STATUS OF THE SUPERCONDUCTING INSERTION DEVICES CONTROL SYSTEM AT TLS

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Abstract

Superconducting insertion devices installed at the Taiwan Light Source serve the rapidly growing community of X-ray users. The control system supports the operation of all these superconducting insertion devices. Control system coordinates the operation of the main power supply and the trimming power supply to charge/discharge the magnet and provide essential interlock protection for the coils and vacuum ducts. Quench detection and various cryogenic interlocks are designed to protect the system. A friendly user interface and control applications are developed to support routine operation. The diagnosis of the tripping of superconducting insertion devices related to machine operation is also addressed. Design considerations and details of the implementation will be summary in this report.

INTRODUCTION

Three superconducting insertion devices a superconducting wavelength shifter (SWLS), a superconducting wiggler (SW6) and an in-achromat superconducting wiggler (IASW-R6) have been installed. Two other such devices, IASW-R2 and -R4, will be installed in the future. These superconducting IDs are applied to enhance hard X-ray production to support diffraction, scattering, spectroscopy, EXAFS, imaging, and protein crystallography. The control system of superconducting insertion devices was designed implemented and commissioned to support the operation of these devices. This control system based on the VME crate system as a standard configuration; interlock protection and a graphical user interface (GUI). The interlock logic is implemented using a programmable logic controller (PLC) to protect the coils of the magnet. The user interface and various application programs enable routine operation.

Table 1:Parameters of Superconducting Insertion Devices

Device	No.	Parameters	Applications
SWLS	1	6 Tesla, 66 poles, 30 mm periods	X-ray Imaging, Diffraction, Scattering, EXAFS, Powder Diffraction
SW6	1	3.2 Tesla, 66 poles, 30 mm periods	Protein crystallography
IASW6 -R6, -R2, -R4	3	3.2 Tesla, 66 poles, 30 mm periods	X-ray Imaging, Diffraction, Scattering, Powder Diffraction

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INFRASTRASTRUCTURE OF THE CONTROL SYSTEM

The system can be controlled using a standard VME crate to accommodate various control modules. The crate includes a PowerPC-based CPU module, which runs a LynxOS 4.0 real-time operating system as a local controller of the superconducting IDs control system. The crate includes analog input/output modules, digital input/output modules and the RS-232 interface module. The control system of superconducting IDs depends on coordinating the operation of power supplies, cryogenic instruments and interlock protection logic. Figure 1 illustrates the infrastructure of the superconducting IDs control system. Control consoles communicate with the VME host module through the control Ethernet.

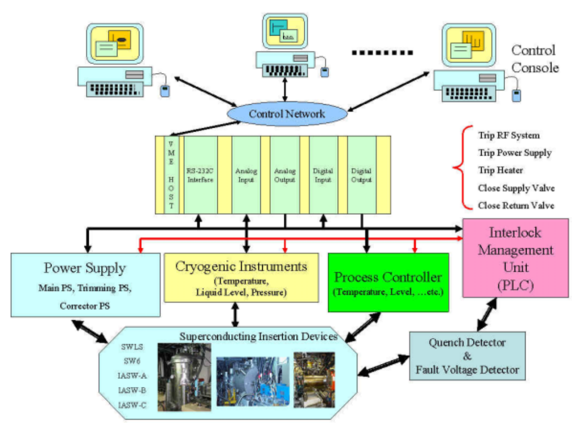


Figure 1: The control system infrastructure of the superconducting insertion devices.

Power Supplies

A precision bipolar main power supply is used to charge/discharge the magnet. The trimming power supplies are used to correct the field error. A low slew rate is used at the beginning because the inductance at low field is high when charging began. The slew rate is high after the field saturates the internal iron core, and the inductance is then considerably reduced. The control applications automatically control the slew rate. The trimming power supply can be set independently or follow the output of the main power supply, according to a predefined table. Two correctors are added upstream and downstream of all of the installed superconducting IDs. The control system coordinates the outputs of the corrector power supplies, to compensate for distortion of the beam orbit.

Cryogenic Instruments

Cryogenic instruments are used to monitor the parameters of the cryostat, which holds the magnets. The coil of the superconducting IDs is cooled by submerging it in liquid helium (LHe). Hence, the LHe level and He pressure in the vessel must be maintained in safe ranges. The instruments include a temperature monitor, level meters for LHe and liquid nitrogen (LN_2), pressure meters for He and N_2, and a vacuum gauge. The limiting high temperature, low level and high pressure can be set using these instruments. The pressure and the liquid level of the superconducting IDs control are also sent to the automatic filling system [4] to maintain the liquid level within the safe region automatically.

Quench Detector

The quench detector and interlock logic are used to protect the coil of superconducting IDs. The first layer of the hardware protection circuit consists of R620 diodes and 6 m stainless steel resistors. The protection circuit is connected in parallel to the coils of the magnet. This circuitry protects the coils form overheating during quenching. The voltage across the coils increases rapidly when a quench occurs. The quenched coil voltage is limited by the conducting diode. The resistors in series with the diodes help to dissipate the energy that was stored in the coils. The diodes provide a bypass route for the coil current. However, this scheme is only for short-term protection; the main power supply must be disabled after a quenching event. The power supply trip is triggered by the quench detector with a response time of less than 10 msec. Figure 2 shows the block diagram of the quench detector circuit and the interlock logic. The quench detector is in a VME form factor. A bridge circuit is used for quench detection. An imbalanced voltage in the bridge circuit implies the occurrence of a quench event. An imbalance between the voltages of the coil arm and the resistor arm cause the signal of the quench detector to trigger the protection logic of the PLC.

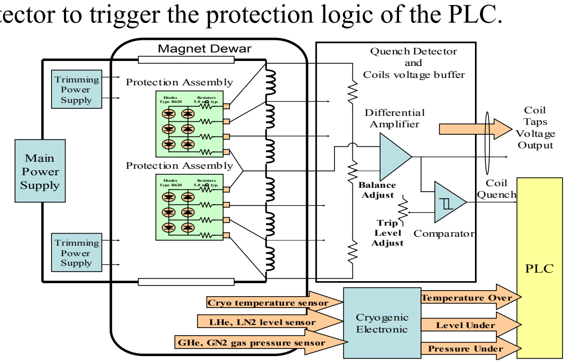


Figure 2 : The superconducting insertion devices protection scheme.

Interlock

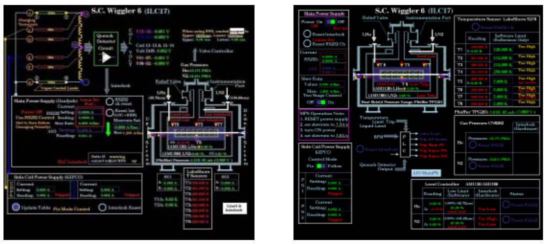
The interlock logic is designed to protect the coils of the magnet. It is integrated in a fast scan PLC. The PLC manages the alarm signal from the cryogenic instruments, which measures the temperature, the LHe and LN_2 levels, and the pressures of He and N_2 in the vessel. The quench detector and the voltage tap monitor are also considered to generate hardware interlock signals. When the temperature is too high or the quench detector is triggered, the protective action is to shutdown the power supply, preventing excess heat from increasing the temperature, and dissipating LHe. The level meters and pressure meters are connected to the process controller of the valve box for an auto-fill system. If the pressure of He or N_2 exceeds the upper limit of the safety range, the PLC will immediately shutdown the power supply. The action of the PLC can make all decisions within 5 msec. The relief valve of the vessel is used to released when the pressure of the vapour of He and N_2 over its rate value. The reliability of the quench detector is important. The coils of the magnet are soaked in LHe, so the variation in the temperature of the magnet caused by quenching is very small. The quench detector is trigger by the large on/off transient of the main power supply. The interlock logic is disabled for 10 sec during the turning on of the power supply. It is safe because no output current flows from the power supply at that time, except up to 10 Amp current spike.

Trip Diagnostic

The trip event diagnostic is essential to obtaining information about the causes of the trip. Identifying the cause of quenching or tripping is helpful. One 16 channel transient recorder with a sampling rate of 100 kS/sec is installed to capture the event. The main coil current, the coil voltage, the quench detector output, and the interlock output of PLC continue to be monitored. The system was improved to help to identify several problems that arose during the last several months.

User Interface

The control system provides various application programs that support the routine operation of all superconducting Ids. They perform on/off control for the power supplies, charge/discharge control for the magnet and software protection for the magnet. The power supply cannot be enabled until the temperature of the magnet, the levels of LHe and LN_2 and the pressures of He and N_2 are all in safe ranges. These predefined protecting values are all stored in the control database. The control system has two types of archivers, which are supported by the control system. A long-term archiver record data every 10 sec. Another fast archiver with a lifetime of 1 week records data every 0.1 sec. The archiver records provide much useful information that can be used to improve the operation of the superconducting IDs. The user interface provides has two pages for all superconducting IDs to support normal operation. In the SW6 case, operators use the first page to monitor the status of the SW6 and set the output current and slew rate of the main power supply, as shown in Fig. 4 (a). The second page presents interlock information and the alarm limits of the SW6, as a temperature threshold, LHe and LN_2 levels and pressures of He and N_2, as shown in Fig. 4 (b). The operator can reset the interlock status and set the alarm limit by software protection on this page. The user interface presents in real time information about the magnet and provides a convenient manipulation environment.



(a) Operation page (b) Maintenance page

Figure 4 : SW6 user interface for routine operation and user interface for interlock information.

SOME OPERATION SCENARIOS

Figure 5 plots a typical charge/discharge current history of the SW6. Figure 6 shows LHe level and pressure of Helium vapor variation. Figure 7 plots the voltage of the coils, the pressure of He vapor, and temperature variation when power supply is suddenly turned off. Trip diagnostics are very helpful for identifying the origins of problems. The main power supply of SWLS turn off occasionally was occurred during September and October 2006. Figure 8 provides trip diagnostic. Clearly, the power supply current decreases to zero before any interlock is activated. This problem was identified as having been caused by a bug in the power supply controller firmware. In Fig. 9, a charge current 270A flows upon occurrence quenching of the IASW during the measurement of the magnet field.

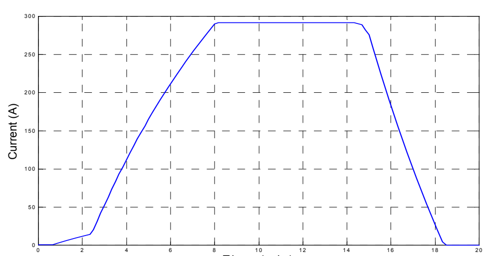


Figure 5 : T typical charge/discharge current history of the SW6.

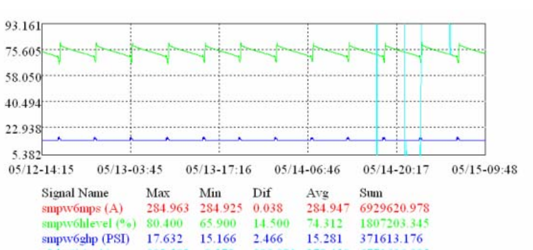


Figure 6 : Typical LHe level and pressure of Helium vapor.

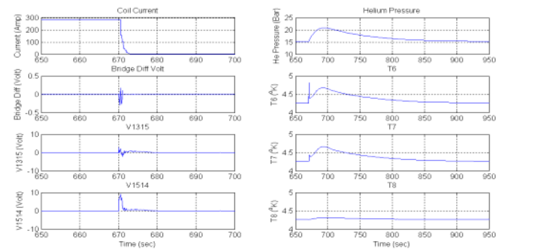


Figure 7 : Coils voltage, pressure of He vapor, and temperature variation when power supply is suddenly turned off.

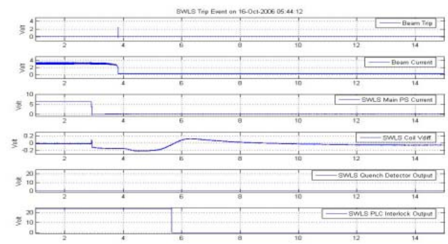


Figure 8 : Beam trip of the storage ring when main power supply trip of the SWLS.

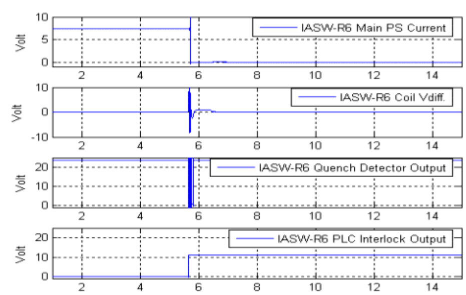


Figure 9 : A charge current history of the IASW when quench happened.

SUMMARY

The control system was implemented to support the routine operation of superconducting IDs. The same infrastructure is adopted, it will benefit to the operation and maintenance. Diagnostics of various trips are also included to elucidate the reasons; the reliability of the system can be improved after the tripping mechanism has been identified. Experiences accumulated during the last several years will help to improve the performance and the reliability of the control system.

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