ILSF BOOSTER MAGNETS FOR THE HIGH FIELD LATTICE

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Abstract

Iranian light source facility is a 3 GeV storage ring. There are currently two choices for the lattice; high field and low field lattices. In this paper magnet design of the high field booster ring is discussed. High field booster ring is supposed to work at injection energy of 150KeV and guide the electrons to the ring energy 3GeV. It consists of 48 combined bending magnets in 1 type and 92 quadrupole in 6 families. Using two dimensional codes POISSON[1] and FEMM[2], a pole and yoke geometry was designed, also cooling and electrical calculations have been done and mechanical drawings were sketched.

INTRODUCTION

The Booster is supposed to work at injection energy of 150Kev and lead the electrons to the ring energy E=3 Gev. It consists of 48 combined bending magnets in 1 type and 92 quadrupoles in 6 families. The dipoles are planned to be run in series with a common power supply while for the quadrupoles, within each family the magnets will be connected in series.

The Booster magnets are designed so that combined magnets are used. The bending magnets are to provide the guiding field as well as correcting chromaticity aberrations while quadrupoles are for focusing/defocusing purpose and also have an integrated sextupoles component.

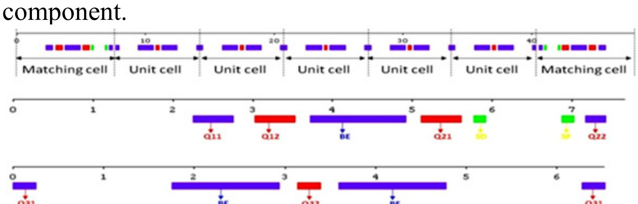

Figure 1: Arrangement of magnets in one superperiod (top), the matching cell (center), and the unit cell of the booster (bottom).

Importance of choosing material is related to the effect of permeability on the saturation and type of use. Iron with high purity shouldn't be used in the booster ring, where we have AC currents, due to being a good electrical conductor. The alternating current results in alternating flux which induces an emf in the core and if the core is a conductor, this emf will cause eddy currents. Eddy currents are objectionable, not only because they decrease the flux, but also because they produce heat and a power loss proportional to i^2R, where i is the eddy current and R is the resistance of its path.

To avoid eddy currents, one should use Silicon-steel 3% with lower electrical conducting instead of carbon silicon steels. Therefore in order to lessen the eddy currents and also keeping the magnetic properties identical along the magnet length, yoke is considered to be a collection of electrical steel $M270-50A$ laminations, with nominal thickness of 0.5mm, instead of an integrated volume.

This electrical steel is one of the main silicon steels, that is coated on both sides with an insulating coating.

DESIGN OF HIGH FIELDBOOSTER MAGNETS

Dipoles

ILSF Booster dipole is combined H-type bending magnet having a weak sextupole component with parallel-ends and a curved yoke; also the yoke can be opened from the middle to facilitate the vacuum chamber placement. Bending magnets are of 1 type BE, in both matching cells and unit cells. The specifications of bending magnets are given in Table 1.

Table 1: ILSF Dipole Parameters

Parameter	unit	Inj/ext
QTY	-	48
Bending radius	m	9.09
Deflecting angle	Deg.	7.50
Field	T	1.1/0.05
Sextupole component	T/m^2	16.03/0.76
Total gap	mm	22.6
Magnetic length	m	1.2
Good field region	mm	±10
Number of turns per coil	-	20
Conductor cross section	mm^2	12 x 12
Cooling channel diameter	mm	4
total A-turns	At	10480
Current	A	524
Current density	A/mm^2	3.99
Resistance of magnet	mΩ	17.80
Power consumption	kW	4.94
Number of cooling circuits	-	4
ΔT	deg	8
Water flow per circuit	l/min	1.46
Pressure drop	bar	3.20
Reynolds NO.	-	2931

A broad low shim was used for magnet to reach the desired field quality within the good-field region and reduce the residual higher-order field components. Designed pole profile including shims and optimized dimensions are demonstrated in Figure 2.

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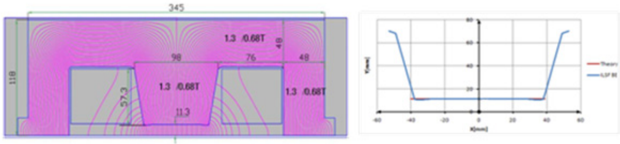

a) b)

Figure 2: a) General dimensions. b) Pole profiles.

Field tolerances of $B(0) + 0.5B''x^2$ is less than 1×10^{-4} within the good field region ±10 (Figure 3). Absolute values of relative multipole components at normalization radius of 10 mm are brought in Figure 4 where B_0 is the sum of both dipolar and sextupolar fields. The calculations have been done with Poisson.

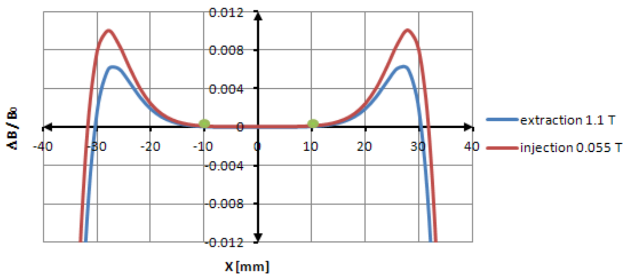

Figure 3: ILSF dipole field tolerances, red line is for injection at 0.055T and , blue line indicates extraction field tolerances at 1.1T .

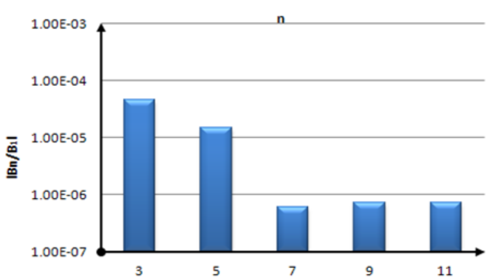

Figure 4: Absolute normalized multipoles' error at radius of 10 mm good field region.

Quadrupoles

ILSF lattice has 92 quadrupoles which 36 of them are normal quadrupoles and others will have an inserted sextupole component. They are in 2 different lengths of 500 and 250 mm. The general layouts of the quadrupoles are the same but with different pole profiles.

Results are presented for a maximum field gradient of 14.93 T/m and an integrated sextupole component of 3.22 T/m2. Cooling calculations have been done for the magnetic length of 0.250 m.

To have an integrated sextupole component the pole profiles are rotated by 0.467º CW. But this rotation causes an unwanted dipolar component in the center, in order to eliminate this dipolar component two different apertures, 18 mm and 18.2mm, are imposed to the left and right poles, also to obtain the required field tolerances within the good field region, some shimming is required and two different shims are imposed on each side

Main parameters for the ILSF booster combined quadrupole are given in Table 2.

Table 2: ILSF Booster Combined Quadrupole Parameters

Parameter	**unit**	**Value**
QTY	-	8
Aperture radius	mm	18,18.2
Pole tip Field	T	0.690
Field gradient	T/m	14.93
Sextupole component	T/m^2	3.22
Magnetic length	m	0.250
Good field region	mm	±10
Number of turns per coil	-	17
Conductor cross section	mm^2	5 x 5
Cooling channel diameter	mm	3
Current	A	168.2
Current density	A/mm^2	6.8
Resistance of magnet	mΩ	15.96
Power consumption	kW	2.38
No. of cooling circuits	-	2
ΔT	deg	8
Water flow per circuit	l/min	1.20
Pressure drop	bar	7.16
Reynolds Number	-	3780

Figure 5 depict general layout and dimensions of the ILSF booster combined quadrupoles. Also field quality for the optimized pole profile and absolute multipoles' error at radius of 10 mm are calculated as shown in figure.6 and figure.7 respectively.

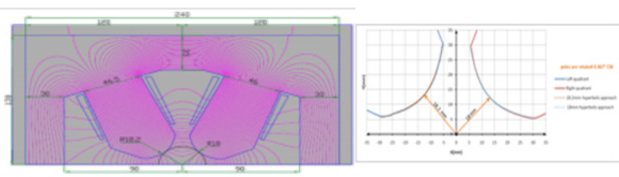

Figure 5: Field lines and dimensions of ILSF quadrupole.

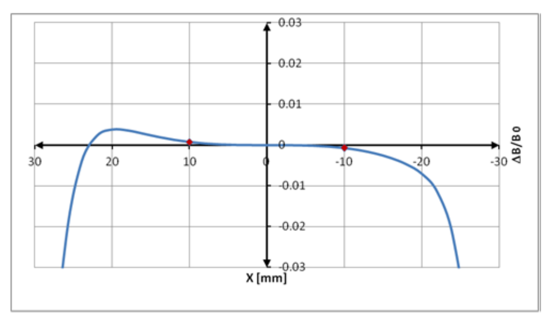

Figure 6: Field tolerance of ILSF quadrupole magnet boundaries of the good field region (±10mm) are shown in red.

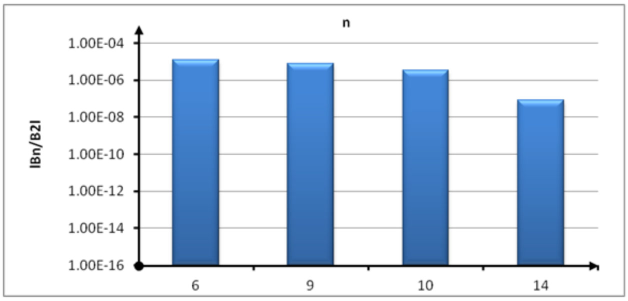

Figure 7: Absolute normalized multipoles' error at radius of 10mm.

CONCLUSIONS

The 3 GeV Iranian Light Source (ILSF) project is at the conceptual design phase. Magnets were designed for the critical parameters. Field uniformity of $\Delta B/B \leq \pm 1 \times 0.01$ % in the dipoles, $\Delta g/g_0 \leq \pm 5 \times 0.01$ % in the quadrupoles at good-field regions are predicted.

ACKNOWLEDGMENT

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REFERENCES

[1] uspas.final.gov/PCprog
[2] www.FEMM.info