Power Supplies for Lattice Magnets of the SPring-8 Synchrotron

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Abstract

Manufacture of power supplies for lattice magnets of the SPring-8 synchrotron. We confirmed that out put current of the power supplies agreed with reference current with 10-4 accuracy using real load. In the synchrotron commissioning, it was certified that stability, reappearance and tracking performance were satisfied with the specifications because electron beam from the SPring-8 linac was extracted to SSBT transport line without beam loss at energy ramping section.

1. Introduction

The synchrotron has a circumference of 396.124 m with a FODO lattice of 40 unit cells. The synchrotron contains 64 dipole, 80 quadrupole (focus 40, defocus 40) and 60 sextupole (focus 30, defocus 30) magnets. It is required to accelerate the electron or positron beam from the SPring-8 linac of 1 GeV upto the full energy of the storage ring of 8 GeV. The repetition time is 1 sec.

Five power supplies were manufactured for above mentioned five types magnets. Excitation pattern are shown in Fig.1. The pattern is designed to be a trapezoid one, and the lower constant excitation of the magnetic field (call flat-bottom) is corresponding to 1 GeV and upper one (call flat-top) is corresponding to 8 GeV. Each period of the flat-bottom and flat-top is 150 msec, and the ramping and falling times are 400 msec and 300 msec, respectively. Smoothing patterns (50 msec) were inserted between any two sections in consideration of tracking ability of power supplies.

Performance tests with dummy load have been finished.[1]

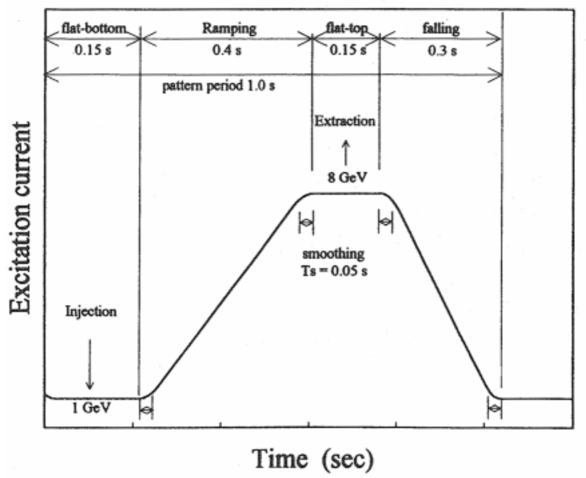

Fig.1 Excitation current pattern of lattice magnets

2. Performance tests of power supplies

The power supplies were manufactured following 5 types, for bending magnets (PS-BM), for focusing and defocusing quadrupole magnets (PS-QF,-QD) and for focusing and defocusing sextupole magnets (PS-SF,-SD). These power supplies are designed the tracking reappearance of 1 x 10-4 to obtain a stable beam. Block diagram of the PS-BM is shown in Fig.2.

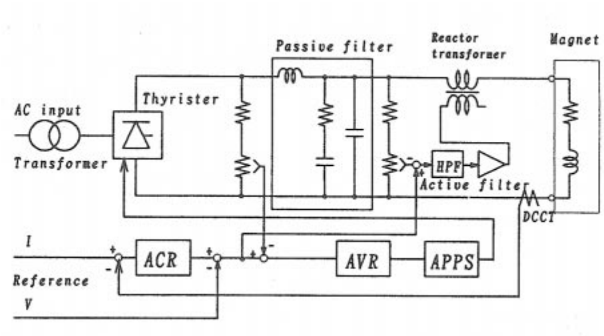

Fig.2 Block diagram of PS-BM. ACR and AVR : Automatic Current and Voltage Regulator, APPS : Automatic Pulse Phase Shifter, HPF : High Pass Filter.

Thyrister converter method with a active filter was selected. Voltage ripple which is produced in the thyrister converter is suppressed by the passive and active filters. The active filter excites inverse voltage of the ripple voltage of the passive filter. Current regulation is realized with a proportional-integral regulation and the voltage signal of the regulation is taken in the feedback circuit directly without some filter to keep the high responsibility of the regulation circuit. Reference current and voltage are sent from synchrotron calculator through VME boards.

Flat-bottom and flat-top currents are shown in Table 1. These currents were decided based on the field measurement of magnets. To keep beam stability, it is necessary to reduce change of the out put current and current ripple about 10-4 as against set up current based on the beam simulation. Specification of the current stability, ripple and reappearance at flat sections and the current deviation at ramping section were shown in Table 1.

Table 1 Set up current and required accuracy

	PS-BM	PS-QF	PS-QD	PS-SF	PS-SD
Current					
Flat-bottom	176.41	57.59	49.20	17.00	19.00
Flat-top	1430.30	468.32	400.10	136.00	152.00
Maximum	1500	535	535	400	400
Precision ($x10^{-4}$)					
Flat-bottom					
stability	2	2	2	4	4
ripple	2	2	2	3	3
Flat-top					
stability	1	1	1	2	2
ripple	1	1	1	1.5	1.5
reappearance	1	1	1	2	2
Ramping part					
deviation	<10	<10	<10	<10	<10

2.1 Stability

To observe the stability of the out put current, all power supplies were operated with direct current during five hours at 12.5 and 60 % as against maximum currents. The change of the out put currents as against set up currents were shown in Table 2. It was confirmed that the current stability of all power supplies were less than 10^{-4}.

2.2 Ripple

Out put voltage ripple were measured at flat sections in pattern-operation. Frequency analysis of the voltage was performed from fundamental of 60 Hz to 20 th high frequency. Based on this result, the voltage ripples were transformed the current one each frequency components assuming that load inductances were L=432mH (PS-BM), 277mH (PS-QF,-QD) and 33mH (PS-SF,-SD). The ripple at flat-bottom and flat-top were normalized by these set up currents. Maximum current ripple among all frequency components were shown in Table 2. It was confirmed that the ripples of all power supplies was satisfied with specification.

Table 2 Current stability and ripple of power supply

Power supply	Stability		Maximum ripple*	
	12.5%	60.0%	flat-bottom	flat-top
PS-BM	$3.8x10^{-5}$	$8.0x10^{-6}$	$8.2x10^{-5}$	$2.6x10^{-5}$
PS-QF	$2.1x10^{-5}$	$9.3x10^{-6}$	$1.6x10^{-4}$	$5.4x10^{-5}$
PS-QD	$1.8x10^{-5}$	$6.3x10^{-6}$	$4.1x10^{-4}$	$1.2x10^{-4}$
PS-SF	$1.0x10^{-5}$	$2.0x10^{-5}$	$2.3x10^{-4}$	$4.6x10^{-5}$
PS-SD	$1.0x10^{-5}$	$1.0x10^{-5}$	$1.9x10^{-4}$	$4.2x10^{-5}$

* The current ripple were maximum at 60 Hz. However, the ripple at 120 Hz was maximum for PS-BM flat-bottom.

2.3 Current deviation and reappearance

The out put current is lagged the reference one in the ramping section. Therefore, the current deviation was defined as,

$$I_d = \frac{I_{ref} - I_{out}}{I_{FT}}$$

where I_{ref} and I_{out} are reference and out put current, respectively and IFT is flat-top current. The deviations of all power supplies were measured in the pattern-operation (Fig.3). In all power supplies, the deviation was maximum at smoothing section between the ramping and flat-top sections. However, it was confirmed that the deviations were less than $2x10^{-4}$. Consequently, it was became clear that the reciprocal current deviation among all power supplies (tracking error) less than $2x10^{-4}$.

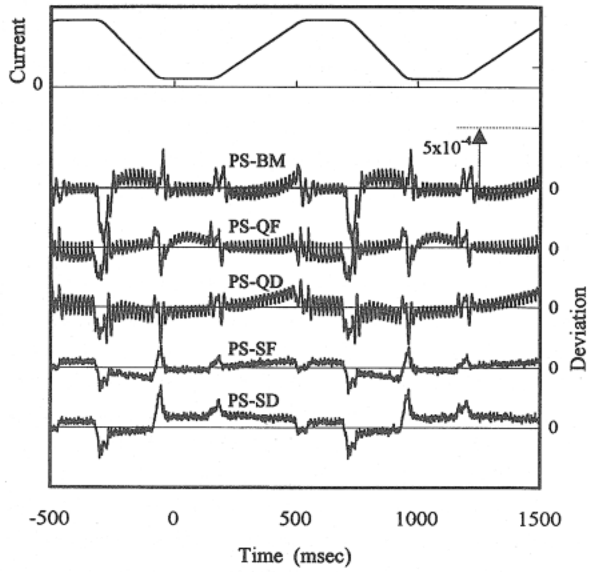

Fig.3 Current pattern and deviation of all power supplies; uppermost figure shows the output current pattern. Lower 5 figures show the deviation between the reference pattern and the output current for PS-BM, -QF, -QD, -SF, -SD.

To observe the current reappearance of flat-top current, the deviation was measured ten times at five-minutes intervals. The reappearance was estimated using the change of the deviation in this period. It was confirmed that the reappearance of all power supplies were less than 2x10-5 as against the flat-top current.

4. Conclusion

The power supplies for magnets were completed with < 10^{-4} accuracy of output current. From now on, to reduce the current deviation at smoothing section, we intend that the reference currents for all power supplies are lagged independently to improve the tracking ability.

Reference

[1] K.Fukami et al; SPring-8 Annual Report 1995, p.101