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Design and development of the power supply system for HL-2A tokamak

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Abstract

HL-2A tokamak operation needs several pulse DC power supplies with peak power of 300 MVA and the energy content of 1200 MJ per shot. To meet this requirement, three flywheel motor-generators (MG) are used, and the diode and thyristor AC/DC converters are developed to power the HL-2A toroidal and poloidal field coils. A new control system of the power supply is implemented. The power supply system is put into operation. The design and development of this power supply system are presented.

Keywords: HL-2A; Power supply

1. Introduction

The HL-2A is a divertor tokamak reconstruction with the main components of ASDEX from IPP [1]. An entirely new power supply system is required to feed its magnetic field coils and the auxiliary plasma heating systems. The power supply system consists of three flywheel motor-generators (MG), one diode rectifier, seven sets of thyristor converters and corresponding transformers. To induce the plasma current of 450 kA with a flat top of 5 s, the peak power is about 300 MW and the energy content can reach 1200 MJ per pulse. The required parameters of the power supply system for every magnet field coils are shown in Table 1.

2. Motor generator facilities

Three MG sets are used to transfer the power and energy from the main grid. There are two original identical motor generator sets from the HL-1M tokamak, each with an output power of 80 MVA, output line voltage of 2100 V and released energy of 100 MJ. These two 80 MVA sets seem to suit powering the TF coils with no need of transformers between the generators and rectifiers, because their apparent power and voltage can almost meet the requirement of TF. However, the released energy of the two existing MG sets is far

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Table 1
The requirements of the HL-2A power supply system

Coils	Power supply	DC voltage (V)	DC current (kA)	Duration (s)
Toroidal field	TFPS	3510	45	5
Ohmic heating system	OHPS(P)	1200	30	5
	OHPS(N)	−800	−30	
Vertical field	VFPS	1000	45	5
Radial field	RFPS	±100	±4	5
Multiple field	MPFPS	600	45	5
		200	15	5
		100	3	5
		100	3	5

from being enough. In order to solve this problem and reduce cost, the two MG sets have to be modified. The modification has been done as follows:

(1) Replacing the original flywheel of 42 t with a new one of 90 t, and thus the total GD^2 of the shaft system is increased from 107 t m^2 to 280 t m^2.
(2) Raising the Maximum rotating speed of the MG shaft up to 1650 rpm from 1500 rpm by adding a variable frequency regulating speed device to the motor.
(3) Boosting the line output voltage of generator up to 2600 V, and extending the MG shaft speed drop span up to 425 rpm (1650–1200 rpm) instead of 128 rpm (1488–1320 rpm).

The modifications of the two MG sets will be finished in 2005. After modification, the maximum apparent power for each generator will be increased to 90 MVA from 80 MVA and released energy will be raised to 500 MJ from 100 MJ.

Another MG set (3# MG set) with an output power of 125 MVA [2] is used to power all the poloidal fields coils and auxiliary heating systems. The rated frequency range of its generator is from 120 Hz to 98 Hz. The high frequency can greatly reduce the ripple, inherent regulation dead-zone time of the rectifier's output, and consequently speed up the response speed of PFPS system. To make full use of its rated power, released energy and frequency, a variable frequency regulating speed device will also be adopted.

3. Toroidal field power supply

The two modified MG are used to power the toroidal field coils via a 12-pulse diode rectifier consisting of four identical three-phase bridges, which are connected in parallel configuration (Fig. 1). As the time constant of the TF coils is about 3.8 s, the control of TF current can be realized by properly regulating of the exciting currents of the two generator sets. A problem, which should be considered, is how to make the two generator's output voltages always almost even. The simple way is to connect the exciting field windings of the two generators in series.

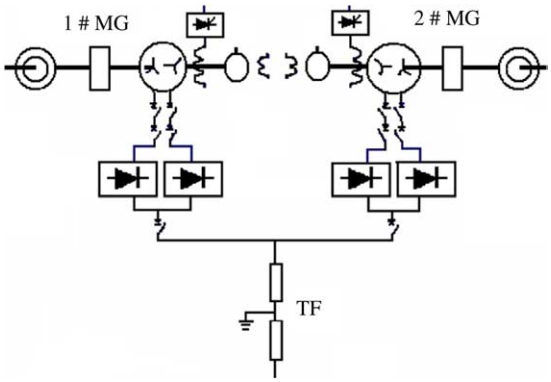

Fig. 1. Schematic of the toroidal field power supply.

4. Poloidal filed power supply

The aim of PF is to produce plasma current, control the plasma positions and shapes [3]. The PF coils are fed from the 125 MVA MG set with transformers and thyristor rectifiers. As the generator has two output buses with a mutual phase shift of 30°, all the transformers and thyristor rectifiers are designed in pairs and are connected to each output bus of the generator, respectively. The currents of all the PF coils are