STABILITY STUDY OF SUPERCONDUCTOR MAGNET POWER SUPPLIES AT TLS

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Abstract

In this paper, performance of three power supplies schemes driving the newly-developed Superconducting Wave Length Shifter Magnet at TLS is investigated. Due to the inherent structure of the Superconducting Magnet, the main and two accessory trimming power supplies are physically correlated with each others. Due to the inherent structure, in order to achieve high performance control of the magnet, slew rate control of the main power supply and the proper operation sequence have to be properly managed, otherwise, small current disturbance can occurs, which may degrade the stability of the performance of Superconducting Magnet.

INTRODUCTION

There has been increasing demand for intense hard X-rays of up to 33 keV recently in the fields of protein crystallography and relative experiments. In medium-energy synchrotron light source, the superconducting insertion devices have been considered to be very potential to generate hard X-rays in a more efficient way. To meet the demand of users, several superconducting insertion device magnets using NbTi wires have recently been built at NSRRC. These magnets are used to generate intensive X-rays from our 1.5 GeV Taiwan Light Source (TLS) and for our future 3 GeV Taiwan Photon Source (TPS).

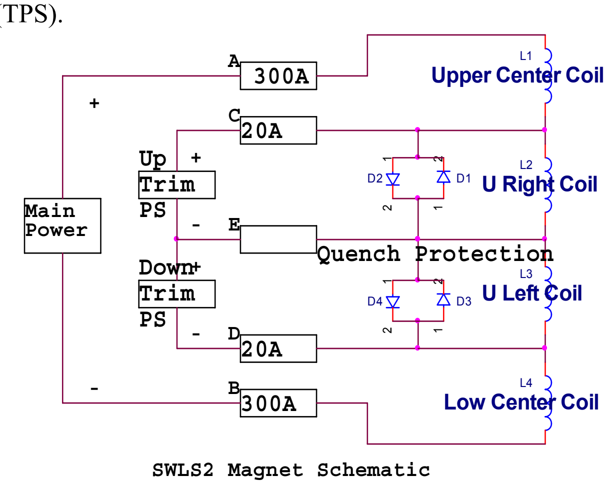

Figure 1: SWLS system connection schematic diagram.

A new superconducting wavelength shifter (SWLS) with a magnetic field of 6.5 T to be operated in cryogen-free environment provides X-rays for high-resolution X-ray applications is developed here at NSRRC. To deliver the desired field, the output stability of the power supplies driving the magnet can not be ignored. Figure 1 shows the power supplies connection schematic diagram for the SWLS magnet.

SWLS system schematic diagram is illustrated in Figure 1. In the diagram, the main power supply is a bipolar 350A/15Vconstant current source, which will provide the major magnet field energy. Besides, there are two 20A trim power supplies attached in the up-stream and down-stream coil respectively. The trim power supplies are for the control of the 1st integral of the magnetic field.

GROUND CURRENT LEAKAGE ISSUE

Due to the inherent connection structure between the power supplies and the superconducting magnetic coil, the power supplies are seeing each others as loads through the coil. It has been observed in the pilot test the there is about 200mA earth leakage current flowing through the earth leakage protection circuit, which presented an interlock and halted the whole system down. In figure 2, the inter-connection among the power supplies are depicted.

The earth leakage current problem may manifest itself in

A. Improper choose of power supplies with non-floating full isolated output stage.
B. Non-isolated analogue command input to the power supplies.

In this case, the earth leakage current is caused by non-isolated analogue single-ended command input to the power supplies. As seen from the figure 2 , the analogue command inputs to the two trim power supplies come from a DAC board embedded in the ILC (Intelligent Logic Control). For the command signal is single-ended , the ground of the DAC board is connected through the trim power supply's ground and then to the main power supply ground. This constitutes a ground loop and hence introduces a earth leakage problem. This problem can be solved by

1) Employing power supplies with isolated input command buffer built-inside or

2) Feeding the DAC outputs to an isolation board which converts the single-ended signals into differential signal pairs and then connecting the differential pairs to the trim power supplies.

Strategy 2 is used here to cut the ground loop even the trim power supplies do not have fully-isolated command input buffer.

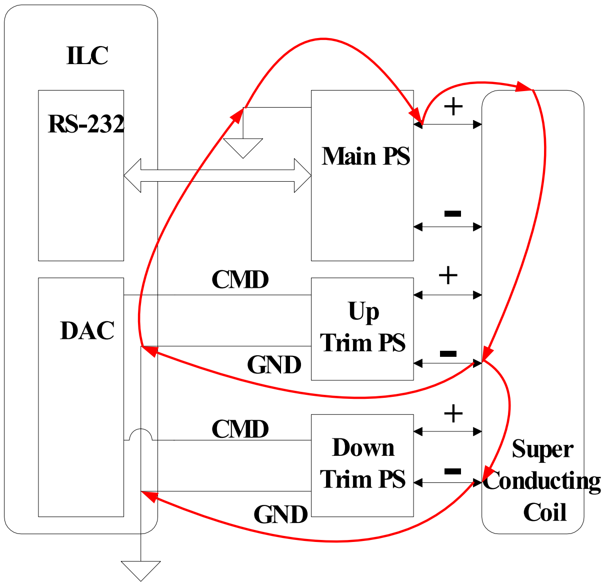

Figure 2: The power supply ground loop in the SWLS system.

LONG TERM STABILITY

NSRRC has officially started its top-up operation mode in the beginning of 2006. The top up operation current and the SWLS main power output current is shown in Figure 3. Due to its 16 hours long user beam time per days, the importance of the main power supply's long term stability performance can not be overstated.

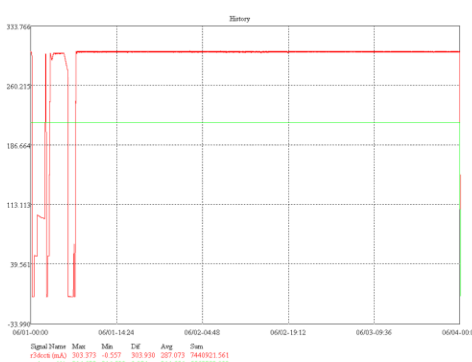

Figure 3: The top up operation current and SWLS main power output current.

Figure 4 shows the main power supply current output observed during an 8 hours period. The upper plot is the operation current sampled every 15 second. In this 15 second time frame, 8 current samples are taken and then averaged. It can be seen from the lower plot that during this 8 hours period, the stability performance is within 0.5ppm at operation current 320 ampere. The long term performance of the SWLS main power supply is far better than its specified 10ppm range.

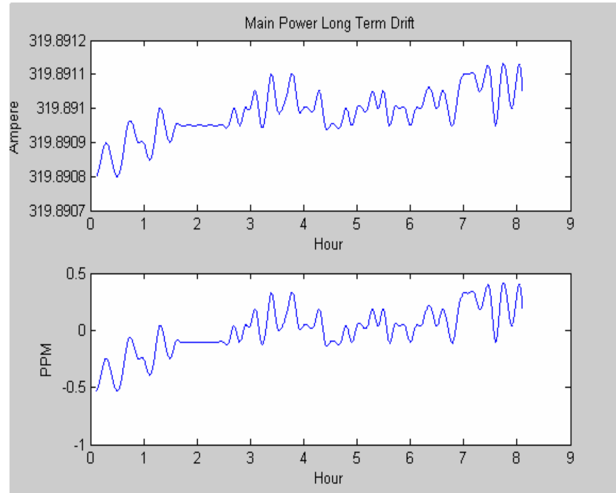

Figure 4: Main power supply long term output current.

SHORT TERM STABILITY

In this section, short term stability performance of the main power supply is examined. Since the main and trim power supplies are correlated with each other through the superconducting coil, the trim power supplies are seen as dynamic loads by the main power supply. The fluctuation of the main power's output caused by tuning the trim power supply is shown in Figure 5 and Figure 6. In Figure 5 the measurement result is obtained when the slew rate(SR) of the main power is set to 0.3A/sec, while in Figure 6 the slew rate is set to its maximum value 1.5A/sec.

The digital slew rate control of the main is to contain large inrush current into the coil, which in turn will induce large output voltage across the coil. It will endanger the coil and then trip the whole system. It is attempted in the measurement to see if increase in the slew rate of the main power supply will decrease the peak of disturbance for higher slew rate means larger control gain.

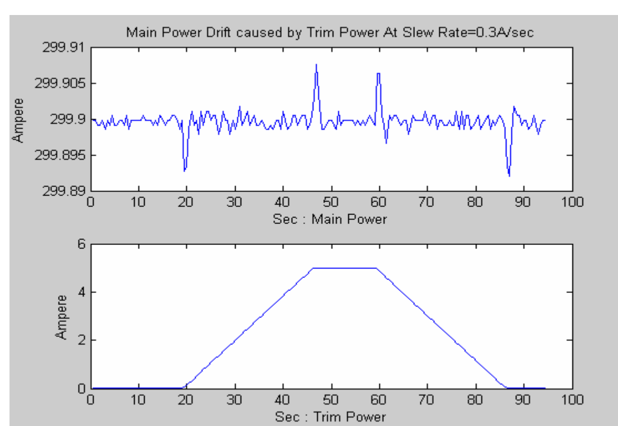

Figure 5: Main power output current@300A SR=0.3 A/SEC vs Trim power current change

Figure 6: Main power output current@300A SR=1.5A/SEC vs Trim power current change

As seen from Figure 5 and 6, the main's output current remains flat as the trim power's current level is not changed. However, if the trim is set from 0A to 5A and then back to 0A, disturbance on the main power's current is observed. The fluctuation is about 20ppm, which is still under the 10ppm short term stability specification. Besides, the current disturbance peaks look like the same when changing the main power supply's slew rate from 0.3A/sec to 1.5A/sec. It seems possible that the slew rate upper bound has to be shifted more upward to compensate this output load variation.

POWER SEQUENCING FOR SAFETY

As mentioned in the previous section, the slew rate for both the main and trim power supplies, when charging up or down the superconducting coil, has to be limited to avoid quench condition from happening, This slew rate cap however decreases the main power's control gain to suppress the current and voltage spike caused by the trim power's on-off or change in current.

Quench will also occur when the main power is turned on or off. In Figure 7, the voltage spike which causes the superconducting magnet to quench in this situation is illustrated.

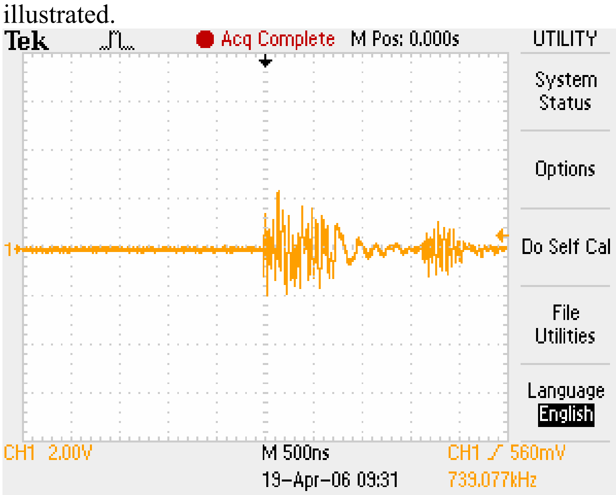

Figure 7: Voltage spike when main power is turned on.

To eliminate the chance of power supply related quench, following power sequencing has been adopted.

A. Set the slew rate to maximum, turn on both the main and trim power supplies.
B. Set the trim powers to their predefined value.
C. Set the slew rate to small value and then charge the main power current up.
D. Set the slew rate to maximum, when the main's current reaches its operation value.
E. No change of the trim current is allowed during full operation.

This power sequencing has been practiced here at NSSRC. System quench related to improper manipulation of the power supply has almost eliminated.

CONCLUSION

In this paper, the interaction between the power supplies and the superconducting magnet is explored. A power sequencing procedure has been established to ensure reliable and consistent operation of the SWLS and other superconducting insertion devices (IDs).

Cares must be taken when there are several power supplied coupled through the superconducting coil. Change in one of them will have influence on the others' output performance. In addition, ground loop problem has to be examined thoroughly before assemble the whole system.

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