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BETA BEATING AND COUPLING CORRECTION OF THE ILSF STORAGE RING

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Abstract

The Iranian Light Source Facility (ILSF) is a 3 GeV synchrotron radiation facility, which is in the design stage. Inevitable errors like imperfection of magnetic field and misalignment of magnets will introduce various destructive effects on the performance of the machine. The possibility of correcting the errors should be thoroughly examined before settling the design. In this paper, the correction process of beta beating and coupling with LOCO is described. The rms beta beating in horizontal and vertical planes after correction are reduced to 1% and 2% respectively. The average coupling ratio of lattice for 100 random error distribution is corrected to 0.2%.

INTRODUCTION

The ILSF storage ring design is based on attaining an ultralow emittance electron beam ring containing sufficient number of straight sections.[1] Horizontal beam emittance of the bare lattice is brought down to 270 pm rad. The final emittance of the lattice is dependent on the number and type of Insertion devices (ID). For all ID straight sections filled with 17 typical IDs, horizontal emittance will be reduced to about 160 pm rad. The high gradient quadrupoles and sextupoles are needed for optimizing linear and non-linear optics of the lattice. Therefore, inevitable errors like imperfections of magnetic field and misalignment of magnets will introduce various destructive effects on the performance of the machine. Because of the inevitable errors such as fabrication errors, calibration errors, or errors of the power supplies, the strength and higher-order multipoles of magnets in the final machine will be different from the design magnets. In addition, alignment of the magnets will not be identical with the ideal design alignment. These errors cause additional kicks, field gradients and sextupole strengths along the lattice. To evaluate the effects of errors on the real machine, the alignment errors and field errors are added to all the magnets.[2] Maximum absolute value of random alignment and filed errors are presented on Table 1. The errors are generated with a Gaussian distribution truncated at ±1σ.

Table 1: Misalignment and Field Errors

Misalignment error	ΔX [μm]	ΔY [μm]	Δθ [μrad]
Element to Girder	30	30	200
Girder to Girder	100	100	200
Field errors	**ΔB/B**	**ΔK/K**	**ΔS/S**
Relative error	10^{-4}	10^{-3}	10^{-3}

There are eight horizontal and eight vertical steering correctors and two skew quadrupoles for coupling correction in each super-period of lattice. The position of BPMs and correctors are shown in Fig. 1.

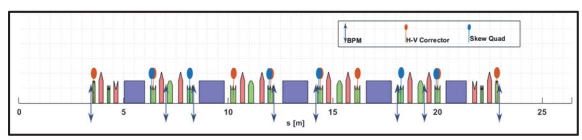

Figure 1:Position of BPMs and correctors.

CLOSED ORBIT CORRECTION

Correction of the orbit distortions generated from the residual misalignments and magnetic field errors is one of the most fundamental processes used for beam control in accelerators. There are 8 BPMs [4], 8 horizontal correctors and 8 vertical correctors in each achromat of ILSF storage ring lattice for this purpose. The algorithm of orbit correction is based on singular value decomposition (SVD) method. Regarding to the sensitivity of the lattice and amount of the used errors on simulation, normally there is no closed orbit in the first tracking. Therefore, the correction process starts with pre-correction or trajectory correction. The maximum COD for 100 random error distribution before correction is 2.5 [mm] and 2 [mm] in horizontal and vertical plane respectively. Maximum closed orbit distortion in both horizontal and vertical direction after correction reduced to 80 and 110 micrometers respectively.

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BETA BEATING CORRECTION

After correcting the closed orbit distortion, for ensuring the designed performances, the linear optics of the lattice must be restored. Error on quadrupole components of magnets (random and systematic errors) besides horizontal orbit offset in sextupoles are the main sources of tune shift and beat beating around lattice. Nowadays, LOCO (Linear Optics from Closed Orbits)[3] is a well-tested and reliable algorithm to measure and restore the linear optics of lattice. This method measures the orbit response matrix and optionally the dispersion function of the machine. The data are then fitted to a lattice model by adjusting parameters such as quadrupole and skew quadrupole strengths in the model, BPM gains and rolls, corrector gains and rolls of the measurement system. The resulting lattice model is equivalent to the real machine lattice as seen by the BPMs. According to the fitting result, one can correct the machine lattice to the design lattice by changing the quadrupole and skew quadrupole strengths. In this study, the Matlab-based LOCO code has been used .

Maximum beta beating after closed orbit correction for 100 random error distribution is about %40 in horizontal direction and %25 in vertical direction and maximum horizontal dispersion error is about 22 [mm]. The beta beating before and after LOCO correction presented in Figs. 2 and 3.

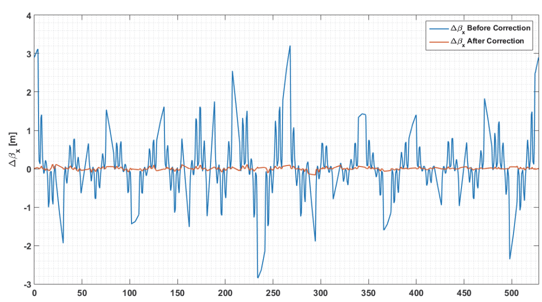

Figure 2: Horizontal beta beating.

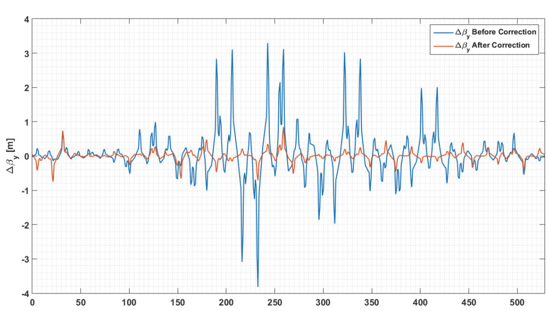

Figure 3: Vertical beta beating.

The average beta beating is corrected from 40% (peak-to-peak) to 1% in horizontal plane and from 25% to 2% in vertical plane. The maximum and average beta beating for 100 seeds through the lattice in shown in Figs. 4 and 5.

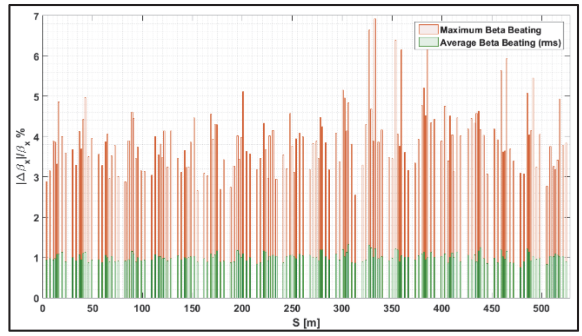

Figure 4: Maximum and average horizontal beta beating.

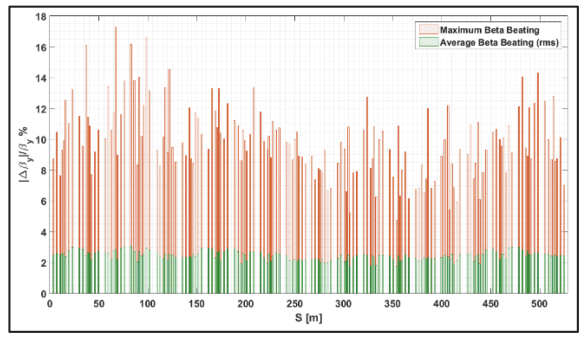

Figure 5: Maximum and average vertical beta beating.

The greatest relative strength change in fitting quadrupoles is related to the Q2 family which is the only defocusing quadrupole family in the ring with 1.63% variation.

COUPLING CORRECTION

The vertical emittance determines the vertical beam size. The vertical beam size directly affects brightness and beam lifetime. The main sources of vertical beam size are betatron coupling and vertical dispersion. The main sources of emittance coupling are betatron coupling and vertical dispersion. The dominant cause of residual vertical dispersion and betatron coupling are magnet alignment errors such as tilting the dipoles and quadrupoles and vertical orbit offsets in sextupoles. Coupling errors lead to transfer of horizontal betatron motion and dispersion into the vertical plane and it corresponds to the off-diagonal part of the orbit response matrix. The response in the vertical BPMs to the horizontal correctors and vice versa.

The betatron coupling and vertical dispersion are corrected by skew quadrupoles, which are considered as a component of sextupole magnets in ILSF storage ring. The coupling correction compensate the off-diagonal parts of the response matrix. The strength of skew quadrupoles are calculated by LOCO. The effect of changing the skew quadrupoles strengths on horizontal dispersion and beta functions is negligible; therefore, the coupling correction is done independently after closed orbit correction and linear optic correction.

The coupling parts of the response matrix before and after correction is shown in Fig. 6.

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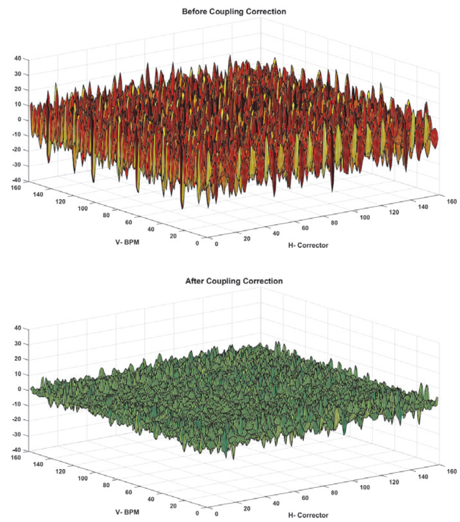

Figure 6: Off-diagonal part of response matrix before and after coupling correction.

The vertical dispersion and betatron coupling are corrected simultaneously with LOCO. Figure 7 shows the vertical correction before and after coupling correction for one seed. The rms vertical dispersion over the entire ring after correction reduced from 2.6 [mm] to 0.15 [mm].

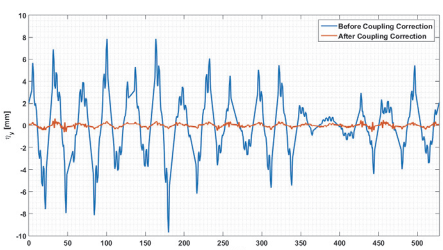

Figure 7: Vertical dispersion before and after coupling correction.

The measurement of the vertical emittance of the stored beam is the most preferable method to know the coupling. The coupling ratio is defined as below:

$$\kappa = \frac{\epsilon_y}{\epsilon_x} \quad (1)$$

The coupling ratio before and after coupling correction for 100 seeds is presented in Figure 8. The average and maximum values of coupling ratio after correction are 0.20% and 0.56% respectively.

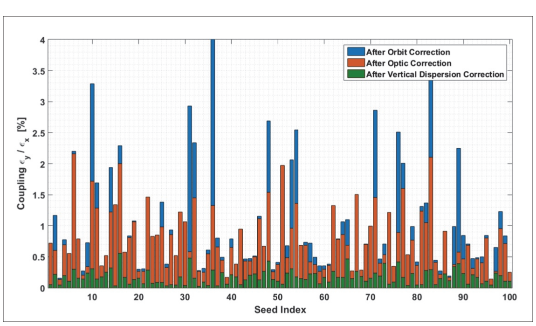

Figure 8: Coupling ratio before and after coupling correction for 100 random seeds.

CONCLUSION

The effect of errors on ILSF storage ring lattice has been studied. The closed orbit correction is accomplished by using SVD method. In this process, 160 BPMs and 160 H-V correctors has been used in the whole ring. The COD correction reduced the maximum deviation from 2.5 [mm] to 80 [μm] in horizontal plane and from 2 [mm] to 110 [μm] in vertical plane. Linear optics correction of the closed orbit corrected lattices has been carried out by using of 160 fitting quadrupoles with individual power supplies in LOCO. The average beta beating is corrected down to 1% and 2% (peak-to-peak) in horizontal and vertical planes respectively. The last correction process is coupling correction. The coupling correction is accomplished by using of 120 skew quadrupoles in LOCO. The average coupling ratio is reduced down to 0.20%.

The obtained results show the error correction scheme of ILSF could correct the realistic errors during the commissioning and operation of the machine to an acceptable level.

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