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SOLVEMENT OF THE ASYNCHRONIZATION BETWEEN THE BPMS AND CORRECTOR POWER SUPPLIES DURING ORBIT CORRECTION IN RCS OF CSNS

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Abstract

This paper proposes a new possible method to re-synchronize the BPM COD data and Corrector Supplies' data during orbit correction in RCS AC-mode beam commissioning of CSNS. This method is promising to improve the effect of the obit correction.

INTRODUCTION

China Spallation Neutron Source (CSNS) is a neutron source of 100 kW in beam power with the potential to be upgraded. Following the conceptual design, CSNS will be built in two phases: 100 kW at CSNS-I and 500 kW at CSNS-II. The accelerator part has the reserved potential to be upgraded to 500 kW.

The accelerator of CSNS is mainly composed of an 80 MeV Linac and a Rapid Cycling Synchrotron (RCS), showing in Fig. 1. [1] After four DTL Tanks, the Linac injects an 80MeV H^- beam to the RCS injection point with a repetition rate of 25 Hz. After transferring over the stripping foil in 0.2Ms, two electrons would be stripped out. H-Beam turns to proton beam. The RCS accelerates the proton beam from 80 MeV to 1.6GeV in 20 ms. In the 20ms, the proton beam transfers over the RCS about 19600 rings.

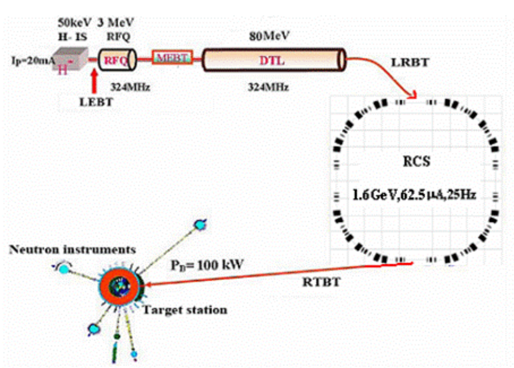

Figure 1: Layout of China Spallation of neutron Source.

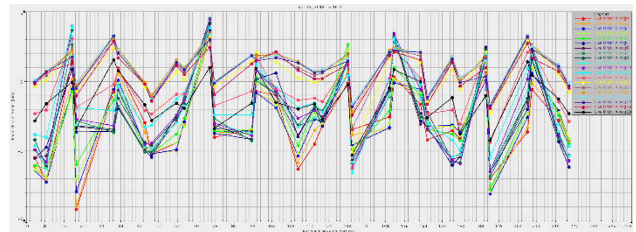

Figure 2: Horizontal Orbit of RCS in CSNS.

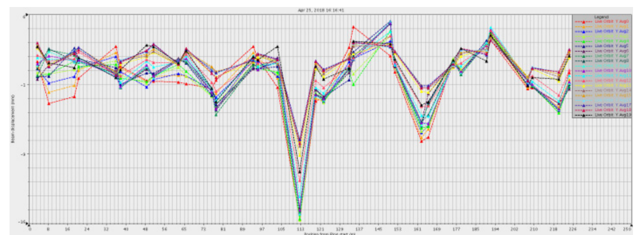

Figure 3: Vertical Orbit of RCS in CSNS.

The beam commissioning of the Linac began in 2015. The RCS beam commissioning began in May 2017. 10 Kw 25 Hz beam was achieved in November 2017. Since then, great efforts have been made to improve the beam parameters. After a lot of optimization, the closed orbit of RCS is still not satisfying. In AC commissioning mode, the 20 horizontal and vertical orbits are shown in Fig. 2 and Fig. 3, respectively.

ASYNCHRONIZATION BETWEEN BPMS AND CORRECTOR SUPPLIES

As described in former work [2], the asynchronization problem between BPMs and correctors was encountered in RCS AC-mode beam commissioning. The 32 BPMs in RCS can only provide COD values in every 2^n (n=7, 8, 9, 10) turns. However, anyone of the 34-corrector power supplies in RCS have a 21-bit Register. Then each power supply has 21 set points during the 20 ms accelerating process that is the first half of the whole 40 ms period. Based on the design, these set points are set into the corrector with regular time intervals 1ms.During obit-correction and response matrix measurement process, BPM COD values are collected. Then the proper corresponding corrector fields are calculated out from the orbit-correction software. However, these calculated values should have different time-stamp from the corrector power supplies current setting values.

Especially in the low energy region during the accelerating period, the negative influence brought out by this kind of asynchronization is more serious., any

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improvements in hardware instruments is impossible. Any improvement in the equipment is impossible, so the remedy from beam commissioning software is necessary.

INVERSE INTERPOLATION SOLUTIONS

The *pick out* method has been discussed in the former work [2], which means selecting 20 BPM COD values from the 39 BPM COD values provided by beam instruments and using these 20 values for orbit-correction. This method is quite simple and has been proved stable and reliable during the beam commissioning of the RCS of CSNS in AC mode.

Although the first "*Pick out*" method was proposed and adopted, it is still not completely satisfying. The "*Pick out*" process would abandon at least 50% of the BPM COD data (50% for N=9; 75% for N=8; 87.5% for N=7). Here 2^N represents that the COD data is provided in every 2^N turns. This inevitable property might result in that the AC orbit-correction performs well in one energy interval, but not so satisfying in another one corresponding to the abandoned data. Another problem is that the time stamp of the selected BPM COD data has small deviation relative to 1ms, 2ms, 3ms…and so on, during the accelerating process.

To preserve all the BPM data during the accelerating process, and to improve the accuracy of the beam orbit correction, the so-called inverse-interpolation method is proposed.

The principle of the *inverse interpolation* is described below: For the corrector power supplies in the current situation, the 21 set points must be set into correctors at every integral Ms in every accelerating process. On the same time, once the AC orbit-correction software is executed, one group of set points of the 34-corrector power supplies in RCS are calculated out. But it must be noticed that these group of set points corresponding to the most primitive BPM COD data, that is to say, different times in the period, not necessarily the integral ms. In the 80MeV injection and 1.6GeV extraction beam commissioning mode, and the RCS BPM COD values are provided in every 2^N (N=10) turns of the beam transferred over the RCS. After carefully calculation, the corresponding time stamps of the BPM COD data are listed in Table 1.

The last BPM COD data is taken during the remaining turns of the beam transferring, less than 1024.

According to the power supply system design specifications, all the corrector power supplies have 21 setting values at every integral ms. During two successive setting values at integral ms, corrector power supplies implement linear interpolation. During the second half of every period, the power supplies implement linear interpolation between the first set point and the last set point.

The main idea of the *Inverse Interpolation* method is to calculate out one set of corrector power supply set points, to ensure that after the automatic linear interpolation, every corrector power supply has the same current value as that has been calculated out in AC orbit correction software at the time corresponding to BPM COD data, in Table 1.

The specific implementation process to realize the algorithm described above is to solve these equations:

$(Set_{n+1}-Cal_n)/(Cal_n-Set_n) = (T_{n+1}-T_{Caln})/(T_{Caln}-T_n);$

In these equations, n is the COD data serial number or the real power supply set point serial number. Set_n represents the real set points that should be set into the power supplies at T_n integral ms. Cal_n represents the calculated out values from AC orbit correction software, which would be a linear interpolation value between Set_{n+1} and Set_n. T_{Caln} represents its corresponding time.

Using the solutions of the above equation and considering the changing slope limitation brought out by the power supplies, this method transforms the calculated values of the 34-corrector power supplies to the actually setting ones. The same as the *pick out* method, this transforming process is executed in EPICS SoftIOC, using the Array Subroutine (ASub) [3][4]. This method avoids the extensive modification of the beam orbit correction software in XAL, which would be complex and tedious work [5].

This *Inverse Interpolation* method seems practicable. It may be more effective and more accurate in AC orbit correction. Because the currents of the corrector power supplies are weak and could easily be disturbed, it is anticipated that this method would decrease the uncertainty in orbit correction, but could not eliminate it. In the coming RCS beam commissioning, this method would also be put into use to see its effect.

Table 1: Time Stamp Corresponding to BPM COD Data

Turn	COD data NO.	time Ms
1024	1	1.94
2048	2	3.61
3072	3	5.03
4096	4	6.27
5120	5	7.39
6144	6	8.43
7168	7	9.41
8192	8	10.36
9216	9	11.28
10240	10	12.18
11264	11	13.06
12288	12	13.93
13312	13	14.79
14336	14	15.72
15360	15	16.49
16384	16	17.33
17408	17	18.17
18432	18	19.01
19456	19	19.85
19639	20	20.00

CONCLUSION

The lack of designing experience leads to the asynchronization problem between BPM's COD measurements and the corrector power supply set points in RCS of CSNS.

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To reduce this kind of negative influence, some methods based on software level have been proposed. These methods might solve the asynchronization problem in beam commissioning to a certain extent, based on the current hardware conditions. The former *pick out* method and this *inverse interpolation* method would be integrated, and this may lead to a better result. The best has been done, and the effect will be tested in the coming RCS beam commissioning.

Other possible solutions will always be considered in the RCS beam commissioning process of CSNS.

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