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POWER SUPPLIES FOR CORRECTORS OF THE 2.5 MeV ELECTRON COOLING SYSTEM FOR THE COLLIDER NICA

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Abstract

To achieve the design luminosity of 10^{27} cm^{-2}s^{-1} in the collider NICA [1] on colliding high-intensity ion beams with energy of up to 4.5 GeV/nucleon in the center-of-mass system, it is necessary to form short bunches with small transverse emittance. That will be done using electron cooling of ion beams at the energy of the experiment, which corresponds to an electron energy of 0.2 to 2.5 MeV. For simultaneous cooling of both ion beams, an electron cooling system consisting of two independent coolers has been designed [2].

INTRODUCTION

Each cooler of the electron cooling system includes the gun, where the electron beam appears, the accelerating/decelerating electrostatic tube, the transport beam line, and the cooling section. For correction of electron beams, both coolers use 144 correcting electromagnets (correctors), which need separate power supplies. All the power supplies of the correctors have been developed and produced at BINP.

The correction system includes six types of correctors:

- Correctors of beam position in the transport beam line and cooling section.
- Correctors for alignment of the force line straightness in the cooling section.
- Correctors for alignment of beam shape in the bends.
- Correctors for reducing the Larmor beam gyration (dipole mode and galloping mode).
- Correctors of the section for coordination of the transition from the electrostatic accelerator to the transport beam line.
- Correctors of the section for coordination of the transition from the transport beam line to the cooling section.

According to the power supply type, all the correctors can be divided into two groups:

- Correctors controlled by current of up to 6 A: 112 pcs.
- Correctors controlled by current of up to 20 A: 32 pcs.

However, correctors relating to the group with power sources of up to 6 A differ greatly in the total winding resistance (from 0.7 to 16 Ω, excluding the resistance of the leads). Therefore, the power supplies within the group have different output voltages.

Table 1 shows the numbers of different power supplies used for correction of the electron beam of the electron cooling system. The magnetic system of the electron cooling includes sections where longitudinal field correction is required, but the design makes it impossible to place free-standing correctors. The longitudinal magnetic field is formed by several series-connected sections, energized from a common power supply. For correction of the magnetic field, each section is connected in parallel with an additional, galvanically isolated, power supply, which produces an additional current of up to 20 A, which corresponds to 15% of the main power source current. In total, there are 16 additional current sources. They use the same power supply as the correctors.

Table 1: Power Supplies of Correctors

Type of power supply	Quantity, pcs.	Output current range, A	Maximum output voltage, V
MPS-6-24	32	-6 ÷ 6	24
MPS-6-60	32	-6 ÷ 6	60
MPS-6-140	48	-6 ÷ 6	140
MPS-20-50	48	-20 ÷ 20	50

STRUCTURE OF POWER SUPPLIES

Correctors with current of up to 6 A are powered by multichannel modular power supplies. Figure 1 shows a block diagram of eight-channel module of power supply MPS-6.

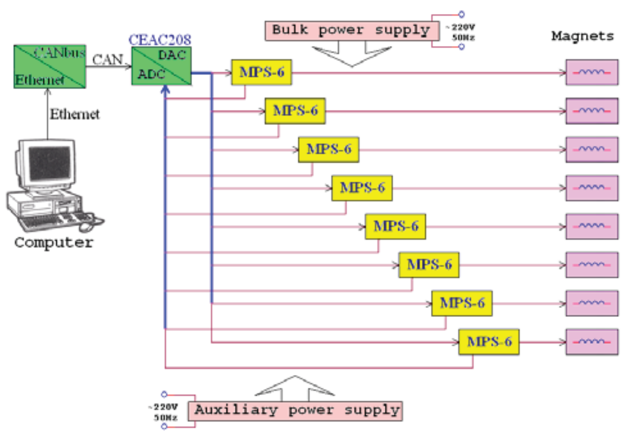

Figure 1: Structure of power module MPS-6.

The module includes 1 to 8 converters of the bulk power supply voltage to DC current. Each of these blocks supplies constant current to the respective load. The MPS-6 converters are monitored and controlled by means of analog signals. All MPS-6 converters within a module have common buffer and auxiliary power supplies, as well as common controller comprising digital-to-analog and analog-to-digital converters. Such a structure has the following advantages:

- The maximum output voltage of all MPS-6 converters within a module is determined by the voltage of the buffer power supply, and thus all the MPS-6 converters can be produced identical, which reduces the number of different blocks.

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- Using a common buffer power supply for a multi-channel module improves the reliability of the power system as compared with single-channel devices, where each power supply has an individual buffer power supply.
- Using common devices in a module lowers its cost.

The multi-channel modular system of power supply has the following disadvantage: all outputs of constant voltage converters are galvanically connected with the buffer power source output. Therefore, these power supplies are not suitable as additional 16 current sources.

The correctors with current of up to 20 A are powered by single-channel power sources MPS-20. In contrast to MPS-6, an MPS-20 unit includes a converter of constant voltage to direct current. Converters for MPS-6 and MPS-20 differ in design because of different output powers, but they have a common block diagram (see Fig. 2).

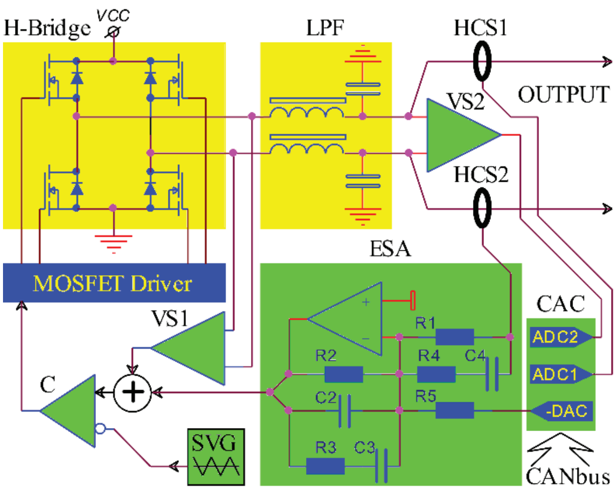

Figure 2: Block diagram of converter of constant voltage to DC. VCC – Bulk power supply voltage: H-Bridge – H-Bridge inverter; LPF – Low-pass filter; HCS – Hall Current Sensors; VS – Voltage sensor; ESA – Error-signal amplifier; CAC – External controller with CANbus interface; ADC – Analog-to-digital converter; DAC – Digital-to-analog converter; C – Comparator; SVG – Sawtooth-voltage generator.

A bridge inverter controls the output current by means of PWM of the buffer supply voltage. A low-pass filter LPF suppresses the fundamental frequency of the invertor and its harmonics. Two independent non-contact sensors HCS1 and HCS2 measure the output current. One sensor regulates the output current and the other is for independent measurements in the monitoring system.

The required quality of regulation is ensured due to application of a dual-feedback system. The first circuit of the current feedback includes elements with integral and differential characteristics. This circuit provides a high open-loop gain of the current feedback of over 10^3. The second circuit of the voltage feedback has zero DC amplification. It is introduced to suppress the bulk power supply ripples in a frequency band up to 1 kHz.

Table 2 shows parameters of the power sources MPS-6 and MPS-20.

Table 2: Parameters of Power Supplies

Parameter	MPS-6	MPS-20
Output current accuracy	$\leq 10^{-3}$	
Output current drift (24 h)	10^{-4}	
Temperature coefficient of output current drift, 1/°K	$4{\cdot}10^{-5}$	
Conversion frequency, kHz	50	
Cooling	Air Natural	Air Forced
Overall dimensions, mm^3	51×227 ×266	432×355 ×133

DESIGN OF THE POWER SUPPLIES

All the power supplies are made in the Eurocard format. Figure 3 presents a photograph of single-channel source MPS-20-50.

Figure 3: Power supply MPS-20-50.

The power supply is structurally designed as a 3U-subunit (432×355×133mm^3) made by Schroff. Monitoring and control are performed by CANbuses using the integrated controller CEAC124 [3], developed at BINP.

Figure 4 presents a photograph of eight-channel module MPS-6.

Figure 4: Eight-channel module MPS-6.

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The module is designed as a 6U-subunit (432×415×266 mm^3) made by Schroff. Monitoring and control of the module are performed from the CEAC208 controller [4], developed at BINP.

The design of the power system for the correctors has been completed; all the necessary power supplies are in production. All the equipment will be located in 10 Varistar cabinets (600 × 800 × 1800 mm^3) made by Schroff; the electrical design of connection of the power system for correctors on the collider NICA is being prepared.

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