APPLICATION OF BPM DATA TO LOCATE NOISE SOURCES

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Abstract

To keep and achieve desired performance of a modern synchrotron light source, it requires continuous efforts including good design of the accelerator, good performed subsystems and sophisticated feedback system. While some wonders happen unexpectedly and could deteriorate performance of the light source. For examples, some strong source occasionally occurred especially after long shut down or malfunction of some corrector power supply and it would result in increased noise level. Non ideal injection element will cause large perturbation as well. This report presents algorithms to spatially locate source and summarize some of our practical experience to identify these sources.

INTRODUCTION

The stabilization of the electron orbit is quite critical for the synchrotron light source because it directly affects the intensity of the photon beam delivered to beam lines. In general, micron level beam stability beam is required especially in vertical plane. To achieve such stringent requirement, various efforts and studies have been continuously performed such as orbit feedback system implement, corrector power supply and BPM electronics upgrade in the TLS. Besides migration to a new fast orbit feedback system [1], efforts to identify various sources and minimize their effects on orbit stability are under way. In this report, we summarize several major sources to deteriorate orbit stability and a simple scheme is also demonstrated to localize the disturbed source.

VARIOUS DISTURBED SOURCES

After commissioning of the new BPM system in 2008, we can observe orbit motion systematically in the range from DC to 5 kHz with better resolution. Through a period of track and study, it can be concluded that the orbit motion is contributed mainly from some ill power supply, ground vibration, thermal effect and septum field leakage during injection.

Ground Vibration

In the third synchrotron light sources, the machines are designed with strong focusing. The orbit amplification factors of quadrupoles are usually as high as 50 or more. Therefore, the vibrations of quadruple are most critical as we investigate in the Fig. 1. Its spectrum shows quite wide-band and spreads between 15~25Hz. Each quadrupole is characterized by its location at different girders. Fig. 2 shows the BPM disturbance caused by the corresponding ground vibration where its spectrum also spreads between 15~25 Hz. Orbit movement contributed by vibrations is around 1 μm and it can be suppressed to at least the half by fast orbit feedback system [1].

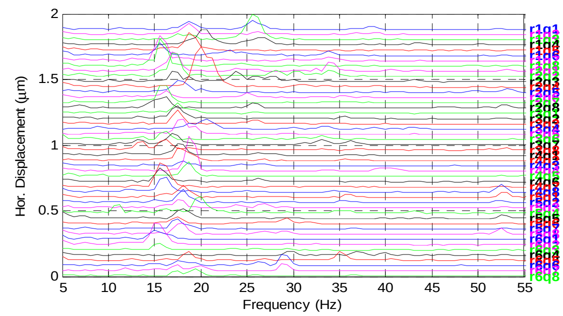


Figure 1: Quadrupole horizontal vibration

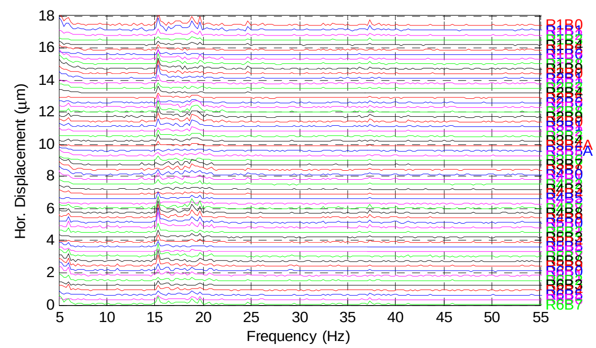


Figure 2: Horizontal orbit motion spectrum. The noise spreading between 15~25 Hz is correlated to the ground vibration.

Malfunctioned Power Supply Example

One strong 120 Hz power line and its corresponding harmonics of a problem power supply was observed, its spectrum and corresponding orbit spectrum is shown in Fig. 3 and Fig. 4 respectively. This disturbance induced orbit swing above 10 micron with several hundreds of Hz spectrum lines. Locating and removing this kind of source is simple, direct but efficient. In the next section, we will present a scheme to localize the single noise source.

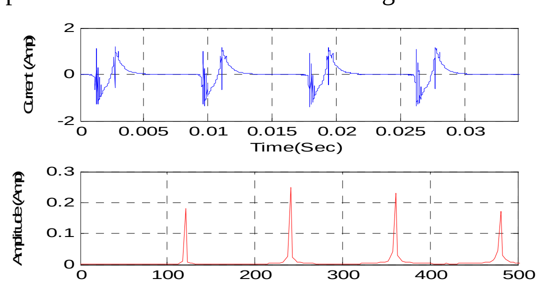


Figure 3: Superconducting wiggler power supply current readings and its spectra amplitude

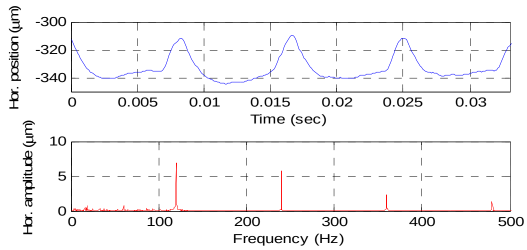


Figure 4: Orbit motion due to the ill superconducting wiggler power supply.

DVM Loading Effect

As Fig. 5 shown, both of horizontal and vertical orbits had a spike pattern regularly happening around 4.8 seconds for several months. After analysis, it was caused by loading effect of measurement system when scanning quadrupole power supplies every 4.8 sec. In the later section, it will be discussed in detail.

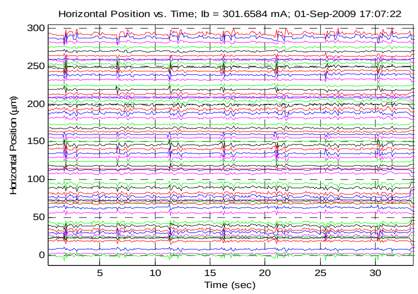
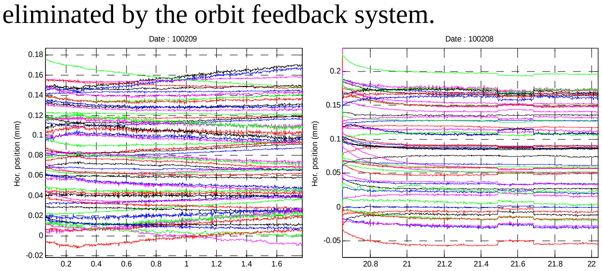


Figure 5: Observation of horizontal orbit change.

Thermal Effect

Fig. 6 shows thermal effect on orbit drift. In the top-up mode, the horizontal orbit drift is slightly lessened than in decay mode but it still could be over 20 micron. In machine operation, it could be almost completely eliminated by the orbit feedback system.



(a) Top-up mode (b) Decay mode

Figure 6: Orbit drift due to thermal effects

Septum and Kicker Field Leakage

TLS is now operated in top-up mode. During the period of injection, the leakage filed of septum and kicker will cause the orbit excursion and make effects on the light source strength and precision where it is shown as Fig. 7.

To improve the orbit excursion, the nu-mental foil is adopted to wrap the chamber and shield from field leakage in March 2010. The Fig. 8 shows the orbit distortion caused by septum leakage before and after chamber shielding. The excursion is improved to reduce around one half.

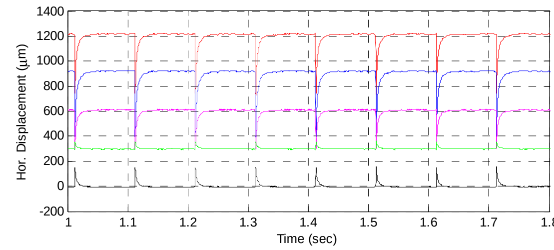


Figure 7: Orbit motions of 5 BPM during injection caused by kicker and septum.

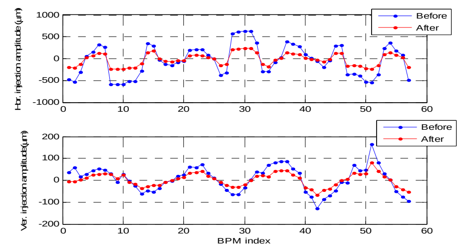


Figure 8: Orbit distortion caused by septum leakage before and after septum shielding.

A SIMPLE METHOD TO LOCALIZE SOURCES

The method to localize a single noise source is demonstrated below. A response matrix can map all correctors to all BPMs in the ring. Through a trigger mechanism built in the Libera, we can collect all BPM synchronous waveform and get its spectrum. The amplitude and phase part of the spectrum at a frequency of interest is extracted. By multiplying amplitude by sign of phase, we construct an AC orbit at the single frequency [2]. This AC orbit correlates with the response matrix and the location of the unknown noise source can be reconstructed. To validate the method, examples are demonstrated as followed.

Malfunctioned Power Supply

A strong power line horizontal noise at 120 Hz was observed. Its orbit amplitude, phase and the corresponding AC orbit at 120 Hz is as Fig. 9. Comparing the AC orbit with all of the horizontal corrector response, we can figure out the largest correlation of the noisy AC orbit and the respective corrector is R5HC3 as Fig. 9 and Fig. 10. It can be concluded that noisy source may locate nearby R5HC3 and finally, we find out the noise produced from one power supply of Superconducting Wiggler 6, which exactly is nearby R5HC3.

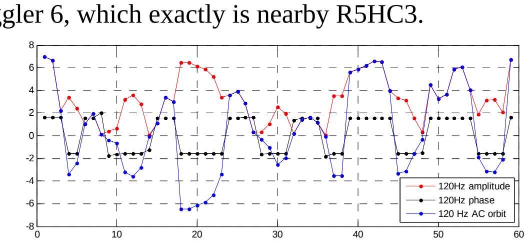


Figure 9: 120 Hz horizontal BPM amplitude, phase and AC orbit

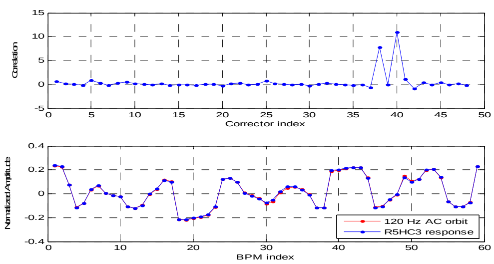


Figure 10: The above figure is correlation between 120 Hz horizontal AC orbit versus all horizontal correctors. The below one shows the AC orbit and its most relevant corrector (R5HC3) response.

DVM Loading Effect on Quadrupole Power Supply

As Fig 5 shown, a continuous and fixed-pattern noise appeared in a period of 4.8 sec. We could observe the phenomenon with fast data sampled by 10 kHz as Fig. 11. It could be seen that there are two apparent noises where the 1st one happened at 0.6 sec and 2nd one at 1.6 sec.

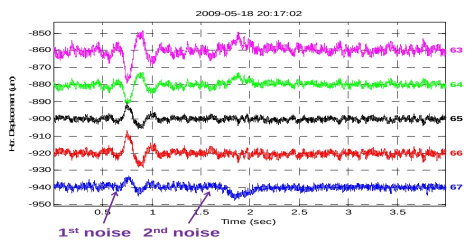
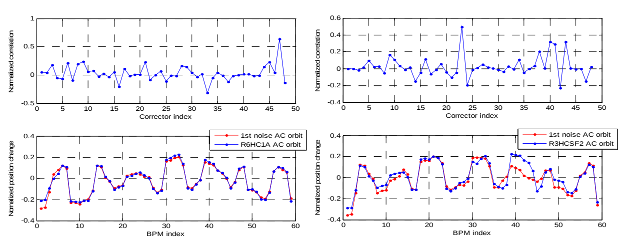


Figure 11: Horizontal orbit motions of 5 BPM for 4.8 sec disturbed source.

We also constructed the two AC orbits of the two noises as Fig. 12 & 13.



(a) (b)

Figure 12: (a) Correlation between AC orbit of 1st noise versus all horizontal correctors. (b) 2nd noise.

It could be seen the two noises were sourced from different location: the first one was nearby the cell 6; the 2nd nearby cell 3 while the two noises had exactly the same periods around 4.8 sec. It seemed being able to infer that the two sources had some conjunction or shared the same source like power supply. Consequently, we found that it was a result of the DVM loading effect when it was scanning the power supply current of all quadrupole at period of 4.8 sec. It is well-known that when the orbit of electron beam doesn't pass the magnet field center of quadrupole, it will cause orbit distortion. As a result, it could be concluded that two quadrupoles: the 2nd one at cell 6 and the 3rd one at 3 cell had larger displacements between the orbit and their magnet center. Fig 13 shows the orbit change for different conditions. The orbit feedback system could suppress the 4.8 sec spike mostly but when DVM power off it could be totally removed.

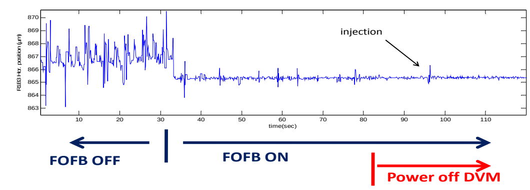


Figure 13: R1BPM3 horizontal position change for fast orbit feedback system on/off and DVM on/off.

Vacuum Pump Vibration

After the long shut down in Spring 2010, it was discovered that the beam stability deteriorated quite a few. Through analysis, a strong 29.2Hz noise was identified at the cell 4 and resulted in beam vertical displacement over several tens microns as Fig. 14~15. It was inferred later that the noise could result from vibration of vacuum pumping for which it was additionally used to lower vacuum after insertion device replacement at cell 4 since the noise disappeared immediately after stop the pump. 29.2 Hz is quite close to the girder natural resonant frequency while it is still required further analysis which component: camber or magnet resulted in such a large beam displacement.

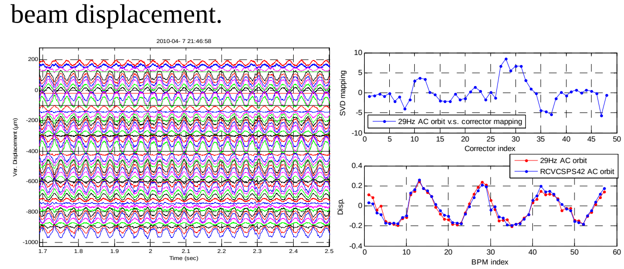


Figure 14: (a) BPM vertical data with strong 29.2Hz noise (b) Correlation between 29.2 Hz vertical AC orbit versus all vertical correctors. Max correlation is RCVCSPS42.

SUMMARY

A scheme for extracting AC orbit and locating the noisy source for the fixed frequency has been developed. This method has been proven to be applied successfully to identify the location of an ill power supply with 120Hz ripples and help to point out DVM loading effect. The diagnostic tool will continuously be developed systematically to locate the source and help to improve orbit stability.

REFERENCES

[1] C. H. Kuo, et al., "Fast Orbit Feedback System Upgrade in the TLS", Proceedings of ICALEPCS 2007.

[2] P. C. Chiu, et al., "Orbit Stability Observation of the Taiwan Light Source" , 2009 OCPA, January, 2009