

CONTROL SYSTEM FOR THE SUPERCONDUCTING INSERTION DEVICES OF NSRRC

Jenny Chen, C.K. Chang, K.H. Hu, Demi Lee, S.-Y. Hsu, C.S. Hwang, C.H. Kuo, K.T. Hsu
 National Synchrotron Radiation Research Center
 101 Shin-Ann Road, Hsinchu Science-Based Industrial Park, Hsinchu, Taiwan.

Abstract

To enhance hard X-ray production in the 1.5 GeV storage ring of NSRRC to serve the rapidly growing X-ray user community in Taiwan, the storage ring are planed to install up to five superconducting insertion devices. A 6 Tesla superconducting wavelength shifter was installed in mid-2002. A 3.2 Tesla superconducting multi-pole wiggler will be installed in the fall of 2003. The project for the other three multi-pole wigglers is launched. The control system had been implemented to support the operation of the superconducting insertion devices. The control system play a role to coordinate the operation of the main power supply and the trimming power supplies to charge/discharge the magnet and provide interlock protection for the magnet coils and vacuum ducts. A friendly user interface and various application programs are used to support routine operation. Design considerations and details of the implementation are also presented.

INTRODUCTION

The 1.5 GeV storage ring of NSRRC is a low-energy machine. Superconducting insertion devices have been installed to increase the photon flux in the hard X-ray spectral range and thus enhance X-ray production, to meet the increasing requirements of X-ray users. A compact cryogen-free 6 Tesla superconducting wavelength shifter (SWLS) has been constructed because of the limited space in the injection straight section [1]. Plans exist to install four superconducting multi-pole wigglers. One (SMPW6) has a designed field of 3.2 Tesla, a period of 6 cm, and 32 poles; it will be installed in the fourth straight section at downstream of the superconducting RF cavity. The other three multi-pole wigglers (SMPW-A) are planned to install near the second bending magnet of the triple bend achromat sections [2]. The control system for superconducting insertion devices is a VME crate based system. A PowerPC-based VME host module runs a LynxOS real-time operating system. The application programs and user interface of the control system are implemented for the superconducting insertion devices routine operation and data acquisition.

ELEMENTS OF THE SUPERCONDUCTING INSERTION DEVICES CONTROL SYSTEM

The basic elements of a superconducting insertion

devices control system are the cryogenics system monitoring, the liquid level control of the cryogenics system, charge/discharge the magnet, quench detector, interlock logic and operation interface. Figure 1 illustrates the structure of the superconducting insertion devices control system. The cryogenics instruments monitor the parameters of the cryogenics system, including temperature, liquid level, gas pressure and gas flow rate in routine operation. Process controllers regulate the liquid helium (LHe) level and the liquid nitrogen (LN₂) level in the cryostat. The main power supply and the trimming power supplies are coordinated by the control system to charge/discharge the magnet coils. Two correctors can be added to upstream and downstream of the insertion devices to compensate for distortion of the beam orbit. Interlock logic protects the magnet when the coils quench and protects the vacuum ducts from damage by a mis-steered beam. The user interface is provided in the control consoles. Control consoles communicate with the VME host module via the control Ethernet.

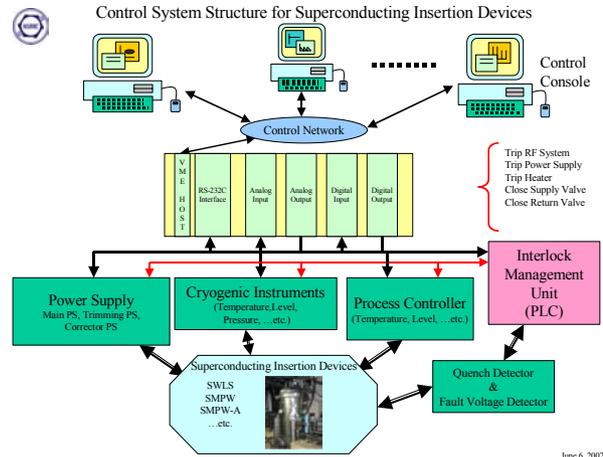


Figure 1. Control system for superconducting insertion devices.

IMPLEMENTATION DETAILS

The control system for superconducting insertion devices adopt standard VME crate running a real-time operating system as a local controller. The crate includes the analog input/output module, the digital input/output module and the RS-232 interface module. The local controller organizes the power supplies, the cryogenics instruments, the process controllers, the quench detector, and the interlock logic. Figure 2 shows the control system for SWLS in the equipment area of NSRRC.

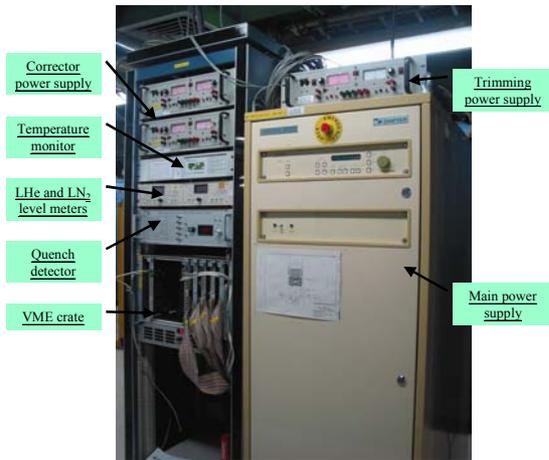


Figure 2. Control system of the SWLS.

Cryogenics Instrumentation

The cryogenics instruments include a temperature monitor, level meters for LHe and LN₂, pressure meters for He gas and N₂ gas, a vacuum gauge, a flow meter of He gas, process controllers and heaters. A LakeShore temperature monitor is used to measure the temperature of the helium space and the vacuum chamber. The SWLS is cryogen-free and the coils are cooled by a cryocooler. The coils of the SMPW6 are soaked in liquid helium to maintain their superconductivity. The cryogenics plant provides LHe and LN₂ to the cryostat of SMPW6. The PID process controllers regulate the LHe and LN₂ levels in the cryostat and the liquid levels are measure by the AMI level meters. The goal is to maintain the level of the liquid and the pressure of the gas at constant values. The heaters in the cryostat are to warm up the magnet and bake out the beam tube.

Power Supply Control

A bipolar main power supply and trimming power supplies are used to charge/discharge the magnet. The output current of the trimming power supply follows the main power supply to nullify the first field integral. If the current is ramping too fast, then the coils will generate excess heat and make increase the temperature. In routine operations, the slew rate of the main power supply of the SWLS cannot exceed 0.6 A/sec, to prevent coils quench.

Quench Protection Circuit

The hardware quench protection circuit is a network of R620 cold diodes and 5 mΩ stainless steel resistors that connects the coils to limit the peak voltage when the coils quench. The diodes do not conduct in the routine operation. When the coils quench, the voltage across the coil will increase quickly. The protection diodes will conduct bypass current. The resistors in series with the diodes assist in dissipating the store energy in the coils. Figure 3 shows the quench protection and detector circuit. A traditionally bridge circuit is used to detect a quench. When the coils of magnets approaches quench, unbalance of the coil arm voltage and the resistor arm voltage lead

the signal of the quench detector to trigger the protection logic in PLC. The voltage signals of the magnet consist of two parts - one is across the charging leads, and the other is across the coils. These signals are available for use in interlock logic.

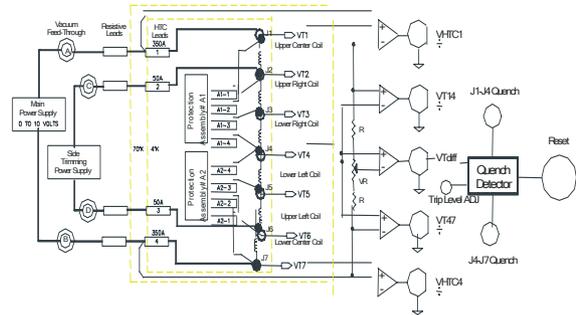


Figure 3. Quench protection and detector circuit.

Interlock Protection

The interlock logic is integrated in a programmable logic controller (PLC) [3]. The PLC collects data on the temperature, the LHe and LN₂ levels and the pressures of the He and N₂ gases in the cryostat, the quench detector and the lead voltage monitor are treated as hardware interlock signals. The protective actions are as follows. When the temperature in the He space exceeds the high limit or the LHe level is below the low threshold or the quench detector triggers the interlock logic, shutting down the power supply. When the pressure of He gas exceeds the high limit, the LHe supply valve is closed and the power supply is shut down. If the temperature of the vacuum chamber exceeds the high threshold, then the control system will shut down the RF system. The software interlock logic is built into the application programs. The power supply stops charging when the temperature in the He space is too high or the LHe level is too low.

USERS' INTERFACE AND APPLICATIONS

Application programs and user interfaces are provided to support routine operation. The user interface of the system for controlling superconducting insertion devices has two pages. On the first page, operators can monitor the statuses of the superconducting insertion devices and set the output current and slew rate of the power supply. Figure 4 shows this page for SWLS. The second page presents the interlock status and the alarm limit. The operator can set the alarm limit and reset the interlock logic on this page. Figure 5 shows the second page of the user interface for SMPW6.

CURRENT STATUS

Installation of SWLS had been done in early 2002. Commissioning has been finished in late 2002. The control system of SMPW6 is being implemented and will complete in June 2003. Preliminary design of the control

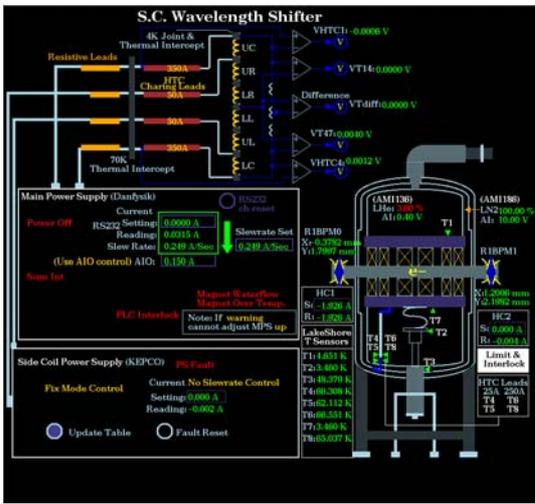


Figure 4. User interface for routine operation.

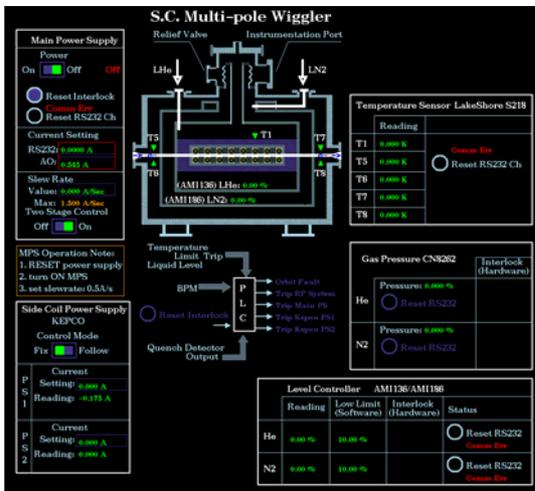


Figure 5. User interface for presenting interlock information.

system for the planned SMPW-A is underway. All superconducting insertion devices share a common structure for ease of maintenance and operation. Following example summarize the typical SWLS operation data to demonstrate the basic functionalities of the control system include control, monitoring and archiving.

Operational experiences of SWLS over the past year confirm that the control system is reliable and easy to operate. A procedure for operating the control system has been provided. The top plot of figure 6 shows magnet current of a typical charge/discharge cycle of SWLS. Magnet current charge from 0 A to 230 A need about 10 minutes. Magnet current 230 A is corresponding to 5.3 Tesla field strength. The middle plot shows the induced voltage in the magnet coils. The induced voltage varies according to slow rate of the output current. The bottom plot of figure 6 shows that the temperature of magnet bottom near cold head. Figure 7 shows the achieved data record a quench event of SWLS. In the top plot, when the coil quench happen, the bridge circuit is unbalance and

the quench detector triggers the interlock logic. Middle plot shows a quench interlock logic trip the main power supply and the magnet current drop to 0 A within a couple of seconds. The temperature at the cryostat rise drastically due the stored energy of the magnet is dissipated at the quench protection circuitry, which mound inside the cryostat as shown in bottom plot. The cooling capability of the cryocooler is limited, it need about 60 minutes to return to nominal operating temperature.

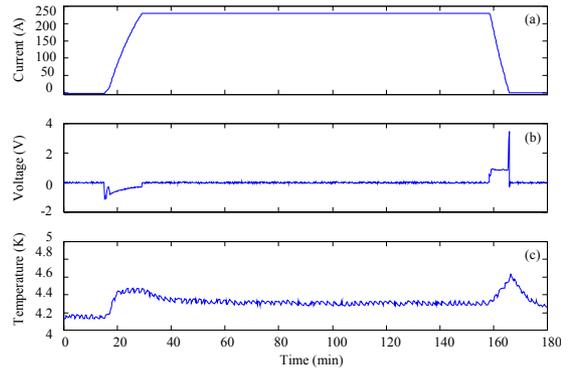


Figure 6. A typical charge/discharge scenario of SWLS.

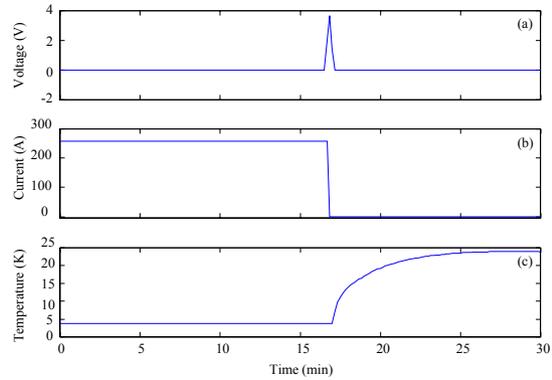


Figure 7. Achieved data record a quench event of SWLS.

SUMMARY

The control system for the superconducting insertion devices is implemented to support the routine operation. Despite there are some difference for the configuration of the magnet, the control system share the same structure. Interlock functions is implemented by a fast scan PLC. The operation experiences from SWLS show the system working well with satisfied performance. Performance and reliability of the control system is improved continuously to ensure smooth operation.

REFERENCES

- [1]. C. S. Hwang, et. al., "Construction and Performance of a Compact Cryogen-Free Superconducting Wavelength Shifter," Proceeding of MT17, Geneva, Swiss, 2001.
- [2]. H. P. Chang, et. al., "Operational Experience of the Insertion Devices and Expectation of the Future Superconducting Wiggler at NSRRC," These Proceeding.
- [3]. <http://www.aromat.com>.