RESONANT MAGNET POWER SUPPLY SYSTEM FOR THE RAPID CYCLE SYNCHROTRON OF CHINESE SPALLATION NEUTRON SOURCE

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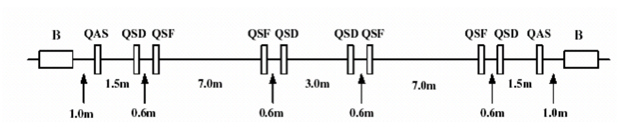
Abstract

A 1.6GeV rapid cycle synchrotron proposed in the Chinese Spallation Neutron Source (CSNS) Project is a 25Hz rapid-cycling synchrotron (RCS) with injection energy of 70MeV. Beam power is aimed to 100kW at 1.6GeV. To build such a high intensity RCS, one of the challenges is the design of its magnet power supply system. The design principle of the power supply system is described in this paper, and some considerations for close B/Q field tracking during beam acceleration period are also discussed.

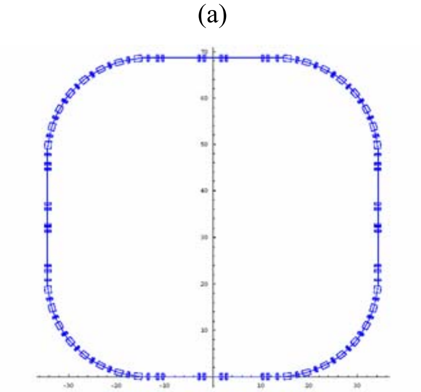
INTRODUCTION

Figure 1 shows the lattice of the 1.6GeV rapid-cycling synchrotron of CSNS, and it will be operated at repetition rate of 25Hz. The typical dipole and quadrupole magnet current waveforms (biased sinusoidal excitation) are of the form, as shown in Fig.2.

$$I_m(t) = I_{DC} - I_{AC}\cos(2\pi f_r t)(A) \tag{1}$$



(a)



(b)

Magnet	Number
Dipole (BM)	32
Quadrupole (QM)	40+28
QSF	16
QAS	8
QSD	16
QAF	16
QAD	12

(c)

Figure 1: (a) Lattice of linear section; (b) Lattice of the RCS; (c) Number of the magnets.

In a rapid-cycling synchrotron, "White Circuit" usually used as the construction of the power supply system [1]. Power source, storage-energy components, and magnets are connected to a multi-cell resonant circuit. The reactive power transforms between magnets and storage-energy components, and power source only makes up the active power. In the CSNS project, the total number of 36 dipole magnets and 64 quadrupole magnets are divided into 6 families, and each family forms an individual "White Circuit" type resonant network. In the following section, the detail design is described, and some considerations for close B/Q field tracking during beam acceleration period are also discussed.

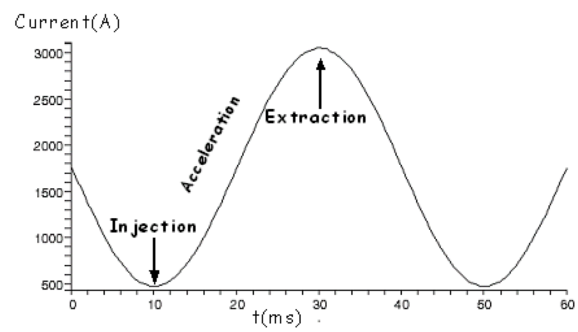


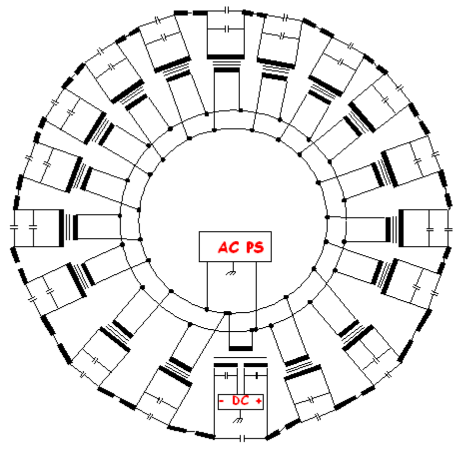
Figure 2: RCS BM current waveforms.

RESONANT NETWORKS

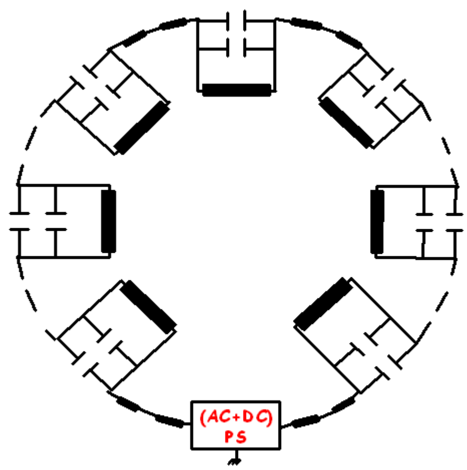
Considering a reasonable magnet AC voltage to the ground and facilitative tracking, the BM adopts parallel resonant network (PR) and the QM adopts serial resonant network (SR). Fig.3 is the illustration of magnet resonant network.

The difference between the PR and SR are the following:

- The AC current source and DC voltage source are separate in PR, and only one serial connected current source provide ac and dc in SR;
- There are distributed chokes (1 choke/mesh) in PR, and simple choke without secondary coil in SR;
- Moderate peak AC voltage in PR comparing with in the SR configuration;
- On the phase control system, the SR configuration is synchronized the BM Network resonant phase or they all follow a common clock, which depends on the power supply structure.



(a)



(b)

Figure 3: (a) BM Resonant Network; (b) QM Resonant Network.

Parameters of typical resonant networks are listed in Table 1. The choice of the mesh number depends on which voltage to ground is limited to a peak of a 10KV.

Table 1: Parameters of typical resonant networks

	BM	QAF	QAD	QAS	QSF	QSD
$I_{dc}(A)$	1766.75	846.38	673.22	255.15	627.48	583.25
$I_{ac-top}(A)$	1288.56	617.22	490.99	186.02	457.59	425.44
$L_M(mH)/cell$	33.6	98	98	98	49	73.5
$L_{ch}(mH)/cell$	33.6	98	98	98	49	73.5
$C_M(\mu F)/cell$	2412	0.827	0.827	0.827	1.654	1.103
Meshes	18	4	2	4	8	4
$P_{ac}(KW)$	7.09	14.51	9.18	1.77	10.73	9.28
$P_{dc}(KW)$	26.63	25.47	16.11	3.11	18.83	16.27
$V_{ac-peak}(V)$	6804	7044	2864	6548	4753	5670

POWER SUPPLY

There are three kinds of power supply schemes used in the RCS. An AC current source and a DC voltage source used in PR, 5 separated current sources provide ac and DC in 5 SR networks.

The DC power supply consists of two six-phase rectifier transformers with a 30° phase difference between their primaries are connected in series. In order to reduce the voltage ripple, one 12-pulse SCR rectifier with a passive low-frequency LC filter is applied. The chopper topology is typically Buck converters. A voltage loop is used to assure the accuracy of the output voltage. It needs fast respondence for dynamic load. Fig.4 shows the scheme circuit.

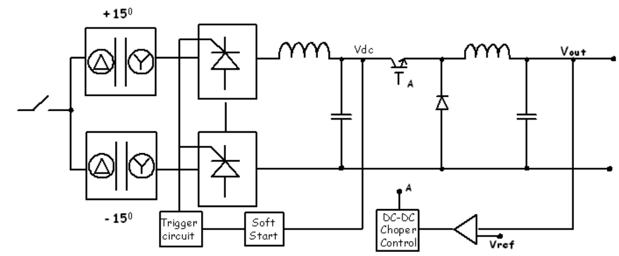


Figure 4: Simplified circuit of dc power supply.

The AC power supply used in PR network has two main functions: first one is making up the AC loss through the choke periodically; the second is realizing the synchronization. According to the output mode, the power supply structures have pulse and continuous sinuous. Fig. 5 and Fig. 6 show the power supply schemes. The main differences are this following:

- The load in the pulse power supply is free resonance. In order to avoid the phase error, the pulse current i_P needs to be synchronized with resonant voltage U_{ch} phase;
- The load in the continuous sinuous output power supply is forced resonance. It is synchronized by common clock with phase delay.

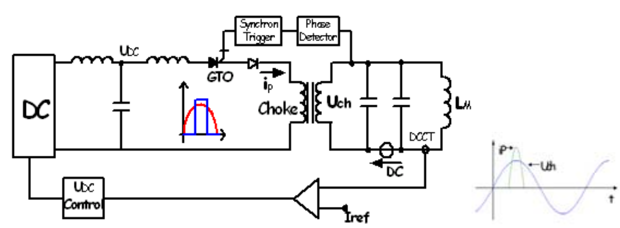


Figure 5: Single direction pulse power supply.

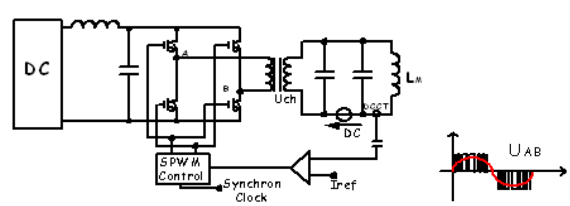


Figure 6: Continuous sinuous output power supply.

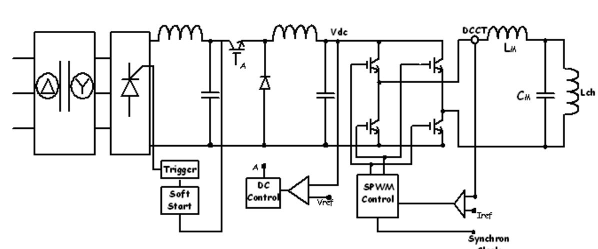


Figure 7: The scheme of ac power supply in SR network.

Fig.7 shows the ac power supply used in SR network. The power supply consists of SCR rectifier, DC-DC chopper, and H type PWM inverter. It operates with unipolar or bipolar mode, which depends on the magnet parameters.

TRACKING AND CONTROL SYSTEM

In the RCS magnet power supply system, the aim of the control system is to ensure the phase control accuracy and constant ratio in amplitude among the magnet currents (magnetic field) in 6 networks during accelerator repetition cycle.

Tasks are Current accuracy better than 0.1% and Phase error less than 10μs.

According to different power supply structure, there are different control schemes, Fig.8 and Fig.9 show the phase tracking, and Fig.10 and Fig.11 show the current regulation loops.

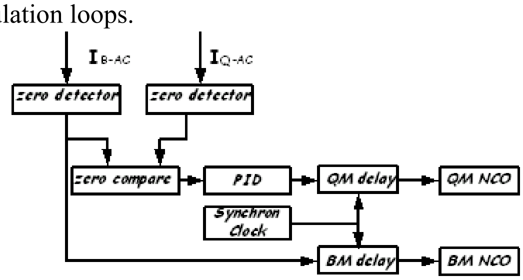


Figure 8: Phase tracking system in pulse stimulation power supply.

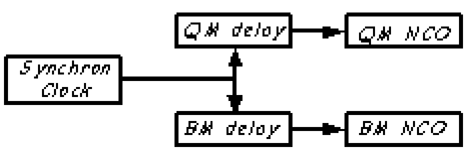


Figure 9: Phase tracking system in continuous stimulation power supply.

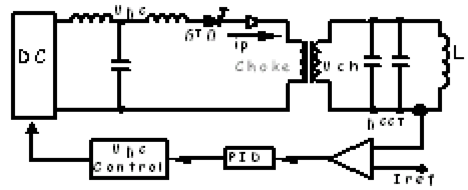


Figure 10: Pulse stimulation power supply source structure.

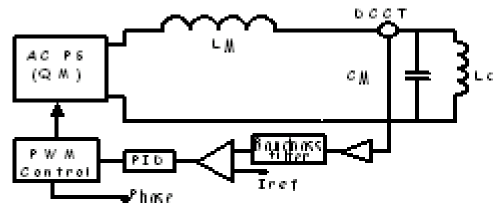


Figure 11: Continuous stimulation power supply source structure.

CONCLUSIONS

There are many technical challenges in the design of power supply structure and control system for the 1.6GeV CSNS Project. The R&D on a small experimental model, which focuses on "White Circuit" system structure and AC power supply structure, is going on.

REFERENCES

[1] White, M.G., et al., CERN-Symposium(1956), 525-529.