm. Without the feedback the horizontal orbit rises steadily up to 10µm for 3.5 hours, and the vertical orbit, not shown in this figure, increases over 10 µm in 2 hours. In this test, the BPM intensity dependence table was used.

Figure 4 shows the feedback reaction for the gap control of an insertion device, EPU6. The feedback is also applied to the vertical plane only. The horizontal orbit (lower figure) shows a very big change of 75 µm when the EPU6 gap approaches 20 mm. In this test the gap motion starts from the gap distance of 30 to 20, 30, 45, and finally to 60 mm. The gap motion speed is set differently at different gap positions: 0.05 mm/s for 30 to 20 mm, 0.1 mm/s for 30 to 45 mm, and 0.2 mm/s for 45 to 60 mm. At the speed of 0.05mm/s it takes 3 minutes 12 seconds to move from the gap distance of 30 to 20 mm. With the speed of 0.05mm/s the vertical orbit rises up to 3.5 µm as the gap approaches 20 mm. After the gap motion stops at 20 mm the vertical orbit decreases below 2 µm by the feedback action. The vertical orbit remains below 2 µm in the gap movement from 30 to 60 mm. In this test an extra feed-forward to correctors is not used.

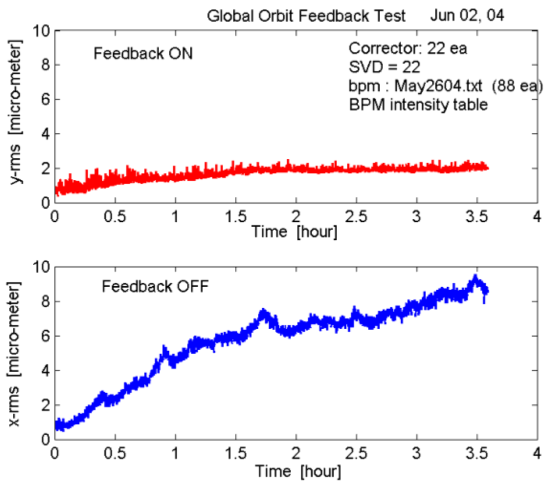

Figure 3: Horizontal and vertical orbit RMS when the orbit feedback is applied to the vertical plane only.

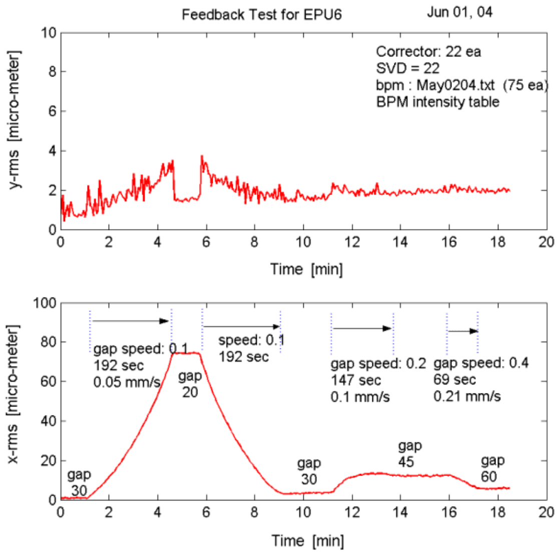

Figure 4: The feedback test for insertion device EPU6. Upper figure is the vertical orbit RMS and lower figure is the horizontal orbit RMS.

The orbit feedback with the 16-bit DAC correctors seems to satisfy the orbit stability requirement of 3µm in the vertical plane. However, as shown in Fig. 3, even with the feedback the vertical orbit seems to rise from zero and get saturated at around 2 µm, which is obviously not related to the minimum step of corrector kick because the orbit RMS due to this kick is only 0.38 µm. It is believed that this is due to the non-linearity of orbit response matrix and BPM readings.

CONCLUSION

The orbit feedback using 22 correctors with 16-bit capability in the vertical plane can maintain the vertical orbit below 2 µm. Bad BPMs with large intensity dependence and reading accuracy over than 1 µm are sorted out in the feedback. With this and the intensity dependence table of BPM it is possible to get orbit stability smaller than 2 µm.

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