DIPOLE POWER SUPPLY FOR THE STORAGE RING OF TAIWAN PHOTON SOURCE

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Abstract

The performance of the TPS dipole power supply for the dipole magnets in the TPS storage ring is important. As the output current of the power supply follows the beam current for operation at 3 GeV, the power supply must deliver enormous energy to the dipole magnets. The target energy corresponds to 700 A at 800 V. The dipole supply for the TPS storage ring is a unipolar switching power supply, also called a bulk power supply.

The TPS dipole power supply modulates the output current regulated by the PWM signal. The switching device is an IGBT module working at frequency 2 kHz. A PID controller and a DCCT are used for feedback control of the output current. We obtained an optimal control gain with long-term stability of the output current under 10 ppm. The performance of the TPS storage ring dipole supply can thus satisfy the TPS requirement. The beam current generates 3 GeV in the TPS ring. This paper reports the excellent results.

INTRODUCTION

The NSRRC power supply group installed the dipole power supply (purchased from Eton Power Company) in the TPS storage ring. We set up all requirements for the power supply including the cooling water, controller setting, a replaced control, cabling and other engineering tasks before testing the performance of the TPS dipole power supply to ensure that it fulfilled the TPS specifications apart from acoustic noise; to solve the latter problem we installed a sound insulation room.

So that the TPS dipole power supply meets the TPS specifications including the sound noise, we measured all the noise data of the power supply to improve the target. We built step by step the installation engineering and solved the noise problem. When the TPS successfully operated at 3 GeV, the storage beam current was 520 mA. We proved that the engineering installation of the TPS dipole power supply is a success. The installation engineering is shown in this paper.

TOPOLOGY

The power supply must thus drive enormous energy into the dipole magnets. The target energy is 700 A at 800 V. The dipole supply of the TPS storage ring is a unipolar switching power supply, also called a bulk power supply. We show the basic topology and load in figure 1. The load consists of the dipole magnets and the cable. The total magnets number 48 units in the TPS storage ring. We use three cables in a parallel connection; the cross section of each cable is 325 mm^2 to connect all dipole magnets.

For circumference 518 m of the TPS storage ring and length about 600 m of the return cable, the power cable requires three cables. To calculate of current density in the cable is 0.718 amperes per mm squared. As the current density of the TPS dipole cables is less than 4 amperes per mm squared, the specification and the safety requirement are absolutely satisfied. We connected the return cables in series, and all the dipole magnets in series. The return cable can decrease the lodged inductance. The installation of the return cables is thus important in the TPS storage ring dipole system. The cable connections for the TPS storage ring diagram are shown in figure 2. The storage ring dipole power supply of TPS in NSRRC to link the power supply and magnets conforms to figure 2. The return cable is effective to decrease the lodged inductance; its function matches our expectation [1, 2].

SUBSIDIARY ENGINEERING SPECIFICATIONS

Table 1 lists the subsidiary engineering requirements of the TPS storage ring dipole power supply for its installation. We applied for a subsidiary engineering request from the Utility and Civil Group. As they built only the foundation utility, we had to build all connections to the subsidiary engineering requirements for the storage ring power supply and a spare machine in the same area.

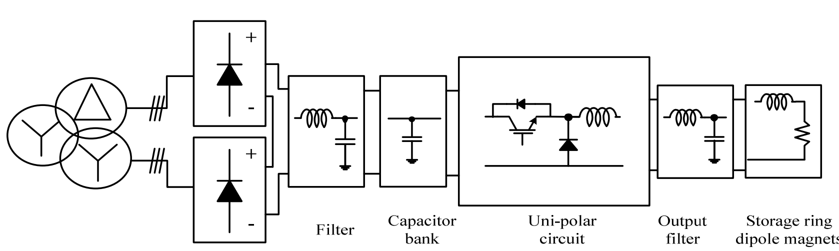

Figure 1: Topology of the TPS dipole power supply and load.

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We built also a sound insulation room, because the acoustic noise of the TPS dipole supply arising from the switching noise was 97 dB. When the building of the sound insulation room was complete, we measured that the noise was decreased to 54 dB outside. The noise outside the sound insulation room is the same as the background noise.

Table 1: Subsidiary engineering requirements for the TPS storage ring dipole power supply

Engineer Item	Name	Amount
Cooling Water	Liquid Flow Rate	7.5 GPM
	Liquid Press Drop	32 PSI
	Liquid Temp. Rise	15 °C
Input Power	Voltage	380 V_{AC}
	Amp	1100 A_{AC}
	Phase	3 phase
	Frequency	60 Hz
Output Power	Voltage	850 V_{DC}
	Amp	750 A_{DC}
	Energy	638 kW
Sound Noise	Switching Noise	97 dB
	Outside Noise	54 dB

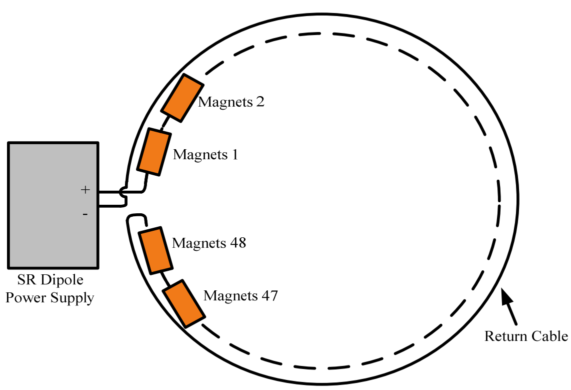

Figure 2: Diagram of TPS storage ring dipole cable connections.

POWER MODULE

The storage ring dipole supply is a forward topology; the power bus is 850 V. The switching power module thus uses an IGBT module at 1700 V and 2400 A to work in a PWM mode. As this IGBT module handle enormous power, the IGBT module switching frequency works at only 2 kHz. Although the typical IGBT module in general can work up to 20 kHz, the high-energy IGBT module of the dipole power supply cannot attain such a high working frequency. Increasing the switching frequency increases the switching loss. Table 2 shows the specifications of the IGBT module for the TPS dipole power supply.

In the future we shall add an IGBT module to the TPS dipole supply. Use of a phase-shift technology can increase the switching frequency to 4 kHz.

Table 2: IGBT module specifications

Manufacturer	Specification	Switching Frequency
Semikron	IGBT Module 1700 V/2400 A	2 kHz

CONTROLLER

The controller of the storage ring dipole power supply is for regulation and tracking; a PID controller is used for this purpose. We tune the PID parameters as a step response. We can finely adjust the PID parameters for the rise time, overshooting and settling time. The TPS storage ring power supply produced a satisfactory result when we obtained the parameters of the PID controller. An analogue PID controller implements R C components to assemble a control circuit; such an analogue controller makes it difficult to obtain a satisfactory result.

The controller works in a regulated state when the power supply runs in the DC mode. The controller can operate with analogue circuits or fully digital regulation. We use analogue circuits to implement the PID controller at present, but we intend to have a fully digital PID controller in the future. We hope that the storage ring dipole power supply can deliver improved performance when we use fully digital PID regulation [3].

LODGED CAPACITORS

How can we improve the lodged capacitors existing in the TPS storage ring? We used a LCR meter to measure the value of the lodged capacitors from the output stage to the ground line. We also used the AC source connection output line and ground line to measure the current. An increased current implies an increased lodged capacitor.

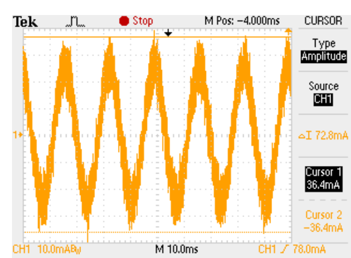

Figure 3: Using the negative output line and ground line of the AC source connection to measure the current.

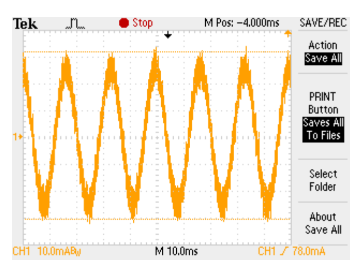

Figure 4: Using the positive output line and ground line of the AC source connection to measure the current.

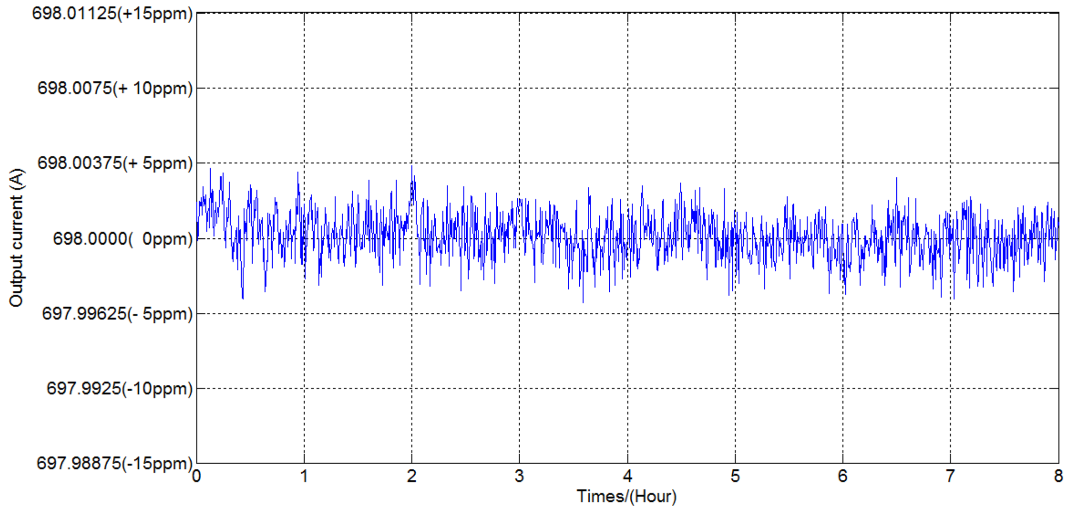

Figure 5: Long-term stability of the TPS storage ring dipole power supply output current.

Figures 3 and 4 show the lodged capacitors existing in the TPS storage ring. The AC source is set to work at 100V and 60 Hz; the peak current is 39 mA. The effect of the lodged capacitors on the performance is large for the booster ring dipole power supply. Because the topology for the booster ring dipole power supply is H-bridge, we retested the topology for the power supply. The power supply is a bulk power supply or unipolar power supply. Measurement of the common noise for the storage ring dipole power supply indicated that the lodged capacitors have no effect [4].

COMMON-MODE NOISE EFFECT

This effect is large when the lodged capacitors in the booster ring work in a ramping mode, but the effect is small for the lodged capacitors in the TPS storage ring power supply. These lodged capacitors do not produce a ripple current in the common-mode path when the storage ring is charged with only a positive voltage. The effect of the lodged capacitors on the performance of the TPS storage ring power supply is small. The dc bus of this supply is 850 V; the topology is a bulk mode as shown in figure 1. No current ripple is produced in the common-mode path. The performance of the output current is within the specifications [5].

We measured the output current for the TPS storage ring dipole power supply and magnets. The current long-term stability is an important flag. We show the long-term stability of the current in figure 5.

CONCLUSION

The TPS storage ring uses 48 dipole magnets in series connection to build the topology. We use a unipolar switching-mode power supply to charge the storage ring dipole magnets. We proved that the lodged capacitors existing in the TPS storage ring do not generate high-frequency current noise. We used a DSA (Agilent 35670A) to prove that the TPS storage ring dipole supply is not affected by common-mode noise. The TPS storage ring dipole supply thus works within specification when the power supply is in the DC current mode. The beam current allows operation to 3 GeV in the DC current mode, according to results shown in this report. The performance satisfies the demands of the TPS storage ring dipole power supply [4].

This year we shall use a fully digital PID controller in the storage ring dipole power supply. We expect that the robust performance of the storage ring dipole power supply can improve when we use a fully digital PID controller.

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