THE PULSED POWER SUPPLY USING IGBT TOPOLOGY FOR CSNS INJECTION SYSTEM BUMP MAGNET

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Abstract

The China Spallation Neutron Source(CSNS) Rapid Cycling Synchrotron(RCS) injection system needs two pulsed power supplies to drive eight painting bump magnets which are connected as four horizontal painting bump magnets and four vertical painting bump magnets. The pulse current of the two pulsed power supplies are respectively 13832A and 8205A in phase-I, 17856A and 10593A in phase-II. The pulse current falling edge is made to work in a controlled manner. This paper will introduce the design of the pulsed power supply and the circuit simulation results.

INTRODUCTION

CSNS accelerator system consists of two accelerators: a linear accelerator (80/130Mev Linac) and a rapid cycling synchrotron (1.6Gev RCS). The injection system in the RCS injects the negative hydrogen ion beam (H^-) coming from Linac into the RCS by the stripping method. To reduce space charge effects on the beam emittance and beam uniformity in the RCS, the injection system uses a phase space painting method to inject the beam of small emittance from the linac into the large ring acceptance. In order to do so it is required to program the pulse current falling edge of the painting bump magnets power supplies[1]. The pulse current fall is profiled in a controlled way. There are eight painting bump magnets in the injection system. Four of them are horizontal painting bump magnets in series driven by one pulsed power supply (BHPS) and the others are vertical painting bump magnets in series driven by one pulsed power supply (BVPS). CSNS project will be constructed in two phases which are phase-I and phase-II. Table 1 shows the main parameters of painting bump magnets pulse power supplies.

Table 1: main parameters of power supplies

	BHPS Phase-I	BVPS Phase-I	BHPS Phase-II	BVPS Phase-II
Frequency (Hz)	25	25	25	25
Rise time (μs)	<2000	<2000	<2000	<2000
Flat-top (μs)	50	50	50	50
Fall time (μs)	330-550 Pro.	150-400 Pro.	500-700 Pro.	250-450 Pro.
Current (A)	13832	8205	17856	10593
Inductance (μH)	6.16	8.52	6.16	8.52
Current stability	<0.5%	<0.5%	<0.5%	<0.5%
Tracking error	<2%	<2%	<2%	<2%

THE DESIGN OF POWER SUPPLY

We will use the IGBT H bridges in series and parallel to realize the high power and high frequency operation[2][3][4][5]. Figure 1 shows the painting bump magnets power supply diagram. The IGBT's operate in switch mode. The pulse current rises from zero to maximum value in 1000μs, the flat top is 50μs, and the current fall in a controlled manner within 550μs with a maximum fall rate of 260A/μs for BHPS, and 220A/μs for BVPS in phase I, the repetition frequency is 25Hz. The simulation results show that to meet a tracking error of less than 2%, a switching frequency of at least 600KHz for BHPS, and 800KHz for BVPS is required. To achieve high power high frequency switching with IGBT switches, we make four IGBT H bridges in series composing as a module to divide the voltage, fourteen modules are in parallel and each H bridge arm consists of four bridge arms to divide the current. With IGBT H bridges, 4 H bridges are phase shifted in series and 14 H bridges are phase shifted in the parallel operation mode. With this IGBT topology we are able to achieve the pulse current at 19600A (each IGBT at 350A), voltage at 4800V with IGBT rating 450A/1200V, and switching frequency at 896KHz (each IGBT at 8KHz).This design of IGBT topology can meet the power supply parameters. It is needed to average the current of each module in parallel to prevent damage of an IGBT because of the large current. The average current circuit has a feedback control loop with current sensors and PI control strategy.

The control strategy of power supply employs the magnet load current feedback control loop with P and PI. The load pulse current is compared with a reference setting waveform coming from an arbitrary function generator. The error is adjusted by P, PI and feeds to the average current loops to produce the PWM signals by comparing it with the triangular waveform to control the IGBT gates. Because the load pulse current tracks the reference setting waveform through the feedback control system of the power supply, we control the pulse current falling edge by programming the reference setting waveform.

In the phase-I, the each power supply will operate within the specification of the 80MeV injection beam, and it can be upgraded to a 130MeV injection beam in the phase II. The specifications of the power supplies for 130MeV operation are listed in table 2.

YOKOGAWA WE7000 series and PLC (program Logic Controller) will be used in the local control system of the power supplies. WE7000 system which includes a

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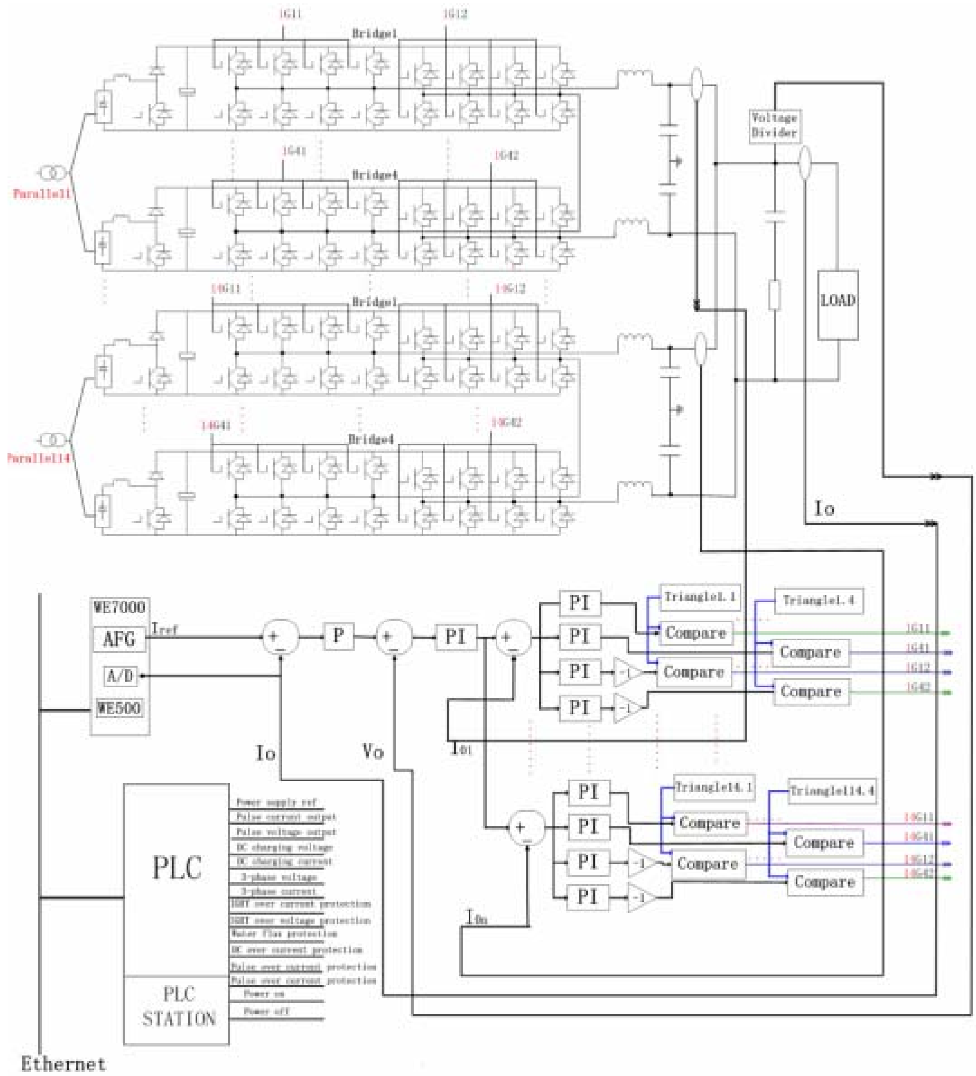

Figure1 the painting bump magnet power supply diagram

Table 2 specification of the power supply for 130 MeV operation

	Current [A]	Voltage [V]	IGBT Rating	Chopper		
				Composition	Total Number of arms	Resultant switching frequency[KHz]
BHPS	17856 (13832)	<3000	1200V 450A	4 stages 14 parallel	448	>800
BVPS	10593 (8205)	<3000	1200V 450A	4 stages 14 parallel	448	>800

10MHz arbitrary function generator module-WE7121, a 2-ch, 1MS/s digitizer module-WE7275 and a measuring station-WE500 programs the reference setting waveform and monitors the output pulse current and voltage in the control room[6][7]. The PLC is used to control and protect the power supply, and send some data, for example temperature, DC voltage and slow signals to the control room for displaying. They both can be controlled by the center control room computer through the Ethernet interface under the EPICS environment.

THE SIMULATION RESULTS

We have done the simulation of the power supply circuit with the single IGBT H bridge by MATLAB and PLECS software. Figure 2 shows the BHPS pulse current simulation waveform with 800KHz switching frequency, 1.77% tracking error and 260A/μs Max. falling rate. Figure 3 shows the BVPS pulse current simulation waveform with 800KHz switching frequency, 1.9% tracking error and 220A/μs Max. falling rate.

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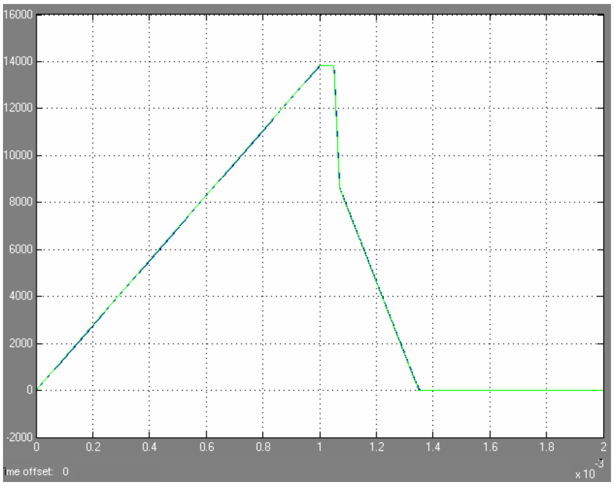

Figure 2: BHPS setting waveform and simulation waveform together

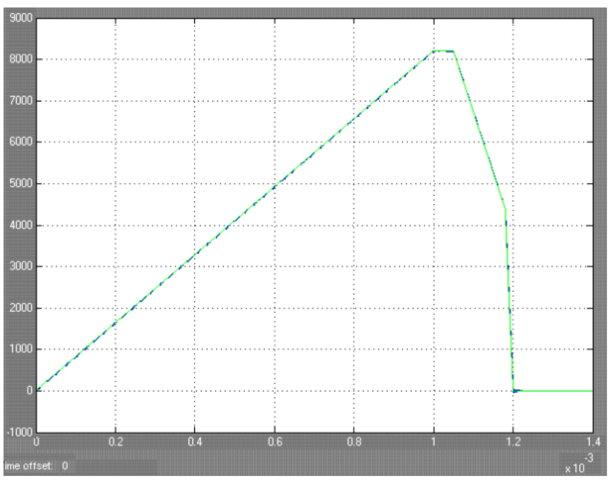

Figure 3: BVPS setting waveform and simulation waveform together

Table3 and Table 4 show the relation between the switching frequency and tracking error for BHPS and BVPS. To meet the tracking error <2% specification, the switching frequency should be >600KHz for BHPS, >800KHz for BVPS.

Table 3: the relation between the switching frequency and tracking error for BHPS

switch frequency	tracking error
400KHz	2.2%
600KHz	1.84%
800KHz	1.77%
1200KHz	1.63%
1600KHz	1.45%

Table 4: the relation between the switching frequency and tracking error for BVPS

switch frequency	tracking error
600KHz	3.0%
800KHz	1.90%
1200KHz	1.60%
1600KHz	1.46%

SUMMARY

This paper has described the design of the painting bump magnets pulse power supply for CSNS. We have done the circuit simulation with the single IGBT H bridge, and the results satisfy the specifications. High power, high frequency, fast speed response and optimal feedback control strategy are the key to the success of this power supply.

REFERENCES

[1] J.Y.Tang, Y.Chen, Y.L.Chi, W.Kang, J.B.Pang, Q.Qin, L.Shen, S.Wang (IHEP), INJECTION SYSTEM DESIGN FOR THE CSNS/RCS, EPAC2006

[2] S. Dewan (DPS), W. Eng (BNL), R. Holmes (IE), R. Lambiase (BNL), K. Rust (SNS),J. Sandberg (BNL), J. Zeng (UOT) , 1.12 MVA Peak Two Quadrant Pulse Switch Mode Power Supply for SNS Injection Bump Magnet EPAC2002

[3] S. Dewan (DPS), W. Eng (BNL), R. Holmes (IE), R. Lambiase(BNL), K.rust(SNS), J. Sandberg (BNL), J. Zeng (UOT), 1400A, +/- 900V Peak Pulse Switch Mode Power Supplies for SNS Injection Kickers , EPAC2003

[4] Yoshiro Irie (JAERI/KEK), Some Aspects of the J-PARC 3-GeV Rapid Cycling Synchrotron, October 13, 2006

[5] T. Takayana, J. Kamiya, M. Watanabe, Y. Yamazaki, Y. Irie, J. Kishiro, I. Sakai, T. Kawakubo, Design of the Injection Bump System of the 3-GEV RCS in J-PARC , IEEE 2006

[6] Sheng Peng , SNS Power Supply and Magnet Control System, 2006

[7] Johnny Tang, Experience With SNS Injection and Extraction Kicker Control Systems Using EPICS, EPICS Collaboration Meeting, June 12-16,2006

