GLOBAL FEEDBACK SYSTEM FOR PHOTON FACTORY STORAGE RING

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Abstract

A fast global feedback system was installed on the upgraded Photon Factory storage ring in order to stabilize vertical orbit distortion, and its performance has been tested. The system that consists of 65 beam position monitors and 28 correctors is designed to suppress fluctuation due to the building vibrations with the spectral range up to 20Hz. The whole closed orbit distortion is measured and excitation currents of the correctors are calculated with the SVD method using floating-point DSPs on a VME system every 10ms . The implementation of the new BPM system, digital signal processing scheme, correction system and results of the beam test are presented.

1 INTRODUCTION

One of the most important properties at a dedicated synchrotron light source is stability of the electron orbit. At the Photon Factory (PF) electron storage ring, commissioning of the high brilliance optics has been completed[1]. In the low-emittance configuration, the transverse beam size are reduced by a factor of two and the requirements for orbit stability become severe. Related parameters of the new optics are shown in Table.1.

Table 1: Related parameters of the PF-ring

Emittance	27nm-rad
Vertical beam size	0.081 mm
Horizontal beam size	0.379 mm
Synchrotron frequency	18 kHz

2 SYSTEM OVERVIEW

There are several sources which disturb the beam orbit such as building vibrations due to the air-conditioners, change in the magnet cooling-water temperature and the noise of the AC power line, etc. The contribution of each effect has been measured[2-5]. We found that the spectral frequency range was widely spread from several mHz to 50Hz. In our design of the orbit feedback system, we start to suppress the vertical beam fluctuations with a range up to about 1Hz in the first stage, and will gradually improve the frequency response up to 50Hz.

Figure 1 shows a block diagram of the new global feedback system. The feedback system in horizontal plane is a future plan.

2.1 Beam Position Detection

In the re-construction of the PF-ring to the low-emittance scheme, the numbers of the BPMs are increased from 48 to 65. We replaced old BPMs at normal-cells with four-button type with SMA feedthroughs. Other BPMs near long straight sections with six buttons and BNC feedthroughs were remain unchanged. The performance of the new BPM system is reported in ref.[6].

LPFs in front of ADCs were set in order to suppress influence of the synchrotron oscillation with the frequency of 18kHz.

2.2 Signal Processing

The VME system contains a DSP board with two 32-bit floating-point DSPs(Texas Instruments TMS320C40), a clock board, a CPU board which communicates with a host workstation via the ATM/Ethernet network, two 16-bit 8-channel ADC boards which sample and hold the output voltage of superheterodyne detectors, four 16-bit 8-channel DAC boards which set the excitation current of the correctors, two digital I/O boards which select the appropriate attenuator at the detector input. The computation performance of the DSP board is fast enough for our purpose[7].

We adopted the singular value decomposition (SVD) method to correct the orbit. From the calculated response matrix, we calculate the inverse matrix for the feedback. The numbers of eigenvalues are determined to be 5. Coefficients of the PID(proportional, integral and derivative) control are calculated with the DPSs.

2.3 Correctors

We use 28 correctors for the vertical feedback. The core of steering magnet is made of 0.35mm-thick silicon steel laminations to keep frequency response up to about 100Hz. In order to maintain isolation between the VME system and correctors we used the isolation amplifier for each power supply.

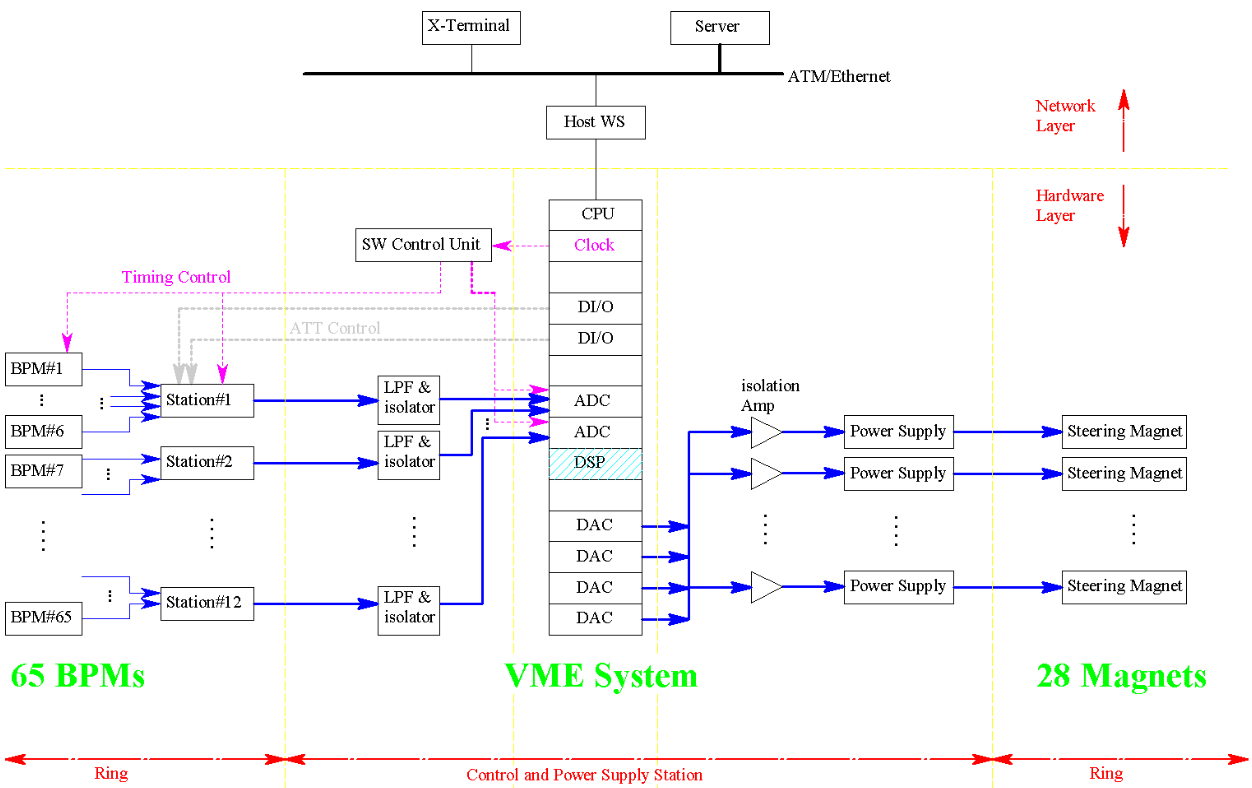

Figure 1: Block diagram of the global feedback system. Station#1-#12 contain multiplexers and superheterodyne detectors. (LPF:Low Pass Filter, ATT: Attenuator, SW Control: Switch control)

3 RESULTS OF BEAM TEST

At the first step of the commissioning of the orbit feedback system, the PF-ring was operated in the medium emittance lattice. We determined the cut-off frequency of the LPF in front of the ADC to be 10kHz to avoid influence of the synchrotron oscillation of 30kHz at the medium emittance. The sampling time of each button electrode was set to 300µs and the whole electrodes were scanned and the beam positions were calculated every 10ms. The beam position was collected and averaged over 10 times to improve the accuracy. The kick angles of the correctors were obtained by multiplying the inverse of the response matrix and the PID control was applied. In the routine operation for SR users we set the feedback period to be 100ms (10ms period sampling x 10 times average).

3.1 DC Characteristics

Figure 2 shows the closed orbit distortion (COD) relative to the standard orbit of the PF-ring. The solid line shows the COD measured just after the injection and the dashed line shows the COD at eight hours after the injection. The two graphs on the right and those on the left are the COD with/without the global feedback, respectively. The two graphs on the bottom are the drifts of the beam position at the BPM #50. As seen in the figures, the drift of the orbit is completely suppressed.

3.2 Frequency Response

3D plots of the vertical beam motion is shown in Fig.3. The feedback system was turned off at 52min and the kick angle of all correctors were set to be zero. It is clearly seen that the beam fluctuation starts at the turn off timing.

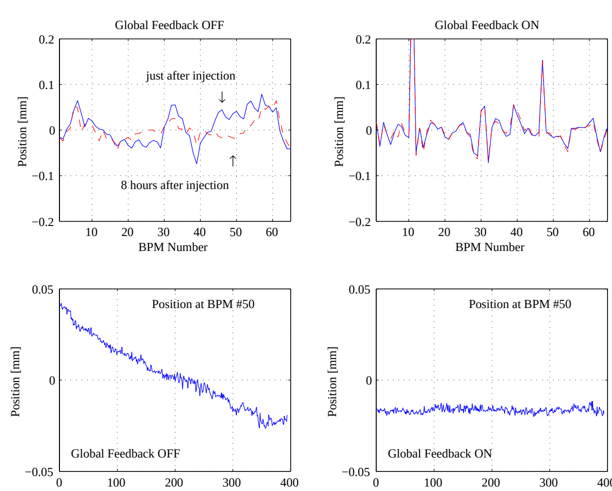

Figure 2: Change in COD without feedback (upper left) and with feedback (upper right) in eight hours. The peaks at the BPM#11 and #47 are due to the trouble of the electrodes. Lower left and right graph show the position change at BPM#50.

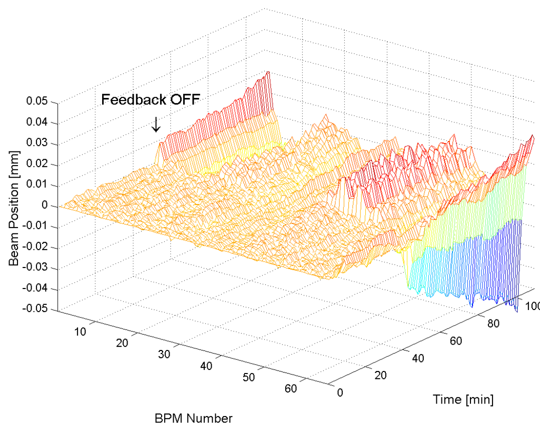

Figure 3: Vertical beam motion with and without global feedback. After the feedback is turned off, drifts and vibrations of the beam positions are observed.

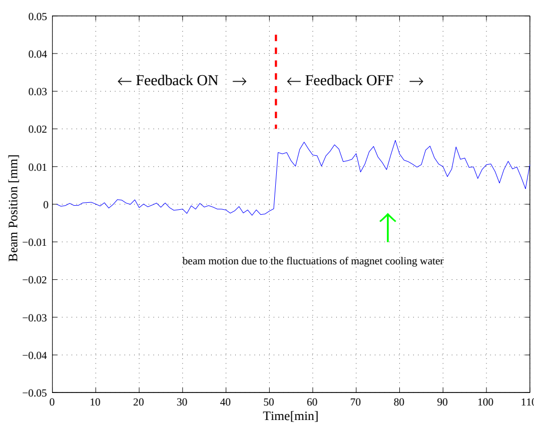

Figure 4: Beam motion at BPM#50.

The excursion of the beam at the BPM#50 is shown in Fig.4. When the feedback is turned off, the beam excursion due to the change in magnet cooling water temperature is observed. In this case, the variations in the water temperature was about 0.1 to 0.3 degree Celsius and the period is about 10minutes.

A frequency response of the beam position to the excitation of a corrector was measured using a signal analyzer(HP35660A). The results are shown in Fig.5. As seen in the figure, -3dB point is 0.3Hz. At present, in the routine operation for SR users, the fluctuation with the frequency range up to 0.3Hz can be stabilized. However, if refining the PID parameters, we can increase the frequency response up to 1Hz.

We have a plan to speed up the sampling period to 2ms in order to suppress the orbit fluctuation with the frequency range up to several tens Hz.

4 SUMMARY AND FUTURE PLAN

The global feedback system works quite well to suppress the vertical beam fluctuation up to 0.3Hz. At present, the system bandwidth is limited by the LPF to avoid the synchrotron oscillation. If we can remove the LPF (if the synchrotron oscillation is suppressed) and optimize the PID coefficient, the feedback bandwidth will be improved up to 50Hz.

We are testing the local feedback system to stabilize the beam axis at the insertion devices using a reflective memory network.

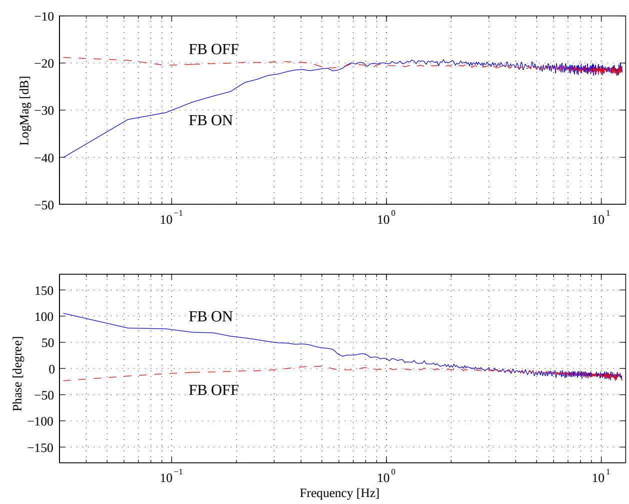

Figure 5: Frequency response of the feedback loop. In this case, -3dB point is about 0.3Hz.

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