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THE STATUS OF THE CSNS/RCS POWER SUPPLY SYSTEM

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Abstract

The 1.6GeV proton synchrotron proposed in the CSNS Project is a 25Hz rapid-cycling synchrotron (RCS) with injection energy of 80MeV. Beam power is aimed to 100kW at 1.6GeV. In this year, the neutron beam was successfully obtained for the first time. This paper will introduce the commission statues of RCS Power Supply System in the last year.

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. This project has started construction in September 2011, and the neutron beam was successfully obtained for the first time at the CSNS on 28th August last year.

POWER SUPPLY SYSTEM FOR RCS

Figure 1 shows the resonant network of the RCS Dipole Power Supply System. Because of the large reactive power from the AC lines, the "White Circuit" type resonant network was adopted widely as the structure of the magnet power supply system for the rapid cycle synchrotron. There are two kinds of resonance configurations: the parallel resonance (PR) and the series resonance (SR) [1]. In the CSNS Project, all magnets adopt the SR network. There are totally 24 dipole magnets and 48 quadrupole magnets, which consist of six families.

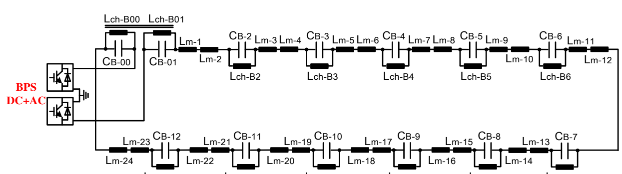

Figure 1: Resonant network of the RCS Dipole PS.

Each magnet is connected in series to the others of its type, and is excited independently by the power supply system. The series magnet number is decided by the resonant mesh voltage, it needs to be less than 10kV. Table 1 shows the parameters of RCS Power Supply System.

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Table 1: Parameters of RCS Power Supply System

/	RCSBPS	RCSQPS1	RCSQPS2
Magnet Number	24	8	16
Resonant Cell Number	12	1	4
Magnet inductance (m H)	76.4	8.13	25.50
Capacitance /cell (μ F)	1062.03	1247.53	795.2
Choke inductance /cell (m H)	76.4	65	102
DC Current (A)	1227.00	813.00	895.00
AC Current (A)	877.00	580.00	638.00
RMS Voltage/cell (kV)	8.2	4.6	8.0
/	RCSQPS3	RCSQPS4	RCSQPS5
Magnet Number	8	8	8
Resonant Cell Number	1	1	1
Magnet inductance (m H)	8.13	8.90	17.70
Capacitance /cell (μ F)	1247.5	1140.9	574.6
Choke inductance/cell (m H)	1247.5	1140.9	574.6
DC Current (A)	813.00	859.00	829.00
AC Current (A)	580.00	612.00	591.00
RMS Voltage/cell (kV)	4.6	5.4	10.0

POWER SUPPLIES

For the topology of the power supply, there are three levels power transportation, first one is diode rectifier, then is Boost, which is used to reduce 25Hz power fluctuation for AC line, and the last one is H type PWM inverter. Each power unit provides peak current, and increase output voltage by serially connect. The unit number generally is even, so the grounding point can connect the symmetry. This structure will reduce the voltage to half, shows in Figure 2. Considering the maintainability of six sets power supply, those power supplies have the same structure and the different serial number. Figure 3 shows the structure of the PS. For BPS, there are 10 power units and the output peak voltage is 6000V.

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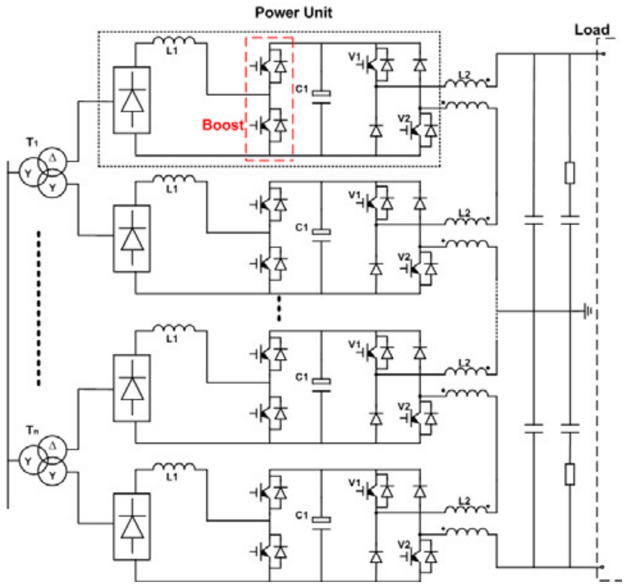

Figure 2: The topology of RCS Dipole PS.

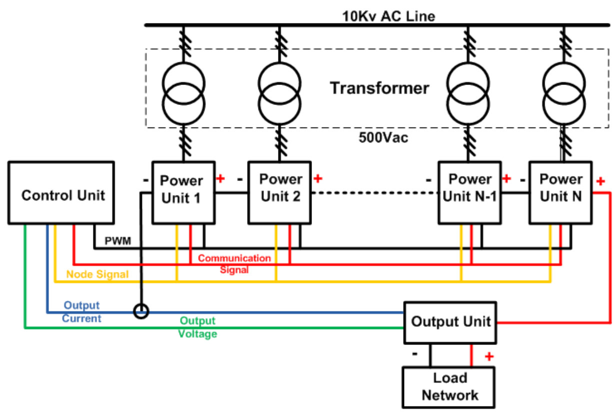

Figure 3: The Structure of the PS.

The key technical of this kind of power supply is to keep the magnet field tracking error. Because of the different magnetic saturation in dipole and quadrupole, it is very difficult to measure the magnet field tracking error online. Under the premise of ensuring the pure sine of magnetic field, the tracking error changes to amplitude stability and phase stability. Table 2 shows the technical specifications of RCS PS.

Table 2: Technical Specifications of RCS PS

Parameter	Value
DC and AC current stability	100ppm /24 h
Ripple of the DC current	≤ 100ppm
Phase stability of 25Hz current	< ±0.01°/24 h

COMMISSIONING

Since 2017, the remote debugging and the beam commissioning have started for the RCS power supply system. Table 3 and Table 4 show the test the long-term current stability of the six sets power supply.

Table 3: The Phase Error Stability in 80MeV Mode

	Output current(A)	DC Stability	AC Stability
BPS	1222.4+876.9·cos(ωt+0.23⁰)	5.62E-5	7.73E-5
QPS1	714.09+521.09·cos(ωt+0.54⁰)	4.35E-5	3.69E-5
QPS2	810.78+583.96·cos(ωt+0.34⁰)	7.53E-5	4.88E-5
QPS3	676.56+491.85·cos(ωt+0.50⁰)	4.98E-5	4.63E-5
QPS4	645.97+465.50·cos(ωt+0.45⁰)	4.33E-5	3.09E-5
QPS5	760.25+550.01·cos(ωt+0.46⁰)	4.26E-5	4.24E-5

Table 4: The Current Stability in 80MeV Mode

	Output current(A)	Phase error
BPS	1222.4+876.9·cos(ωt+0.23⁰)	<±0.008°
QPS1	714.09+521.09·cos(ωt+0.54⁰)	<±0.009°
QPS2	810.78+583.96·cos(ωt+0.34⁰)	<±0.007°
QPS3	676.56+491.85·cos(ωt+0.50⁰)	<±0.004°
QPS4	645.97+465.50·cos(ωt+0.45⁰)	<±0.005°
QPS5	760.25+550.01·cos(ωt+0.46⁰)	<±0.005°

Figure 4 shows the output current waveforms of the BPS and the QPS1, Figure 5 shows the output current waveforms, output voltage and the voltage fluctuations of the DC-Link for QPS3. All of these shows the power supplies work well [2].

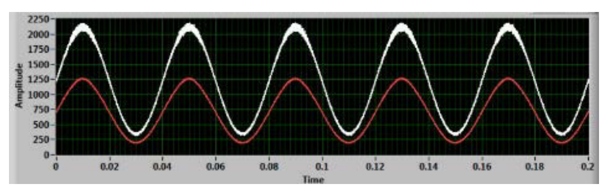

Figure 4: The output current for BPS (white) and QPS1 (red)

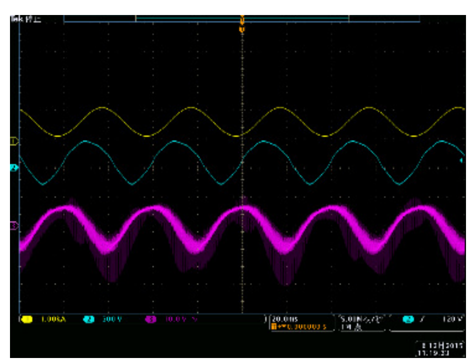
Figure 5: The output current (ch1), the output voltage (ch2) and the voltage fluctuations of the DC-Link for QPS3.

When the chokes were working, they appeared abnormal vibration phenomenon. This problem has

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troubled us for a long time. After the disassembly of the equipment in factory, it was found that the bonding between the upper iron yoke and the iron core column was not performed in accordance with the design requirement. Table 5 shows the vibration amplitude of the choke BLch-02 before repaired and after repaired. Finally, we repaired those chokes and after one year of operation, the maximum amplitude is less than 50μm.

Table 5: The Vibration Amplitude of the Choke BLch-02

	Before Repairs	**After Repairs**	
AC current	300 A	300 A	750A
station	**vibration amplitude** (μ m)	**vibration amplitude** (μ m)	**vibration amplitude** (μ m)
1	42.37	2.83	5.95
2	91.64	6.37	12.01
3	100.54	4.55	8.55
4	70.80	4.51	9.29
5	108.56	6.88	14.63
6	117.19	6.87	13.90
7	113.73	8.95	16.02
8	104.74	6.82	13.79

For the capacitor, the running temperature also is another key concern. It will change the resonant point, which will increase the output peak voltage of the power supply. We monitor the local temperature varies from 10 degree to 34 degree in one year, and the output peak voltage for BPS changes from 4.4 kV to 5.8 kV. Theoretical calculations are consistent with the actual test.

CONCLUSIONS

In one year of operation, all of this equipment of RCS power supply system has work well.

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