IRANIAN LIGHT SOURCE FACILITY STORAGE RING MAGNETS

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Abstract

Iranian Light Source Facility (ILSF) is a 3 GeV synchrotron which is in the conceptual design phase. The ILSF storage ring is consist of 32 combined bending magnets of 2 types with a field of 1.42, 104 quadrupoles in 9 families with a maximum gradient of 23 T/m and also 128 sextupoles in 9 families with a maximum sextupole component of 700 T/m2. Using two dimensional codes POISSON [1] and FEMM [2] and RADIA [3] a pole and yoke geometry was developed for all these magnets. ILSF has also attempted to design and build prototype magnets which are ongoing at this stage.

INTRODUCTION

The ILSF 3GeV storage ring with a circumference of 297.6 m has 4 fold symmetry structure. Each symmetry includes 3 unit cells with DBA/TME structure and 2 matching cells.

In order to have a more compact lattice dipoles are designed to be combined, to bend and focus the beam simultaneously. The quadrupoles and sextupoles are pure magnets but it's also planned to insert in the sextupoles the horizontal and vertical correctors as well the skew quadrupoles. Dipoles will be powered in series by a common power supply and minor differences in field shall be corrected by individually trim coils. Each quadrupole has its own power supply while a common power supply will be used for each family of sextupoles.

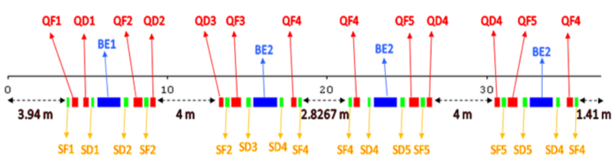

Figure 1: Arrangement of the magnets in a half-superperiod of ILSF storage ring.

Yoke is considered to be a collection of laminations for each magnet in the ring where laminations have nominal thickness of 1mm. Using laminations result to having uniform magnetic properties along the magnet length; it also makes the magnets more uniform. It is supposed to use steel 1200 – 100A coated with Stabolit 70 from EBG co. in ILSF magnets. This is a low-carbon (< 0.003%) steel with medium silicon content (1.3%).

DESIGN OF RING MAGNETS

Dipoles

ILSF dipole is combined C-type bending magnet with parallel-ends and curved yoke which follows the beam path to reduce the effect of field errors on the beam and decrease the amount of required yoke material; also the yoke can be opened from the middle to facilitate the vacuum chamber placement. Bending magnets are of 2 types BE1, in matching cells and BE2 in unit cells with different gradients. The general layout of both bending magnets is the same, and only the pole profile is changing because of the difference in required gradients. The small variation of required power for each type will be compensated by individual power supply of each magnet trim coils. The specifications of bending magnets are given in Table 1.

Table 1: ILSF Dipole Parameters

Parameter	unit	BE 1	BE 2
QTY	-	8	24
Bending radius	m	7.047	7.047
Deflecting angle	Deg.	11.25	11.25
Field	T	1.42	1.42
Field gradient	T/m	-3.837	-5.839
Total gap	mm	32	32
Magnetic length	m	1.384	1.384
Good field region	mm	±10	±10
Number of turns per coil	-	40	40
Conductor cross section	mm^2	14.3 x 11.4	14.3 x 11.4
Cooling channel diameter	mm	6	6
total A-turns	At	18455	18450
Current	A	461.125	461.25
Current density	A/mm^2	3.42	3.42
Resistance of magnet	mΩ	42	42
Power consumption	kW	8.89	8.89
Number of cooling circuits	-	4	4
ΔT	deg	8.8	8.8
Water flow per circuit	l/min	3.62	3.62
Pressure drop	bar	8.86	8.87
Reynolds NO.	-	6398.04	6401.5

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.

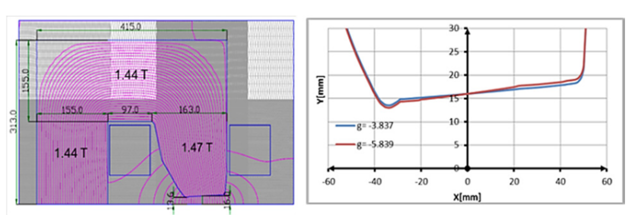

Figure 2: a) General dimensions for both BE.1 and BE.2. b) BE.1 and BE.2 pole profiles.

Field tolerances of B(0) and G(0) are less than 2×10^{-4} within the good field region ±10 (Figure 3). Absolute

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values of relative multipole components at normalization radius of 15 mm are brought in Figure 4 where B_0 is the sum of both dipolar and quadrupolar fields. The calculations have been done with Poisson.

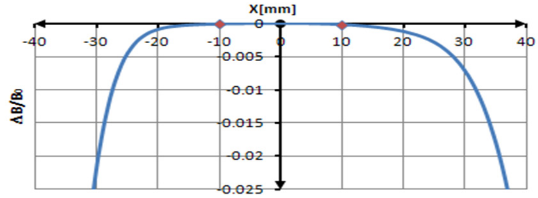

Figure 3: ILSF dipole field tolerances.

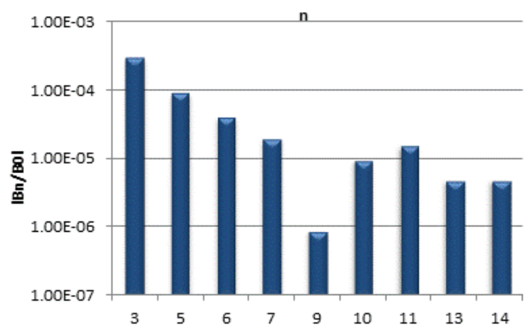

Figure 4: Absolut normalized multipoles' error at radius of 15 mm.

Quadrupoles

ILSF lattice has 104 quadrupoles in 9 families with the maximum field gradient of 23 T/m, maximum magnetic length of 0.53 m and with same cross sections. There are 40 quadrupoles with the length of 260 mm, 32 with the length of 310 mm and 32 with the length of 530 mm. Gradient field homogeneity of under 0.1% over a bore radius region of ±18 mm is required.

The other quadrupoles can be easily simulated by reducing the ampere-turns. Also the designs of the cross section of quadrupoles are constrained to accommodate the vacuum chamber with its antechamber. Main parameters for the ILSF quadrupole are given in Table 2.

Table 2: ILSF Quadrupole Parameters

Parameter	unit	Value
QTY	-	104
Aperture radius	mm	30
Pole tip Field	T	0.690
Field gradient	T/m	23
Magnetic length	m	0.530
Good field region	mm	±18
Number of turns per coil	-	50
Conductor cross section	mm^2	8 x 8
Cooling channel diameter	mm	4
Current	A	168.2
Current density	A/mm^2	3.27
Resistance of magnet	mΩ	119
Power consumption	kW	3.37
No. of cooling circuits	-	4
ΔT	deg	10
Water flow per circuit	l/min	1.20
Pressure drop	bar	9.71
Reynolds Number	-	3204.50

Figure 5 depict general layout and dimensions of the ILSF quadrupoles. Also field quality for the optimized pole profile and absolute multipoles' error at radius of 20 mm are calculated as shown in figure.6 and figure.7 respectively.

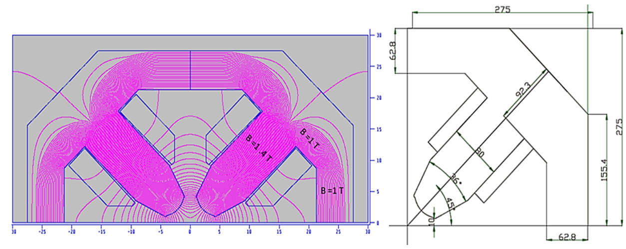

Figure 5: Field lines and dimensions of ILSF quadrupole.

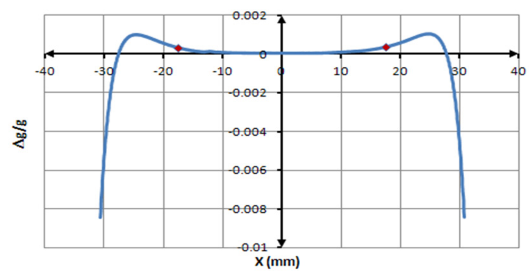

Figure 6: Field tolerance of ILSF quadrupole magnet boundaries of the good field region (±18mm) are shown in red.

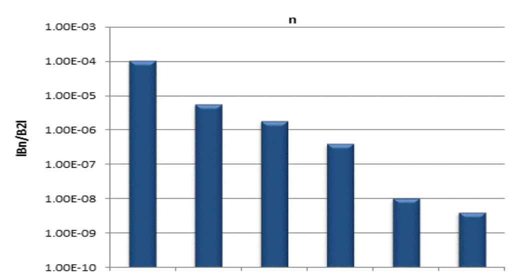

Figure 7: Absolute normalized multipoles' error at radius of 20mm.

Sextupoles

Overall 128 sextupoles in 9 families, 4 in each matching cell and 8 in each unit cells, will be installed in ILSF lattice. The maximum sextupole component is 700 T/m^2. Cooling and electrical calculation has been done for the maximum yoke length of 220 mm and presented in Table 3.

Figure 8 shows one half on sextupole field line distribution and one sixth dimensions. Also the field hemogenity in horizontal plane is depicted in Figure 9.

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Table 3: ILSF Sextupole Parameters

Parameter	unit	Value
QTY	-	128
Aperture radius	mm	34
Pole tip Field	T	0.405
Field gradient	T/m^2	700
Magnetic length	m	0.22
Good field region	mm	±16
Number of turns per coil	-	34
Conductor cross section	mm^2	7×7
Cooling channel diameter	mm	3.5
Current	A	111.18
Current density	A/mm^2	2.82
Resistance of magnet	mΩ	85
Power consumption	kW	1.056
No. of cooling circuits	-	2
ΔT	deg	10
Water flow per circuit	l/min	0.75
Pressure drop	bar	8.87
Reynolds NO.	-	2294.8

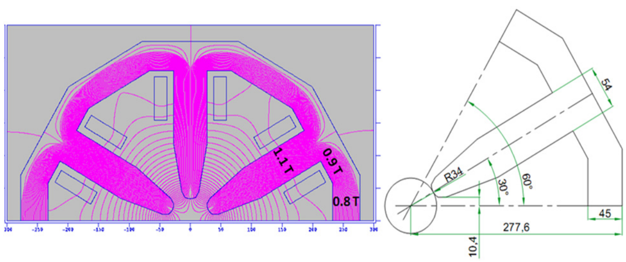

Figure 8: Field lines and dimensions of ILSF sextupole.

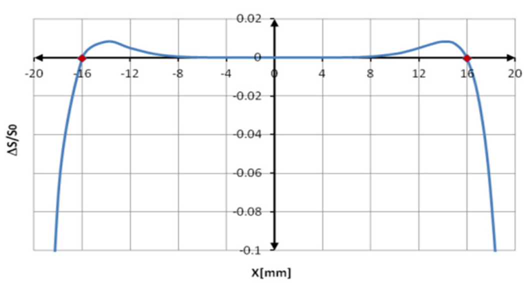

Figure 9: ILSF sextupole field tolerances.

The sextupole will equipped with additional coils to provide skew quadrupoles and, horizontal and vertical dipole corrector. Absolut values of relative multipoles for the 4 first harmonics are shown in Figure 10.

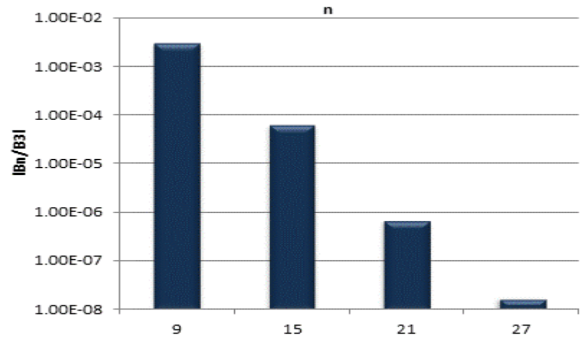

Figure 10: Absolute normalized multipoles' error at radius of 20mm.

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 $\Delta B/B \leq \pm 2 \times 0.01$ % in the dipoles, $\Delta g/g_0 \leq \pm 4 \times 0.01$ % in the quadrupoles and $\Delta S/S_0 \leq \pm 4 \times 0.01$ % in the sextupoles at good-field regions are predicted.

Moreover, RADIA [3] and Mermaid [4] 3D software are being used for 3D calculations which are not finalized yet and will be presented later.

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