CHARACTERIZATION AND EQUALIZATION OF THE AC RESPONSES OF THE CORRECTOR MAGNETS FOR THE APS LOCAL ORBIT FEEDBACK SYSTEM

C. Doose and S. H. Kim
Advanced Photon Source, Argonne National Laboratory
9700 South Cass Avenue, Argonne, Illinois 60439

Abstract

Local feedback for the APS storage ring uses local bumps to control the position and angle of the positron beam through each x-ray source point. Induced eddy currents in the aluminum vacuum chamber dominate the AC characteristics of the corrector magnetic fields. Small differences in the geometries at each magnet location change the eddy current effects and result in bump closure errors which must be reduced in order to minimize the coupling between each of the many local loops and the global control loop. By a combination of flux-damping coils, flux-shielding copper sheets, and a set of steel laminations for end-flux clamping, the differences of the eddy current effects between two corrector magnets were reduced from 0.18 Gm/A to 0.035 Gm/A in the frequency span of 0.1-100 Hz.

1 INTRODUCTION

Around the 40 sectors of the Advanced Photon Source (APS) storage ring [1], 360 rf beam position monitors (BPMs) and 318 horizontal/vertical corrector magnets have been installed for both local and global orbit correction feedback systems [2]. The local feedback systems control the position and angle of the positron beam locally at the source points for the x-ray beams. The corrector magnets, which correct local orbit bumps up to 0.1 mrad from DC to 30 Hz, induce eddy current in the relatively thick aluminum vacuum chamber and other metallic components. The effects of the eddy current in the magnet laminations, which have a thickness of 0.64 mm, are negligibly small [3].

The local feedback system uses four correctors, two on each side of an insertion device. The sections of the vacuum chamber near the two corrector magnets, BH1 and BH2 on a girder upstream or downstream of the insertion device, are machined differently for the vacuum port and flange couplings, which changes the eddy current effects. Therefore, when the two magnets are energized with certain ratios of the magnet current, the differences in the eddy current effects result in bump closure errors as a function of frequency. The closure errors must be reduced in order to minimize coupling between each of the many local loops and the global control loop.

2 AC RESPONSE MEASUREMENTS

The two corrector magnets BH1 and BH2 were measured on a storage ring spare girder assembly that has all the eddy-current-related components, including the aluminum vacuum chamber. The two magnets were connected in series to a bipolar power supply/amplifier, Kepco BOP 20-20M [4], in order to have a common-current phase reference for the measurement. The power supply was driven in a current-controlled mode by a random frequency signal from a Hewlett Packard 35670A four-channel analyzer [4]. The signals from two “printed circuit” coils located in each magnet gap inside the vacuum chamber were processed using the analyzer to obtain the response of the integrated magnetic field strength to the magnet current in the frequency domain.

Figure 1 shows the magnitudes of the vertical field strength $B\ell(\omega)/I(\omega)$ of magnet BH2, and that of the difference between BH1 and BH2. The frequency span for the measurements was 0.1-100 Hz with a resolution

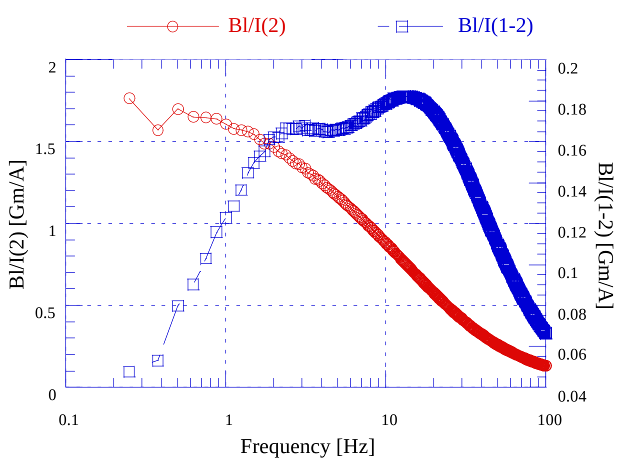

Figure 1: Magnitudes of the vertical field strength per current $B\ell(\omega)/I(\omega)$. $B\ell/I(2)$ for magnet BH2 and $B\ell/I(1\text{-}2)$ for the difference between magnets BH1 and BH2.

of 0.125 Hz, and rms magnet current for the frequency span was 10 A. The corresponding spectra of the phase shift for the field strength are plotted in Fig. 2. Magnet BH1, located closer to the stainless steel flange of the vacuum chamber at the end section of the girder, has 5-

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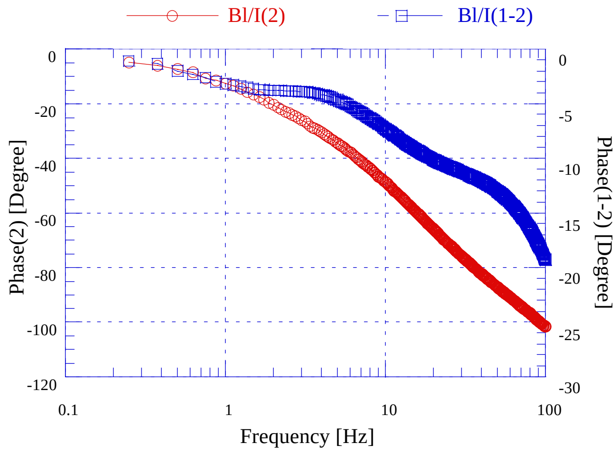

Figure 2: Phase delays of the vertical field strength per current $B\ell(\omega)/I(\omega)$. Phase(2) for magnet BH2 and Phase(1-2) for the difference between magnets BH1 and BH2.

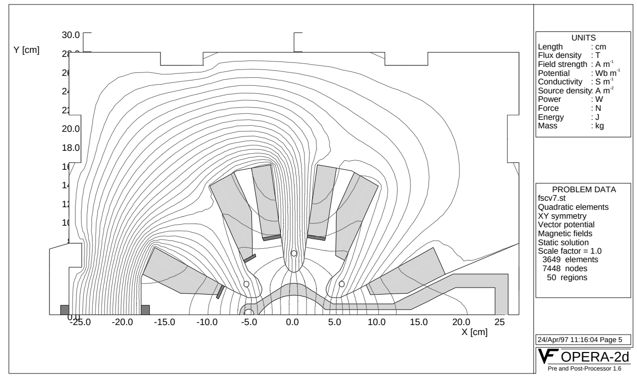

Figure 3: Upper half of the 2-D cross section of the magnet laminations, magnet coils, and vacuum chamber along with flux lines for DC current. The flux-damping coil and copper sheets for the flux shielding on two magnet poles are shown

20% less attenuation and phase shift of the magnetic field compared to those of magnet BH2.

3 EQUALIZATION OF THE AC RESPONSE

Three methods of compensation were used to equalize the response of BH1 on the AC magnet current to that of BH2. The first method installed a one-turn flux-damping coil (4/0 cable) around the "back leg" of the flux-return core near the midplane of the magnet in Fig. 3. (The upper half of the two-dimensional cross section for the steel lamination, magnet coils, and vacuum chamber is shown in Fig. 3. The flux lines in the figure are for a DC current.) The damping coil was most effective in changing the response in the frequency band of 4-15 Hz.

The second method shielded and damped the magnetic flux using 1-mm-thick copper sheets as shown in the left two poles in Fig. 3. The copper sheets were cut approximately 7 cm × 2.5 cm to fit on the pole tips of the magnet. The copper sheets were effective in changing the response above 15 Hz.

The third method used a set of U-shaped steel laminations (approximate cross section of 1.2 cm × 1 cm) hung on top of the magnet core across the 7-cm-long magnet near the center pole. This method was effective in the overall frequency band. The laminations diverted a small fraction of the flux from the air gap of the magnet similar to a flux shunt or end-flux clamping scheme.

Using a combination of these three methods for magnet BH1 significantly reduced the differences in the magnitude and phase delay between the two magnets. The results of the combination are plotted in Fig. 4. The difference in phase delay is now less than 1°, and the difference in magnitude is now less than 0.035 Gm/A, a fivefold reduction compared to 0.18 Gm/A before the compensation.

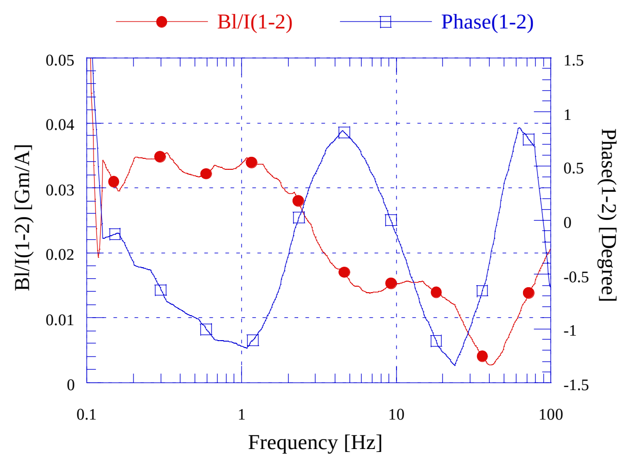

Figure 4: The differences of the magnitude, $B\ell/I(1\text{-}2)$, and phase delay, Phase(1-2), of the AC responses between magnets BH1 and BH2 with the three methods of flux compensation.

4 CONCLUSION

To minimize the local orbit closure errors, AC response differences in the vertical field strengths of two corrector magnets were reduced from 0.18 Gm/A to 0.035 Gm/A in the frequency span of 0.1-100Hz. This was achieved by three methods of flux compensation: damping, shielding, and shunting. Similar compensation methods for the correction of horizontal field have to be tested. The methods need to be simplified for easy installation in the storage ring.

5 ACKNOWLEDGMENTS

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6 REFERENCES

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[3] Y. Chung and J. Galayda, "Effect of Eddy Current in the Laminations on the Magnet Field," LS Note 200, ANL, 1992.

[4] An explicit reference to a particular product does not imply that other vendors might not be able to supply equivalent products.