CORRECTING MAGNET POWER SUPPLIES FOR THE NSLS-II BOOSTER

K.R. Yaminov, O.V. Belikov, A.S. Medvedko, V.V. Kolmogorov, A.I. Erokhin, S.R. Singatulin, S.E. Karnaev, P.B. Cheblakov, Budker INP SB RAS, Novosibirsk

Abstract

Budkers Institute of Nuclear physics builds booster for synchrotron light source NSLS-II. Booster should accelerate electrons from energy 200MeV to energy 3GeV, acceleration phase duration is 250msec, repetition rate — up to 2Hz. Booster magnet system includes 16 sextuples and 36 dipole correcting magnets powered separately. Forth-quadratant current sources for sextuples and correcting magnets have maximum output current ±6A, maximum output voltage ±100V, maximum output current ripples and long-term stability are better than 0,1% relative to 6A. In ramping mode with current slew rate up to 200A/sec time lag between setpoint and output current is not more than 1msec and can be compensated by software. Results of power supplies system tests and commissioning will be presented in paper.

INTRODUCTION

The National Synchrotron Light Source II is a third generation light source under construction at Brookhaven National Laboratory. The project includes a highly optimized 3 GeV electron storage ring, linac pre-injector and full-energy booster-synchrotron. Budker Institute of Nuclear Physics builds booster for NSLS-II. The booster should accelerate the electron beam continuously and reliably from minimal 170 MeV injection energy to maximal energy of 3.15 GeV and average beam current of 20 mA. The booster shall be capable of multi-bunch and single bunch operation. A nominal repetition rate of the booster is 1 Hz with possibility to upgrade it up to 2 Hz. Main booster parameters are presented in the Table 1.

Table 1: Main booster parameters

Parameter	Value
Beams Energy: Injection/Ejection	200MeV/3GeV
Number of periods	4
Circumference, m	158.4
Repetition rate, Hz	1(2)
Bunch number	40-150
Revolution Frequency, MHz	1.893
Synchrotron frequency, kHz	35.5/20.3 (0.2/3GeV)
Betatron tunes: *νx/νy*	9.65/3.41
3D Damping time, sec	16.2s to 7.7s (0.2GeV) 4.8ms to 2.3ms (3GeV)
Energy rise time, sec	0.26

SEXTUPOLES AND CORRECTING DIPOLE MAGNETS

Quadratic nonlinearity of the magnetic field at the quadrupole lenses are proposed to be tuned using 16 sextupole lenses (8 lenses to X direction and 8 – to Y one). All the lenses are identical in design and in electrical parameters. The specified parameters of sextupole lenses are presented in Table 2.

Table 2: Sextupoles parameters

Magnet	I_{max}, A	R, OHm	L, H
BR-SXV	5,6	1,2	0.104
BR-SXH	5,6	1,2	0.104

It is proposed that for the beam orbit correction 36 dipole correcting magnets will be installed in the Booster magnet system. 20 dipole correctors are for X coordinate and 16 – for Y one. The specified parameters of correctors are presented in Table 3.

Table 3: Dipole correctors parameters

Magnet	I_{max}, A	R, OHm	L, H
BR-CX	5	2	0. 4
BR-CY	5	2	0.25

POWER SUPPLIES REQUIREMENTS

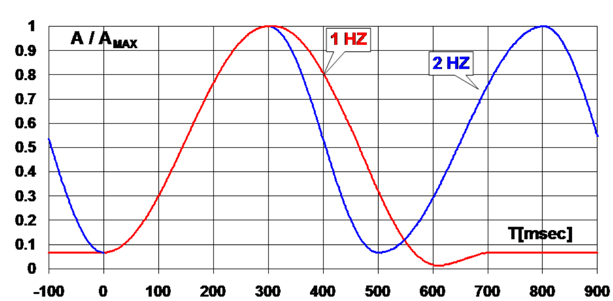

Figure 1: Magnetic field evolution during the ramp.

Cosine approximation of magnetic field evolution during the ramp for 1 and 2Hz modes is shown in Fig. 1. Sextupoles and dipole correctors are used to compensate higher harmonics caused by non-linearity of magnetic system. Therefore, power supplies should provide output voltages enough for necessary current slew rate. Output

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voltage requirements for sextupoles and dipole correctors power supplies are presented in Table 4.

Table 4: Power supplies output voltage requirements

Magnet	Resistive voltage, V	Inductive voltage, V	Peak voltage, V
BR-SXH(V)	6.7	10	16.7
BR-CX	10	40	50
BR-CY	10	25	35

Power supplies for sextupoles and correcting dipole magnets should provide error better than than 0,1% relative to the I_{max} in static mode (during injection/extraction) and .better than 1% relative to the I_{max} during beam acceleration.

MPS-6 STABILIZED CURRENT SOURCE

MPS-6 stabilized current source developed earlier in BINP is used to supply sextupoles and correcting magnets of the booster.

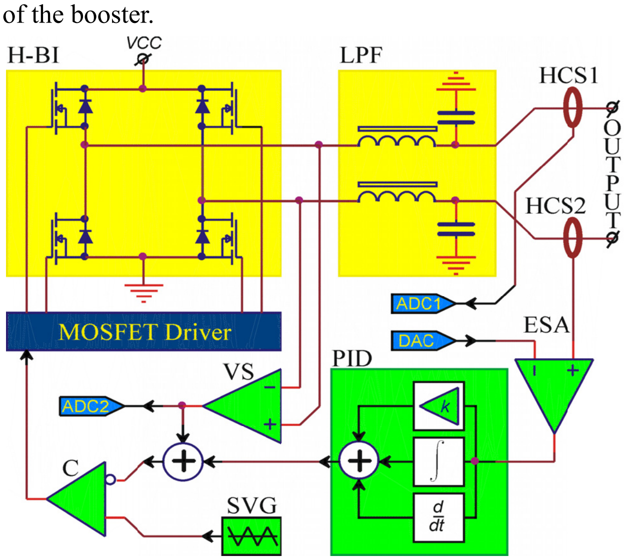

Figure 2: The MPS-6 structural scheme.

Structural scheme of the MPS-6 power supply is shown in Fig. 2. H-bridge DC/DC converter is assumed as a basis. The output current adjustment is made by pulse-width modulation operating at 50kHz frequency. There is a second-order LPF filter on the output of the bridge-inverter, providing the damping of carrier frequency by 60dB. The measurement of output current is realized by two identical contactless compensatory Hall sensors. One sensor is used in the feedback circuit, the other – as an independent measuring device for the control system. H-Bridge output voltage is used for the voltage feedback loop which is intended to dump the LPF filter. The feedback loop contains elements with differential and integral characteristics to provide necessary accuracy and dynamic characteristics. Main parameters of the MPS-6 power supply are presented in Table 5.

Table 5: Parameters of the MPS-6 current source

Parameter	Value
Output current	±6 A
Maximum output voltage	±80 V
Conversion frequency	50 kHz
Absolute error of regulation	0.1% relative to I_{max}
Output dispersion for 10hours operation	100 ppm relative to I_{max}
Output current ripples	<0.1%
Output current temperature drift	50 ppm/°K
Output current hysteresis	5 mA
Heat dissipation in the unit	<15 W

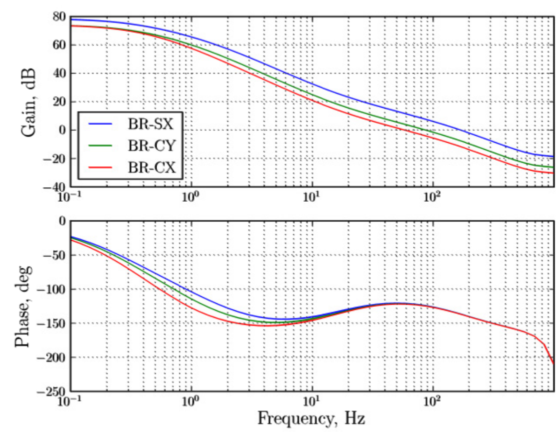

Figure 3: Open feedback loop frequency response.

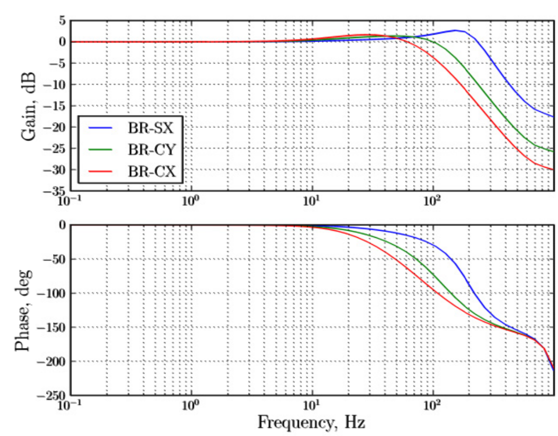

Figure 4: Closed feedback loop frequency response.

Feedback loop was optimized to meet dynamic error requirements and conserve high static parameters. Calculated frequency responses of open and closed loops are presented in Fig. 3 and Fig. 4 respectively. Simulation

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shows a presence of time shift between preset and output currents. The time shift value is not more than 1msec and can be compensated by software.

The design of single-channel MPS-6 power supply is the insert module in "Euromechanics" standard (Fig. 5).

For the resistive/inductive load the output power of power supply source can be of positive and negative values. Therefore, the four-quadrant volt-ampere characteristic of current source is required for correctors and sextupoles. Such a source allows recuperation of a part of energy from a load inductance in the decreasing output current mode to the buffer capacity. It is more optimal to use common buffer capacity per several power supply channels for multichannel power supply system in frames of one multichannel module (Fig. 5). Such multichannel module can include up to 8 MPS-6 power supplies.

Figure 5: MPS-6 power supply and multichannel module with inserted units.

POWER SUPPLY CONTROLLER AND POWER SUPPLY INTERFACE

Power supply controller (PSC) and power supply Interface (PSI). were developed at BNL for the NSLS-II magnetic system power supplies control.

PSI has one or two precision 20-bit DACs, three channels of precision 16-bit ADC for each DAC, six channels of 16-bit ADC for each DAC, sixteen digital inputs, 8 digital outputs. PSI is connected to PSC via fiber-optic 50 Mbps data link. The PSI can digitize up to 10 analog signals at a 100 KHz sample rate. Up to four dual channel PSIs are used to control MPS-6 multichannel module. Three analog and two digital signals are used for each power supply.

The PSC has two major functions. The first function is to provide communication between a PSI and EPICS IOC. The second major function of PSC is to provide a large memory for storing large amount (half Gigabyte) of data. The data can be used for power supply ramping waveforms or various diagnostic data.

Transition board installed in multichannel module is used to connect each power supply with PSI For one MPS-6 it is proposed to use one DAC channel and 2 ADC channels (one – for load current measurement, the other one – for load voltage measurement), one bit of input command and one bit of output command of digital IN/OUT registers for control and monitoring of each power supply sources MPS-6.

RESULTS

Bench tests included long-term stability test, output current ripples measurement and dynamic error measurement for 2Hz sinusoidal ramp. Some results are presented below.

The diagram given in Fig. 6 presents output current drift during 7-hour long-term stability test. After warming up during 2 hour discrepancy doesn't exceed 0,02% relative to the maximum output current 6A. Temperature after warming up changes in ±1°C range. Output current ripples are given in Table 6.

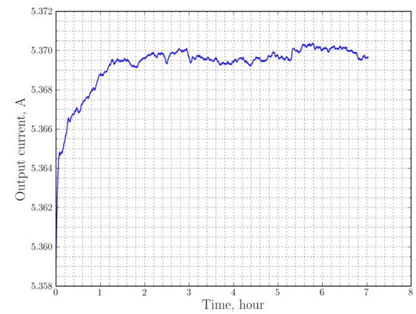

Figure 6: Output current drift during 7-hour long-term stability test.

This dynamic error for 2Hz sine output current is shown in Fig. 7. Curve 1 – is the sinusoidal ramp, curve 2 – dynamic error measured with compensated time shift, curve 3 – dynamic error without time shift compensation.

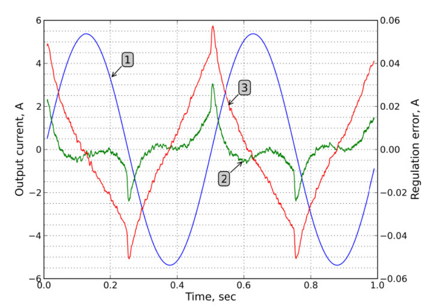

Figure 7: The dynamic error for 2Hz sinusoidal ramp.

Table 6: Output current ripples

Output current	**RMS ripples, mA**	**RMS ripples % of I_{max}**
0A	1.38	$2.3*10^{-4}$
3A	1.56	$2.6*10^{-4}$
6A	1.74	$2.9*10^{-4}$

REFERENCES

[1] O. Belikov et al. "Four quadrant power supplies for steering electromagnets for electron-positron collider", RuPAC-2008, BINP SB RAS

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