BEAM TRIP EVENT DIAGNOSTICS FOR THE TLS

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Abstract

Analyzing the reasons of various trip events is essential for improvement of system reliability. To identity the causes of trip at Taiwan Light Source (TLS), various diagnostics tool were employed. These diagnostic tools can capture beam trip, interlock signals of superconducting RF system, waveform of the injection kickers, quench and interlock signals of the superconducting insertion device, and instability signals of the stored beam. These diagnostics can be routine monitor signal and record beam trip event. Features of trip diagnostic tools are available now and future plan will be summarized in this report.

INTRODUCTION

The beam trip event diagnostic is important for a modern light source as well as the TLS to improve its operation reliability. A complete beam trip diagnostic system can clearly present and track causes of the beam trip and provides enough information for maintains. Currently available diagnostic tools include data archiver of the control system with 100 msec time resolution, sixteen channel recorder with 16 bits and 10 μsec resolution, many oscilloscopes for fast data capture with up to nanosecond time resolution. Different tool have its own operation method and limitation. Many trip events have been identified during the last several years and very beneficial to improve reliability of TLS. To provide a better diagnostic environment, an integrated diagnostic environment is planning to achieve complete diagnostic of trip.

BEAM TRIP DIAGNOSTIC TOOLS

The beam trip event related signal includes beam trip, beam current, superconducting RF system signals and interlock, and kicker waveforms, quench detector output and interlock of superconducting insertion devices, beam position and beam instability. Sufficient time resolution is spanned from nanosecond to second - near nigh order of magnitude. Beam related event requires higher time resolution than trip caused by ambient parameters beyond some threshold (temperature, flow rate, liquid level ..etc.).

Therefore, a complete beam trip event diagnostic system consisting of the fast data recorder and the slow archiver is developed. This system requires time resolution form nanosecond to second range as shown in Fig. 1. Existing available beam trip event diagnostic tools includes control system archiver, oscilloscope, Vision XP data recorder [1] and post-mortem data buffer inside of BPM electronic - Libera Electron [2].

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Control system of TLS supports a 10 Hz logger with one week lifetime and a slow logger with 10 seconds resolution. Control system archiver can provide enough information related to the beam trip. However, it is unable to clarify the fast beam trip with msec resolution or better time resolution. The other recorder system with higher sampling rate is necessary to capture fast event.

The Vision XP is a data recorder with real-time scrolling, triggered or XY displays. And like a tape recording, it has continuous, gap-free data storage over very long recording times. Vision XP can save 16 channels of 16-bit data continuously to 72 GB hard drive 100 kS/s per channel. Its 10 μsec time resolution satisfies minimum requirement to clarify reasons of beam trip by the captured beam trip signals. However, it still was insufficient to observe turn-by-turn phenomenon in the 100 nsec time resolution. Standard archiver viewer incompatible with the data of this recorder is the shortage.

Oscilloscopes are used to observe fast events with nanosecond resolution, such as pulse magnets waveform, beam signal, RF related fast signals. Therefore, establishing complete function and high time resolution beam trip event diagnostic system are necessary.

The post-mortem buffer inside the BPM electronic – Libera Electron is used to capture turn-by-turn beam intensity, position and phase 16 kilo samples before the beam trip trigger happened. Contents of this buffer can be dump for further analysis.

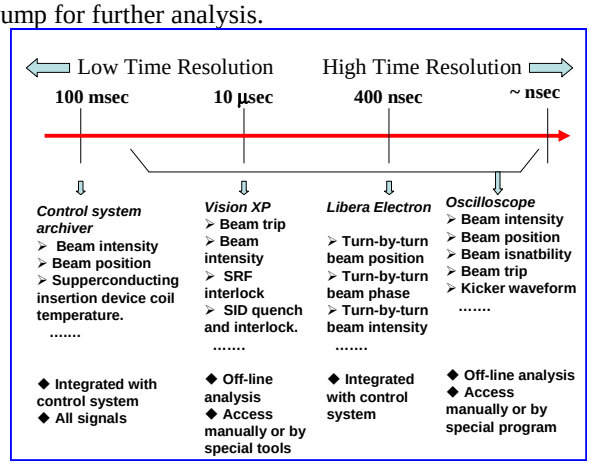


Figure 1: Available beam trip event diagnostic tools.

Beam Trip Detection

To synchronize the data captured by various devices, a beam trip detector was implemented to generate a trigger for all trip diagnostics. The beam trip condition is defined when beam intensity drop more than 50% within 10 turns. This condition can be charged if necessary. The beam intensity signal is derived from the sum signal of four buttons from a beam position monitor.

Quench Detector for Superconducting Insertion Devices

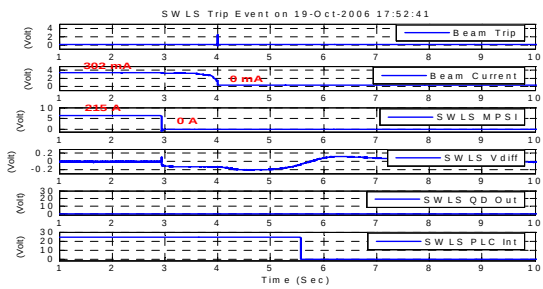
Three superconducting insertion device SWLS, SW6 and IASW-R6 have been installed. Two superconducting wiggler IASW6 will be installed in incoming years. The quench detector and interlock logic are developed for all superconducting IDs to protect the coil from damage. Some unknown trip event of the superconducting insertion devices during operation which accompanies beam trip and/or superconducting RF system trip is still unclear. A diagnostic system that can elucidate the reason for a trip will be established and a useful solution is being sought. Better diagnostics of a superconducting IDs trip event are essential to obtain detailed information; according to results of analysis of this information, system reliability is improved.

SOME TRIP SCENARIOS

The beam trip diagnostic tools is applies to clarify resulting causes of trip. Some real scenarios are summarized in here to demonstrate the usage of these diagnostic tools.

The main power supply of SWLS trips firstly due to bugs of control firmware as shown in Fig. 2. Coil current is dropped to zero suddenly while coil voltage fluctuates after main power trip that activates the quench detector. After check of the power supply, its actual cause is the firmware bug of the controller. After upgrade of the power supply control firmware, this error is cleared. Figure 2 (a) is the archiver data showing something wrong of the SWLS. It still cannot clarify the reason. Adopt the data captured by Vision XP is shown in Fig. 2 (b), It is easily to identify the problem resulted from the power supply itself rather than real quench of the coil, because, coil current drops to zero firstly.

(a) Control system 10 sec logger data shown that the SWLS trip happened.



(b) Details data acquired by Vision XP.

Figure 2: The beam trip caused by SWLS main power supply fail.

The 10 Hz logger of the control system is also helpful to the trip diagnostic. Newly installed IASW-R6 superconducting wiggler has some problems of its current lead, frequently quench happened before the problem solved as shown in Fig. 3. Data captured by the Vision XP reveals the causes of IASW-R6 trip is due to coil quench as shown in Fig. 4 (a). This event also causes trip of SRF system trip and SW6 as shown in Fig. 4 (b). The reason that beam trip lead quench of SW6 is still obscure. It might be a consequence of local heating of the coil due to the beam loss. Based upon the realization of reason of trips, various measures are done systematically and properly. Reliability of superconducting insertion devices are therefore improved drastically.

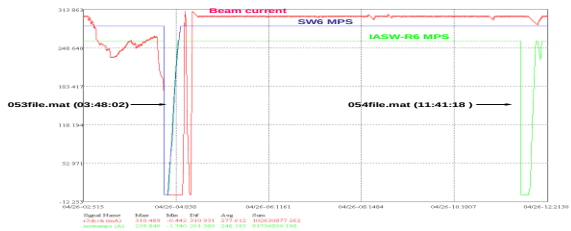
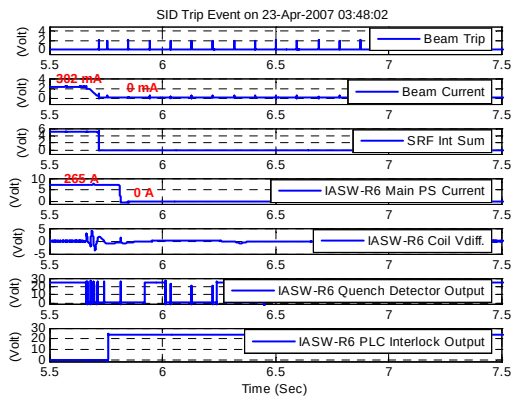
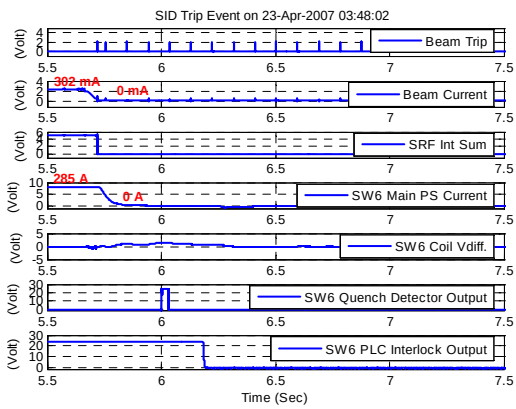


Figure 3: Control system 10 Hz logger shown beam trips of the IASW-R6 superconducting wiggler.



(a) The beam trip caused by IASW-R6 quench.



(b) SW6 quench due to beam loss.

Figure 4: The beam trip due to IASW-R6 quench.

Miss fired, spontaneous fired without trigger, and large timing jitter or drift was happened occasionally of the injection kickers. When these happened during top-up operation will cause–unintentional beam loss, the SRF system trip and superconducting insertion devices trip. Figure 5 shows miss filed of one of a kicker pulse in top-up operation. This event also caused the sequence SRF system trip.

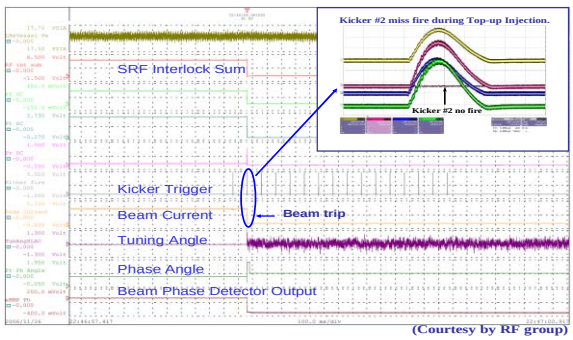


Figure 5: The beam trip vs. kicker waveform.

Arcing inside of the oil tank of the klystron stand in the linear accelerator will induce malfunction of the klystron modulator. Arcing in single cycle will not cause trip of the klystron modulator, but arcing of consecutive cycles will. Oscilloscope working in segmented trigger is used to capture such kind of event as shown in Fig. 6. This observation helps to clarify the problem quickly.

Figure 6: Oscilloscope working in segmented trigger mode to capture arcing problem of the klystron modulator in the linear accelerator system.

Post-mortem of the new electronics for BPM is also useful to record beam intensity, position, and phase before beam trip. A half of BPM electronics in the storage ring adopts the Libera Electron with a 16 k post-mortem buffer available for beam trip event recording.

FUTURE PLANS

Available tools for trip events diagnostic have several disadvantages, such as lack of sufficient time resolution timestamp, non-uniform operation environment, difficulty to put all necessary data together, and etc. An integrated trip event diagnostics tools are in planning phase. A multi-channel digitizer VME module which has a maximum 100 MS/sec sampling rate with 14 bit ADC and a fibre link connected up to eight modules and maximum 64 channel critical channels per link is considered [3]. Necessary decimation and gating data acquisition is utilized to reduce the sampling rate to kilo-samples per second. It can meet high time resolution and low rate data requirement in an overall system. Increased number of fibre link is possible if more than 64 channels are required. Precision timestamp (~nsec) is supported for synchronizing and capturing various signals from different modules. Functional block diagram of the proposed system is shown in Fig. 7. All data acquisition modules are linked by a dedicated fibre link and connected to a PC/Linux computer. Data acquisition and analysis can be done at the control console level easily.

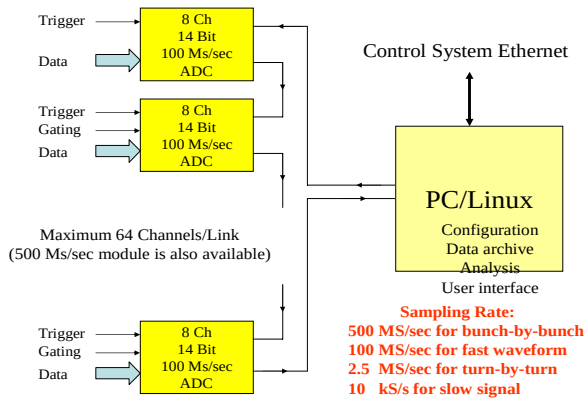


Figure 7: The proposed all-in-one beam trip diagnostic system.

SUMMARY

To keep of desired reliable operation of a synchrotron light source, analysis details of various trip events are essential. Trip event analysis can be aids of learning appropriate action to improve sub-system, to avoid dangerous operation conditions, and to improve system reliability. Several diagnostics tools are available for the TLS. New integrated system is being planned to provide better system integration and analysis environment. It is expected the reliability of the TLS can be improve further by the aids of these tools.

REFERENCES

[1] Vision XP: http://www.lds-group.com.
[2] Libera Electron: http://www.i-tech.si.
[3] VME digitizer: http://www.caen.it/.

