

## DESIGN OF BEPC-II POWER CONVERTER SYSTEM

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### Abstract

The Design of BEPC-II Magnet Power converter System and the various magnet power supplies scheme are introduced. The current Magnet Power converter System which include the dipole, quadrupole, sextupole and steering magnet power converter for the Storage Ring and transport line, will be described in same time.

### 1 INTRODUCTION

The storage ring magnet power converter is designed to meet the requirement of operating the beam stability in various modes. The power converter's specifications, which include DC stability and current ripple mainly, are based on the allowable tune shift, the closed orbit offset and operation energy stability, etc. For this purpose static converter are used to convert alternating current to direct current. And these converters (power supply) are required to provide precision DC regulation over wide range with low ripple and high stability for long term, meanwhile the power converter can be controlled by computer in the central control room.

The transport line magnet power converter is designed to meet the requirement of transporting the beam efficiency and stability to the storage ring, and suitable changing lattice for matching the performance of the beam in the storage ring. The parameters are the same as those in the storage ring.

### 2 PRESENT SITUATION OF MAGNET POWER CONVERTER FOR BEPC

The major requirements for BEPC magnet power supplies are listed in table1. Storage ring power converter are mounted at building 3#, which has water cooling system and air condition system. Transport line power converters are mounted at building 11#. The main magnet power converters are interlocked with the magnets coil temperature. All the power converters are controlled by computer from the control room.

### 3 MAGNET POWER CONVERTER FOR BEPC II

#### 3.1 Design requirement

BEPCII is an upgrade of BEPC that is a single-storage-ring collider. The arc region of BEPC and the circumference should be kept. The changes are mainly in

the injection region and the interaction region. For the new lattice requirement, the quadrupole family is changed. So more power converters are needed, and the main parameters are the same as BEPC's. And in same time superconducting magnets are used for micro- $\beta$ , so the superconducting magnets power converters are designed. The main parameters are listed in table 2. According to the requirement for BEPC II, the amount of quadrupole magnets power converter will be increased from 18 sets to 34 sets, and sextupole magnet power converter will be increased from 4 sets to 18 sets. Therefore new type power converter will be designed, which has small volume and high efficiency than SCR power converter, because there are no more space to mount so many power converter with SCR type at building 3#. In the same time we need design a new type power converter for the superconducting magnet, which has very low output voltage and high output current. It has very high reliability. For the reparability, all switch model power converter will be design in fast plug-in modules, and each module must not exceed 20 kg to permit one operator to do a fast exchange. To meet this soft switch model power converter will be used.

The main circuit of SCR type dipole magnet power converter will be kept, but the control circuit and fire system will be renovation. The transistor type dipole magnet power converter will exchange with same type as quadrupole magnet power converter.

#### 3.2 Dipole magnet power converter

SCR type dipole magnet power converters include storage ring dipole magnet power converter and transport line dipole magnet power converter (TPB and TEB). Transister type dipole magnet power converters will use switch mode(TEP17 and TPB17). The main dipole magnet power converter is still used SCR type, because the output voltage and power is high, figure1 show the block diagram of Dipole Magnet Power Converter.

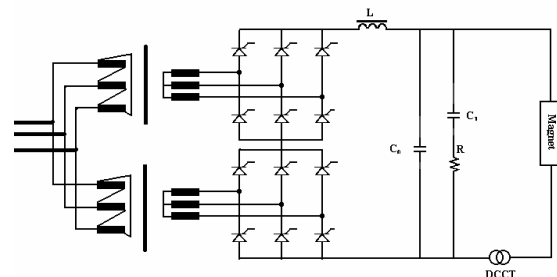


Figure 1 block diagram of Dipole Magnet Power Converter

Table 1 Magnet power converter of BEPC

	Magnet	Number of Power Converter	Type	Stability For Current	Voltage Ripple
Storage ring	Dipole	1	SCR	$\pm 1 \times 10^{-4}$	$\pm 1 \times 10^{-2}$
	Quadrupole	21	SCR	$\pm 1 \times 10^{-4}$	$\pm 1 \times 10^{-2}$
	Sextupole	4	SCR	$\pm 1 \times 10^{-4}$	$\pm 1 \times 10^{-2}$
	LMS	2	Transistor	$\pm 1 \times 10^{-4}$	$\pm 1 \times 10^{-2}$
	Corrector	60	Switch Model	$\pm 1 \times 10^{-3}$	$\pm 1 \times 10^{-2}$
Transport line	Dipole	5	SCR, Transistor	$\pm 3 \times 10^{-4}$	$\pm 1 \times 10^{-2}$
	Quadrupole	27	Switch Model	$\pm 3 \times 10^{-4}$	$\pm 1 \times 10^{-2}$
	Corrector	20	Switch Model	$\pm 1 \times 10^{-3}$	$\pm 1 \times 10^{-2}$

Table 2 Magnet power converter of BEPC II.

	Magnet	Number of Power Converter	Type	Stability For Current	Voltage Ripple
Storage Ring	Dipole	1	SCR	$\pm 1 \times 10^{-4}$	$\pm 1 \times 10^{-2}$
	Superconducting magnet	9	Switch Model		
	Quadrupole	34	Switch Model	$\pm 1 \times 10^{-4}$	$\pm 1 \times 10^{-2}$
	Sextupole	18	Switch Model	$\pm 1 \times 10^{-4}$	$\pm 1 \times 10^{-2}$
	LMS	2	Switch Model	$\pm 1 \times 10^{-4}$	$\pm 1 \times 10^{-2}$
	Corrector	60	Switch Model	$\pm 1 \times 10^{-3}$	$\pm 1 \times 10^{-2}$
Transport Line	Dipole	5	SCR Switch Model	$\pm 3 \times 10^{-4}$	$\pm 1 \times 10^{-2}$
	Quadrupole	27	Switch Model	$\pm 3 \times 10^{-4}$	$\pm 1 \times 10^{-2}$
	Corrector	20	Switch Model	$\pm 1 \times 10^{-3}$	$\pm 1 \times 10^{-2}$

It is difficult to design a switch model power converter at such high output voltage and power. So its main circuit will be kept. The interlock circuit is replaced by the PLC circuit. The fire system use numeric logic circuit to produce the fire pulse, the control loop still use two loop control system, first fast voltage loop gives a high rejection at low frequency (at 600 Hz), a high precision current loop control the output current with very high stability and resolution. The numeric logic circuit has 1024 bit resolution. This system has been used in BEPC quadrupole magnet power converter, and it works very well.

### 3.3 Normal quadrupole power converter and sextupole power converter

A full range ZVS phase shifted power converter with "poles" is designed, figure 2 show a ZVS phase shifted converter with two different pole circuits giving a rectangular waveform for one and a triangular for the other, and figure 3 show its logic control waveform.

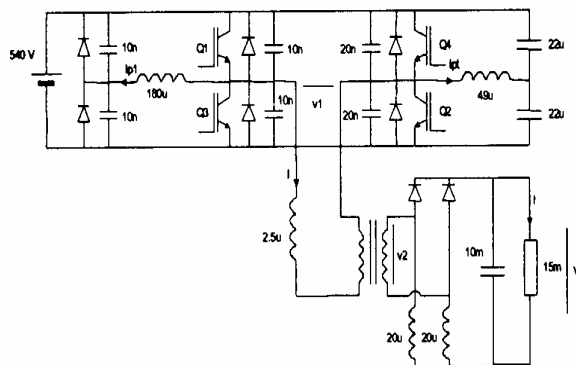


Figure 2 ZVS phase shifted converter with poles

The control of the power semiconductors are: instead of turning off the diagonally opposite switched in the bridge simultaneously as for a classical PWM, a phase shift is used between the two legs of the bridge.

This phase shift determines the output power

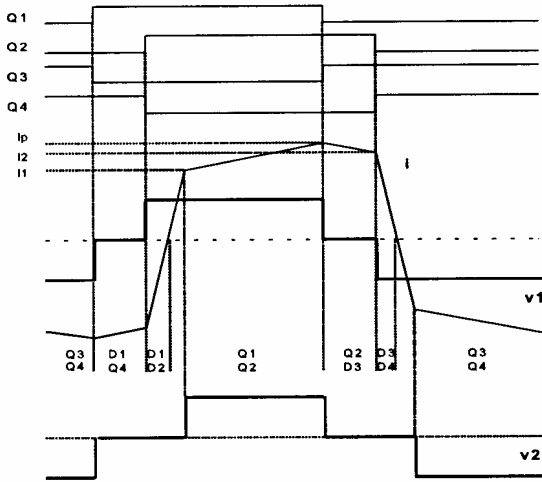


Figure 3 Phase shifted waveform

and the control is made at fixed frequency. According to figure 2 and figure 3, the set of Q1-Q3 switched is called leading-leg and the Q2-Q4 set is called lagging-leg. The ZVS conditions are obtained if the energy stored in the inductances is enough to discharge the parallel switch capacitances. For the leading-leg (Q1 or Q3 turn on), the ZVS conditions are easily fulfilled due to the high energy stored in the filter inductance  $L_f$ . Soft commutation is maintained for output current greater than 3-4 percent of the maximum current.

For the lagging-leg (Q2 or Q4 turn-on), only the energy stored in the leakage inductance  $L_{lk}$  is used. So for the lagging-leg, it is difficult to get the soft switch. To improve the above compromise and to increase the  $I_{max}/I_{min}$  range with soft-commutation, we introduce a pole network. With this, it supply an extra current to the inverter current in order to fulfill the upper equation. This extra current is handled by passive circuits (called poles) which was connected to the middle point of each leg. According to the commutation asymmetry of the two legs, the two-

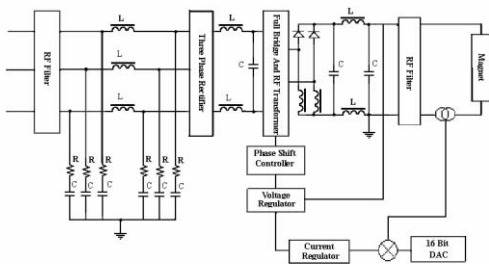


Figure 4 block diagram for the prototype

pole current can be different: a smaller current for the leading-leg than the lagging-leg at the turn-off instant. To minimize the conductive losses and to achieve fast change of the phase shift, we choose different waveform for the two poles: a rectangular waveform with low current for the leading-leg; a peak waveform with greater current for the lagging-leg. We insert HF filter at the input and output side of the power converter to suppress the HF noise. Figure 4 show the block diagram of it.

### 3.4 Superconducting magnet power converter s

The superconducting magnet (SCQ1, SCQ2) has normal quadrupole component, skew quadrupole component, banding component, and also has an anti-solenoid coil, it need 9 sets of power converter to power them, but we do not know the scale of the power converters now. The same topologic circuit that we has described before is used.

### 3.5 Corrector Power Converter

These power converters are just been renovated, it can be still used for the BEPC II Figure 5 show the block diagram for the prototype.

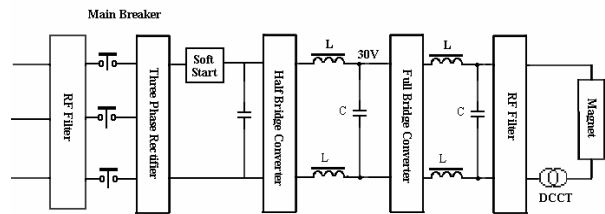


Figure 5 block diagram for the prototype

The interface will be design according to requirement of control system.

This paper is a drift of the preliminary design of BEPCII power converter system. We will discuss the issue with other experts and our colleagues working on the accelerator center of IHEP.

## REFERENCES

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