COD CORRECTION AT THE PF RING AND PF-AR BY NEW ORBIT FEEDBACK SCHEME

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Abstract

The eigen vector method with constraint conditions (EVC) is the new orbit feedback scheme. When the global COD correction is made with the EVC, the local orbit correction can simultaneously be done without the deterioration of the global COD correction. In order to demonstrate the advantage of the EVC, we made the machine studies at the PF ring and the PF-AR, and the results successfully confirmed the advantage of the EVC.

INTRODUCTION

For the user operation at a third generation synchrotron light source, it is critical to stabilize the electron beam orbit in the insertion devices to fix the light source points. In addition to the usual orbit feedback for the global COD (closed orbit correction) correction, the fast local orbit feedback is necessary to satisfy the user requirements. In general, however, it is difficult to operate the independent local orbit feedback system simultaneously with the global one because of the interference between two feedback loops. For example, it may happen that the both systems try to correct the same orbit distortion at the same time. In order to avoid such interference, we adopt the eigen vector method with constraint conditions (EVC) [1], [2], which has both functions of the global and local COD corrections.

From the simulation results, the local orbit correction by the EVC works very well. Furthermore, with the EVC, the COD at the place without any constraint condition is not much deteriorated and the kick angles of the steering magnets do not significantly increased. In the real machine, however, both the beam position monitors (BPMs) and steering magnets have errors, and there is a certain amount of the nonlinearity for the COD. Thus, in order to confirm the advantage of the EVC under these "real machine" effects, the machine studies were carried out in the PF ring and PF-AR. In this paper, we report the results of the machine studies.

PRINCIPLE OF THE EVC

First, we give the brief description of the eigen vector method (EV) as used for the ordinary COD correction. The kick angle of the steering magnets can be calculated from the measured COD by the equation

$$M\vec{x} + \vec{y} = 0 \leftrightarrow M^T M\vec{x} + M^T\vec{y} = 0 \rightarrow \vec{x} = -\widetilde{A}^{-1} M^T \vec{y},$$

where $\vec{y}$ is the measured COD, $\vec{x}$ the kick angle of the steering magnets, and M the response matrix. M^T is the transposed matrix of M and $A = M^T M$ is the square matrix that has the dimension of the steering-magnet number. When we calculate the inverse matrix of A, we use only a certain number of the eigen vectors in order to prevent the large kick angle corresponding to the unrealistic COD caused by the BPM errors. Then the generalized inverse matrix $\widetilde{A}^{-1}$ is calculated and the kick angles of the steering magnets are given.

In order to apply the EVC instead of the EV, the conversion matrix from COD to kick angles should be modified. The new conversion matrix is calculated so as to include the local orbit correction as the constraint condition of the global COD correction using the Lagrange's undetermined multiplier method. The problem is to find the minimum value of the function

$$S = \frac{1}{2}\left(M\vec{x} + \vec{y}\right)^2 + \sum_i \lambda_i \left(\vec{c}_i \cdot \vec{x} + z_i\right),$$

where λ is the indeterminate multiplier and $\vec{c}_i \cdot \vec{x} + z_i = 0$ the constraint condition. For fixing the orbit at the i-th BPM, z_i is the measured COD ($= y_i$) and $\vec{c}_i$ is the i-th line of the response matrix M. The final solution is given as

$$\vec{x} = \left(-\widetilde{A}^{-1} + \widetilde{A}^{-1}C\left(C^T\widetilde{A}^{-1}C\right)^{-1}C^T\widetilde{A}^{-1}\right)M^T\vec{y} - \widetilde{A}^{-1}C\left(C^T\widetilde{A}^{-1}C\right)^{-1}\vec{z}.$$

The details of the method are shown in the reference [1] and [2].

OUTLINE OF MACHINE STUDIES AND ORBIT CORRECTION SYSTEMS

The existing orbit correction systems in the PF ring and the PF-AR were used in the machine studies without any modification of the hardware. In this chapter, we give the brief descriptions of the original orbit correction systems of both rings and the machine studies.

PF-AR

The PF-AR is the 6.5GeV electron storage ring of the circumference of 377m. For the machine study, the PF-AR is operated as the single bunch mode at 6.5GeV, which is the same as the user operation. The beam current is about 20mA during the whole machine study (c.f. 60mA for user operation).

For the orbit correction system of the PF-AR, the back leg coils of the bending magnets are used as the horizontal correctors. Due to the large hysterisis and the nonlinearity of them, we neglected the horizontal orbit distortion and focused on the vertical one in this machine study. 79 vertical dipoles (VDs) were used for the vertical orbit correction. The configuration of the BPM and

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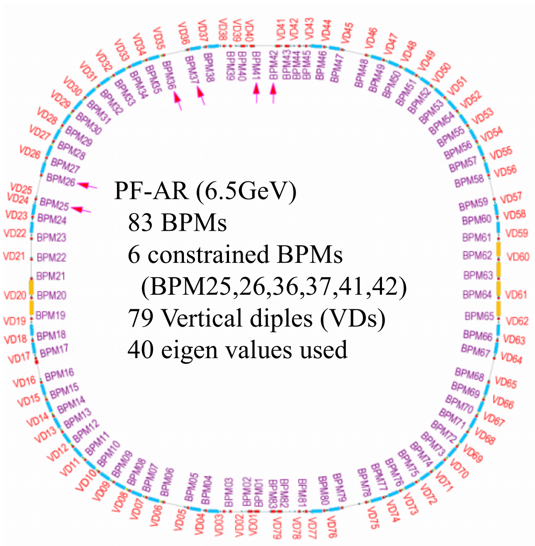

Figure 1: Configuration of the BPM and vertical orbit correction system at the PF-AR.

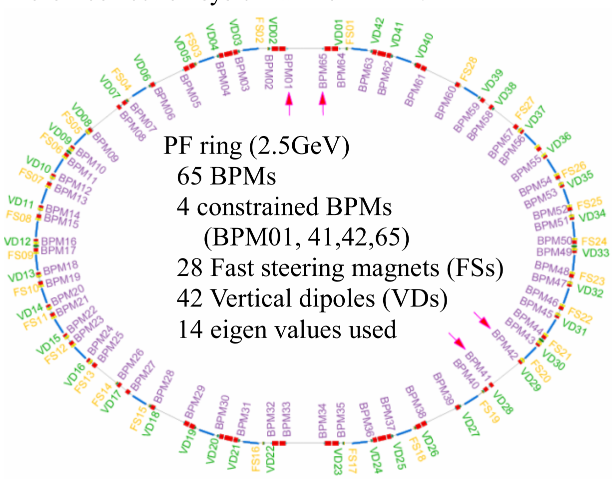

Figure 2: Configuration of the BPM and vertical orbit correction system at the PF ring.

vertical correction system is shown in Fig. 1. The PF-AR has eighty-three BPMs, but has only four signal processors. Due to the slow switching of the mercury relay that connects each BPM to the signal processor, it takes ten seconds to measure the COD of the whole ring. The resolution of the BPM is about 8 μm.

The constraint conditions for the EVC were applied to six BPMs placed on both sides of three insertion devices of ID-NW12, ID-NW2 and ID-NE1. We generated a vertical COD using one vertical steering magnet and then corrected it using the other ones. Finally we compared the residual COD and kick angle of the steerings of the EVC with those with EV.

PF ring

The PF ring is a 2.5GeV electron storage ring of the circumference of 187m. There are seven insertion devices in the PF ring. Similar to the PF-AR, all the horizontal correctors are the back leg coils of the bending magnets.

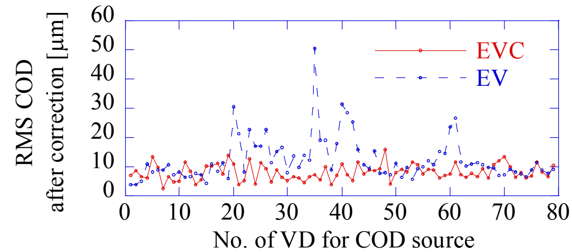

Figure 3: RMS of the COD at the constraint point for the PF-AR.

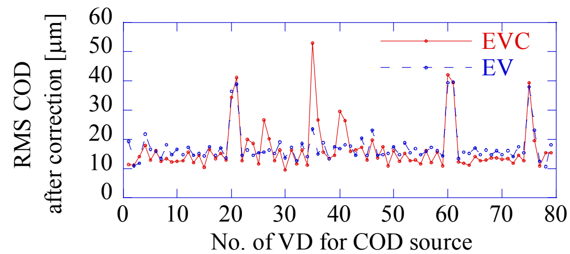

Figure 4: RMS of the COD of all 83 BPMs.

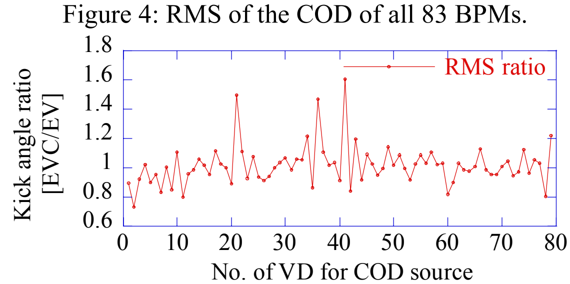

Figure 5: RMS ratio of the kick angles of the steering magnets.

In order to avoid the complexity, we also focused on the vertical orbit correction in this machine study. The configuration of the system is shown in Fig. 2. The PF ring has sixty-five BPMs and the resolution of the BPMs is very high and is about 1μm or smaller. Other than 42 vertical dipoles(VDs) of the solid core, the PF ring has twenty-eight fast vertical steering magnet of the lamination core for the vertical fast orbit feedback system[3]. For the machine study, the vertical COD was generated by each vertical dipole, and then corrected by the fast orbit feedback system. The constraint conditions were imposed on the both sides of the two insertion devices of ID-02 and ID-19 in this study.

RESULTS OF THE MACHINE STUDY

PF-AR

The initial COD generated by the COD source had the amplitude of about ±400μm. Figure 3 shows the RMS values of the COD at the constraint points after six times correction. The EVC well corrected the COD in the insertion devices and reduced all of the RMS COD values at the constrained six BPMs to as small as 8 μm that is about the resolution of the BPMs. On the other hand, the EV could not reduce all of them to the BPM resolution level, because the orbit distortion in the insertion devices

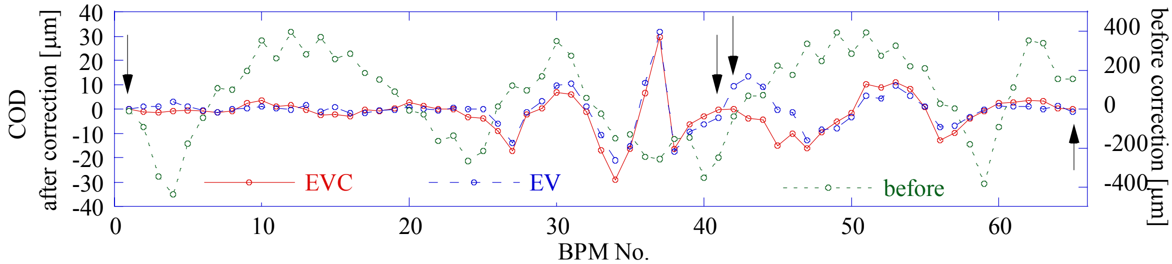

Figure 6: The typical vertical CODs before and after correction by the EVC and EV.

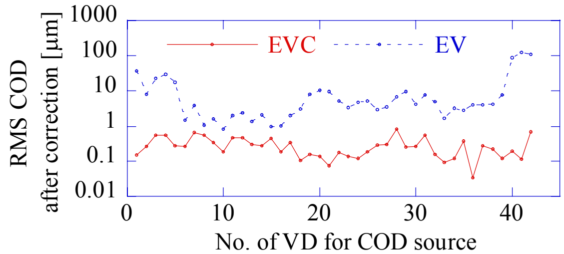

Figure 7: RMS of the COD at the constraint point for the PF ring.

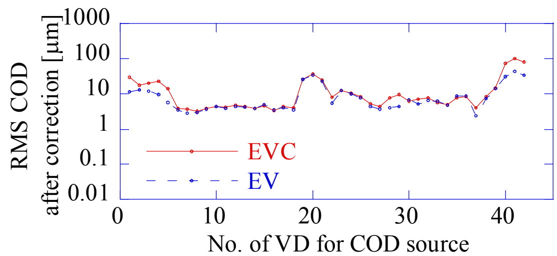

Figure 8: RMS of the COD at the all BPM for the PF ring.

was largely remained even after the COD correction. As shown in Fig. 4 and 5, for most of the cases, there is no large difference between the EV and EVC in the RMS of the CODs of all the BPMs and the RMS of the kick angles of the steering magnets. Namely the EVC has almost the same global correction performance as the EV.

The EVC had large RMS COD values at all the BPMs for a few COD sources, for example VD35 and VD40, compared with the EV. This is because the COD at the place just before the COD source became large by achieving the zero COD at the constraint point next to the COD source. Since we used each vertical dipole itself as a COD source in this machine study, the COD correction around the COD source was sometimes insufficient. If we have another vertical dipole in these sections, the COD can easily be corrected to the small amplitude everywhere.

PF ring

The initial COD generated by the slow steering magnet had the amplitude of about ±150µm. The COD correction was instantaneously finished after the fast orbit feedback was operated. Figure 6 shows typical vertical CODs before and after correction by the EVC and EV. The beam positions at the constrained BPMs are pointed by the arrows. The local orbit correction at the four BPMs by the EVC is excellent, but that of the EV is not so good. Figure 7 shows the RMS values of the CODs at the constrained four BPMs after correction. The EVC reduced all of the RMS CODs to a sub-micron level. But the EV could not reduce to this level. Because of the good BPM resolution of the PF ring, one can more clearly find the advantage of the EVC and its local correction performance for many cases than in the PF-AR study. On the other hand, there is no great difference between the EVC and EV in the RMS CODs for all the BPMs, as shown in the Fig. 8. The global correction performance of the EVC is nearly the same as that of the EV. However you may notice that the global correction performance is worse for several COD sources (VD 1 – VD 5 and VD 40 – VD 42), similar to the case with PF-AR. The reason is that there are only three steering magnets in this section. In addition two constraint conditions at the two BPMs are imposed here. The deterioration of the global correction performance can easily be compensated by adding one or two fast steering magnets in this section.

CONCLUSIONS

From the results of the machine studies, the advantage of the EVC is successfully demonstrated. The RMS CODs of the constraint BPMs are suppressed to about the resolution of the BPMs, that is about 8 µm for the PF-AR and below 1 µm for the PF ring. For many cases, there is no large difference in the RMS COD of all the BPMs and the kick angles of the steering magnets between the EV and the EVC.

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