ANALYSIS OF THE POST-MORTEM EVENTS AT THE TLS

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Abstract

Analyzing the reasons of various trip events is basis to improve reliability of the accelerator system. Understanding the mechanisms to cause trip of the machine will be very helpful to decide what the adequate measures to improve availability. To identify the causes of trips at Taiwan Light Source (TLS), various diagnostics tool were employed. These diagnostic tools can capture beam trips, interlock signals of superconducting RF (SRF) system, quench and interlock signals of the superconducting insertion device (SID), waveform of the injection kickers, and instability signals of the stored beam for post-mortem analysis. Experiences of recently post-mortem events are presented.

INTRODUCTION

The beam trip event diagnostics are deployed in the TLS to improve operation reliability [1, 2]. A complete beam trip diagnostics can clearly reveal and track causes of the beam trips and provide enough information to help repair and maintenance works. Time resolutions of the available diagnostic tools are spanned from nanosecond to tens of seconds - ninth orders of magnitude. Different tools have their usages and constraints. Many trip events have been identified during the last five years and contributed to improve reliability, and availability for TLS users.

FAULT DIAGNOSTIC TOOLS

The beam trip related signals include trip trigger, beam current, SRF system signals and interlock, kicker waveforms, quench detector and interlock output of the SID, and beam position. Beam related events (intensity, turn-by-turn beam position, RF related parameters, etc.) require higher time resolution than trips caused by the supporting system related parameters (temperature, flow rate, liquid level, etc.) out of operation threshold. Beam trip diagnostics consists of the data acquisition system with high timing resolution with short record time and low timing resolution with longer record time. The system possesses time resolution from several tens seconds down to nanosecond, required to use different hardware and software [1, 2].

The control system of TLS supports a 10 Hz logger for one week lifetime and a 10 seconds resolution archiver for permanent storage. However, it cannot clarify the reasons for fast beam trip. The ACQ196CPCI [3] is a cPCI form factor 96 channels simultaneous sampling 16 bits digitizer with up to 500 kHz sampling rate. It can be applied to acquire low speed signal data of the diagnostics system. The post-mortem buffer inside the Libera Brilliance [4] is used to capture turn-by-turn beam intensity, position and phase up to 256 K samples when beam trip trigger happened. This buffer can be dumped for further analysis. Two dedicated diagnostic nodes for 10 kHz and 400 Hz rate data capture up to 10 sec when predefine trigger conditions happen for either software or hardware are set up accompany with the orbit feedback system. Oscilloscopes are used to observe fast events with nanosecond resolution which is necessary for pulse magnets waveforms, beam signals, and RF related fast signals observation. Segmented capture is very useful to capture fast signal with longer record time.

The beam trip is detected by the fast beam current drop of the storage ring. The post-mortem data acquisition system are triggered by the combination of beam trip, SRF interlock sum, temperature alarm, pressure alarm and quench detector output form all SID, and so on.

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HIGHLIGHT OF SOME RECENTLY TRIP EVENTS

The beam trip diagnostic tools are applied to clarify the resulting causes of trips and essential to obtain detailed information and can elucidate the reason for a trip will be established and a useful solution is being sought. In this section, some recently events are summarized.

Superconducting Insertion Device Faults

The trip resulted from the superconducting wiggler IASW-R6 main power supply itself rather than real quench of the coil was easily determined because coil current dropped to zero first. The beam loss induced quench of the SID. Fig. 1 shows the tune change induced the instability growth, the beam loss induce the SRF interlock active caused beam trip. After check over interlock message, it was found out power supply water flow meter fail caused power supply internal interlock active. After replace of spare main power supply, this error was cleared.

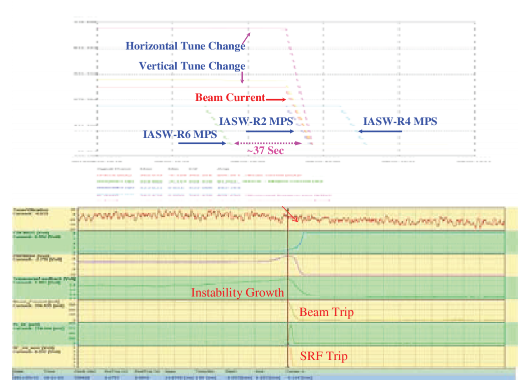

Figure 1: The beam trip caused by IASW-R6 main power supply failed.

Scenario of a partial beam loss event is shown in Fig. 2, the partial beam loss induced the SRF interlock active caused beam trips during top-up injection period and the coil quench of the IASW-R6 was clearly observed, the beam trip induce IASW-R2 and IASW-R4 coil quench.

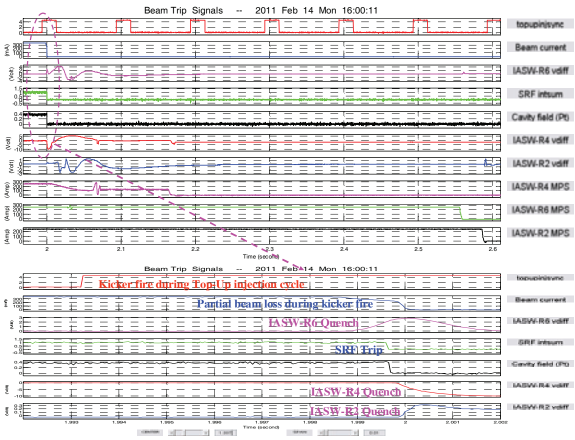

Figure 2: The partial beam loss during Top-Up injection cycle induce SRF trip caused super-conducting insertion device quench.

In the Fig. 3, the N_2 gas pressure over pre-defined trip threshold during LN_2 auto-filling period activate IASW-R4 interlock logic to trip main power supply which cause tune change, then partial beam loss happened caused SRF interlock active to trip beam induce IASW-R2 and IASW-R6 quench is shown in Fig. 4.

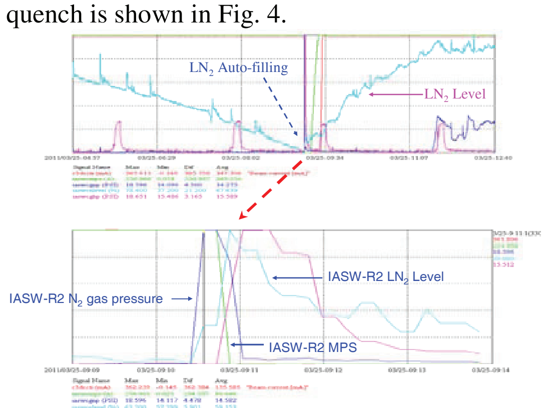

Figure 3: Too large N_2 pressure during LN_2 auto-filling period caused IASW-R4 interlock active.

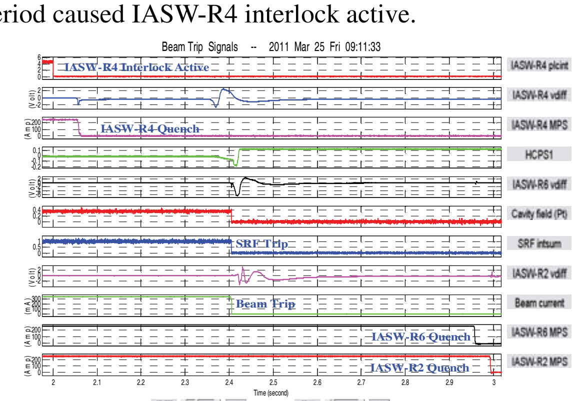

Figure 4: The IASW-R4 interlock active trip main power supply, then tune change caused beam loss and SRF trip.

Dipole Power Supply trip Caused Fault

The dipole power supply fault caused the SRF interlock active to trip beam, and then the beam trip induce IASW-R6 and IASW-R2 coil quench. The dipole power supply trip hang caused beam loss and SRF trip is shown in Fig. 5. The dipole power supply trip can induce orbit change and beam intensity decay. The horizontal position of BPM fast access data and the sum signal of BPM turn-by-turn data is show in Fig. 6.

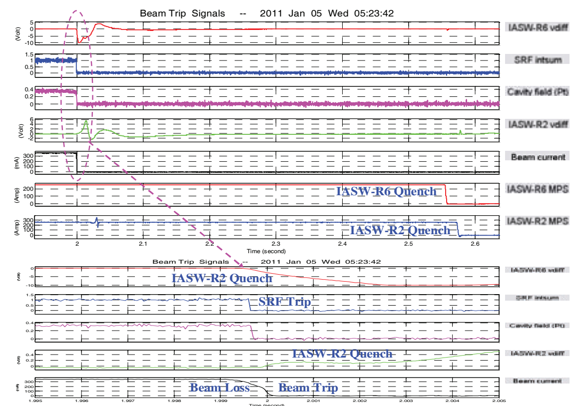

Figure 5: The dipole power supply fault caused the SRF interlock active to trip beam, and then the beam trip induce IASW-R6 and IASW-R2 coil quench.

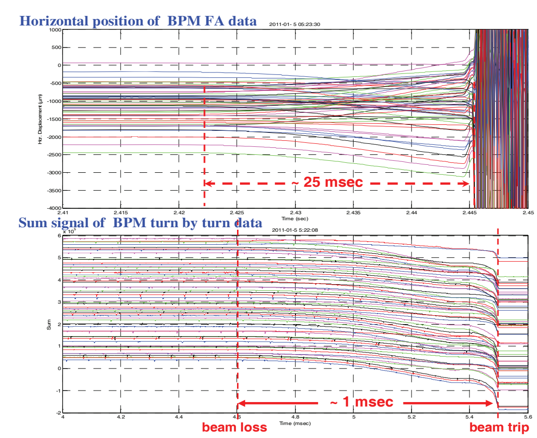

Figure 6: The dipole power supply trip can induce orbit change and beam intensity decay. The horizontal position of BPM fast access data and the sum signal of BPM turn-by-turn data are clearly observed.

Power Line Sag Caused Fault

Too large voltage sag of the power line caused problem also. This power line sag caused fault is shown in Fig. 7 for about 26% line voltage sag within 12 power line cycles (~200 msec) caused the SRF and the SWLS、the IASW-R2 and the IASW-R4 three SID trip simultaneously. The superconducting wavelength shifter (SWLS) is cooled by a cryo-cololer. Limited cooling power of the SWLS led more than two hours recovery time. To eliminate such kind of events, a dedicated UPS for all SID was installed.

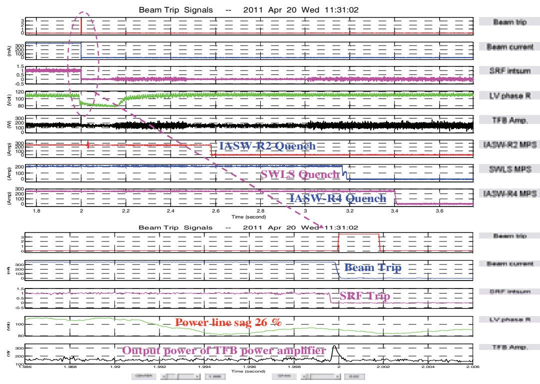

Figure 7: The stored beam current drop to zero due to power line sag. Severe trip due to power line voltage sag. Near 26% lines voltage drop caused SRF system interlock active and beam trip, the beam trip induce SWLS 、IASW-R2 and IASW-R4 devices trip simultaneously.

Ground Vibration Caused Faults

The earthquake induce SRF interlock active caused the beam trip and the IASW-R2 quench. The earthquake caused beam trip is shown in Fig. 8. The orbit change and beam current from 362 mA drop to 0 mA caused sum signal drop of the BPM during the SRF trip. The orbit change and sum signal of the BPM are show in Fig. 9.

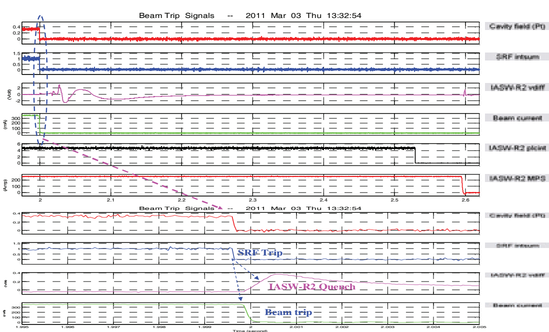

Figure 8: Earthquake induced SRF interlock activate which caused the beam trip and the IASW-R2 quench.

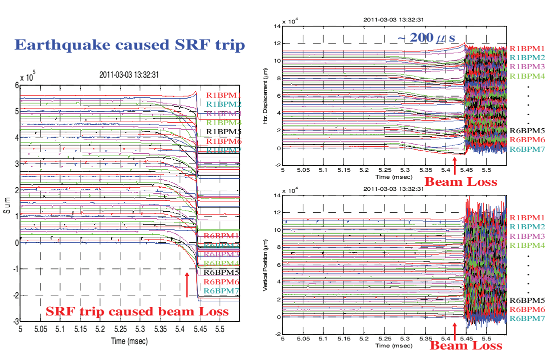

Figure 9: Earthquake caused beam trip, the orbit change and beam intensity from the BPM are clearly observed.

The ground vibration caused by the pile-sinking of the TPS civil construction caused the SRF trip is shown in Fig. 10, the transmitter trip of the SRF system and the SRF interlock active caused the beam trip and the IASW-R2 quench as show in Fig. 11. The ground vibration of the TPS civil construction caused the transmitter trip of the SRF system and the SRF interlock active caused the beam trip and the IASW-R2 quench.

Figure 10: The ground vibration caused by the pile-sinking of the TPS civil construction caused the SRF system trip.

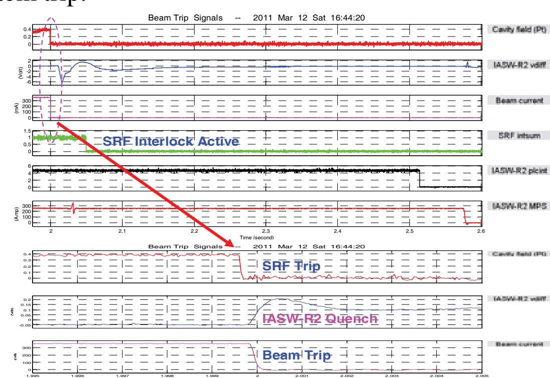

Figure 11: The SRF transmitter trip and the SRF interlock active caused the beam trip and the IASW-R2 quench.

SUMMARY

The TLS has suffered from many uncomfortable faults for user service since its dedication in late 1993. It takes a long time to dig out problems for non-trivial fault. For non-trivial faults, debate between "Guilty until proven innocent" and "Innocent until proven guilty" always happened with expense of prolong time before problem solved. Better fault diagnostics help to solve the problem quickly and avoid fruitless efforts. Fault diagnostics are useful tools to help to dig out where the problems within a short time, minimized downtime, minimize required expertise of the maintenance staff, and save more beam time which might be loss due to various faults. Some events are avoidable and some are unavoidable. How to prevent events which can avoid would be continue efforts.

REFERENCES

[1] K. H. Hu, et al., "Post-mortem Diagnostic for the Taiwan Light Source", Proc. of EPAC08, Genoa, Italy, 1932 (2008).

[2] K. H. Hu, et al., "Post-mortem Diagnostics for the Taiwan Light Source", Proc. of ARW2009, Vancouver BC, Canada, (2009).

[3] http://www.d-tacq.com.

[4] http://www.i-tech.si.