MAGNETS AND THEIR POWER SUPPLIES OF JHF 50-GEV SYNCHROTRON

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Abstract

The JHF 50-GeV Synchrotron [1], high intensity proton synchrotron, consists of 96 bending magnets, 176 quadrupole magnets and 48 sextupole magnets. The design study of the magnets is now in progress. Also, the conceptual design study of the power supply system has been started. The bending magnet is of a modified window frame type, 6.2 m in length and 1.8 T in magnetic field in peak. Field gradient of the quadrupole magnet is 20 T/m in peak and the bore radius is 66 mm. The total active power of bending and quadrupole magnets is estimated to be 80 MW in peak.

Recent results of the design studies of magnets and power supply system are described in this paper.

1 MAGNET DESIGN

The JHF 50-GeV synchrotron ring consists of 96 bending magnets, 176 quadrupole magnets and 48 sextupole magnets. Main parameters for magnet design of the bending and quadrupole magnets are summarized in Table 1. Based on these requirements, the bending magnet and the quadrupole magnet have been designed.

Table 1. Main Parameters for Design of 50 GeV Synchrotron Magnets

Injection	3 GeV
Maximum	50 GeV
Circumference	1442 m
Repetition Rate	0.29 Hz (~3 Hz in future)
Bending Magnet	
Magnetic Rigidity	12.76 - 170 Tm
Field	0.135 T (for 3 GeV)
	1.8 T (for 50 GeV)
Length	6.2 m
Number	96
Quadrupole Magnet	
Max. Field Gradient	20 T/m
Length	1.5 - 2 m
Total Number (8 families)	176
Magnet Aperture (full width)	
B-Magnet	106 mm^h
	(x 106^W for useful)
Q-Magnet	132 mm^ϕ

1.1 Bending Magnet

Figure 1 shows a cross sectional view of the bending magnet. The side slopes of the pole are determined carefully to avoid partial magnetic saturation in the pole. In order to reduce a magnet size and an excitation power requirement, the bending magnet is designed as to be of a sector type one.

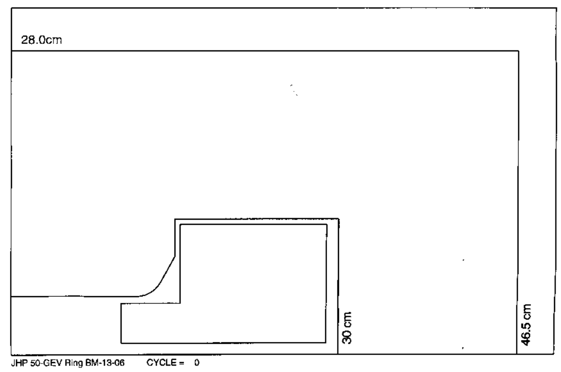

Fig. 1. Cross sectional view of the bending magnet

Figure 2 shows field distributions at the field level of 0.135, 0.5, 1.0, 1.5 and 1.8 T calculated with the program code of Poisson. Vertical beam sizes in the bending magnet at the energy of 3 GeV and 50 GeV is estimated to be about 50 mm and 18 mm in half, respectively. In these regions, the field distortion is suppressed to the level of +- 0.02 % or less as be seen in the figure. The main parameters of the bending magnet are listed in Table 2.

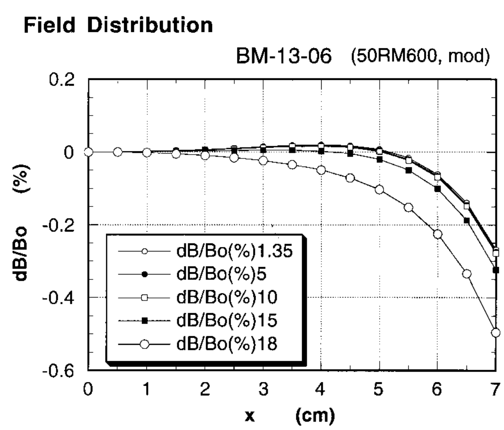

Fig. 2. Field distributions of the bending magnet

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Table 2. Main Parameters of Bending Magnet

Magnet Size	
Length	6.2 m
Width (iron yoke)	93 cm
Height (iron yoke)	56 cm
Coil	17 turns x 2
Weight	25 ton
Excitation Current	
Injection (3 GeV)	336 A
Maximum (50 GeV)	4978 A
Power	
Active Peak Power	54.0 MW
Dissipation Power	12.0 MW
Cooling Water	8.5 ton/min.

1.2 Quadrupole Magnet

Figure 3 shows a cross sectional view of the quadrupole magnet and figure 4 shows a distributions of calculated field gradient at the excitation level of 0.15, 1.0, 1.5, 1.8 and 2.0 T/m. Some quadrupole magnets in the section of a slow extraction straight are designed separately, because the extraction orbit will be sfifted from the center and beams go through the region of coil and/or return yoke of the normal design.

The main parameters of normal bending magnet are listed in Table 3.

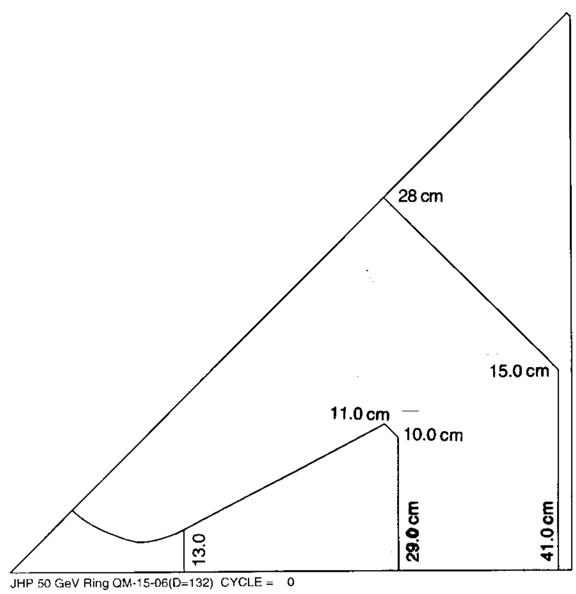

Fig. 3. Cross sectional view of the quadrupole magnet

Table 3. Main Parameters of Quadrupole Magnet

Magnet Size	
Length	1.5 and 2.0 m
Width (iron yoke)	82 cm
Height (iron yoke)	82 cm
Weight	6.7 ton
Excitation Current	
Injection (3 GeV)	2630 AT
Maximum (50 GeV)	48430 AT
Power	
Active Peak Power	24.0 MW
Dissipation Power	7.0 MW
Cooling Water	5.0 ton/min.

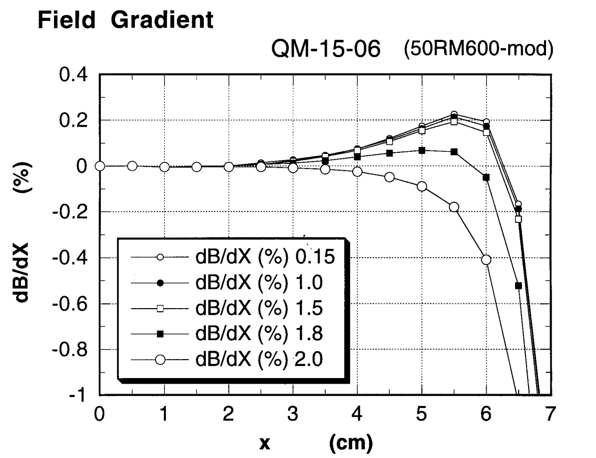

Fig. 4. Distributions of field gradient view of the quadrupole magnet

2 POWER SUPPLIES

Figure 5 shows an example of an excitation pattern of the bending magnet operated up to the peak energy of 50 GeV.

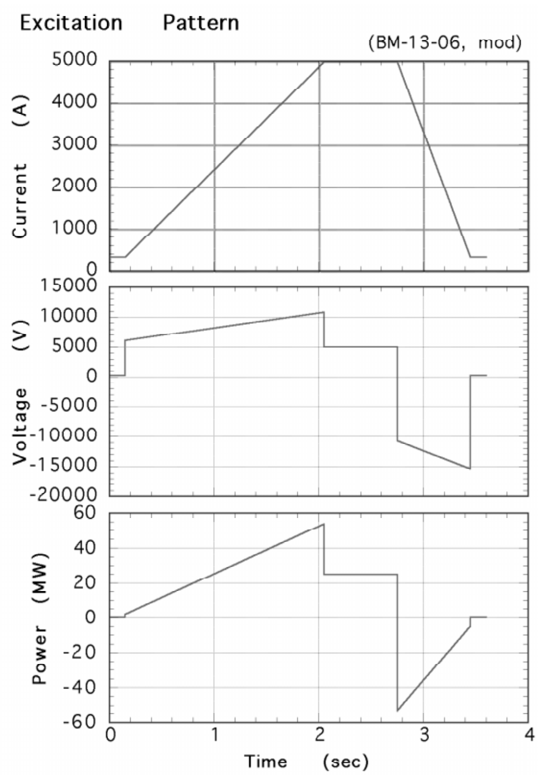

Fig. 5. An example of an excitation pattern of the bending magnet

As seen in Tables 2 and 3, the total peak active-power becomes about 80 MW. In a case of a power supply like this, a SCR system is generally used to convert electric power from AC to DC and to generate trapezoidal wave form current. However, as well known, it makes very large reactive peak power and significant higher-order AC current, and as a result, it gives rise to a problem of serious voltage fluctuation in an external AC line. In our case, a voltage fluctuation has been estimated to become about 8 - 10 %, which exceeds an allowable level. Therefore, in order to connect a power supply with a large SCR system to an external AC line directly, a very large reactive power compensator and many filters to reduce higher-order current components in the AC line are required inevitably.

On the other hand, the 50 GeV synchrotron is to be constructed in the KEK campus in which there exist some big accelerators, namely the 2.5 GeV electron linac, the PF ring and, in near future, KEK-B. From this circumstances, it is strongly expected to smooth the variation of active power itself as long as possible.

To resolve these difficulties, a power supply system shown in the figure 6 is investigated optionally as a power supply for the bending magnet of the JHF 50-GeV synchrotron ring. By using a rotating machine between an external AC line and a SCR system, problems of the very large reactive power and higher order AC current in the AC line are removed perfectly and, furthermore, the variation of active power is smoothed significantly.

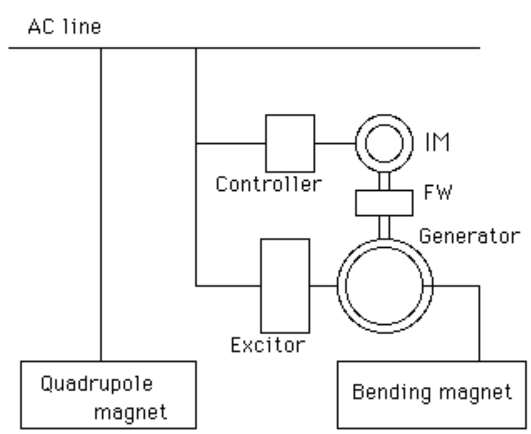

Fig. 6. One idea of a power supply system for the bending magnet

The principal parameters of the rotating machine are listed in Table 4.

Table 4. Principal Parameters of Rotating Machine

Induction Motor	
Input Power	17 MW
Voltage	6.6 kV
Generator	
Output Power	70 MVA
Voltage	6.6 kV
Rotating Frequency	600 Hz +- 5 %
Total Weight	200 ton

On the other hand, for the quadrupole magnet, it is studied to use IGBT (Insulated Gate Bipolar Transistor) as an element of power convertor from AC to DC of a power supply and connect it to the external AC line directly. By using IGBT, it becomes possible to construct a power supply which generate no reactive power in spite of forming a trapezoidal wave-form current. If using a SCR for this case, a reactive peak power is estimated to become about 20 Mvar with corresponding to the active peak power of 24 MW (total of 8 families, see Tables 1 and 3).

Eight power supplies using IGBT will be installed because the 176 quadrupole magnets are divided into 8 groups (families). In which, the largest power rate of active peak power is about 5 MW.

By employing a rotating machine and IGBT power supplies, the voltage fluctuation of the external AC line is finally expected to be suppressed to the level of about 1 %.

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REFERENCES

[1] to be reported elsewhere in this conference.