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BEAM TRIP DIAGNOSTICS FOR THE TPS

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Abstract

The Taiwan Photon Source (TPS) is available to users since March 2016. A beam trip diagnostic system is used as an important tool to analyze the cause of beam trip events since the beginning of 2017. The main function of the system is to record relevant signals when the stored beam is suddenly lost. In the past few months, some useful features have been added, such as capturing trigger signals for pulsers, power line voltage, and auto generated beam trip reports. A detailed system architecture, implementation and progress will be summarized in this report.

INTRODUCTION

The Taiwan Photon Source (TPS) is a low emittance, high brightness synchrotron light source, located in Hsinchu, Taiwan. After commissioning [1], the TPS became available for user service in September 2016. During oper-ation, inevitably there will be unexpected beam trips due to subsystem failure or other abnormal circumstances. In or-der to find out the reason for such an event, a beam trip diagnostic system is developed to serve as an important tool for beam trip analysis. In the past few months, some useful features have been added, such as capture of the pulser trigger signals in case of spontaneous firing of the pulser, capturing the 3-phase power line voltage for power quality monitoring, auto generated beam trip reports, and web-based interface allowing for a quick review of the trip event through the web browser. The main system features are: Generate a trigger signal to subsystems when the stored beam current is lost abnormally; Record relevant signals when a beam trip occurs; View the report from the GUI tool or web browser to analyze each event for cause and effect. Reliability and availability of the TPS operation improved dramatically with the help of this beam trip di-agnostics.

SYSTEM DESCRIPTION

The architecture of the TPS beam trip diagnostic system is shown in Fig. 1. A trigger signal is generated through the beam trip detector when the stored beam current suddenly drops. This trigger is sent to many places (here to the data acquisition system) through an evented-based timing system (EVG/EVR) [2]. The data recorders will be updated on receiving this trigger. After a few seconds delay, all data from the recorders and subsystem parameters of interest will be saved through a PV access. The probable cause of the event will be analyzed by the program and identified by a simple description. Then, a beam trip report will be generated and saved as a web page. After that, operators can access and analyze the event data from the viewer GUI or web browser at any time.

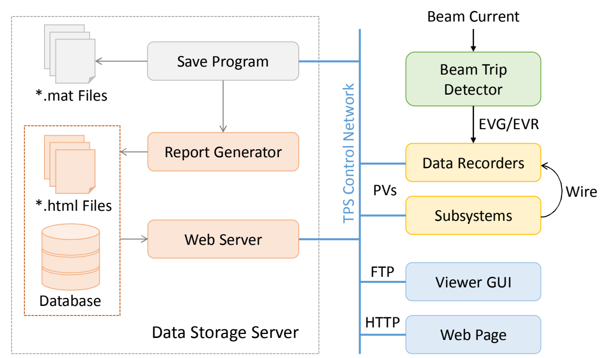

Figure 1: Schematic layout of the TPS beam trip diagnostic system.

Beam Trip Detection and Trip Trigger Generation

A beam trip detector is configured to generate a beam trip trigger signal, when the stored beam current drops abnormally more than 25 mA within 0.1 milliseconds (configurable). This trigger signal is broadcast via the event-based timing system to all data acquisition nodes (BPM platforms and data recorders) to synchronize the data captured. So far, known possible causes for the stored beam trip include: RF system trips, BPM orbit and angle interlock, vacuum interlock, front-end interlock, and abnormal firing of the injection pulse magnets.

Data Recorder

The TPS BPM system [3] provides turn-by-turn orbit post-mortem data which can be used to analyze beam positions during the trip event. In addition, several EPICS embedded standalone data recorders support distributed data acquisition capability to collect data from different subsystems. The quantity and parameters of the data recorders are shown in Table 1. Each data recorder has eight input channels with two types of configurations. These recorders provide waveform type signals which can be captured by many subsystems, including the storage ring beam orbit, machine protection system (MPS), RF and pulsed magnet system. In addition to these signals, some subsystem parameter set values need to be logged when an event occurs. The data to be saved are compiled in Table 2.

Table 1: List of Data Recorder Units used in TPS

Device	BPM platform	Data recorder (8ch)	
Quantity	173	4	1
Sampling rate (kHz)	~578	100	50,000
Time span (ms)	~17.28	100	6
Data length (point)	10,000	10,000	300,000

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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 parameters: forward power, reflect power, gap voltage, and ready-chain signal
Interlock signals	BPM, Vacuum, Frontend, Beamline, Safety	Subsystem interlocks to shutdown the RF system
Pulser	Kickers	SR injection kicker waveform with trigger signal
Machine parameters	Set values	Subsystem parameters, alarm list
Power line	L1, L2, L3	3-phase voltage
Seismic signals	X, Y, Z	Up-down, north-south, and west-east acceleration (in planning)

Data Storage Server

The data storage server is used to automatically store post-mortem data, and provides FTP and web services for viewer GUI and web page access. A capture program, written in Matlab, is running in the background of the server and can detect an event by monitoring BPM post-mortem PV changes. When an event occurs, a two-step saving process starts, one is to save currently subsystem set parameters without delay, the other is to wait a few seconds for the data recorders to get ready, followed by PV channel access to store data as a Matlab file format (*.mat).

The save program also performs a simple timing analysis of the recorded signals in order to give possible event identification, such as a trip caused by a kicker or by other subsystems. The report generator program is used to generate an html file format report and writes the event description to the database for web page access.

Viewer GUI

The viewer GUI is designed to list and plot beam trip events and the graphic user interface is developed with the Matlab guide tool as shown in Fig. 2. It can list the beam trip event with a simple note and provide a signal list check box to select for display the desired data, which can be downloaded from the server using the FTP. Some of the subsystem interlocks, like the BPM orbit (position and angle), vacuum, front-end and beam line interlocks need to shut down the RF system for machine protection. Figure 3 shows that the vacuum interlock is active during 400 mA operation. The RF system is shut down within a few milliseconds. Finally, the BPM position interlock is active.

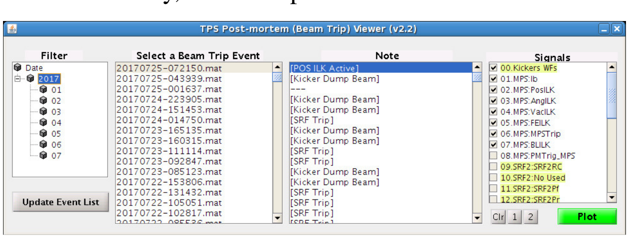

Figure 2: Main page of viewer graph user interface.

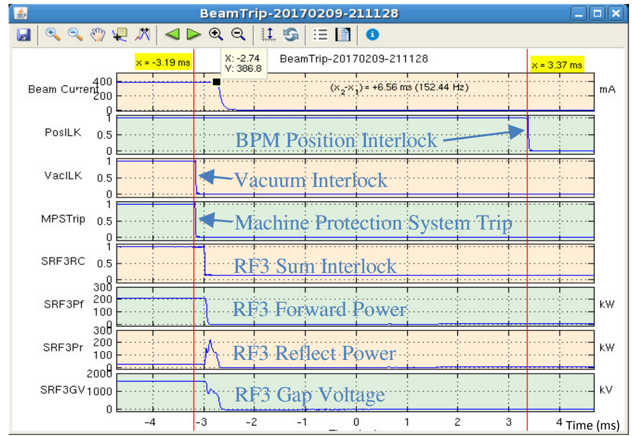

Figure 3: Plot page of vacuum interlock event. A customized toolbar can provide simple data adjustment functions.

Website Interface

The website of the beam trip report is designed to list and view beam trip events. The main page is developed with the Python/Django tool as shown in Fig. 4. It can list a beam trip event similar to the viewer GUI, but only the prepared report can be read. As shown in Fig. 5, the report is generated from the report generator immediately or from the viewer GUI later (regenerate). This web-based interface is useful to quickly review a trip event by any device through the web browser.

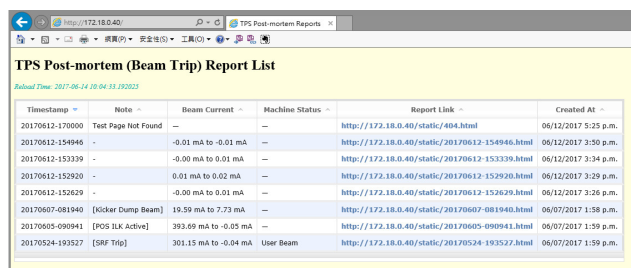

Figure 4: Web interface of TPS beam trip report list.

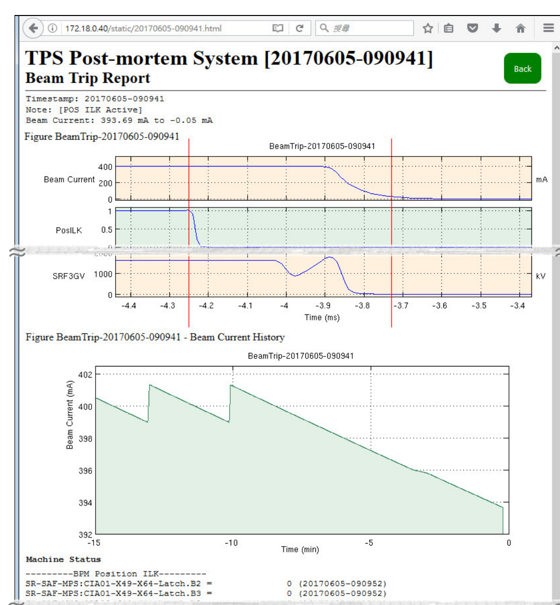

Figure 5: Web page of beam trip report.

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SPONTANEOUS PULSER FIRING

So far, typical beam trip events include RF trips, sub-system interlock trips, and spontaneous kicker firings. Sev-eral trip scenarios can be found in reference [4]. The 4-channel / 5 MHz sampling rate oscilloscope is replaced with an 8-channel / 50 MHz sampling rate data recorder for data acquisition to understand the spontaneous pulser firing problem. These 8 channels are used to capture the current waveforms of the four kickers and the four trigger signals generated from the control system. It is clear that under normal circumstances, the current waveforms and the trigger signals of the four kickers should exist at the same time, as shown in Fig. 6. This design can be used to determine pulser miss or spontaneous firings, which are caused by the system or spontaneously.

There have been a few beam events caused by spontaneous kicker firing when injection is not active. Some kickers were unexpectedly triggered without trigger signal, causing an instant loss of the electron beam, as shown in Fig. 7. The K1, K3, K4 spontaneously fire although no trigger signal could be observed. In a number of spontaneous firing events similar situations were observed, pointing to spontaneous kicker firing due to noise interference rather than from the trigger control system. In order to solve the possible noise interference, the improvement scheme proposed at present is to use a fiber link instead of copper wires to transmit the trigger signal, hoping to reduce noise pickup.

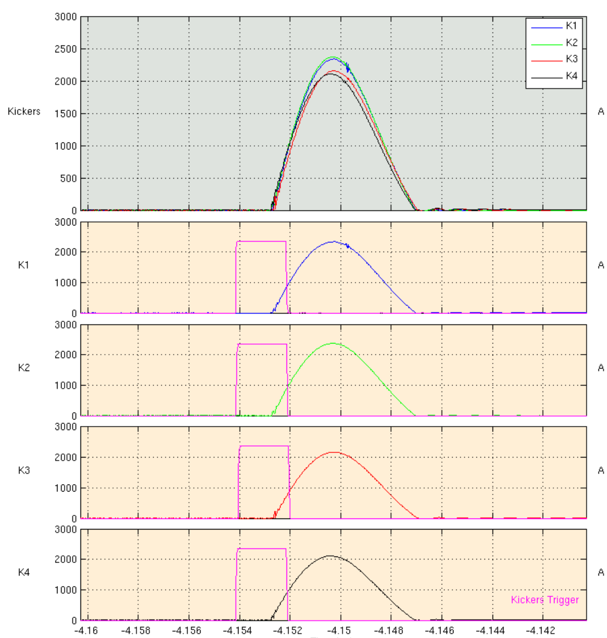

Figure 6: Kicker waveforms (K1: blue, K2: green, K3: red, K4: black) with trigger signals (pink) during normal operation (dump beam).

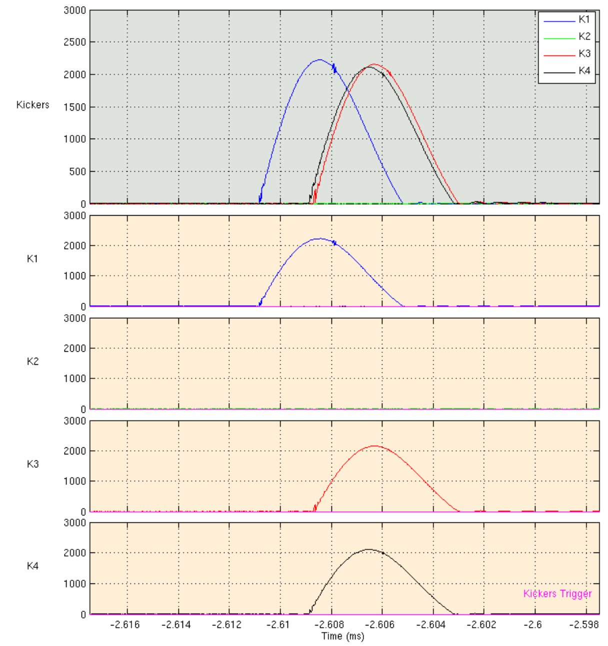

Figure 7: Kicker waveforms (K1: blue, K2: green, K3: red, K4: black) without trigger signals (pink) during spontaneous fired kickers K1, K3, and K4 while the K2 is misfired causing a beam trip.

SUMMARY

A beam trip diagnostics for the TPS is an important tool to analyze the cause of beam trip events during normal operation. The main function of the system is to record relevant signals when the stored beam is suddenly lost abnormally. Some features have been implemented such as: capture of the pulser trigger signals to diagnose miss firings, capturing 3-phase power line voltage for power transient monitoring, auto generated beam trip reports, and web-based interface for quick analysis of trip events through the web browser.

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