DESIGN AND FABRICATION OF MULTIPOLE CORRECTOR MAGNET

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Abstract

Taiwan Light Source (TLS) started operating using top-up mode injection in October 2005. The Elliptically Polarized Undulator (EPU5.6) operated very well in decay mode; however, partial beam loss occurred when the top-up injection was executed at the magnet gap and array phase, which are fixed at the minimum gap and π (vertical polarization mode), respectively. This work presents a novel multipole corrector magnet installed downstream of the EPU5.6 to compensate for multipole field error and eliminate partial beam loss. This multipole magnet provides normal and skew components of the dipole, quadrupole, sextupole, octupole, and dectupole field components. A changeable multipole field component mechanism was designed using an electrical circuit. Additionally, the measurement system of Hall probe was used to measure magnet field quality.

INTRODUCTION

Several laboratories have designed and fabricated a 12-pole geometry that provides multipole functions in a magnet [1, 2]. In contrast with other magnets, the magnet in this work has the same number of turns of the coil, and one power supply is used to achieve multipole function via the power supply control system. The magnet was fabricated and installed downstream of the Elliptically Polarized Undulator (EPU5.6) on a 1.5 GeV storage ring at the National Synchrotron Radiation Research Center (NSRRC) in February of 2008. Additionally, the control system for the power supply was constructed and tested. This work discusses magnet circuit design, magnet fabrication, the power supply control system and field measurement results.

MAGNET CIRCUIT DESIGN

The magnetic field is simulated using the RADIA code from ESRF Insertion Devices Laboratory. The magnet replaces the existing skew quadrupole magnet; thus, magnet dimensions are limited. Figure 1 shows the magnet front and side views. Magnet pole tip diameter is 104 mm, height and width are 480 mm and depth is 70 mm (only the core). The magnet core is divided into 12 identical poles. Pole width is 10 mm and pole tip radius is 6 mm.

The coils were energized using the same current density in different configurations, which can provide different magnetic components magnet. Figure 2 presents the different configurations of the energized coil that are related to different magnetic components. The left of Fig. 2 shows the configurations of normal-type magnets and the right side shows configurations of skew-type magnets. The magnetic pole of N is red coil and magnetic pole of S is blue coil.

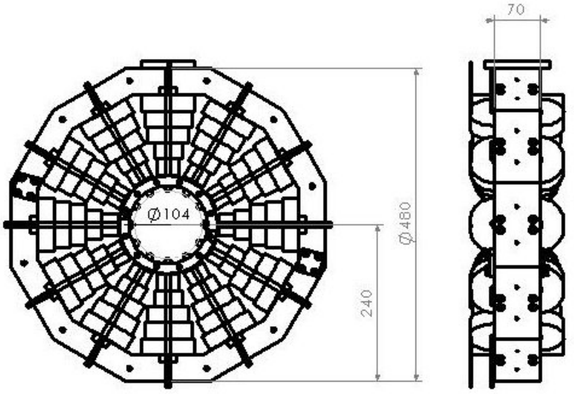

Figure 1: Front and side views of the multipole magnet.

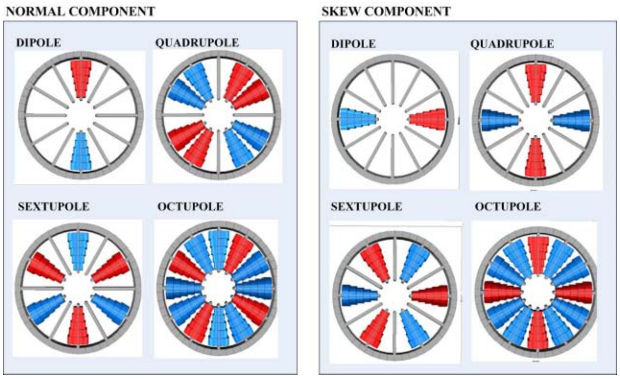

Figure 2: Different configurations of the energized coil create different magnetic components.

MAGNET FRABRICATION

The magnet core is divided into 12 identical poles and 2 identical return yokes for installation of coils and the vacuum chamber. The magnetic core must be accurate, inexpensive and easily maintained. The solid plate of SAE 1006 low-carbon steel meets these requirements. With CNC wire-cut electrical discharge machine tools the steel core can be machined with high accuracy and repeatability. The poles are bolted together after the coils are wound onto the poles. The pole angle is maintained by the half circular jig made of SUS304 stainless steel; each jig can fix six poles.

This magnet has 12 coils; each coil has 322 turns of mica-tape-coated copper wire; the dimensions are 3×2 mm^2. Coils are impregnated in a vacuum potting mold via epoxy resin. The coil reached a final temperature of 57°C when operated at 10 A.

POWER SUPPLY CONTROL SYSTEM

The basic components of the power supply control system are relays (HG2, Panasonic), 24 Vdc power supplies and one programmable logic controller (PLC) (NAIS, FP2SH), which were assembled on a 19-inch instrument case (Fig. 3). The front panel has some switch for local control to change magnet type. The rear panel has some connectors includes 12 connectors that are used to connect to the magnet coils via an extended power cable, remote control signal connector and current input of the power supply.

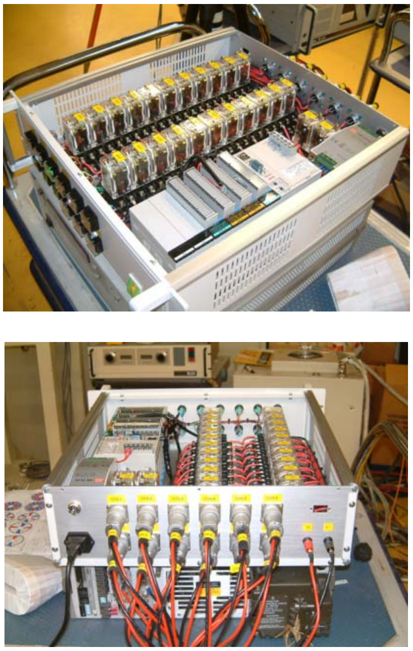

Figure 3: Instrument case of the power supply control system.

The control system uses one power supply that supplies current to the magnet. The control system supports local and remote control for changing magnet type. The PLC-input module is used for selection of magnet type. The module is connected to a switch or Digital Output (DO) card, which comes from the VME crate for remote control. The PLC-output module is also used as relay control. These relays determine coil polarity and whether current is passing through the coil. According to magnet design, a control program was written and then this code was uploaded to the PLC.

This system has 24 relays, which is DPDT type. Maximum working current is 20 A. The maximum working current of the magnet is ±10 A; thus, the relay selected is safe. These relays are divided into two groups, the POLARITY and ON/OFF group. Each group has 12 relays (Fig. 4). The POLARITY group (P1–12) is responsible for magnetic polarity of the coil switch, which is individually connected to the magnet coil. The magnetic polarity of the coil is N type when the relay is inactive and S type when active. The ON/OFF group (S1–12) is responsible for ON/OFF of coil switch. The current does not pass through the coil when the relay is inactive and passes through the coil when the relay is active.

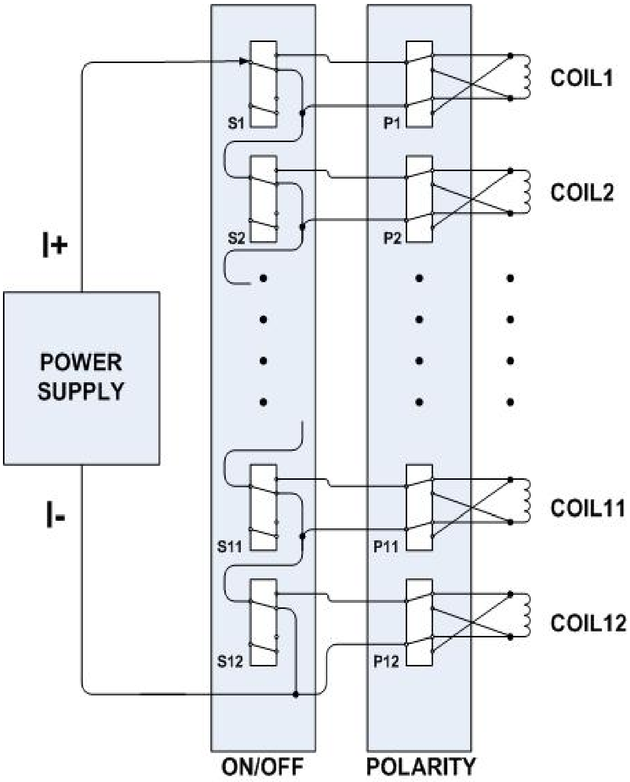

Figure 4: Structure of the power supply control system.

The PLC has 1 DC input module (X16D2, 12–24 Vdc) and 2 relay output modules (Y16R) (Fig. 5). An input module has 16 inputs (X_0 to X_F); each input is treated as a magnet-type selection. The input module is connected to the front panel switch, which used in local control mode, and remote signal connector, which is used in remote control mode. In remote control mode, the control signal is connect from the DO card of VME crate. The operator easily changes the magnet-type via control network. Each output module has 16 outputs; each output controls 1 relay. Two output modules (Y_{10} to Y_{1F} and Y_{20} to Y_{2F}) are individually connected to the POLARITY and ON/OFF group relays.

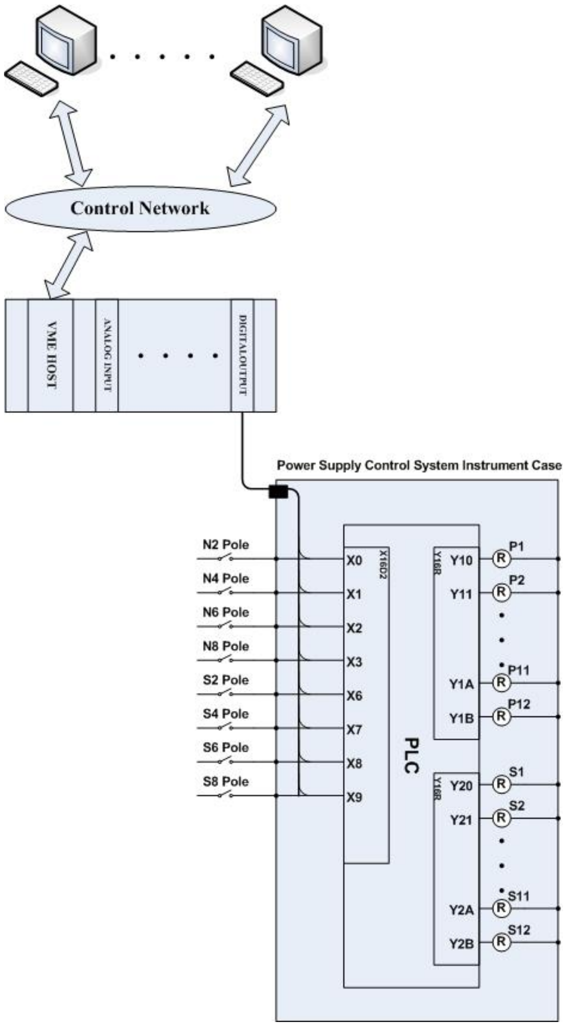

Figure 5: Wiring diagram of switches and relays to the PLC.

FIELD MEASUREMENT RESULTS

A Hall probe was used to measure the magnetic field. The calculations and measured field of the central magnet (z=0 mm) by using a polynomial fit, the data fitting range in the horizontal axis is ±30 mm, and the normalized range is ±20 mm. Figures 6 and 7 show the calculated and measured normalization of harmonic components for the normal-type and skew-type magnets. The measured result is narrower that the design value; additionally, norm-type and skew-type octupole.

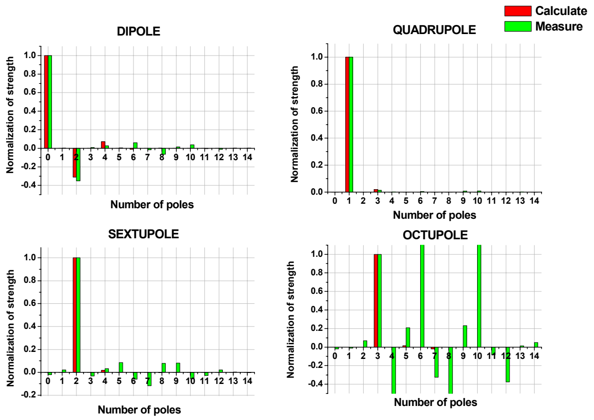

Figure 6: Calculated and measured normalization of harmonic components for a normal-type magnet.

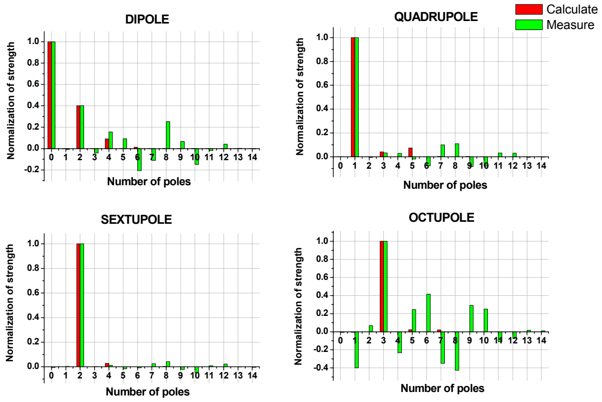

Figure 7: Calculated and measured normalization of harmonic components for a skew-type magnet.

REFERENCES

[1] M. Fedurin, *et al.*, "Multipole Design for CAMD Storage Ring"PAC'05, May2005.

[2] D.J. Harding, *et al.*, "Design and Fabrication of a multi-element corrector magnet for the Fermilab Booster Synchrotron"PAC'07, June 2007.