ISBN: 978-3-95450-208-0 doi:10.18429/JACoW-IPAC2019-THPRB091

APPLICATION PROGRAMS FOR TPS BEAM TRIP ANALYSIS

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Abstract

For the Taiwan Photon Source (TPS), the orbit interlock system is one of the most important machine protection systems. It is the fastest and the most preferred system to detect abnormalities to prevent possible damages caused by magnet power supply failures or subsystems failures. In order to monitor electron orbit changes during a beam trip, we developed the “orbit monitoring and recording tool”, the “TBT BPM analysis tool“ and the “magnet power supply recording and analysis tool” to assist us in the failure analysis as will be discussed in this paper.

INTRODUCTION

During storage-ring (SR) operation, electron orbit changes have a direct impact on user experiments. A large change of the beam position may cause negative effects such as insertion device (ID) damage, vacuum chamber heating, unpredictable radiation dose distribution, etc. Therefore, a fast-orbit feedback system (FOFB) [1] for orbit correction and a machine protection system (MPS) [2] are very important. The MPS controls the orbit interlock system for beam position monitors (BPM) to monitor beam positions within protected ranges. We need to know the difference between beam positions and protected ranges as well as a record of the BPM orbit evolution to allow a beam trip analysis. The sources of orbit vibrations are mostly dipoles, quadrupoles, sextupoles, corrector magnets and associated power supplies. A single power supply failure can cause orbital variations and even beam loss. The existing data archive system [3] continuously saves magnet information and if there exists a record-analysis tool, the time to find the problem can be greatly minimized. In this report, we discuss a record-analysis tool for beam orbit and magnet power supplies.

ORBIT MONITORING AND ANALYSIS PROGRAM

The SR has a circumference of 518.4m and is divided into 24 cells [4] with 7~8 BPMs per cell to record the horizontal (BPMx) and vertical (BPMy) orbit. If the BPMx and BPMy values are positive, they are displayed outside or above the SR centerline and conversely, negative BPMx and BPMy values indicate an orbit position inside or below the SR centreline. Presently, twenty BPMs are included in the orbit interlock system and are located up- and downstream of IDs as well as on either side of upstream dipoles nearest the IDs. For the BPM interlock protected ranges, the horizontal orbit variation is limited to 2 mm from the SR centerline and the vertical limits to within 0.2 mm from the SR mid-plane. In order to distinguish between the orbital position and security protection settings during injection and decay mode, we developed a MATLAB based GUI program to monitor the SR orbits shown in Fig. 1. The orbit data are obtained from BPM fast data (FA) at 10 kHz in form of minimum and maximum amplitudes. When the orbit reaches a security protection limit, the MPS initiates an immediate SRF shut down and the electron beam will be lost (beam trip). At the same time, the program will automatically access the database to download turn-by-turn (TBT) BPM data and save it as a text file to help in the analysis of the beam trip. The downloaded TBT BPM Data are the BPMx and BPMy values, which are recorded during the first 9499 turns and recording while the current is decaying to zero within the next 500 turns for a total of 10,000 turns.The sampling rate of the TBT BPM data is 578 kHz, and the total recording time is 17.3 ms. In order to observe the BPM interlock or all BPM changes before the orbit interlock is triggered, we developed a MATLAB based GUI program to analyse the TBT BPM data, as shown in Fig. 2. The program can show during which turn the security protection setting was triggered and can automatically calculate into which direction the beam was moving. The program provides orbit tracking even after a beam trip and calculates to deviation to the reference orbit (e.g.: deduct the first turn). The program functions to observe the behaviour of the SR orbit can help us to analyse an abnormal position of the whole orbit.

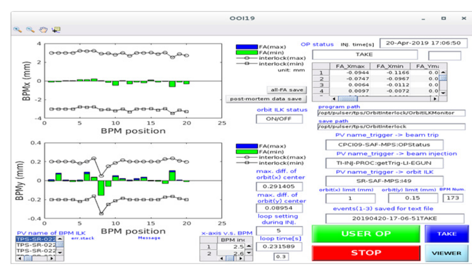

Figure 1: Orbit interlock monitoring and recording tool.

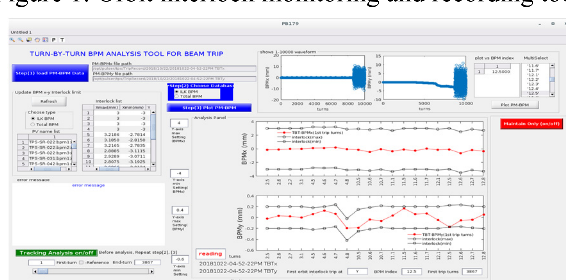

Figure 2: TBT BPM analysis tool for beam trips.

MAGNET POWER SUPPLY RECORD AND ANALYSIS PROGRAM

During SR operation, the dipole magnets, quadrupoles, sextuples and corrector magnets need to be stable to keep the electrons close to the storage ring centerline. The magnet stability can be diagnosed by monitoring the magnet

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power supply currents. Whenever a magnet current experiences a spike [5] or dip, the orbit will be affected and if it reaches the safety protection limits it will lead to a beam trip. In order to provide a fast analysis after a beam trip, we developed two programs to monitor the magnet current status a data recording program, and an analysis program. The program uses the MATLAB based GUI script, as shown in Fig. 3 and Fig. 4. The recording program can access the magnet currents at 10Hz and keep all data within one minute of operation. If a beam trip occurs, the program will save more than one minute of data and store it in a text file. An analysis program will then load the text file and automatically analyse the magnet currents for abnormal behaviour during the beam trip.

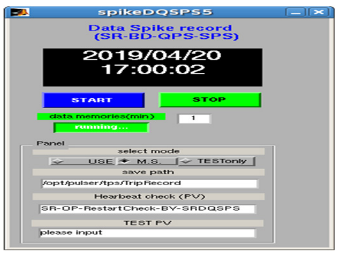

Figure 3: Recording tool for magnet power supplies.

Figure 4: Analysis tool for magnet power supplies.

BEAM TRIP ANALYSIS

During TPS operation, a beam trip, such as caused by the SRF system, miss firings in the SR kicker pulser system or orbit interlock triggers, can be analysed with the post-mortem system [6], in which the source of orbit variations can be diagnosed with a home-developed TBT BPM analysis tool. Figure 5 shows the orbit data during a SRF system trip event, while the electrons travel around the SR orbit for 7118 turns, the orbit interlock BPMx is triggered and the BPMy is still within the permitted range. Tracking the BPM changes, the beam orbit is moving towards the SR inside, which is consistent with lack of energy from the Rf-cavities. Figure 6 shows the orbit for a kicker miss firing event and we can observe a large horizontal orbit deviation near the kicker system, while the orbit oscillates relatively stably away from the kicker. For the kicker miss firing event, the horizontal BPM interlock is triggered while the vertical orbit change is still within the protection limits. Many possible reasons exist for orbit interlock trigger events, including earthquakes, magnet power supply failure or current spikes, an abnormal BPM, an abnormal FOFB, etc. With the developed tools, we can, for example, analyse a beam trip event for a sextuple magnet current (SD-165) spike. The magnet current record shows that the SD-165 magnet behaved abnormal at zero beam current, as shown in Fig. 7. In the analysis, the electrons travel along the SR orbit for 3867 turns and the BPMy orbit interlock was triggered while BPMx remained within permitted limits, as shown in Fig. 8. Furthermore, subtracting the first turn orbit, while the orbit interlock is not yet triggered, from all other orbits, we find a vertical orbit dip in turn #1393 and turn #3016 close to BPM04 and BPM05 in the SR cell-16 as well as close to the SD-165 magnet, as shown in Fig. 9. The results of Fig. 8 and Fig. 9 are in contrast to SD-165 magnet problems for the orbit interlock trigger event. Based on these analysis results, the developed tool will be a useful to analyse a variety of beam trip events.

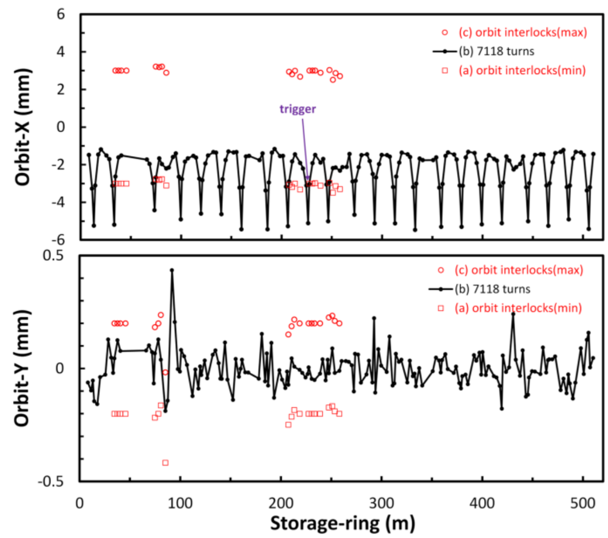

Figure 5: Orbit interlock triggered by an SRF trip.

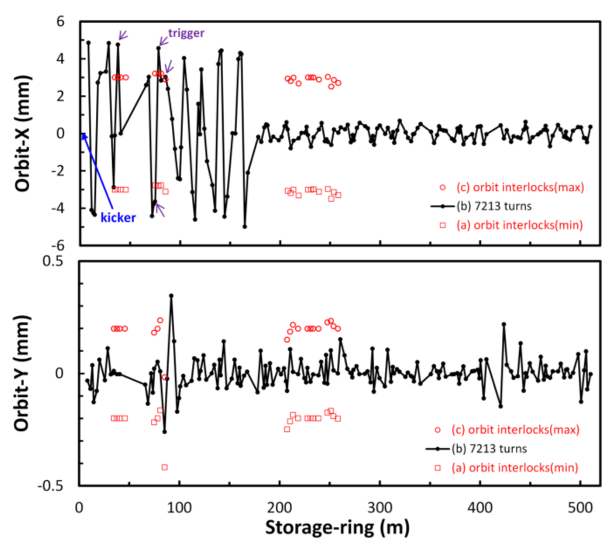

Figure 6: Orbit interlock triggered by kicker miss firing.

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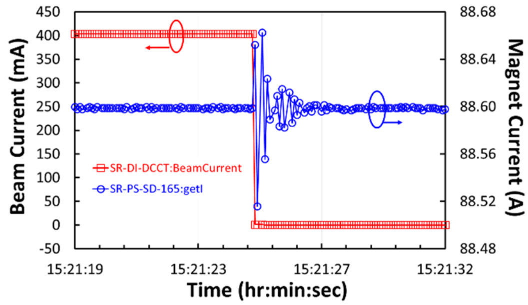

Figure 7: SD-165 magnet current record.

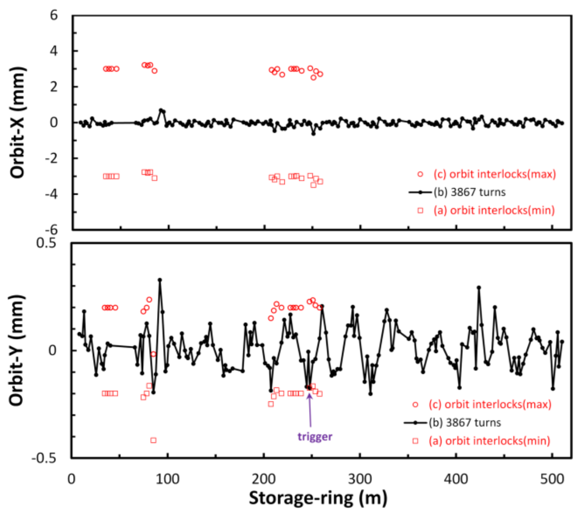

Figure 8: Orbit interlock triggered by a SD-165 current spike event.

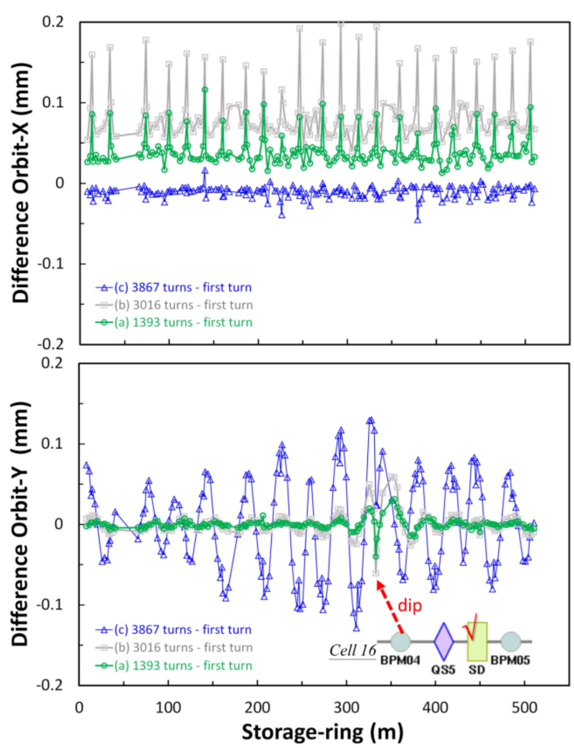

Figure 9: TBT-BPM Data analysis for a SD-165 current spike event.

SUMMARY

In this report, we have discussed orbit monitoring and recording tools to allow the analysis of TBT BPM data and magnet power supply currents after a beam trip. The tools are well suited to assist in the analysis of beam trips such as caused by magnet power supply spikes, SRF system trips or kicker miss firings.

ACKNOWLEDGEMENTS

The authors would like to express their gratitude to the instrument and control group for providing the EPICS system.

REFERENCES

[1] P. C. Chiu, K. T. Hsu, K. H. Hu, C. H. Kuo, and C. Y. Wu, "Fast Orbit Feedback Scheme and Implementation for Taiwan Photon Source", in *Proc. 4th Int. Particle Accelerator Conf. (IPAC'13)*, Shanghai, China, May 2013, paper TUOCB202, pp. 1146-1148.

[2] C. Y. Liao *et al.*, "Design of Machine Protection System for the Taiwan Photon Source", in *Proc. 3rd Int. Particle Accelerator Conf. (IPAC'12)*, New Orleans, LA, USA, May 2012, paper WEPPD046, pp. 2618-2620.

[3] Y.-S. Cheng *et al.*, "Implementation of the EPICS Data Archive System for the TPS Project", in *Proc. 4th Int. Particle Accelerator Conf. (IPAC'13)*, Shanghai, China, May 2013, paper THPEA049, pp. 3255-3257.

[4] TPS Design Handbook, version 16, June 2009.

[5] C. C. Liang *et al.*, "Diagnosis Application by Great Amount Operation Data Analysis Program for Taiwan Photon Source", in *Proc. 9th Int. Particle Accelerator Conf. (IPAC'18)*, Vancouver, Canada, Apr.-May 2018, pp. 2323-2325, ***doi:10.18429/JACoW-IPAC2018-WEPAL064***

[6] C. Y. Liao, Y.-S. Cheng, K. T. Hsu, K. H. Hu, C. H. Huang, and C. Y. Wu, "Post-Mortem System for the Taiwan Photon Source", in *Proc. 8th Int. Particle Accelerator Conf. (IPAC'17)*, Copenhagen, Denmark, May 2017, pp. 422-424, ***doi:10.18429/JACoW-IPAC2017-MOPAB125***