Fig. 3: The energy and power produced in one day.

due to the good weather and high temperature recently. With this high efficiency and PV capacity, the net income though the energy selling to the Tai-power Company might reach 5.5–6.0 million TWD per year. The payback period for the capital expenditure is thus between 8 and 9 years. The profit gained once the original expenditures are paid back will be stable and reliable and used to benefit all at the NSRRC by improving the synchrotron radiation research, the encouragement of the outstanding performances, and the support of welfare activities of the staff.

The rooftop PV system project at the NSRRC has already helped the environment and will continue to for many years. However, for a beautiful earth, we must and will pay attention to the manufacturing processes of PV materials to minimize the possible pollution and establish an end-of-life recycling protocol for the existing PV panels. (Reported by Jau-Ping Wang)

This report features the NSRRC Rooftop PV System Project led by Ming-Tsung Lee and Jau-Ping Wang.

The TPS Post-Mortem System

The Taiwan Photon Source (TPS) is a low emittance and high brightness synchrotron light source, located in Hsinchu, Taiwan. The TPS operates as user mode since September 2016. From the very beginning, several electron beam trip events occurred at the TPS; those trip events mainly resulted from the failure and malfunction of the subsystem and some of these events are still not clarified yet. In order to figure out the root cause to trigger the electron beam trip, the Instrumentation & Control (I&C) group established the TPS Post-mortem (PM) System to analyze trip events. This implementation has been followed by the developments of several useful utilities, such as the trigger capture of the spontaneous firing caused by the pulser magnets, the monitoring of 3-phase line voltage provided by the power supply, the report auto-generator and the web-based interface for the quick survey. With the help of the TPS PM system, the reliability and availability of the TPS operation were improved significantly.

Figure 1 shows the infrastructure of the TPS PM system, including the beam trip detector, EPICS (Experimental Physics and Industrial Control System) embedded standalone data recorders, the data storage server and the viewer. While the beam current stored in the storage ring of the TPS decreased more than 25 mA within 0.1 millisecond, the beam trip detector will output a trip signal as the trigger. The trigger signal will be broadcasted to the beam position monitor (BPM) platforms and the data recorder via the event-based timing system for the synchronization of the data capture. Then, the data recorder will record the relevant information. The PM data stored in the data storage server are used for the report auto-generation. Based on the PM viewer graph user interface (GUI) and/or the beam trip report, we could analyze the root cause of the trip event. Up to now, the recognizable sources which result in the trip of the electron beam involve the trip of RF system, the interlock of BPM system, the interlock of vacuum system, the interlock of front-end system, and the irregular firing of the injection pulsed magnet.

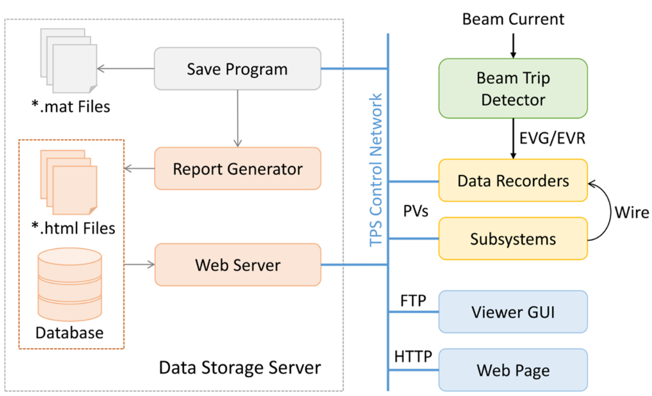


Fig. 1: The schematic layout of the TPS Post-mortem System for the diagnosis of beam trip.

The BPM system helps to avoid damage to accelerator components by high-energy particle beams or radiations. The interlock of BPM is activated by two scenarios: the electron beam position exceeds the defined limitation in the transverse plane and in case of saturated ADC (analog-to-digital converter) counts. The dedicated memory buffer of each BPM can contain 10,000 sets of turn-by-turn data for the PM system. These data could provide the information of transverse beam position and the signal change on each button for the trip analysis, helping to enhance the reliability of the accelerator.

Table 1: The data recorder units used in TPS. Each data recorder consists of eight input channels with two types of configurations.

Device	BPM platform	Data recorder (8 channels)	
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

In addition, the embedded EPICS standalone data recorders are capable of distributed data acquisition from several subsystems. The data recorders installed in the TPS are listed in **Table 1**. The essential data saved for the TPS PM system are listed in **Table 2**.

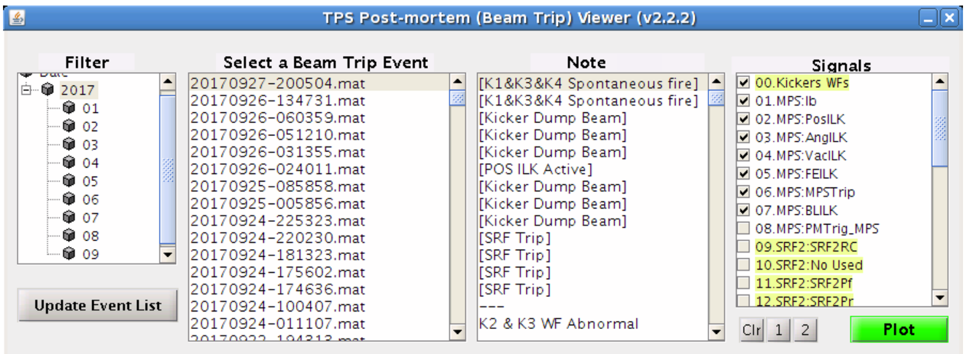


Fig. 2: Main page of PM viewer graph user interface.

The data storage server is designed to save the PM data automatically by monitoring the change of the BPM values through a background MATLAB process. While the trip occurs, a two-step saving process starts. In the first step, the process saves the setting parameters of related subsystems immediately. Followed by the PV channel access, the second step stores the data as MATLAB format while the data recorder is ready. In order to identify the possible source, such as the trip resulted from an irregular firing of the kicker magnet, the saving process also performs a preliminary time analysis from the recorded signals. At the same time, the report generator will output an html-formatted report involving the event description to the database for the web browser access.

The TPS PM viewer GUI is developed to list and plot the trip event by utilizing the MATLAB GUIDE toolbox, as shown in **Fig. 2**. The PM viewer can list the trip events with a simple note and provide a check box filled with the saved signals for the display selection.

A customized toolbar of the PM viewer equipped with simple data adjustment function are shown in **Fig. 3**. **Figure 4** shows the demonstration of the data cursor and dual cursor function of the PM viewer about the forward power, the reflected power and the gate voltage of 3rd superconducting RF system installed in the storage ring of TPS. (The sampling points are displayed if the time scale is small enough to visualize them).

Two real trip events are shown in the following **Figs. 5 and 6** for the demonstration of TPS PM system. In the first trip event, shown in **Fig. 5**, three kicker magnets un-

Table 2: List of saved PM data

Group	Signals	Description
Beam signals	Ib, Orbit	Stored beam current and turn-by-turn BPM 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 shut down the RF system
Pulser	Kickers	SR injection kicker waveform with trigger signal
Machine parameters	setting values	Subsystem parameters and the 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)

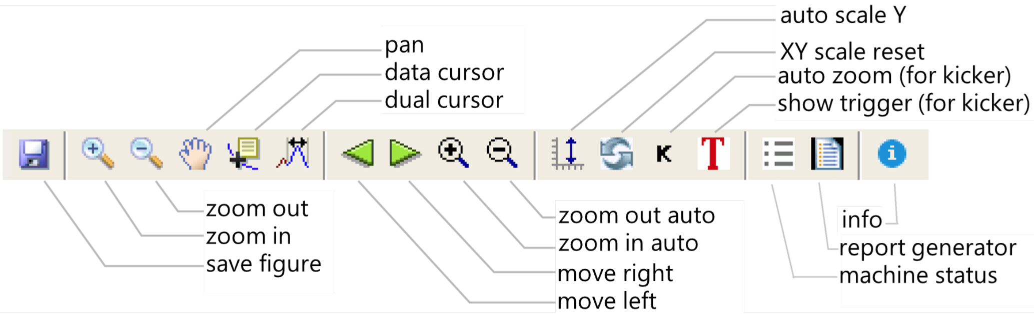


Fig. 3: The text description of the toolbar of PM viewer.

expectedly fired with the system trigger, and caused an instant particle loss. Lots of spontaneous firing events were observed to be triggered from the noise interference rather than the trigger from the control system. In order to solve the possible noise interference, instead of the copper wire, a fiber link was implemented for the signal transmission with relatively small noise pickup.

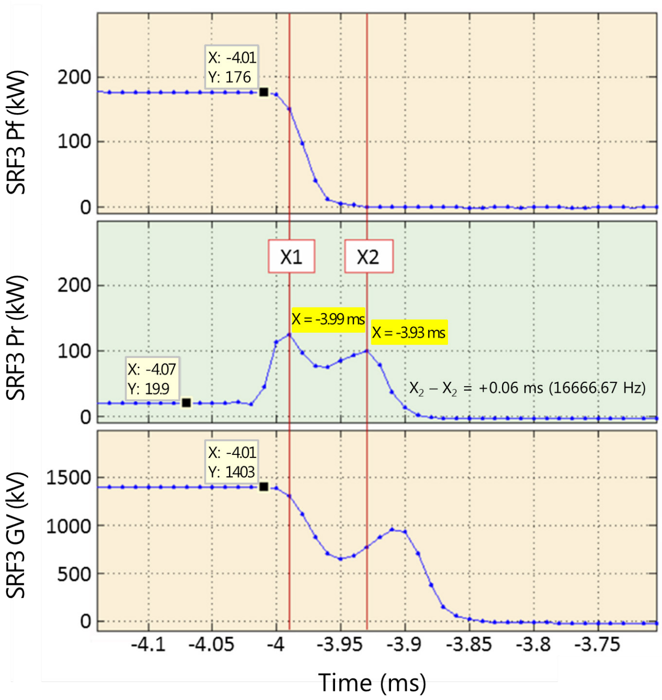


Fig. 4: Demonstrations of the data cursor and dual cursors functions. Three plots from top to bottom show the forward power, the reflection power and the gate voltage of 3rd superconducting RF system, respectively.

The second demonstration in **Fig. 6** is the four sequential trip events occurred within one day caused by the drastic change of the beam position. Especially for the horizontal beam position, the change of the position can reach up to 6 mm within 10 milliseconds, and can trigger the interlock causing the beam abortion. Four sequential trip events have shown similar horizontal and vertical beam position patterns, indicating the possibly same trip source.

The TPS PM system identified as possible trip sources ono sextupole magnet (SD125), one horizontal corrector magnet (HC125) and the HC125 physically winded on the body of the SD125. The SD125 had four unexpected transient spikes ahead of four individual trip events whereas the HC125 had two transient spikes on the first and fourth trip events, as shown in **Fig. 7**. Based on the design of SD125, it was unable to detour a 6-mm orbit distortion and therefore the HC125 was the only possible suspect. It turned out that 1-Hz sampling rate of the PM system was not fast enough to catch the response of the corrector magnet. In the end, it has been verified that the trip was due to the malfunction of the power supply for the HC125. At this event, the BPM post mortem data effectively helped to point out the suspicious components and quickly identified the true trip source.

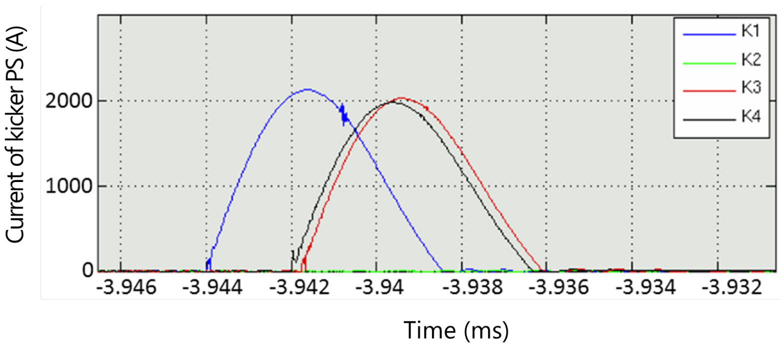


Fig. 5: The beam trip caused by the spontaneous firing of kicker magnets K1, K3 and K4 while the kicker magnet K2 misfired.

Figure 8 shows the web-based main page of the TPS PV report system. It was developed by the Python/Django with SQLite database. The auto-generated report is available by clicking the "Report Link" for the specific trip event. The information within the report include the timestamp of the trip event, the note, the beam current, the waveforms of the kicker magnets, the waveforms of the subsystem interlock signal, the history of the beam current and the machine parameter. Because of the web-based interface, the report can be reviewed by all web browsers from various electronics devices.

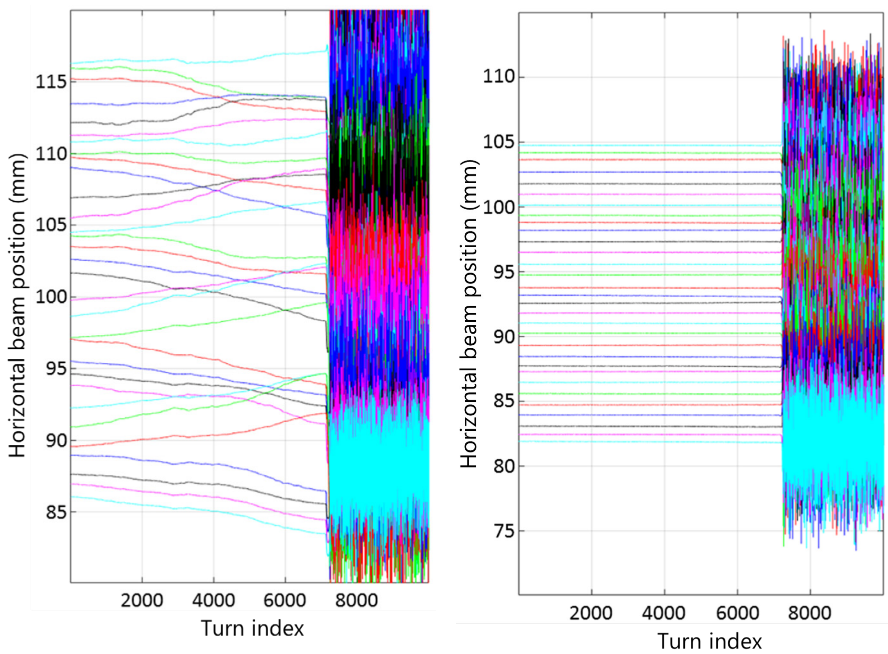


Fig. 6: The horizontal (left panel) and vertical (right panel) beam positions of the BPMs from #58 to #88 are shown by different colors for the first 10,000 turns while the trip event occurred.

The TPS Post-mortem system plays an important role on the trip event diagnosis since 2017. The main function of the PM system is to record the relevant information while the trip event occurs. The reliability and availability of the TPS operation improved significantly with the help of PM system. In the past few months, more functions were added to enable the completeness of the PM system. The MATLAB-based PM viewer and web-based viewer were developed for the fast identification of the trip source. More useful information including the user' feedbacks and an improved viewer interface will be implemented into the PM system in the next. With the help of the TPS PM system, a highly reliable TPS operation could be expected in the near future. (Reported by Chun-Yi Wu)

This report features the project developed by Chun-Yi Wu, Chih-Yu Liao and Pei-Chen Chiu.

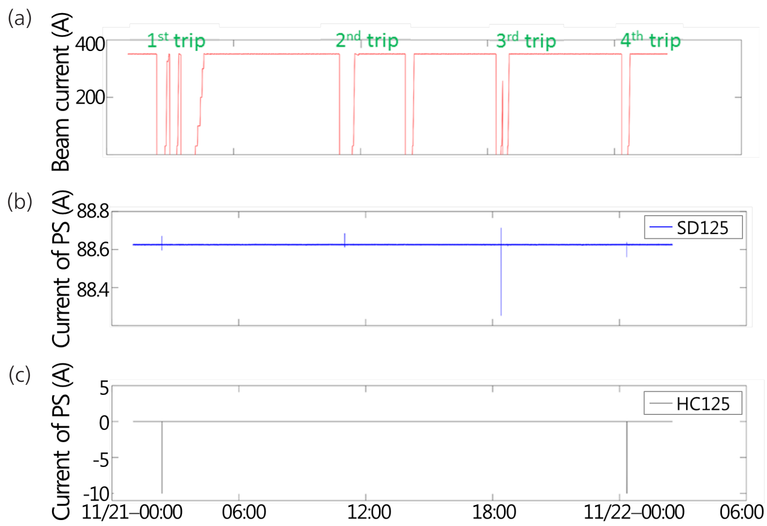
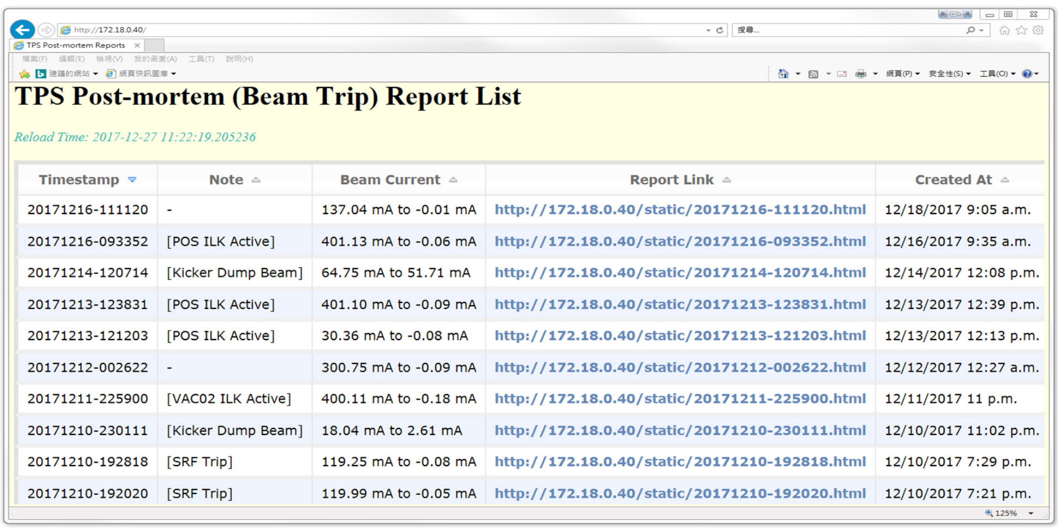


Fig. 7: (a) Four sequential trip events occurs within one day from 2017/11/21. (b) Four transient spikes occurred on SD125 ahead of four trip events accordingly. (c) Two transient spikes happened on HC125 ahead of first and fourth trip events.



TPS Post-mortem (Beam Trip) Report List

Reload Time: 2017-12-27 11:22:19.205236

Timestamp	Note	Beam Current	Report Link	Created At
20171216-111120	-	137.04 mA to -0.01 mA	http://172.18.0.40/static/20171216-111120.html	12/18/2017 9:05 a.m.
20171216-093352	[POS ILK Active]	401.13 mA to -0.06 mA	http://172.18.0.40/static/20171216-093352.html	12/16/2017 9:35 a.m.
20171214-120714	[Kicker Dump Beam]	64.75 mA to 51.71 mA	http://172.18.0.40/static/20171214-120714.html	12/14/2017 12:08 p.m.
20171213-123831	[POS ILK Active]	401.10 mA to -0.09 mA	http://172.18.0.40/static/20171213-123831.html	12/13/2017 12:39 p.m.
20171213-121203	[POS ILK Active]	30.36 mA to -0.08 mA	http://172.18.0.40/static/20171213-121203.html	12/13/2017 12:13 p.m.
20171212-002622	-	300.75 mA to -0.09 mA	http://172.18.0.40/static/20171212-002622.html	12/12/2017 12:27 a.m.
20171211-225900	[VAC02 ILK Active]	400.11 mA to -0.18 mA	http://172.18.0.40/static/20171211-225900.html	12/11/2017 11 p.m.
20171210-230111	[Kicker Dump Beam]	18.04 mA to 2.61 mA	http://172.18.0.40/static/20171210-230111.html	12/10/2017 11:02 p.m.
20171210-192818	[SRF Trip]	119.25 mA to -0.08 mA	http://172.18.0.40/static/20171210-192818.html	12/10/2017 7:29 p.m.
20171210-192020	[SRF Trip]	119.99 mA to -0.05 mA	http://172.18.0.40/static/20171210-192020.html	12/10/2017 7:21 p.m.

Fig. 8: The webpage of the TPS post-mortem (beam trip) report system shown by the IE web browser.