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PROGRESS ON THE CSNS POWER SUPPLY SYSTEM

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Abstract

The 1.6 GeV proton synchrotron proposed in the CSNS Project is a 25 Hz rapid-cycling synchrotron (RCS) with injection energy of 80 MeV. Beam power is aimed to 100 kW at 1.6 GeV. The power supply system consists of seven subsystems. Those power supplies have three operation modes: DC mode, AC plus DC mode and programmable pulse mode. This paper will introduce the Power Supply System status in recent years.

INTRODUCTION

The CSNS is designed to accelerate proton beam pulses to 1.6 GeV at 25 Hz repetition rate, striking a solid metal target to produce spallation neutrons. The accelerator provides a beam power of 100 kW on the target in the first phase. It will be upgraded to 500 kW beam power at the same repetition rate and same output energy in the second phase. This project has started construction in September 2011, and plans to complete the first phase in March 2018.

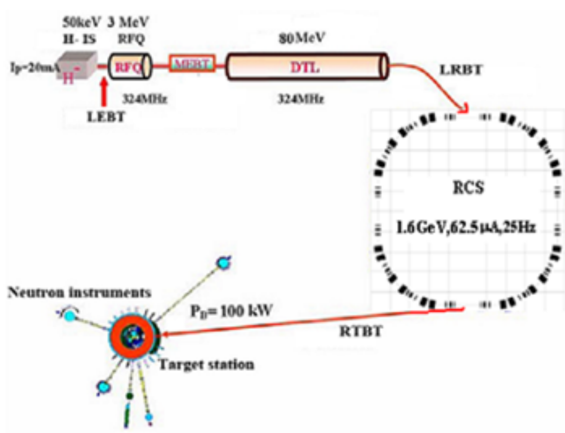

Figure 1: The structure diagram of CSNS.

Figure 1 shows the structure diagram of the CSNS. An ion source produces a peak current of 25 mA H- beam. RFQ linac bunches and accelerates it to 3 MeV. DTL linac raises the beam energy to 80 MeV. After H- beam is converted to proton beam via a stripping foil, RCS accumulates and accelerates the proton beam to 1.6 GeV before extracting it to the target. The Power Supply System consists of the LEBT, MEBT, DTL, LRBT, injection and extraction system, RCS and RTBT Power Supplies. All of them are Digital Power supply. Figure 2 shows the Digital Power Control Module (DPSCM), which is specially designed for CSNS. There is only one FPGA fulfilling the fully-digital control, and the design principle of system on a programmable chip (SOPC) has been implemented [1].

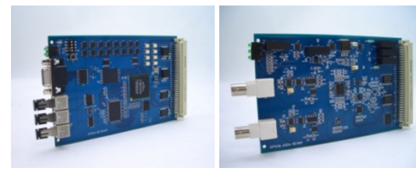

Figure 2: The DPSCM for CSNS Power Supply.

Table 1: Technical Specifications of DC PS

Number(sets)	239
Output Current(A)	10~1700
Output Voltage(V)	5~220
Output Power(Kw)	0.1~73
Stability(24 hours)	100ppm/500ppm
Ripple	≤ 0.01%

DC MAGNET POWER SUPPLY

Table 1 shows the technical specifications of CSNS DC magnet PS. Depending on the power level, this kind of PS has different topology. For the power less than 10 kW, the topology uses the DC/DC half-bridge or full-bridge switch PS; for the power less than 100 kW, the topology uses the Chopper.

In the past year, most of them have completed the production, testing and installation. Now the PS for LEBT and MEBT has worked for beam commissioning.

POWER SUPPLIES FOR RCS

In order to avoid drawing a large reactive power from the a.c. lines, the "White Circuit" type resonant network was adopted widely as the structure of the magnet power supply system of the rapid cycle synchrotron. There are two kinds of resonance configurations: the parallel resonance (PR) and the series resonance (SR) [2]. Usually, dipole magnets adopt the PR network because of the huge power variation and quadrupole magnets adopt the SR network. Considering the convenient machine repair and the controllability of magnet current, all magnets will adopt the SR network in the CSNS Project.

There are totally 24 dipole magnets and 48 quadrupole magnets, which consist of six families. Each magnet is connected in series to the others of its type, and is excited independently by the power supply system.

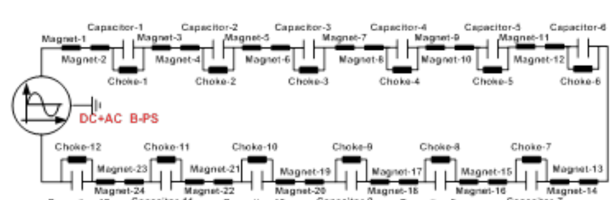

Figure 3: Resonant network of the RCS Dipole PS.

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Table 2: Parameters of RCS Power Supplies

	RCSBPS	RCSQPS1	RCSQPS2	RCSQPS3	RCSQPS4	RCSQPS5
Idc (A)	1350	900	990	900	950	910
Iac peak (A)	970	640	700	640	670	650
Output voltage (V)	6000	1000	4000	1000	1000	1000
Average Power (kW)	2400	212	1280	212	320	330
Power Module	3par.*10ser.	2par.*2ser.	2par.*8ser.	2par.*2ser.	2par.*2ser.	2par.*2ser.
Switching Freq (kHz)	2	4	2	4	4	4
Equivalent SF (kHz)	40	16	32	16	16	16

Figure 3 shows the resonant network of the RCS Dipole PS. Series magnet number is decided by the resonant mesh voltage, it needs to be less than 10 kV.

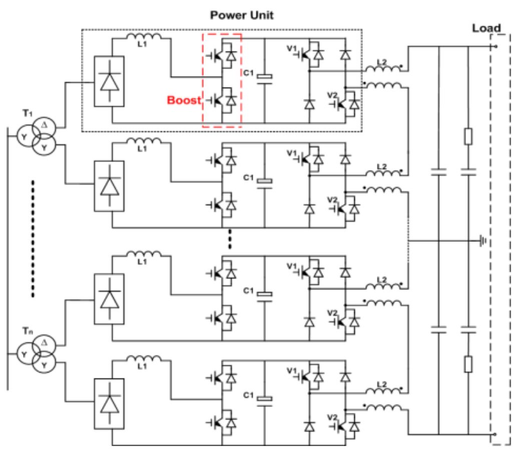

Figure 4: The topology of RCS dipole PS.

Table 3: Technical Specifications of RCS PS

DC and AC current stability	100ppm /24 h
Ripple of the DC current	≤ 100ppm
Phase stability of 25Hz current	< 0.01°/24 h
Tracking error	< 0.1%

Taking into account the maintainability of six sets power supply, those power supplies have the same structure and the different serial number. Table 2 shows the parameters of power supply. In Figure 4, the topology has three levels, first is diode rectifier, then is Boost, which is used to reduce 25 Hz power fluctuation for AC line, and the last one is H type PWM inverter. Each power cell provides peak current, and increase output voltage by serially connect. The cell number generally is even, so the grounding point can connect the symmetry. This structure will reduce the voltage to half. Table 3 shows the technical specifications of RCS PS.

The key technical of this kind of power supply is to keep the magnet field tracking error. Because of the serious magnetic saturation, the non-linearity of dynamic inductance of BM is approximately 11%, QM is about 17%. It is very difficult to control the current to be as pure sinusoidal as possible, and also cannot keep the magnet field tracking error.

Table 4: AC Magnetic Field with the High Order Harmonic Current Vector Control

	B03#	B05#	B09#	B04#	B11#
BL50/BL25	1.60E-4	1.90E-4	1.60E-4	1.60E-4	2.10E-4
BL75/BL25	7.00E-5	1.10E-4	1.00E-5	6.30E-5	1.10E-4
BL100/BL25	3.60E-5	E-5	E-5	E-5	E-5
BL125/BL25	E-5	E-5	E-5	E-5	E-5
BLtotal/B25	2.70E-4	3.00E-4	2.50E-4	4.10E-4	4.30E-4

The new control strategy has been used- the high order harmonic current vector control [3]. Based on the magnet field measurement, one with the original harmonic magnetic field of similar amplitude, phase contrast harmonic field is injected to reverse the original harmonic field, which makes the harmonic field small enough. Table 4 shows the measurement of harmonic magnet field with the high order harmonic current vector control for dipoles.

In the last year, dipole PS has completed the manufactory and testing, and now all of quadrupole PS are testing. Those PS will be installation in September and start debugging in November.

PROGRAMMABLE PULSE PS

There are 34 sets PS used for Trim-B. Table 5 shows the Technical Specifications of Trim-B PS; the output current is any programmable pulse waveform. The topology is the parallel resonant half-bridge rectifier and H type chopper, shows in Figure 5. Those power supplies will be completed the production and testing in October, installation in November.

Table 5: Technical Specifications of Trim-B PS

Number(sets)	34
Output Current(A)	±28 A
Output Peak Voltage(V)	400
Maximum di/dt	≥5.6A/mS
Tracking error:	< 3%

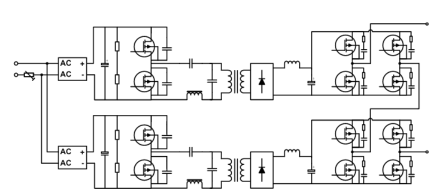
Figure 5: The topology of Trim-B PS.

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SUMMARY

All of the power supplies will be completed installation in November this year. For the RCS power supplies, need to complete the six families debugging in nine months, this is a challenging work.

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