POST-MORTEM SYSTEM FOR THE TAIWAN PHOTON SOURCE

C. Y. Liao, C. Y. Wu, C. H. Huang, Y. S. Cheng, K. H. Hu, K. T. Hsu
NSRRC, Hsinchu 30076, Taiwan

Abstract

The Taiwan Photon Source (TPS), a 3-GeV third-generation synchrotron light source located in Hsinchu, is available to users since 2016. During operation, it will inevitably encounter system trips caused by beam losses. Thus, a post-mortem (PM) system is an important tool to analyze the cause of such events. Main functions of the PM system are: (i) PM trigger will be generated when the stored beam is suddenly lost abnormally; (ii) storage of relevant signals when the server receives such a trigger; (iii) PM Viewer to analyze each event and understand the cause and effect of a beam trip event. The post-mortem system architecture, plans and implementation will be discussed in this report.

INTRODUCTION

The Taiwan Photon Source (TPS) is a low emittance, high brightness synchrotron light source, located in Hsinchu, Taiwan. On December 12 of 2015, the TPS, equipped with two superconducting RF cavities and ten insertion devices has achieved a beam current of 520 mA. After commissioning [1], the TPS became available to the general users community in September 2016. During operation, inevitably there will be system trip events caused by sudden beam losses. In order to find out the reason such an event, a post-mortem (PM) system is under development to become an important tool for beam trip diagnostics. The main features of the PM sys-tem are: (i) generate a PM trigger when the stored beam current is lost abnormally; (ii) stores relevant post-mortem signals when the server receives a PM trigger; (iii) the operators can use the PM Viewer to analyze each event for cause and effect. A detailed system architecture, plans and implementation will be presented in this report.

SYSTEM DESCRIPTION

The architecture of the TPS post-mortem (PM) system is shown in Fig. 1. A PM trigger signal is generated when the stored beam current suddenly drops and is sent to the data acquisition system through an event based timing system [2]. The data recorders will be updated on receiving a trigger, followed by a wait period for the PM server to respond. At the same time, the PM server also detects the occurrence of the event and, after a few seconds delay to make sure that all data recorders are ready, all data from the recorders and important machine parameters will be saved through a PV access. The probable cause of the event will also be analyzed by the program and identified by a simple description. After that, operations can access and analyze the event data at any time through the user interface.

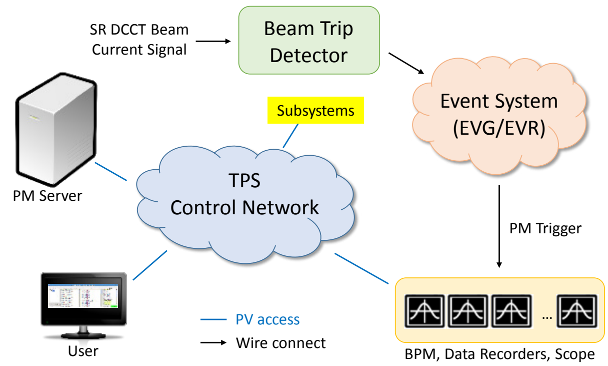

Figure 1: Schematic layout of the TPS PM system.

PM Trigger Generation and Transmission

If the stored beam current drops abnormally fast (for example drop 0.5 mA within 0.1 ms), a set of PM triggers will be generated and transmitted via the timing system. Objects that accept this trigger signal include data recorders and beam position monitors (BPMs) which are distributed around the accelerator facility. Known possible causes for the stored beam current to drop abnormally include: RF system trips, BPM orbit interlock, vacuum interlock, front end interlock, and abnormal firing of pulsers.

The event generator and receiver (EVG/EVR) timing system is used to send the PM trigger via the downlink and uplink functionality. The system not only distributes events to EVRs but also delivers event uplink functionality with the help of the fan-out concentrator. Measurements of the global response time for the TPS timing system uplink and downlink are presented in Fig. 2 for the two stage fan-out concentrator and a 310 m OM3 optical fiber connection. The global response time is less than 5 μs.

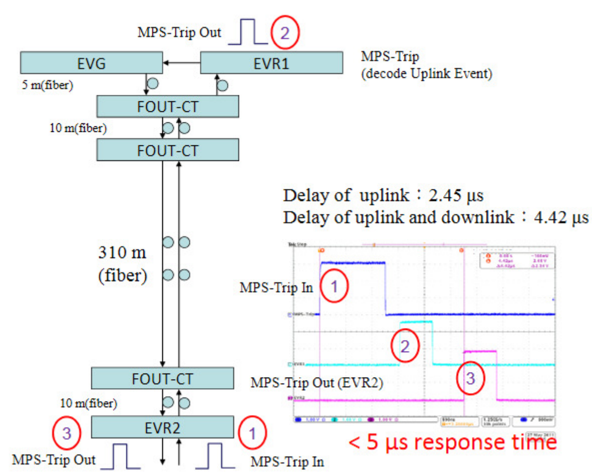

Figure 2: Timing measurement of uplink and downlink with a 310 m fiber and three stage fan-out concentrator.

Data Recorder

The TPS BPM system [3] provides post-mortem data which plays a significant role in recording turn-by-turn orbit information to analyze beam positions during the trip event. In addition, the data recorder includes a standalone data acquisition system and oscilloscope. The quantity and parameters of the data recorders are shown in Table 1. The standalone data acquisition system allow more channel requirements. Some applications need a high sampling rate capture, which is currently done by an oscilloscope. These recorders can provide waveform type post-mortem signals which can be captured from many subsystems, including the storage ring beam orbit, ma-chine protection system (MPS), RF and pulsed magnet system. Some of the subsystem parameter set value need to be logged when an event occurs. The saved post-mortem data are tabulated in Table 2.

Table 1: List of Data Recorder Units used in TPS

Device	BPM platform	Data recorder (8ch)	Oscilloscope (4ch)
Qty.	173	4+	1+
Data length	10k	10k	30k
Record time	~17.28 ms	100 ms	6 ms
Sampling rate	~578 kHz	100 kHz	5 MHz

Table 2: List of Saved Post-mortem Data

Group	Signals	Description
Beam signals	Ib, Orbit	Stored beam current and turn-by-turn orbit data
RF signals	Pr, Pf, GV, RC	RF system forward power, reflect power, gap voltage, and ready-chain signal
Interlock signals	BPM, Vacuum, Frontend, Safety	Subsystem interlocks for RF system trip
Pulser	Kickers	SR injection kicker waveform
Machine parameters	Set value	Other subsystem parameters
Power line	L1, L2, L3	3-phase voltage (in planning)
Seismic	X, Y, Z	Up-down, north-south, and west-east acceleration (in planning)

PM Data Storage Server

The PM Server is used to store post-mortem data, and provide FTP service for PM Viewer access. A capture program written in Matlab is running in the background of the PM server. It can detect an event by monitoring the BPM post-mortem PV changes. When an event occurs, it waits a few seconds for the data recorders to get ready followed by PV channel access to store data. The program also performs a simple timing analysis of the recorded signals in order to give possible event identification, such as trip caused by a kicker or by other subsystems. The hard disk size of the server is 1.1 TB, which is enough capacity for more than 10k trip events. The storage size of each event including BPM turn-by-turn data, three standalone data recorders, one oscilloscope and other machine parameters is less than 100 MB.

TPS PM Viewer

The PM Viewer is designed to list and plot beam trip events. The graphic user interface is currently in development with the Matlab guide tool as shown in Fig. 3. It can list the beam trip event with a simple note, and a signal list check box can be used to select the desired data for display, which can be downloaded from the PM server using the FTP.

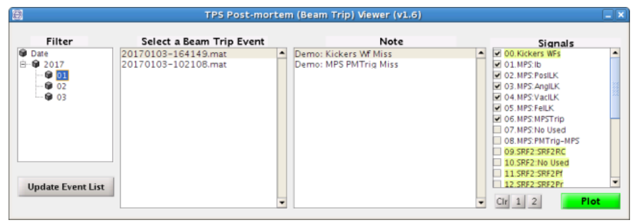

Figure 3: TPS PM Viewer user interface.

SCENARIO FOR SOME TRIP EVENTS

So far, typical beam trip events include RF trips, subsystem interlock trips, and kickers miss firings for which captured data are shown below.

RF Trip Event

A RF trip event usually occurs under test or during machine study. Figure 4 shows a RF system trip during beam processing at a stored beam current of 450 mA. When the RF trips, the BPM post-mortem turn-by-turn, horizontal, vertical, and sum signals are shown in Fig. 5.

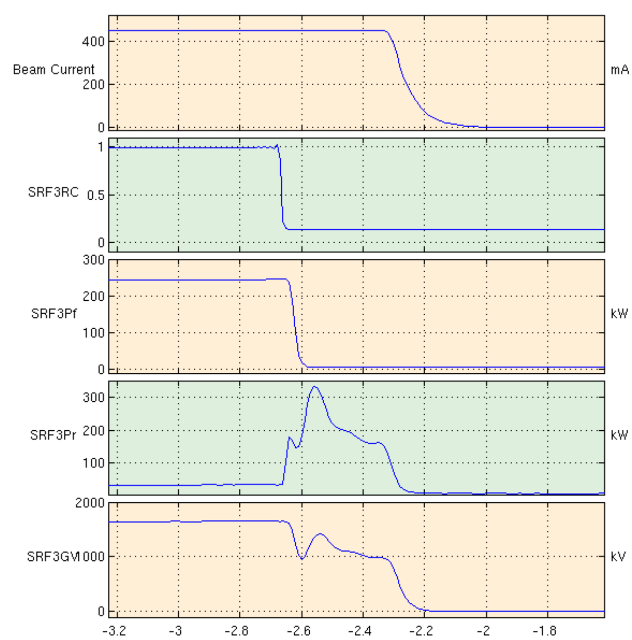

Figure 4: Post-mortem signals for a RF trip event.

ISBN 978-3-95450-182-3

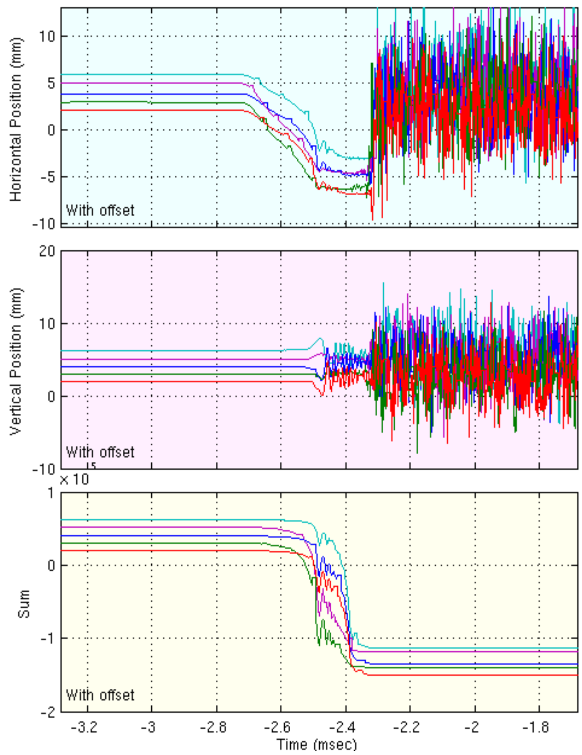

Figure 5: Post-mortem BPM turn-by-turn data for a RF trip event. Upper and middle axes are the horizontal and vertical position with 1 mm offset. Bottom is the sum signal with 10000 count offset.

Subsystem Interlock Trip Event

Some of the subsystem interlocks, like the BPM orbit (position and angle), vacuum and front end interlocks need to shut down the RF system for machine safety. Figure 6 shows that the front end interlock is active during normal operation.

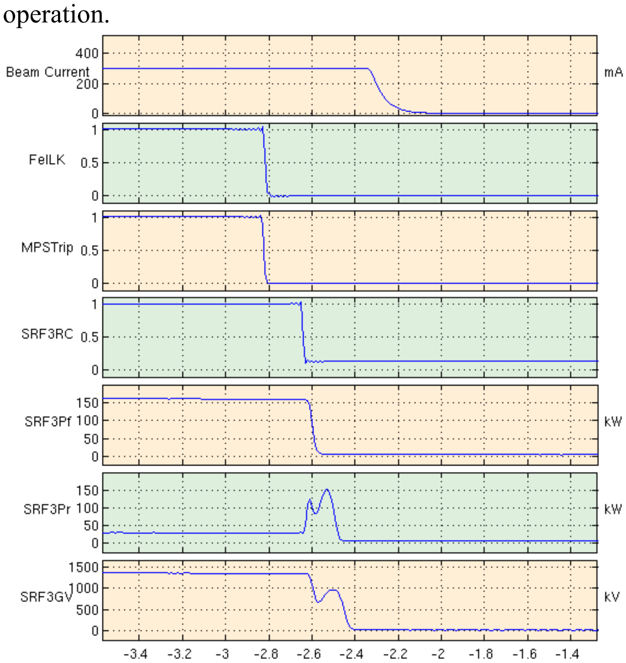

Figure 6: Post-mortem signals of a subsystem (front end) interlock event.

Kickers Miss Firing

There have been a few events of injection kickers miss fires in the past, when injection is not active. Some kickers were unexpectedly triggered, causing an instant loss of the electron beam. Figure 7 shows that the K1, K3, K4 miss fires cause the stored beam to trip. When this type of event occurs, the stored current is immediately lost, while the data indicate that the kicker trigger is not matched to the time of the current loss. This may be the time delay of the DCCT (Direct-Current Current Transformer) system. In the future we will add a pulser trigger signal to the data acquisition system which may help to distinguish between a trigger from the timing system or from noise.

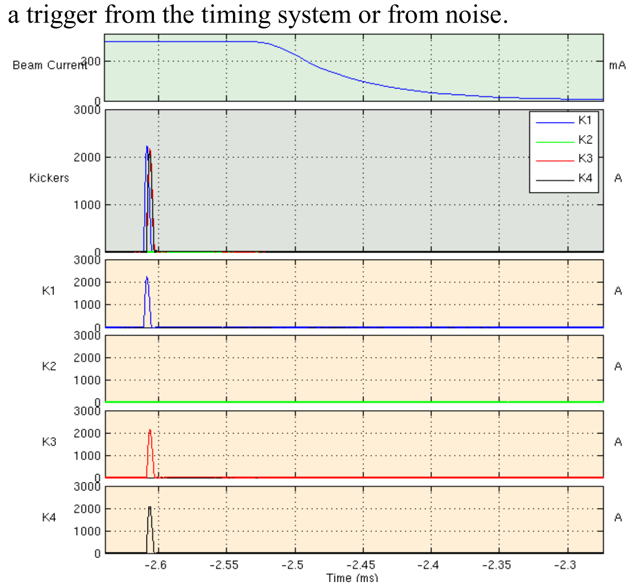

Figure 7: Post-mortem kicker waveform data for a kicker miss firing trip event.

SUMMARY

The TPS post-mortem system is an important tool for beam trip diagnostics during normal operation. It can be used to find the cause for each event. The PM system generates a trigger when stored beam current is lost ab-normally, and stores signals to the server, where the client can view the stored data. The basic functionality of the PM system has been completed, and is currently used on-line during operations. It also can provide reliable information to the operator to analyze a sudden beam loss event. We are considering adding more useful signals, such as from power lines and seismic signals. The features of the PM Viewer are also continually being updated and developed.

REFERENCES

[1] C. C. Kuo et al., “Commissioning of the Taiwan Photon Source”, Proceedings of IPAC2015 (TUXC3), Richmond, VA, USA.

[2] C. Y. Wu et al., “Status of the TPS Timing System”, Proceedings of ICALEPCS2013 (THPPC109), San Francisco, CA, USA.

[3] P. C. Chiu et al., “Commissioning of BPM System for the TPS Project”, Proceedings of IBIC2015 (TUPB068), Melbourne, Australia.