TPS MAGNET POWER SUPPLY SYSTEM

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Abstract

The Taiwan Photon Source (TPS), a third-generation synchrotron radiation light source, should be installed with 1032 sets of magnet power supplies for the storage ring and 152 sets for the injector. All of the power supplies are preferred in PWM switched mode with IGBT or MOSFET. A high precision DC power supply for 48 dipoles of the storage ring; there are 240 quadrupole magnets and 168 sextupole magnets in storage ring, the main winding of quadrupole and sextupole magnets are powered by individual power supplies. In the booster ring, one set of dynamic power supply for the dipole magnets and four sets for quadrupole magnets run at the biased 3Hz quasi sinusoidal wave. There are several hundred corrector (fast and slow) magnets and skew quadrupole magnets in storage ring and injector are powered by the same bipolar power converters.

INTRODUCTION

There are more than thousand of power supply will be installed at TPS, based on the different requirements of power supplies for different magnets and budgetary concern, all power supplies are divided into three categories. These three categories include two outside procurements and a cooperative project.

Outside procurements:

- AC and large magnet power supplies
  - A storage ring dipole magnet power supply
  - A booster ring dipole magnet power supply
  - Four booster ring quadrupole magnet power supplies
- Medium power supplies
  - 240 units of storage ring quadrupole magnet power supplies
  - 168 units of storage ring sextupole magnet power supplies
  - LTB dipole& quadrupole、BTS dipole& quadrupole and DC septum power supplies

A cooperative project with CMS, ITRI

- Corrector magnet power converters
  - Booster ring horizontal & vertical corrector
  - Trim coil of storage ring sextupole magnet(include horizontal dipole 、vertical dipole & skew quadrupole)
  - Fast feedback corrector

AC AND LARGE MAGNET POWER SUPPLIES

TPS is required to operate 24 hours per day, 7 days per week, for several successive weeks. Consideration of minimizing repair and recover time, the large and AC power supplies must be designed to maximize the use of plug-in modules, especially for regulation circuitry and power stage. These power supplies shall be switched mode with digital current and voltage regulation loop.

The following features should be designed into a modular architecture:

- A high degree of modularity is desired.
- An N+1 redundant architecture for power stage.
- An N+1 redundant architecture for chopper regulator module.
- Identification of failed modules should be accessed by the remote control system.
- 'Hot Swap' replacement of failed modules.

Storage ring dipole power supply

A single power supply will be adopted to power 48 dipole magnets connected in series, and the main specification of magnet and power supply are as follows:

Table 1: Storage Ring Dipole Magnet

Magnet designation	Dipole
No. of magnets	48
Peak current	640A
Inductance	31mH
Resistance	20.82 mΩ

Table 2: Specification of Storage Ring Dipole Power Supply

Output(A/V)	750A/850V
Short term stability(0~30min)	±5ppm /± 3.75mA
Long term stability(0~8hrs)	±10ppm /± 7.5mA
Resolution	18bits
Accuracy	±50ppm

Booster ring dipole power supply

The operating repetition rate of booster ring is 3Hz, and the power supplies will output a biased sinewave to power booster magnets to generate a field profile from injection to peak field over the beam energy range 130MeV-3.0GeV.

There are two different kinds of dipole magnet, their parameters are listed in table 3.

Table 3: Booster Ring Dipole Magnet

Magnet designation	BD	BH
No. of magnets	42	12
Peak current	1034	1034
Inductance	1.8mH	0.9mH
Resistance	8.1mΩ	5.1mΩ

A single power supply(table 4) will be adopted to power 54 dipole magnets connected in series. The current reference function generation shall include:

- Direct current setting command
- An arbitrary waveform:
  - Store the waveform with programmable current setting points (maximum is 65,000).
  - After cycling the arbitrary waveform, the output current setting of power supply shall be keep at bottom value of the arbitrary waveform.
- Direct current setting command + arbitrary waveform

Table 4: Specification of Booster Ring Dipole Power Supply

Output(ampere/voltage)	1200A/±1300V
Short term stability	±5ppm /± 6mA
Long term stability	±10ppm /± 12mA
Resolution	18bits
Accuracy	±50ppm

Booster ring quadrupole power supplies

There are two different kinds of quadrupole magnets, and these magnets are grouped into four families, table 5 is the list of these quadrupole magnets.

Table 5: Booster Ring Quadrupole Magnets

Magnet designation	QF	Q1/Q2/QM
No. of magnets	48	12/12/12
Peak current	82A	104/66/31A
Inductance	2.03mH	2.03mH
Resistance	47mΩ	47mΩ

Although there is a large difference on inductance and resistance between QF(48 magnets in series) and Q1/Q2/QM(12 magnets in series), but concerning about maintenance, power supplies with the same specification will be adopted to power these four families of quadrupole magnets, the specification is listed in table 6.

Table 6: Specification of Booster Ring Quadrupole Power Supply

Output(A/V)	120A/±425V
Short term stability	±5ppm /± 0.6mA
Long term stability	±10ppm /± 1.2mA
Resolution	18bits
Accuracy	±50ppm

MEDIUM POWER SUPPLIES

There are 240 quadrupole magnets and 168 sextupole magnets in TPS storage ring, and all these magnets are powered by individual power supply. The power supply with the same 250A/30V power rating to power all quadrupole and sextupole magnets, but quadrupole magnets shall be powered by more stable power supplies than that for storage ring sextupole magnets, so there are two different specification on the performance of output current but with the same control function. Table 7 list the main parameters of quadrupole and sextupole magnet, table 8 is the main parameters of specification of quadrupole and sextupole magnet power supplies.

Table 7: Storage Ring Quadrupole And Sextupole Magnets

Magnet	Quadrupole	Sextupole
No. of magnets	240	168
Peak current	188A	135A
Inductance	13.6/23.5mH	5.8mH
Resistance	72.2/81.6mΩ	43.8mΩ

Table 8: Specification of Quadrupole & Sextupole Magnet Power Supplies

	quadrupole	sextupole
Output(A/V)	250A/30V	250A/30V
Short term stability	±1.25 mA	±6.25 mA
Long term stability	±2.5mA	±12.5 mA
Resolution	18bits	16Bits
Accuracy	±10mA	±50 mA

These power supplies will be embedded with some special functions:

- Waveform data
  - Up to 64 k samples Post-mortem buffer shall be built inside, and this buffer must record data of output current.
  - Sampling rate must be adjustable and maximum sampling rate is 10 ks/sec.
  - External trigger (pre-post trigger mode).
- Series and parallel operation with Master/Slave control function.

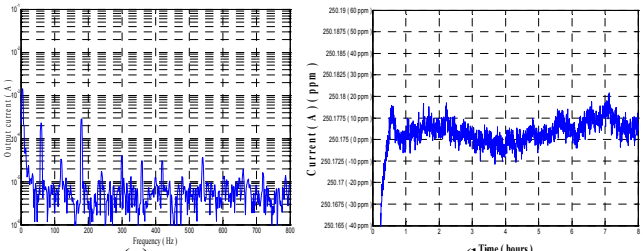
With post-mortem function, if there is a beam trip or any fault of power supply it will be much easier to identify which power supply is the causality.

With series and parallel operation, there are some magnets could be powered with sextupole power supplies such that don't need several different rating power supplies and types of power supply could be minimized that could save lots of maintenance. The magnets could be powered with sextupole power supplies are presented in Table 9.

Table 9: Magnets Powered by Sextupole Power Supplies

Magnet	Quantity of power supply
LTB dipole	2
LTB qudrupole	1
DC Septum	3
BTS dipole	3
BTS qudrupole	1

The bid of medium power supplies was held at 16th, APRIL, and CHROMA ATE INC., Taiwan won the bid. There is a standard power supply product 62075H-30[1] of CHROMA suitable to use as the sextupole magnet power supply and just need a little bit of modification. The performance of CHROMA 62075H-30 power supply is demonstrated in figure 1.



(a) (b)

Figure 1: The performance of 62075H-30 power supply
(a) Frequency spectrum (b) Stability within 8 hours

The main ripple current containment are 3Hz、60Hz and 180Hz, their magnitude are 1.2mA(4.8ppm)、0.2mA(0.8ppm) and 0.3mA(1.2ppm), 0~1kHz integral ripple magnitude is under 5mA(20ppm). The stability within 8 hours is better than 30ppm, it is obvious that the performance of CHROMA 62075H-30 power supply is better than the requirement of sextupole magnet power supply.

CORRECTOR MAGNET POWER CONVERTER

With corporation between power supply group of NSRRC and Center for Measurement Standards of Industrial Technology Research Institute (CMS, ITRI), a new high performance corrector magnet power converter is fulfilled. Figure 2 is the structure of corrector power converter.

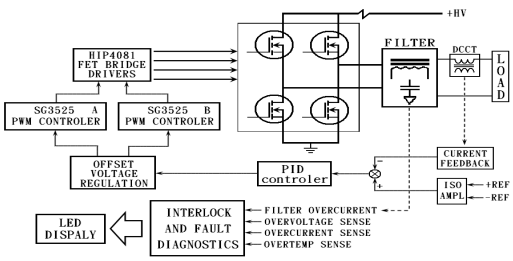


Figure 2: The structure of corrector power converter

The overall system of corrector power converter can be divided into four functional sections：Power regulation and filtering、Error amplifier / offset circuit & PWM control、Fault diagnosis / protection / monitoring and high precision current feedback circuit.

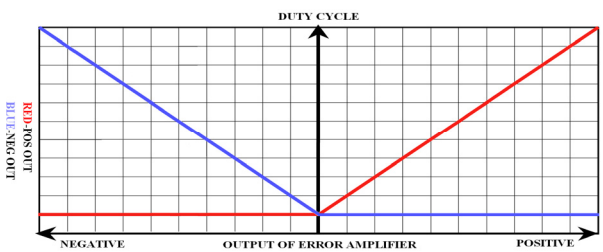
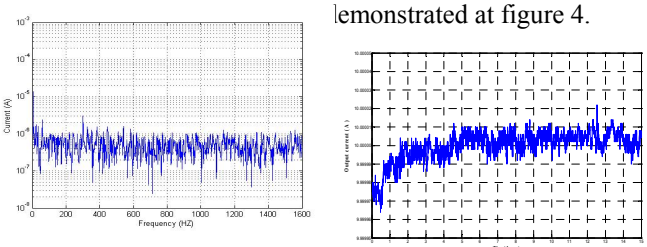


Figure 3: The relationship between the switching duty cycles and the output of error amplifier

In the power converter, PWM controllers are driven by an offset circuit, with this offset circuit the non-linear performance of PWM control IC which results in low frequency output noise when the duty cycle is close to zero is well improved. Figure 3 shows the relationship between the switching duty cycles and the output of error amplifier.

Low ripple、high stability and accuracy output current are the requirements of the corrector magnet power converter. Here we adopt the Danfysik Ultrastab 866-20I DCCT as the current feedback element. Frequency spectrum and long-term stability of corrector power converter are demonstrated at figure 4.



(a) (b)

Figure 4: Performance of corrector power converter
(a) Frequency spectrum (b) Stability within 15 hours

This corrector power converter could output current with 5ppm stability within 15 hours、20uA ripple(0~1kHz) and with suitable tuning on PI parameter of error amplifier, 1.5kHz high frequency response bandwidth is reached.

This corrector magnet power converter is versatile to meet any kind of requirements for magnets to be powered within ±10 amperes that include booster ring corrector (horizontal & vertical)、trim coil of storage ring sextupole magnet (include horizontal dipole、vertical dipole & skew quadrupole) and fast feedback corrector. By using this power converter could save a lot of work in maintenance and quantity of spare parts is minimized.

SUMMARY

The first batch of magnets will be delivered to NSRRC before JULY, after parameters of magnets are confirmed the procurement process of AC and large magnet power supplies will be held immediately.

The bid of medium power supplies was held at 16th, APRIL, and CHROMA ATE INC., Taiwan won the bid. CHROMA will design a whole new unit for quadrupole magnet power supply and the standard 62075H-30 power supply product will be modified to meet the requirement of sextupole magnet power supply.

A cooperative project with CMS, ITRI to develop the corrector magnet power converter is well done, the outsourcing contract of corrector magnet power converters to CMS, ITRI will be held soon.

REFERENCE

[1] Catalog of CHROMA power supply product