BNL-223399-2022-TECH

NSLSII-ASD-TN-377

Reduction of orbit corrector strengths with degeneracy

Y. Li

September 2022

Photon Sciences

Brookhaven National Laboratory

U.S. Department of Energy

USDOE Office of Science (SC), Basic Energy Sciences (BES) (SC-22)

Notice: This technical note has been authored by employees of Brookhaven Science Associates, LLC under Contract No.DE-SC0012704 with the U.S. Department of Energy. The publisher by accepting the technical note for publication acknowledges that the United States Government retains a non-exclusive, paid-up, irrevocable, world-wide license to publish or reproduce the published form of this technical note, or allow others to do so, for United States Government purposes.

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, nor any of their contractors, subcontractors, or their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or any third party's use or the results of such use of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof or its contractors or subcontractors. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

NSLS-II TECHNICAL NOTE BROOKHAVEN NATIONAL LABORATORY	NUMBER **NSLSII-ASD-TN-377**
AUTHORS: Yongjun Li	DATE 09/01/2022
Reduction of orbit corrector strengths with degeneracy	

Reduction of orbit corrector strengths with degeneracy

Yongjun Li

NSLS-II, BNL
Sep. 1, 2022

Introduction

In the NSLS-II ring, 180 slow orbit correctors are closely arranged along the ring. Due to the small phase advance in-between and the periodicity of the lattice, almost each corrector has some degeneracy with its neighboring ones. The disadvantage is that a pair of highly degenerated correctors might fight with each other and then result in an over-correction. On the other hand, we can take advantage of it to reduce corrector strength peaks, if exist, by shifting part of their contributions to their degenerated neighbors.

The degeneracy of two correctors is quantitatively measured with the Pearson correlation coefficient [1] (PCC) of their orbit response vectors (ORV) observed at 180 BPMs. More closely the value of a pair of correctors' PCC can approach +/-1, a more degeneracy they have. In Fig. 1, the PCC of the 90^{th} horizontal corrector with other 171 correctors are illustrated. Some of neighboring correctors are observed highly degenerated (with $|PCC| > 0.99$). Table 1 shows that part of the most degenerated correctors pairs in the NSLS-II ring. Consider that BPMs has some reading errors, and the lattice has some imperfections, the degeneracy among these correctors might be difficult to distinguish. Rather than resolving the degeneracy completely, we might be able to take advantage of it.

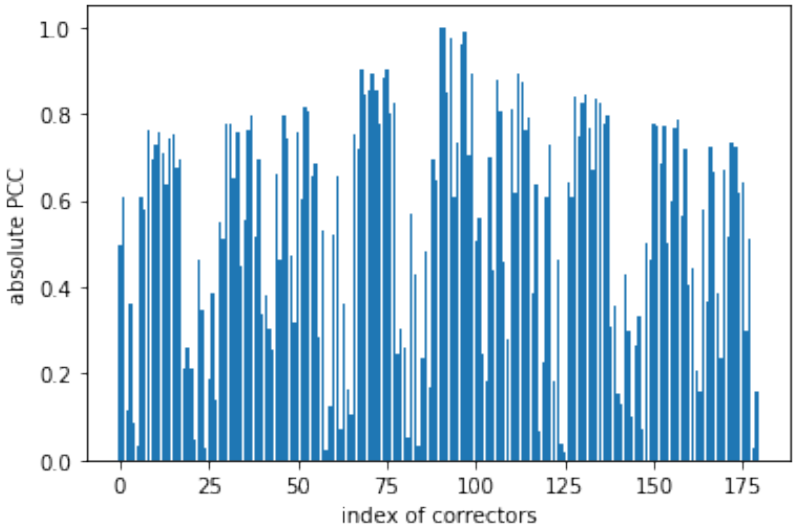

Figure 1. PCC of the 90th horizontal corrector with other 171 correctors

Table 1. Part of the most degenerated correctors pairs in the NSLS-II ring

Index1	Index2	PCC
00000	00177	-0.9945
00001	00174	0.9869
00002	00179	-0.9935
00003	00176	0.9916
00004	00005	0.9979
00005	00004	0.9979
00006	00007	0.9979
00007	00006	0.9979
00008	00015	0.9916
…	…	…

Based on the signs of corrector strengths and PCC, we can determine if a potential over-correction pair exists or not, as shown in Table 2. For example, the first two rows mean, if two correctors' PCC is close to +1, and the signs of correctors strengths are opposite, they might fight with each other, so we can reduce their magnitudes correspondingly based on the ratio of their ORV moduli.

Table 2. Pattern of degeneracy

sign(PCC)	sign(cor1)	sign(cor2)	degenerated
+	+	-	Y
+	-	+	Y
+	+	+	N
+	-	-	N
-	+	+	Y
-	-	-	Y
-	+	-	N
-	-	+	N

Experiment study

An experiment study has been carried out on the NSLS-II ring. First, a 9.404A peak was observed at the 137th horizontal corrector. By checking the signs of the ORV PCCs and strengths of its neighboring correctors, the 136th corrector was suspected having a potential degeneracy:

```
-------------------------------------------------------
      I1(A) index       I2(A)     corrcoef (PCC)
-------------------------------------------------------
     -9.404   136      6.0311      0.99794
```

Then the following recommendation was given:

```
recommendation:
zero down   136 corrector from      6.0311 to 0
reduce   137 corrector from      -9.404 to      -2.435
```

Here, all correctors are assumed having a same unit conversion coefficient (0.044 mrad/A for the NSLS-II slow correctors). This assumption might not be true for other rings. In this case, each corrector needs to be scaled with its corresponding conversion coefficient.

When the above recommendation was fully implemented, some residual bumps usually showed up. Therefore, we only implemented a 50% current reduction, then used a global orbit correction to suppress the residual orbit. In the meantime, some quadrupoles were used to suppress the tune shift. The same procedure was repeated for the next peak and so on. Eventually, in the horizontal plane, several largest corrector peaks were reduced, the overall corrector status changes are:

```
Sum: 43 -> 39A, RMS: 2.97 -> 2.86A, Lower: -8.01 -> -5.76A, Upper: 8.01 -> 6.70A
```

Here “Sum” means to add up all horizontal corrector currents. The “Upper” and “Lower” values are the maximum currents in the outboard and inboard directions.

Same procedure was also implemented in the vertical plane as well.

```
Sum: -68 -> -67A, RMS: 2.48 -> 2.21A, Lower: -8.31 -> -5.97A, Upper: 7.15 -> 4.84A
```

After shifting the peaks to their neighboring degenerated correctors, various parameters, such as the injection efficiency, local ID bumps, beam lifetime etc., were verified to stay almost same.

Some peaks don’t have the potential degenerated opponent with the patterns as shown in Table 2. In this case, we shouldn’t attempt to reduce their amplitudes. Otherwise, the closed orbit distortion can be spoiled. Practically, we only implemented the reduction when the PCC is above 0.97. For example, in Figure 2, for one specific corrector (peak), the rest 179 correctors are sorted with their PCCs. Here 0 stands for the peak itself, then only next 3 correctors (with $|PCC|>0.97$) could be considered as the potential candidates for shifting.

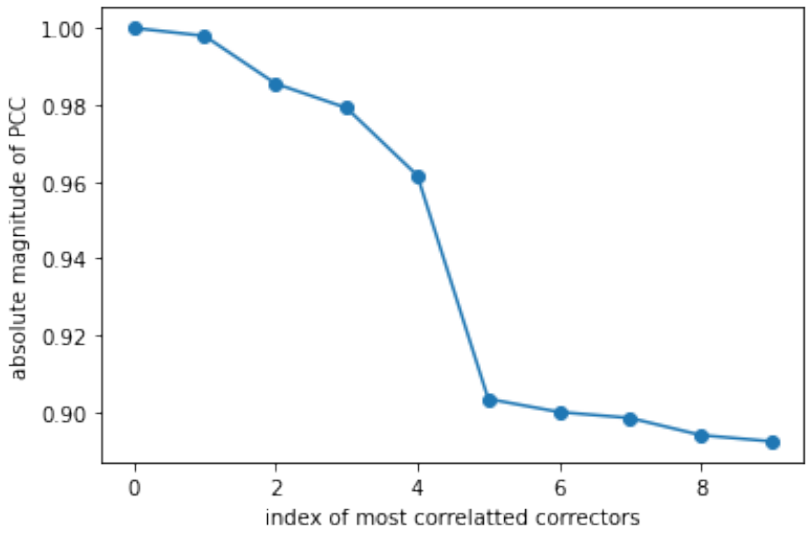

Figure 2. Sorted correctors based on probability of degeneracy (PCC magnitude)

Reference:

[1] https://en.wikipedia.org/wiki/Pearson_correlation_coefficient