CLOSED ORBIT CORRECTION OF HLS STORAGE RING

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Abstract

The closed orbit of the stored electrons in HLS storage ring often shifts due to some nonideal errors. In order to correct this shift, we developed an orbit correction system which can be periodically or manually invoked to correct the global closed orbit. It can also be used to adjust the orbit position at some point using local bump. The system is based upon EPICS (Experimental Physics and Industrial Control system). It gets BPM data and sets corrector strength via Channel Access. SVD method is used to obtain the corrector strength or corrector factors in global or local orbit correction.

1 INTRODUCTION

HLS (Hefei Light Source) is a dedicated synchrotron light source. Electrons run at 800Mev in the storage ring[1]. The closed orbit of the stored electrons was often perturbed due to some nonideal errors. According to the experience of machine operation, the perturbed closed orbit, known as COD (Closed Orbit Distortion), has many bad effects. First, it excites the non-linear effect and leads to the decrease of the beam lifetime. Second, it changes the position of the light at the front-end of beam lines, which reduces the brightness of the light going into the beam line and affects the experiment at the responding experiment station. In order to correct the orbit distortion, we developed an orbit correction system, which can be periodically or manually invoked to correct the global closed orbit. In other circumstances, it needs to change the orbit locally and not affecting the orbit at other site, for example, the measurement of BPM-to-quadruple misalignment. This system can also be used to adjust the orbit position at some point using local bump. The system is based upon EPICS (Experimental Physics and Industrial Control system). There are 32 corrector along the storage ring, 16 of them are used for horizontal correction and others for vertical. EPICS controls the power supplies of these correctors[2]. The BPM system is a labView based system, which works in client/server mode[3]. Acting as clients, a number of EPICS records read the BPM data from the server. The COD correction system gets BPM data and sets corrector strength via Channel Access. SVD method is used to obtain the corrector strength or corrector factors in global or local orbit correction. The response matrix is measured by varying the strength of the horizontal and vertical corrector magnets or constructed from calculated optics.

2 RESPONSE MATRIX

There are 22 BPMs distributed along the storage ring. The response matrix between these BPMs and 16 horizontal and 16 vertical correctors can be constructed from calculated optics or measured on the machine. Both kinds of matrices are in the correction.

2.1 Theoretical response matrix

A corrector at point s_i deflect the beam by a angle θ_i, then at point s_j, the beam position would be[4]:

$$u_0(s_j) = \frac{\sqrt{\beta_j}}{2\sin(\pi\upsilon)}\theta_i\sqrt{\beta_i}\cos\upsilon[\varphi_j - \varphi_i - \pi]$$

(1)

Writing it in matrix format, we get:

$$U = M\Theta \qquad (2)$$

Where, U is the beam orbit position, Θ is the strength of correctors, M is called response matrix between BPM and correctors, whose elements are:

$$M_{ij} = \frac{\sqrt{\beta_i\beta_j}}{2\sin(\pi\upsilon)}\cos\upsilon(\varphi_i - \varphi_j + \pi) \quad (3)$$

2.2 Measured Response Matrix

The response matrix can also be measured by changing the strength of each corrector by a small amount and then measuring the resulting beam motion at all BPMs. In our case, the strength of each corrector is changed in 5 step. For each step, the power supply of this corrector is changed 1.0 ampere. The measured matrix is used in horizontal correction and got good result.

2.3 SVD method

Solving equation (2), we get,

$$\Theta = M^{-1}U \qquad (4)$$

In our case, M is a 22 by 16 matrix. Its inverse matrix can't be directly solved. According the SVD method, M can written as the product, $M = U^T W V$, of three matrix[5]. Where W is an 16 by 16 diagonal matrix with non-negative diagonal elements called the *singular values*, U is 22by 16 matrix with $UU^T=1$, and V is an 16 by 16matrix with $VV^T=1$. Then the pseudo-inverse matrix of M can be written as:

$$M^{-1} = V^T W^{-1} U \qquad (5)$$

Where M^{-1} is a 16 by 22 matrix.

3 LOCAL CORRECTION WITH BUMP

There are some conditions that need steering the beam locally, for example, in the measurement of BPM-to-quadruple misalignment. Local correction is based on three-correction local bump theory. The local bump is determined by the ratio of the strength of the three correctors, which is $\frac{\sin \varphi_{23}}{\sqrt{\beta_1}} : -\frac{\sin \varphi_{13}}{\sqrt{\beta_2}} : \frac{\sin \varphi_{12}}{\sqrt{\beta_3}}$ [6]. But on HLS storage ring, we can't get good bump with this ratio especially in horizontal plan, because there are some not known non-ideal errors. So we use the response matrix to construct the bump.

Let us suppose that we use three correctors c1, c2 and c3 to form a bump at the point of BPMs b1, b2. Now we must construct two matrices. The first, M1, is a 22 by 1 matrix, which corresponding to the column for corrector c1 in the response matrix but haven't the row corresponding to b1 and b2. Another, M2, is a 22 by 2 matrix, which corresponding to the columns for corrector c2 and c3 in the response matrix but haven't the row corresponding to b1 and b2. Let us further suppose that the strength of c1 is 1, so we can get the strength of c2 and c3 with the following equation,

$$\begin{bmatrix} c2 \\ c3 \end{bmatrix} = -M_2^{-1} M_1 I \qquad (6)$$

Where I is unit matrix. Equation (6) means that c1 with strength 1 change the closed orbit to M_lI and corrected with c2 and c3 outside of the bump.
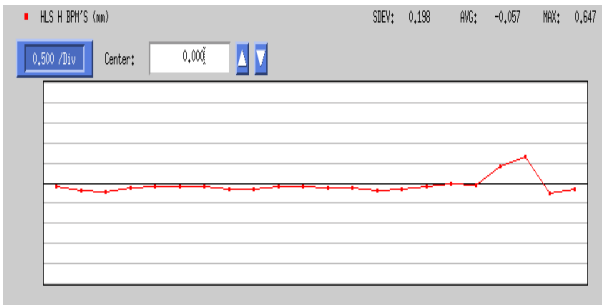

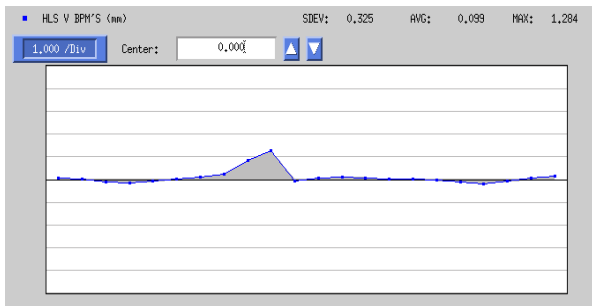Fig 1 Local Bump in horizontal plane with Corrector CQ4N, CQ5N and CQ8N

Fig 2 Local Bump in vertical plane with corrector CQ2S, CQ3S and CQ6S

With this method, we get good result in both planes. Figure 1 and figure 2 shows the local bump in horizontal and vertical plane respectively.
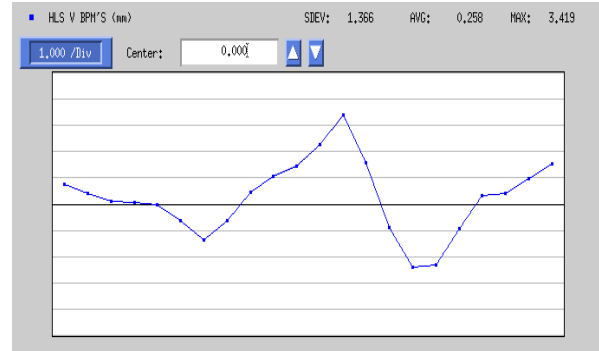
4 GLOBAL CORRECTION

We use sddscontrollaw to do the global orbit correction, which is a SDDS-compliant EPICS tool developed at APS and based upon the integral control equation described as[7]:

$$U_n = U_{n-1} - KX_n \qquad (7)$$

The quantity X_n is the vector of measured BPM data at step n. U_n is the corrector strength at step n. K is the inverse response matrix plus a gain number. We get a good result in vertical plane. Figure 3 shows the closed orbit before correction. Figure 4 shows the closed orbit after correction. The standard deviation is reduced from 1.366 to 0.034. The maximum orbit deviation is reduced from 3.419mm to 0.079mm.

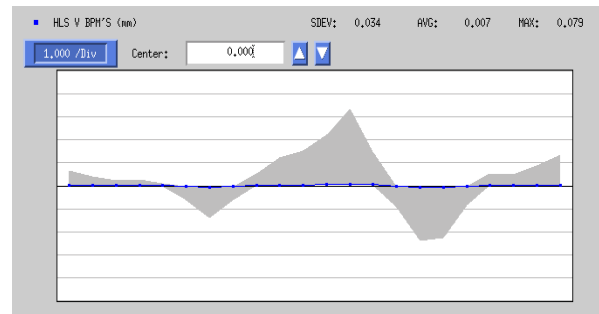Figure 3 Closed orbit in vertical plane before global

correction

Figure 4 Closed orbit in vertical plane after global correction

5 CONCLUSION

This system works fine in both local orbit correction and global orbit correction. The local correction with three-corrector bump is successfully used in the measurement of BPM-to-quadruple misalignment and get good result. The global correction in vertical plane also shows good result. Because the corrector power supply upgrade is not completed, we can't do the global correction in horizontal plane. This system should work

fine in horizontal plane after the power supply upgrade finished.

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