CONTROL SYSTEM FOR THE SUPERCONDUCTING WIGGLER OF NSRRC

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Abstract

A 3.2 Tesla superconducting wiggler (SW6) has been installed in the 1.5 GeV storage ring at NSRRC to enhance hard X-ray production for dedicated protein crystallography research. A control system was implemented to support the operation of the SW6 system. The control system coordinates the operation of the main power supply and the trim power supplies to charge/discharge the magnet, and provides the essential interlock protection to the magnet. A friendly user interface supports routine operation. Various applications have also been developed to facilitate the operation of the SW6. The design considerations and details of implementation are presented herein.

INTRODUCTION

The superconducting wiggler (SW6) was installed in January 2004 to enhance hard X-ray production in the 1.5 GeV storage ring at NSRRC for dedicated protein crystallography research. The SW6 has 32 poles, with 6 cm period, 18 mm gap. The field strength is 3.2 Tesla [1]. The control system of the SW6 is implementing and commissioning. It is based on the VME crate. The interlock logic is implemented using a programmable logic controller (PLC) to protect the coils of the magnet. Various application programs and user interface are provided to enable the routine operation.

IMPLEMENTATION OF THE CONTROL SYSTEM

The control system adopts a standard VME crate to coordinate relevant instruments. The crate includes a PowerPC-based host module, which runs LynxOS real-time operating system, as a local controller of the NSRRC control system. The crate also includes analog input/output modules, digital input/output modules and the RS-232 interface module. The routine operation of the SW6 depends on power supplies, cryogenic instruments and interlock protection. Figure 1 illustrates the infrastructure of the SW6 control system. The control system integrates the listed elements and ensures reliable operation. Control consoles communicate with the VME host module through the control Ethernet network.

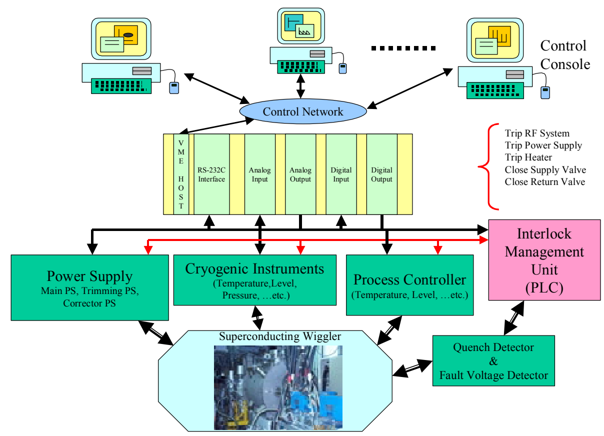

Figure 1: The control system infrastructure of the SW6.

Hardware Structure

A bipolar main power supply and two trimming power supplies are used to charge/discharge the magnet. The main power supply charges all coils in series and the two trimming power supplies are connected to the two end pole coils respectively. The control system provides a strategy for charging the SW6. The control system can changes the slew rate when the main power supply is ramping. The control system causes the output current of trimming power supplies to follow the output of main power supply. The purpose is to nullify the first and second field integrals. Two correctors are added upstream and downstream of the SW6. The control system coordinates the outputs of the corrector power supplies to compensate for beam orbit distortion.

The cryogenic instruments monitor the parameters of the SW6 during routine operation. Unlike the superconducting wavelength shifter (SWLS) is cooled by the cryocooler, the coil of the SW6 is cooled by submerging in liquid helium (LHe). Hence, the level of LHe 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. Figure 2 shows the control system of the SW6 in the equipment area of NSRRC. The control system monitors these data to present the operational situation of the SW6. The limiting of high temperature, low level and high pressure can be set by using these instruments.

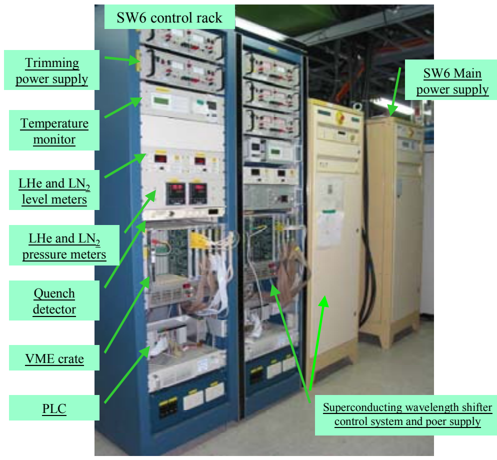

Figure 2: The control system of the SW6.

Interlock Protection

The hardware quench protection circuit consists of R620 diodes and 6.0 mΩ stainless steel resistors. The circuit is connected to the coils of the magnet. When a quenching event occurs, the voltage across the coils increases rapidly. The diodes conduct and current bypasses the coils. The circuit can limit the peak voltage of the coils. The resistors in series with the diodes help to dissipate the energy stored in the coils. Figure 3 shows the quench protection and quench detector circuit.

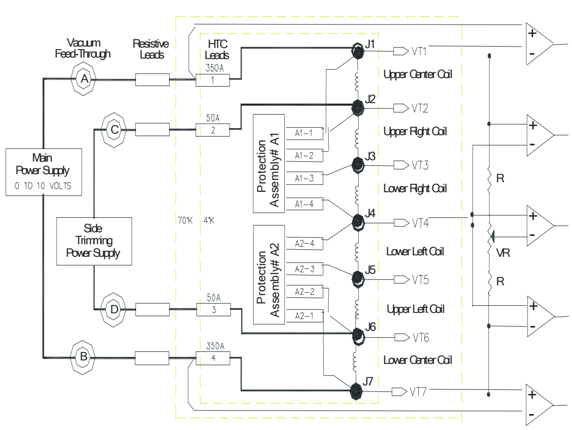

Figure 3: Quench protection circuit.

A bridge circuit is used to detect quench events. An imbalance voltage in the bridge circuit implies the quench event is occurring. 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 in PLC.

The interlock logic is designed to protect the coils of the magnet. The interlock logic is integrated in a fast scan PLC [2]. The PLC manages the alarm signal from the cryogenic instruments, which measure 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 treated as 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 temperature, and dissipating LHe. The level meters and pressure meters are connected to the process controller of the valve box for auto-fill system. The auto-fill system fills the vessel with LHe and LN_2 respectively to keep the certain level. [3]. If the pressure of He or N_2 is outside the safety range, the protective action will be enabled to shutdown the power supply. The relief valve of the vessel is use to release highly pressure He and N_2.

Software Environment

The control system provides various application programs for the routine operation of the SW6, which involves cold start and shutdown of the power supplies and charge/discharge strategy for the magnet. The control system also provides software protection for magnet. The power supply cannot be enabled until the temperature of the magnet, the level of LHe and LN_2 and the pressure of He and N_2 are in safe ranges. The data archives are stored in the database. It is useful information to improve the operation of the SW6.

User interface provide two pages for the SW6. Using the first page, operators can monitor the status of the SW6 and set the output current and slew rate of the main power supply, as shown in Fig. 4. The second page presents interlock information and the alarm limit of the SW6, such as the temperature, the level of LHe and LN_2 and the pressure of He and N_2, as shown in Fig. 5. The operator can reset the interlock status and set alarm limit of software protection on this page. The user interface presents the real time information about the magnet and provides a convenient manipulation environment.

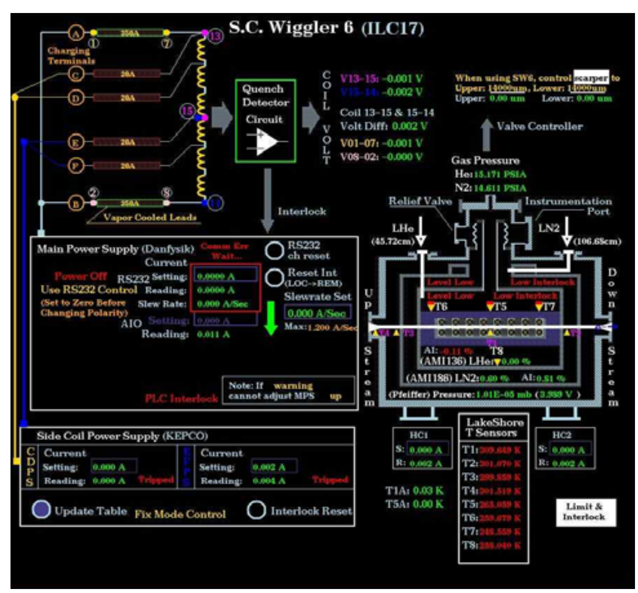

Figure 4: User interface for the SW6 routine operation.

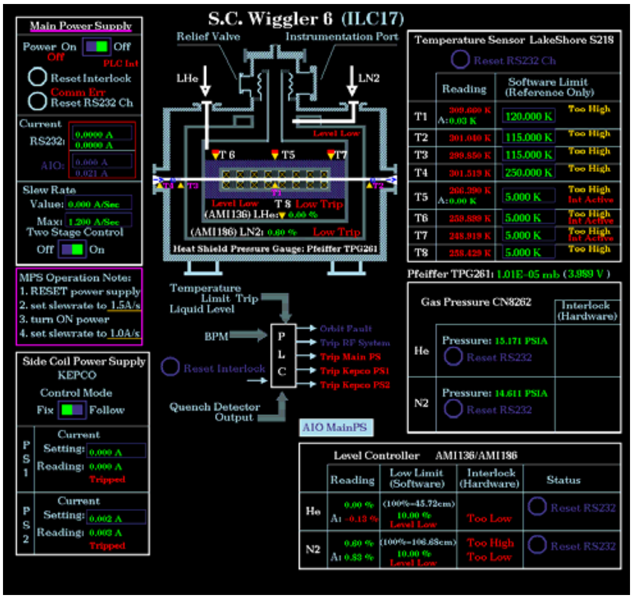

Figure 5: User interface for the SW6 interlock information.

PRELIMINARY TEST

Figure 6 plots the output current of the main power supply during preliminary charge/discharge scenario. Ramping the output current from 0 A to 291.5 A takes around 8 minutes and reducing it from 291.5 A to 0 A takes around 4 minutes. The lower slew rate at the beginning of charging is intentional to test the main power supply. The output of trimming power supplies nullifies the field integral. The control system also coordinates the correctors at upstream and downstream to compensate for the distortion of beam orbit.

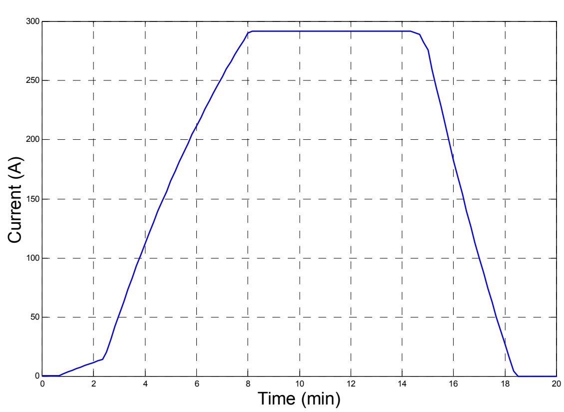

Figure 6: A charge/discharge proceeding of the SW6.

The reliability of quench detector is important. The coils of the magnet are soaked in the LHe, so the variation in temperature due to quench is very small. When the main power supply is turned on, the surge as a fault alarm signal triggers the quench detector. It causes to shutdown the power supply. The interlock logic applies a 10 sec delay to disable this condition currently.

The working condition of auto-fill system refers to the boil-off rate of of LHe and LN_2 in the vessel. Figure 7 plots the roughly approximates the level of LHe and LN_2. In the preliminary test, the magnet operated at 291.5 A and the LHe level exceeds the top of the upper coil. The LHe and LN_2 level decrease around 7% and 10% respectively in 7 hours.

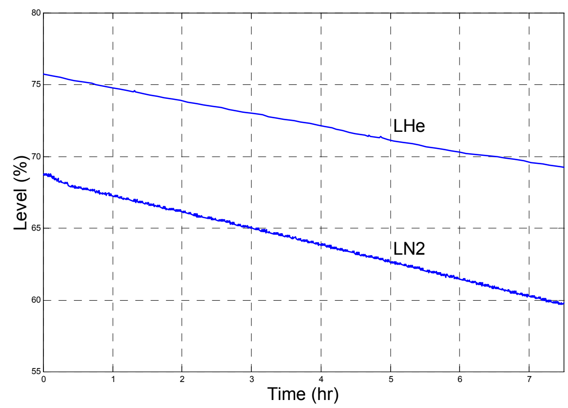

Figure 7: The level of LHe and LN_2 in the SW6 vessel.

SUMMARY

The control system is implemented to support routine operation and provide interlock protection to the SW6. The infrastructure is similar to the control system of the SWLS. Some works are underway as follows: (1). A large surge generated when the main power supply is turned on. The cause of surge generated needs to understand. (2). The procedure for operating must be determined. The purpose is to ensure an efficient operation. (3). The quench events need to diagnose. It is helpful to investigate the source of quenching. Experiences of commissioning control system of the SW6 will be helpful in developing the control system for in-achromat superconducting wigglers (IASW), which are planned to install in the storage ring at NSRRC. The both control system of the SW6 and the SWLS will be continually improved to ensure its stable operation and highly reliable.

REFERENCES

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[2] http://www.aromat.com.

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