PROGRESS ON THE R&D OF THE CSNS 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 80MeV Linac. Beam power is aimed to 100kW at 1.6GeV. In this paper the designs of the prototype of DTL-Q power supply and the prototype of the resonant network with one mesh exciting in series will be introduced.

INTRODUCTION

In the Linac, a drift tube linac (DTL) accelerates the H-beam from 3MeV to 80MeV. Electro-magnetic quadrupole magnets form an FD lattice for beam focusing. Due to the DTL-Q magnet is located in the vacuum tank, to avoid the heat distortion, the slow pulse power supply is selected [1].

In the RCS, the "White Circuit" type resonant network is adopted widely as the structure of the magnet power supply system, in order to avoid drawing a large reactive power from the A.C. grid. There are two kinds of resonance configurations: the parallel resonance (PR) and the series resonance (SR) [2]. Considering the convenient machine repair and the controllability of magnet current, all magnets will adopt the SR network in the CSNS Project. This is a challenge for the dipole magnets power supply, which input-power is 3.5MW.

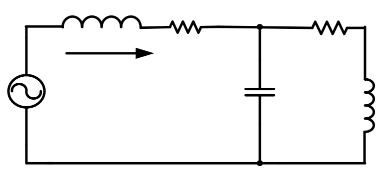

Figure 1: One mesh SR network.

One prototype of DTL-Q power supply and one prototype of one mesh resonant network are designed and manufactured. For the resonate network, it is consists of a dc-biased ac power supply, a choke and a resonant capacitor bank, which are showed in Figure 1.

DTL-Q POWER SUPPLY

A solid state pulse switch used IGBT is designed to deliver the trapezoidal shaped pulse current into the Q magnet. The energy stored in the capacitor bank, which is charged by a resonant power supply when the IGBT turned off. First the IGBT turned on as a switch, the current raise according to the time constant of the load. When the output current reached the setting current, IGBT become a linear regulator to stable the flat top of the current. After 1ms to 2ms, which can be programmed, IGBT switched off, the current flow into the free-wheel diode and fell down. The magnet specification are listed below:

- Excitation current: 600A
- Inductance of coil: 31.66μH
- Conductor area: 16 mm^2
- Resistance of coil: 9.08mΩ @80° C

The prototype has been manufactured and tested in IHEP. Figure 2 show the power supply and the output waveform at 600A. The specifications for the power supply output current are listed below:

- Repetition rate: 25Hz
- Raise and fall time: < 5ms
- Max flat top current: 600A
- Flat top current stability: < 0.1%
- Flat top time: 1ms - 2 ms programmable

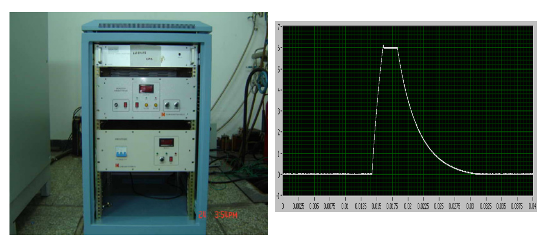

Figure 2: P.S. and current waveform.

DC-BIASED AC POWER SUPPLY

Fig 3 shows the photo of power supply, which is consist of a three-phase PWM converter and an H-Bridge inverter. The switch device is IGBT module EUPEC FZ1200R12KF4. Each bridge is combined with two units in parallel. The converter adopts Siemens Active Front End CUSA control board and voltage sensing board. In the inverter, IGBT switching frequency is 10 kHz and output frequency is 20 kHz though double-frequency control.

Major specifications of system are shown below:

- Magnet Inductance: 54.5mH
- Magnet effect dc resistance: 24mΩ
- Magnet effect eddy resistance: 12mΩ
- Choke Inductance: 54.5mH
- Choke effect dc resistance: 35mΩ
- Choke effect eddy resistance: 54mΩ

- Resonant capacitors bank: 1488.79µF
- Output current: 1260-900sin(2πft)
- Output frequency: 25Hz
- Output average power: 152 kW

Figure 3: Photo of power supply.

According to the beam dynamics, the tracking error of the magnet exciting current (magnet field) among the nine magnet families should be less than 0.1%. The specifications for the power supply output current are listed below:

- Amplitude stability ≤0. 1%
- Phase error ≤ 10µs
- Frequency stability ≤ 0.01%
- THD (Total Harmonic Distortion) ≤ 0.02%

For satisfying the tracking error, the digital control technology will be used. Figure 4 shows the schematic of digital control [3].

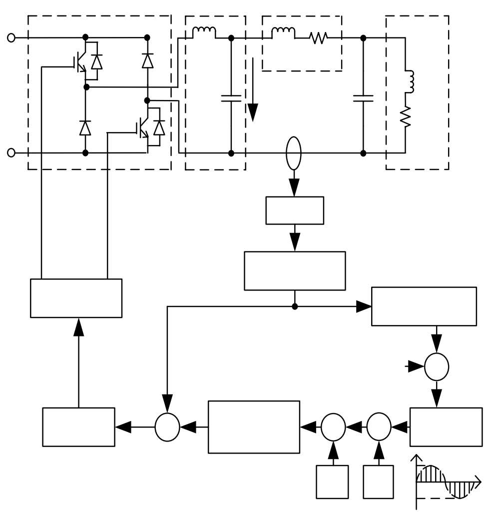

Figure 4: The DC-biased AC current regulation.

CHOKE

In the R&D, the current and inductance of the choke are matching the dipole magnet. The key technology is the nonlinearity of the inductance less than 1%, which is chiefly induced by the magnet field saturation and the construction. The core is made of TYPE 30Q130 grain-oriented steel. Corresponding the current varies from 329 A to 1961 A, the B field varies from 0.31 Tesla to 1.67 Tesla. In this region, the variation of the magnetic permeability is low, which can keep the linearity of the field.

Figure 5 shows the choke construction, multiple air-gapped is adopted. The choke is design with oil cooling tank, and the copper strip is used for the winding.

The preliminary design shows that the total weight is about 31 Tons.

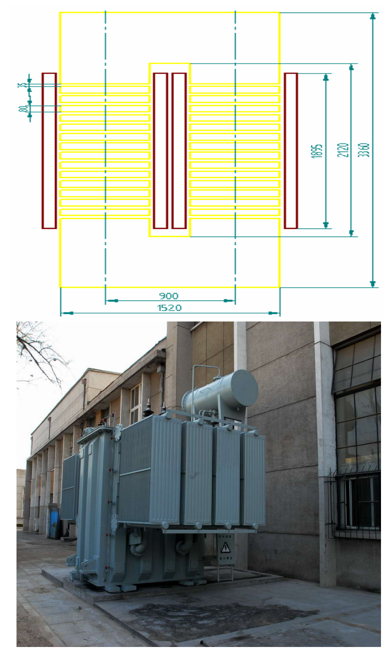

Figure 5: Choke construction.

RESONANT CAPACITOR BANK

Resonant capacitor bank adopts all-film power capacitors with very low dielectric losses and long lifetime. The manufacture techniques and the measure standard are strictly according to China standard GB/T 11024-2001 [4]. Figure 6 show the capacitor bank.

Major parameters are follows:
The rated voltage: 5.7 kV
The capacitance drift: ≤ - 0.0003/° C
The tangent of the loss angle≤0.1%

Figure 6: Capacitor bank.

SUMMARY

All of the prototypes are mounted at IHEP and tested with the prototype of the dipole, the whole system is operated in full current at last May, and preliminary test shows the design can meet the requirement. We hope the test finished at the end of this year, and another prototype for Quadrupole will be started soon.

REFERENCES

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