A.8 : Sextupole magnets with skew quadrupole component for Indus-2

The Indus-2 storage ring consists of total 32 sextupole magnets for chromaticity correction. Skew Quadrpole magnets are necessary to regulate the coupling between the horizontal betatron oscillations and the vertical oscillations for adjustment of the vertical beam size. Skew quadrupoles are incorporated in the 16 sextupole magnets by auxiliary windings on each of these sextupole magnets that are located at 6 and 12 o'clock (shown in blue in Fig.A.8.1) and are energized with the same polarity. Incorporation of additional windings on the core of a sextupole magnet breaks the sextupole symmetry and introduces higher order multipoles including skew quadrupole component. It is important to estimate the presence of unwanted multipoles for proper functioning of the ring. Indus Operations & Accelerator Physics Design Division of RRCAT has used an analytical approach to design this magnet based on 2-D first order perturbation theory for iron-dominated magnets developed by Halbach, and then calculated the field using 2D POISSON code. Finally, all the magnets are characterized using a rotating coil system. Integrated skew quadrupole and sextupole gradients and higher order multipole components with excitations are measured. Results obtained from all the above three methods are presented in Table A.8.1 and found to be in good agreement with one another.

Estimation based on perturbation theory:

This theory calculates the effect of perturbation on an iron-dominated 2D symmetric 2N pole magnet whose centre coincides with the origin (x=y=0). The perturbation effects are expressed in terms of generation or changes of multipole coefficients. The field components can be calculated from the complex potential, $F(z)=\Sigma C_n Z^n$. For a 2N pole symmetric magnet it can be expressed as

$$F(z)=\sum_{m=0}^{m=\infty} C_{N(2m+1)} z^{N(2m+1)}$$

where $C_N z^N$ is the fundamental harmonic. The ratio of the absolute value of the n^{th} order harmonic field to the fundamental harmonic (N) is given by

$$\frac{|H_n|}{|H_N|}=\frac{nC_n}{NC_N} z^{n-N}$$

In order to generate the skew quadrupole component, additional current is provided in the auxiliary winding to increase the total current at the 6 and 12 o'clock poles by a perturbation factor ε. The perturbation to the n^{th} harmonic can be expressed as

$$\frac{|H_n|}{|H_N|}=i\varepsilon\left[\frac{n}{Ni\varepsilon}\Delta C_n(o)\right]\sum_i e^{-in\alpha_i}$$

where $\Delta C_n(o)$ is the perturbation of the reference pole whose vertex lies on the positive x-axis, and the α_j is the angular location of the pole centre of other poles. The summation term is called the geometrical factor. Here, the summation is over the two poles shown in the figure. The value in the parenthesis is called normalised sensitivity coefficient that can be calculated from the perturbative theory.

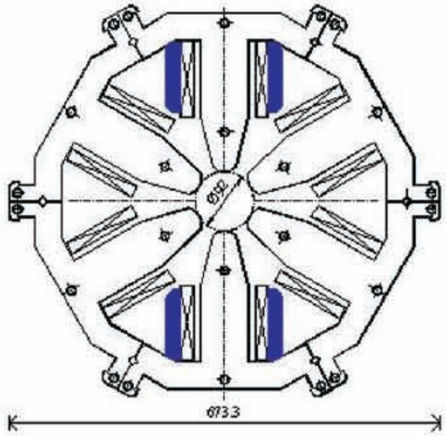

Fig.A.8.1. Design details of sextupole with main and skew coils. The latter are shown in blue.

Results:

The nominal sextupole gradient required in Indus-2 is 400 T/m², achieved by sending around 200 A current in a sextupole. Skew quadrupole gradient of 0.29 and 0.49 T/m can be obtained by sending 30 A and 50 A current, respectively in the additional winding.

Table A.8.1: Absolute value of multipole ratios at 32mm radius for skew QP and sextupole excitations.

For G'= 403.2 T/m² and G= 0.29 T/m

n	4	8	10
H_n/H_3(Theory)	1.85E-02	3.48 E-04	1.43E-04
Experiment	1.74E-02	2.61E-04	1.09E-04
POISSON-2D	1.95E-02	3.6 E-04	1.47E-04

For G'= 401.36 T/m² and G= 0.497 T/m

n	4	8	10
H_n/H_3(Theory)	3.14E-02	5.93E-04	2.44E-04
Experiment	2.93E-02	4.62E-04	1.67E-04
POISSON-2D	3.24E-02	5.97E-04	2.41E-04

For G'= 403.209 T/m² (220A.) and G= 1.743 T/m (200A)

n	4	8	10
H_n/H_3(Theory)	1.11E-01	2.10 E-03	8.67E-04
Experiment	1.23E-01	1.95E-03	7.24E-04
POISSON-2D	1.21E-01	2.33E-03	9.29E-04

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