THE SSRF STORAGE RING DIPOLE AND SEXTUPOLE MAGNET POWER SUPPLIES

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Abstract

SSRF is a third generation synchrotron radiation light source. It has a full energy injection storage ring of 3.5GeV.[1] The storage ring dipole magnet string and sextupole magnets strings are powered by 10 large magnet power supplies. The power supply output current ranges from 250A to 800A, and the output voltage ranges from 140V to 840V. These power supplies are digitally controlled, with bridge topology, and diode rectifiers with step-down transformers. In this paper, the commissioning results and the operation experience of these power supplies are presented, together with the circuit topology and the control schemes.

INTRODUCTION

The storage ring have 40 dipole magnets and 140 sextupole magnets. The 40 dipole magnets are connected in a string and excited by a single power supply. The 140 sextupole magnets are divided into 9 families, namely S1-S6, together with SF, SD1 and SD2. In fact, SD1 and SD2 are of one family but excited with two separate power supplies.

Based on the maximum operating current and voltage, the sextupole power supplies have two types, type A and type B. S1 and S2 are of type A. The rest are of type B. The rating values of dipole and sextupole power supplies are listed in table 1.

Table 1: Power Supply Ratings

power supply	B	SA	SB
Number	1	2	7
Nom. current	800A	250A	280A
Nom. voltage	840V	140V	300V

The stability requirements of the power supplies are listed in table 2.

Table 2: Stability Requirements

Power Supply	B	S
resolution	15ppm	30ppm
stability	20ppm	100ppm
reproducibility	100ppm	100ppm

The dipole and sextupole power supplies are installed in the power supply hall(RPH), which located next to the storage ring main power distribution hall. Within the power supply hall, there are the power distribution cabinets for the Sextupole power supplies, a PLC cabinet for magnet interlock, and a control cabinet, containing the VME crate for power supply control.

The input power for dipole power supply is 10kV, and is fed from the main power distribution hall.

The power supply hall is air conditioned. The temperature control accuracy is ± 1℃.

DIPOLE POWER SUPPLY

Dipole power consists of two multiple converters, which are connected in parallel. Each converter is a two-level bridge. As is shown in Fig.1. Though two quadrant converter it is, one quadrant converter it is used as.

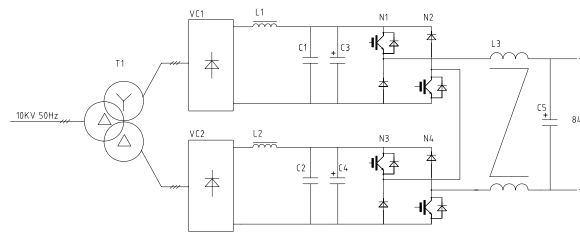

Figure 1: Topology of half the dipole PS.

The two-bridge converter consists of two basic bridges, which are connected in cascade. Multiplex control scheme is used. The IGBT operating frequency is 5kHz, while the equivalent switching frequency is 20kHz.

Input power is fed by two step down Δ/Δ-Y line transformer with diode rectifier. The two transformers are phase-shifted to allow a 24-pulse rectification. A resistive step start system limits the in rush current during power on.To reduce the conductive interference, both the input AC lines and the output buses are led through magnetic cores. The cabinets are grounded to the earthing bus in the power supply hall.

Mechanically, The power supply consists of a control cabinet, 2 power cabinets, and two 10kV transformers. The 10kV transformers located in another room. The cabling length is less then 10m. The volume of the power supply is W3200xD1000xH2200.

SEXTUPOLE POWER SUPPLIES

The power supplies are two-quadrant converters. The IGBT operates at 10kHz. The output ripple frequency is 20kHz.

Input power is fed by step down transformer followed by diode rectifier. Phase-shifting transformers are used for sextupole power supplies, to allow a simulated 24-pulse rectification.

Individually, type A consists of one transformer and one 6-pulse rectifier. Type B consists of two transformers and a 12-pulse rectifier. A resistive step start system limits the in rush current during power on.

Sextupole power supplies are one cabinet structure, with the transformer housed inside. The cabinet volume is W1200 xD1000x H2200. The cabinets are grounded to the earthing bus.

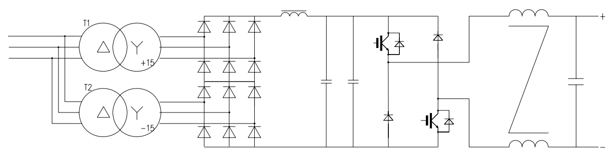

Figure 2: Topology of sextupole supply (SB).

CONTROL AND FAULT PROTECTION

The power supplies are digitally controlled, as the other power supplies used in SSRF.[2] PSI controller are used for dipole and sextupole power supply control.[3] The PSI controller consists of an AD/DA converter card and a DSP controller and PWM card. The DSP card is also a control interface to the control system IOC.

The sextupole supplies are full digital control. The two quadrant converter is regulated by the PWM signal generated from the DSP card.

For the dipole power supply, the PSI cards are used for load current control. An expanded analog card is developed for the current sharing control, between the two parallel multi-level converters. The output PWM from the DSP card is filtered and is used as setpoint for the analog card.

To expand the control bandwidth, a capacitor branch is connected in parallel with the magnet load. The capacitor together with the load inductance will provide a second order zero to match the second order pole generated by the output filter.

Fault protection and alarming reporting of the power supply is done with a PLC module. When the power supply and all the interlocks from outside are in normal states, the PLC enables the PSI cards. The PSI cards can operate. An Ethernet module allows the PLC to join the intranet.

TESTING AND COMMISSIONING

In factory stage, the acceptance test focused on the power circuit. After the 8hr's running at 90% nominal current, DC link capacitor bank was found with temperature raise more than acceptance. More capacitors were added to the capacitor bank, the surface temperature falls to a reasonable level.

The power factor measured was 0.96 at 40% nominal current for the SB, and 0.98 at 90% nominal current.

After installation, commissioning was carried on. It was not difficult to reach the current limited by the magnets. It is comparably easy to meet with the stability requirements for sextupole power supplies. Based on DANFYSIK DCCTs and the digital PSI cards, the long term stability are better than 20 ppm, with reference to nominal current.

For the dipole power supply, careful commissioning was carried out. During the commissioning, a low frequency variation on the output voltage was found. The frequency is around 5Hz, which will generate a current deviation. It was found related with the balance between the two parallel converters. By tuning of the feedback parameters on the expanded card, it was suppressed down.

Radiate and conductive emission was observed with HP-E7401A EMC Analyzer. Spectrum for conductive emission on the output magnet cable was recorded. The conductive emission comes from the switching frequency and its multiplex. The peak observed is about 50dBuV above the noise. The amplitude is not related to working current. The influence from the other power supplies is very little.

For radiate emission, 20dBV/m was found adding to the background spectrum, ranging from 100kHz to 5MHz. After 5MHz, the spectrum was not obviously observed.

OPERATION EXPERIENCE

The operation is quiet stable. Only few minor fails was met. During the operation, the stability is kept testing, together with the DC voltage and the temperature. It is proved that a line variation within 3% is invisible on the load current. But a jump of 3% will cause a transient of more than 20ppm on the load current.

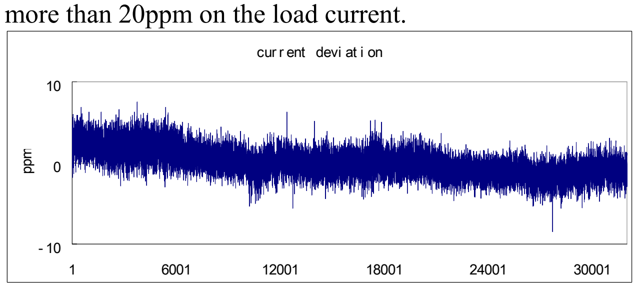

Figure 2: dipole PS 72 hour stability

Figure 2 shows the long term stability of the dipole power supply. The 72hr stability is better than 20ppm. The operation current is 548A, while the relative deviation is referenced to 800A.

CONCLUSIONS

Bridge converters are used for sextupole power supplies. Multiple bridge converters are used for the dipole power supply. Multiplexing control method is used. The equivalent switching frequency is 20kHz.

Phase-shifting transformers and diode rectifiers are used to improve the input power line characteristics.

The power supplies have been in operation for more than half a year. The performance is agreeable.

REFERENCES

[1] http://ssrf.sinap.ac.cn/english/

[2] T. J. Shen, etal. " SSRF Magnet Power Supply System", this proceedidng.

[3] F. Jenni, L. Tanner, "Digital control for highest precision Acceerator Power Supplies", PAC'01, Chicago, June 2001, p3681.