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A Generic Method for Diagnosing Orbit Related Issues in the NSLS-II Storage Ring

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Abstract

In the following we describe a generic method, which is applicable to different types of orbit related issues occurred in the NSLS-II storage ring. By applying this method to two different cases, the first one is the sudden drop of the beam lifetime from 8 hours to 4.5 hours occurred ~3:10pm on January 2017, we were able to narrow down the problematic area to cell 30; the second one is to shift the fast-to-slow corrector strengths when the FOFB is on to avoid saturating fast correctors.

Generic Method

NSLS-II FOFB system is designed to keep the beam stability < 10% of beam size [1]. Therefore, the orbit needs to be held in sub-micron level at the center of the short straights. If any orbit distortion occurs when FOFB is on, FOFB tries to compensate it while keeping the orbit stable. In order to discover what really happens beneath, one has to remove the impact of the FOFB system. The procedure for doing so is as the following:

1. Find the beam orbit before and after the distortion, called $orb(t_1)$ and $orb(t_2)$ respectively.
2. Find the fast corrector settings before and after this change, called $fcor(t_1)$ and $fcor(t_2)$.
3. Orbit Response Matrix from fast corrector to BPM is available either by model or by measurement, called *ORM*, since the machine lattice is corrected very close to the design lattice in operation.
4. Remove the impact of the fast corrector change *dfcor* [= $fcor(t_2)$ - $fcor(t_1)$] in the beam orbit change *dorb* [= $orb(t_2)$ - $orb(t_1)$] during the orbit distortion using Eq. 1:
$$\Delta orb = dorb - ORM \cdot dfcor \qquad \text{(Eq. 1)}$$
5. Find the source of such orbit distortion.

Application #1

A sudden drop of the beam lifetime from 8 hours to 4.5 hours occurred ~3:10pm on January 2017. It was coincident with turning on the FOFB system. FOFB was off at ~3:00pm (called t_1) when the beam lifetime was about 8 to 9 hours; however, the lifetime dropped to 4.5 hours after FOFB was turned on for several minutes at ~3:10pm (called t_3). All the orbit data and fast corrector settings have been achieved; therefore, they were able to be retrieved afterwards. The measured difference orbit [$\Delta x = x(t_3)$-$x(t_1)$] after and before the lifetime drop is shown in Fig. 1(a) as the blue curve, and the predicted difference orbit by $(ORM_{xx} \cdot dfhcor)$ is shown as the green curve. They are very similar. Here, ORM_{xx} is the horizontal fast corrector $(fhcor)$ to the horizontal BPM response matrix. The noise locator described by Eq.2 is shown in Fig. 1(b), no abnormal behaviors.

$$\left(ORM_{xx}{}^{T} \cdot ORM_{xx}\right)^{-1} \cdot [ORM_{xx}{}^{T} \cdot (\Delta x - (ORM_{xx} \cdot dfcor)] \qquad \text{(Eq. 2)}$$

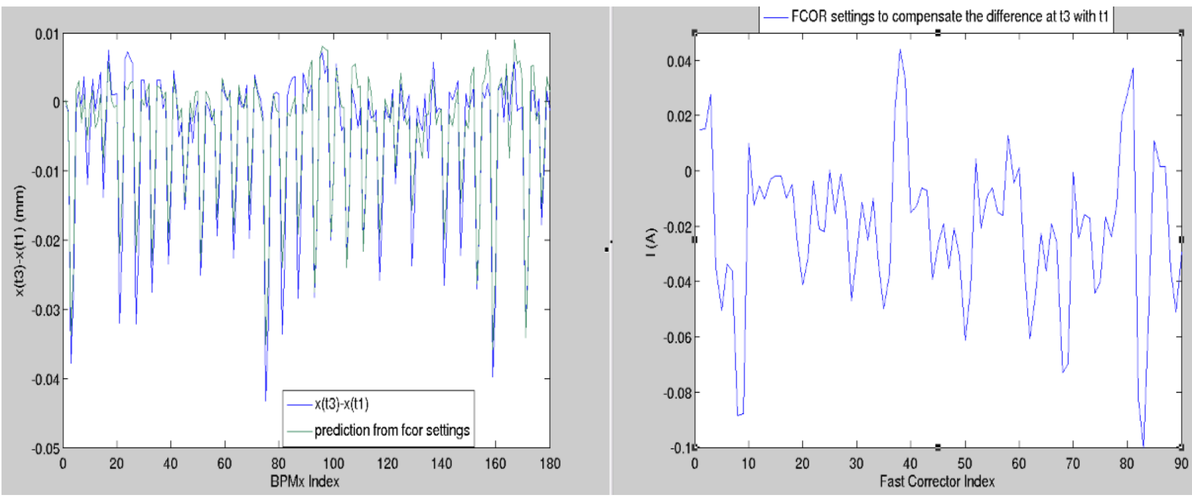

Fig. 1(a) (left) The measured and predicted difference orbit *via* the difference of horizontal fast corrector settings are shown as the blue and green curves respectively. Fig. 1(b) (right) The result of noise locator.

Similarly, we analyzed the vertical orbit variation during the lifetime change. We applied the same procedure described in ***Generic Method*** section to the vertical orbit. After removing the impact of vertical fast corrector changes, the real vertical orbit distortion is shown as the blue curve in Fig. 2(a). It is similar to the observed vertical orbit when there is a combination of the beam energy offset and coupling. Therefore, we vary the beam energy and skew quad settings and indeed, we are able to reproduce the vertical difference orbit, which is shown as the red curve in Fig. 2(a). The corresponding skew quad setting is shown in Fig. 2(b), and there is a clear peak at cell 30, where the vertical scraper locates and later was found as the likely cause of the lifetime drop [2].

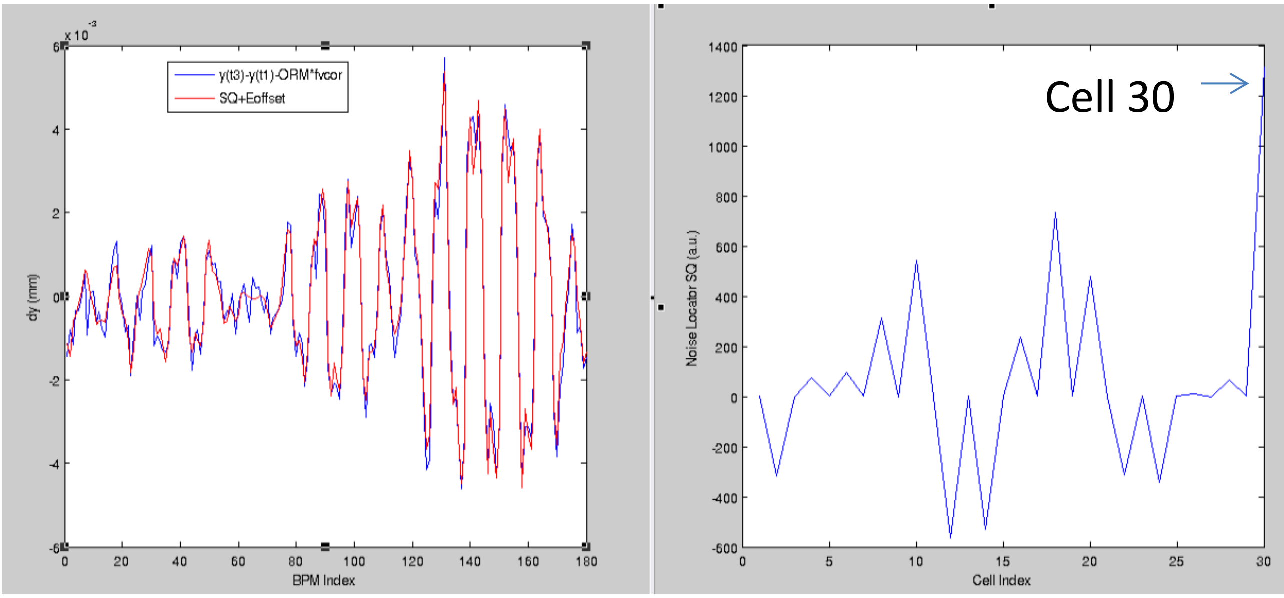

Fig. 2(a) (left) The real vertical orbit distortion and the predicted orbit distortion *via* the energy offset and skew quad settings are shown as the blue and red curves respectively. Fig. 2(b) (right) The corresponding skew quad setting.

Application #2

Similarly, the shifting of fast-to-slow corrector strengths can be implemented *via* ***Generic Method***. The orbit, which corresponds to the present fast corrector settings, can be treated as the orbit distortion. By removing the impact of fast corrector settings (*fcor*), we obtain the distorted orbit ($dorb = -ORM_{AC} \cdot fcor$). Such orbit can be corrected by the slow corrector variations (*dcor*) *via* Eq. 3.

$$dcor = \left(ORM_{DC}{}^{T} \cdot ORM_{DC}\right)^{-1} \cdot \left[ORM_{DC}{}^{T} \cdot dorb\right] \quad \text{(Eq. 3)}$$

Here ORM_{AC} and ORM_{DC} are fast corrector-to-BPM and slow corrector-to-BPM response matrices respectively. The shifting matrix from fast-to-slow corrector can be rewritten as Eq. 4:

$$ORM_{shift} = -\left(ORM_{DC}{}^{T} \cdot ORM_{DC}\right)^{-1} \cdot \left(ORM_{DC}{}^{T} \cdot ORM_{AC}\right) \quad \text{(Eq. 4)}$$

By following the above analysis, we can obtain the shifting matrix ORM_{shift} from fast-to-slow corrector strengths in the horizontal direction, as show in Fig. 3. Here, we select 90 most effective slow correctors in each plane for the shifting. The phase advance between the closest fast to slow corrector is less than 3 degree.

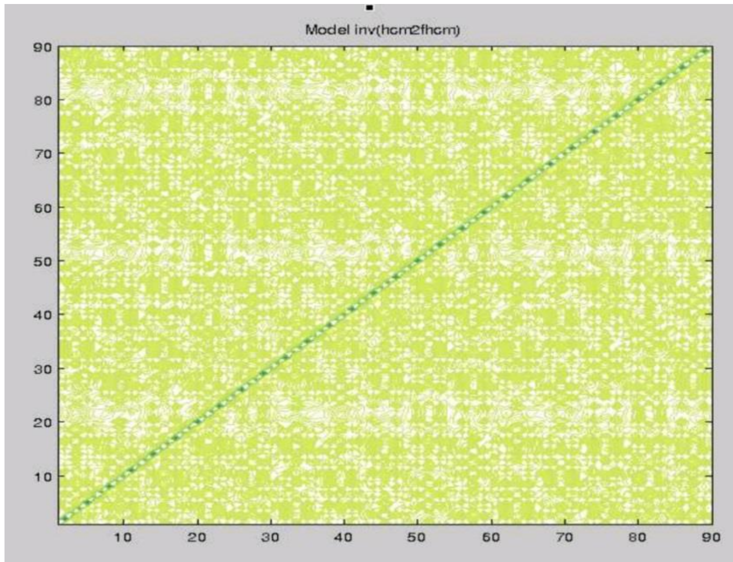

Fig. 3 Modeled shifting matrix of fast-to-slow corrector strength.

Conclusion

We are able to apply the Generic method proposed by Li Hua to solve two different NSLS-II orbit related issues. It can be standardized in the future for debugging the machine error sources using the orbit data and corrector settings.

References

[1] Y.Tian, L.H.Yu, "NSLS-II Fast Orbit Feedback with Individual Eigenmode Compensation", Proc. of PAC'11, New York, 2011.

[2**] Talk by Guimei representing team work of orbit issue investigation in AP meeting, "Orbit issue investigation".**