CONTROL SYSTEM FOR THE SUPERCONDUCTING WAVELENGTH SHIFTER OF SRRC

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Abstract

A 6 Tesla superconducting wavelength shifter (SWLS) was installed in the 1.5 GeV storage ring at SRRC to enhance hard X-ray production. The control system is implemented to support the operation of SWLS system. The control system focuses mainly on coordinating 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. A friendly user interface and application a program support routine operation. This article summarizes the design considerations and detail of implementation.

1 INTRODUCTION

A 6 Tesla superconducting wavelength shifter (SWLS) was installed to increase the photon flux in the hard X-ray spectral range in the 1.5 GeV storage ring of SRRC. A compact cryogen-free SWLS has been constructed because of the limited space in the injection straight section. The SWLS is 610mm long and has a 20 mm warm bore gap (and a coil gap of 55 mm). Two bipolar power supplies (the main power supply and the trimming power supply) are used to charge/discharge the magnet and nullify the first field integral. Two horizontal correctors are added to the upstream and the downstream of SWLS to correct the beam orbit.

The control system of the SWLS is based on the VME crate. The VME host is a PowerPC CPU module that runs a LynxOS real time operating system. The crate includes the analog input/output module, digital input/output module and RS-232 interfaces module. The system consists of signal conditionings for the cryostat, power supplies, quench detector and interlock protection. The interlock protection is integrated in a programmable logic controller (PLC). The application program and user interface are implemented to operate for the control system for operation.

2 SUPERCONDUTING WAVELENGTH SHIFTER (SWLS)

The SWLS includes three pairs of racetrack NbTi superconducting coils that can produce a maximum magnetic field of 6 Tesla at the central pole. The coil bobbin is made of 1mm thick OFHC sheets and insulated with two layers of high thermal conductivity Kapton. The superconducting wire of the coil is conduction-cooled. A 60 K aluminum thermal shielding surrounds the 4 K cold mass in the cryostat, and is comprised of the pole pieces, coils, aluminum block, return yoke, a stainless reservoir that holds 40 liters liquid helium, equipped with a reservoir that holds 10 liters liquid nitrogen. Both reservoirs are used to protect the magnet from the power supply and from the cryocooler failure, and to shorten the initial cooling time. A 1.5 W Gifford-McMahon cryocooler is used to simplify the operation and maintenance [1].

3 SWLS CONTROL SYSTEM

Figure 1 illustrates the structure of the control system. The VME crate coordinates the signal conditionings for the cryostat, the input/output control for the power supply, the quench detector of the coil and the interlock protection. The user interface is provided in the control console. The control console communicates with the VME crate via an Ethernet.

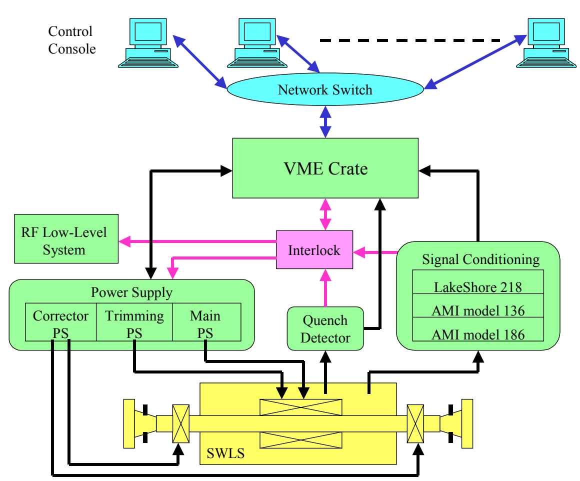

Figure 1. Structure of the control system for SWLS.

3.1 Signal Conditioning

The signal conditionings of the cryostat include temperature, liquid helium (LHe) level and liquid nitrogen (LN_2) level. Eight temperature sensors are located in the upper copper plate (T1), lower copper plate (T7), flexible OFHC foil (T2), cryocooler (T3) and HTC current lead (T4, T5, T6 and T8). (See Fig. 4.). All the temperature sensors have a calibration range from 4 K to

300 K. The LakeShore 218S is used to obtain these temperature data. The temperature monitor has an alarm feature and eight relays for interlock protection. The AMI model 136 with an LHe level sensor is used to readout the LHe level; the AMI model 186 with an LH_2 level sensor is used to readout the LN_2 level. These level monitors provide two interlock outputs to indicate for high and low levels.

3.2 Power Supply Control

The control system coordinates the main power supply and the trimming power supply to charge/discharge the magnet. The trimming power supply follows the main power supply to correct the current of the side coil when the power supplies charges/discharge the magnet. Furthermore, if the current increases too quickly, the heat load will make the coil quench. Thus, the slew rate of the output current of the power supply is a function of the coil temperature. The maximum slew rate of the output current is limited to 1.2 A/sec. The slew rate can be set from the user interface. The control system also sets the output current for the power supplies of upstream and downstream horizontal corrector. Figure 2 presents the picture of control system for the SWLS in the core area of SRRC.

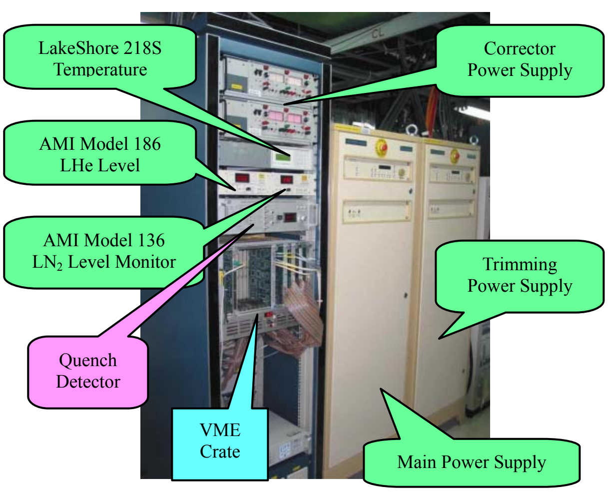

Figure 2. Control system of the SWLS.

3.3 Quench Detector

When the coil of SWLS approaches quenching, the quench detector enables the interlock protection. The aim of the design is to protect the magnet because the heat load from the charging current will damage the coil during quenching. Figure 3 predicts the quench protection circuit. A pair of back-to-back R620 cold diodes, with 5 mΩ stainless steel resistors, is connected across each one of the six coils to form the hardware quench protection circuit. The six pairs of diode in series also maintain the capability for fast ramping of the current. The voltage signals from the coil are separated into two sets, VT14 (J1-J4) and VT47 (J4-J7). The signal VTdiff is the difference between the voltage VT14 and VT47. This quench protection circuit is active when the VTdiff exceeds 2.5 V or VT14 or VT47 exceeds 4V. Five voltage signals (VHTC1, VHTC4, VT14, VT47, and VTdiff) can be used in software quench protection. That against (1) coil over voltage below 300 V, (2) coil over temperature below 200 K, (3) unbalanced current below 10%, and (4) external open circuit including burn out of HTC lead.

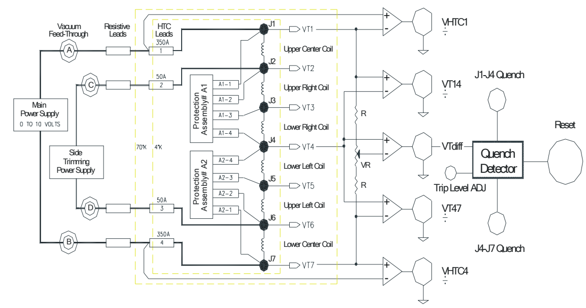

Figure 3. Functional block diagram of quench detector.

3.4 User Interface

An application program and a user interface are provided for routine operation. Figure 4 shows the graphical user interface (GUI) of the control console for the SWLS. The user interface monitors the status of the cryostat and the quench detector. The user interface enables the parameters relating to the power supplies to be set.

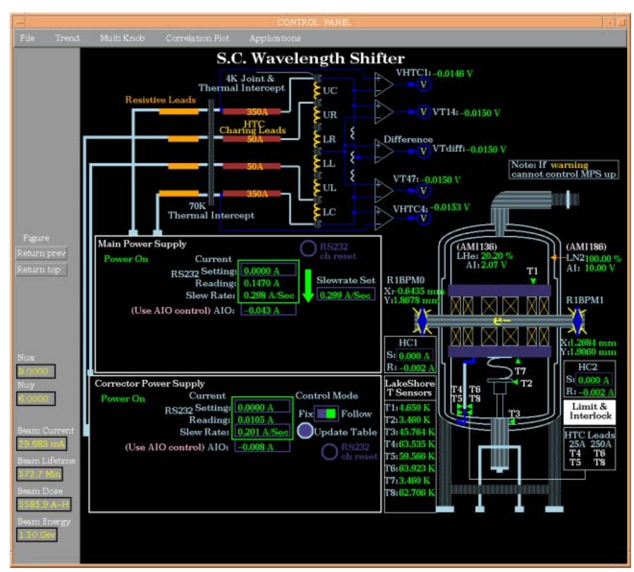

Figure 4. SWLS user interface for the control system.

4 INTERLOCK PROTECTION

The design of essential interlock protection for the superducting wavelength shifter aims to protect the coils and vacuum ducts [2]. The NAiS FP2SH PLC [3] manages the signal according to the temperature, and the levels of LHe and LN_2 in cryostat, the quench detector and the power supply status, to integrate the interlock protection of SWLS. If SWLS meets one of the three following conditions, interlock protection is enabled. (1) The temperature measure of any sensor in the cryostat exceeds a specified value (T1, T2 and T7 - 4.9 K, T3 - 65 K and the others - 75K); (2) the LH_e level is less than 28% of the high liquid level or the LN_2 level is less then 30% of high liquid level or (3) the quench protector is enabled. The coil quench depends on these conditions. The interlock protection executes two commands when enabled. Firstly, power supply stops charging the magnet. Secondly, the interlock trips the low-level RF system and the beam is dumped to avoid damaging the vacuum chamber of the storage ring. Conversely, interlock protection also sends the ready chain signal to the power supply and the low-level RF system.

5 PRELIMINARY COMMISSIONNING RESULTS

Figure 5 to 7 show some results of preliminary testing of the control system over past two months. Figure 5 shows the ramping of output current when the main power supply charges the coil. The slew rate of the output current is set to 0.3A/s. The slew rate is corrected by the controller of the main power supply when output current increase. (Thus, the ramp of the output current is not a straight line.). Ramping from 0 A to 260 A takes about 16 minutes.

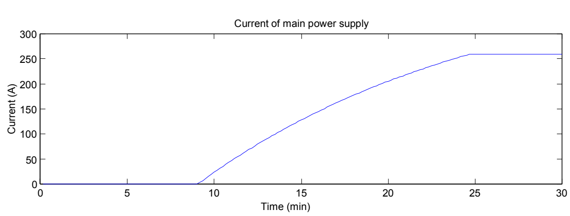

Figure 5. Output current of the main power supply.

The ripple of output current of the power supply present in early testing. The phenomenon generates about a 1 V fluctuation of the voltage, VT14, of the quench detector (See Fig. 6(a).). The ripple of output current also cause extra heat load on the coil. A filter was used to modify the output current, reduced the fluctuation of the voltage VT14 to below 0.01 V. Figure 6(b) shows the result.

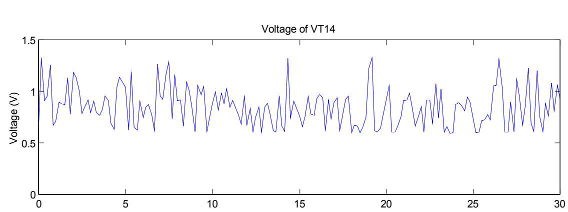

Figure 6(a). Voltage VT14.

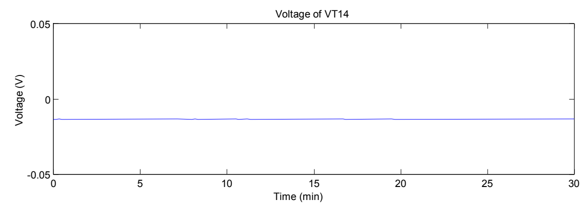

Figure 6(b). Voltage VT14.

Figure 7 shows the responses of the quench detector, the power supply and the temperature of the cryostat to coil quench. When the coil is quenched, the voltage VT14 in the quench detector immediately increase and the quench detector enables interlock protection. Then, the power supply is tripped by the interlock protection. Eddy current appears in the coil during the quenching. Temperature T1 is seen on the user interface to increase because the heat load is generated from the eddy current during the coil quenching.

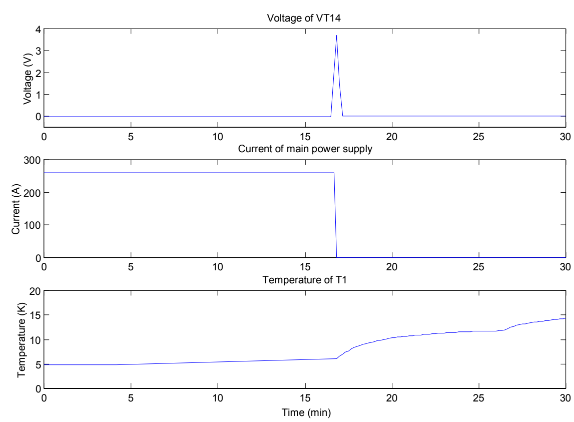

Figure 7. The response to coil quench.

6 SUMMARY

A control system for the superconducting wavelength shifter has been established at SRRC. Testing of the system has been completed and its performance satisfies requirements. It can be conveniently maintained and operated. A new control system will be expanded from this system and applied to the superconducting multipole wiggler at SRRC in the future.

7 REFERENCES

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