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COLLIDER NICA POWER SUPPLY MAGNET SYSTEM

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Abstract

A power supply system for Collider structural magnets is considered, which consists of precision current sources, energy evacuation devices for superconducting elements, additional sources, and control and monitoring equipment. The status of the equipment and the plan of its placement in Collider bldg. 17 are presented.

INTRODUCTION

The NICA (Nuclotron-based Ion Collider fAcility) project is a new acceleration and storage complex that is currently under construction at JINR [1]. The Collider is the main installation of NICA.

The power supply system of the Collider's structural superconducting magnets should provide:

- formation of magnetic fields in accordance with the required cycle,
- set ranges of variation and accuracy of currents in groups of structural magnets,
- reliable operation of superconducting magnets in the event of a normal zone.

The main parameters of the Collider's structural magnets are: inductance of 36 mH for dipole magnets and 4.6 mH for focusing and defocusing lenses, magnet current of 10.4 kA, and field/current stability of $2 \cdot 10^{-5}$ on a plateau and $2 \cdot 10^{-4}$ in other modes.

The working cycle of the magnetic field is shown in Fig. 1.

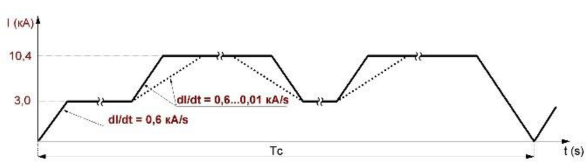

Figure 1: Current cycle of Collider magnets.

BASIC CIRCUIT OF THE POWER SUPPLY SYSTEM

The Collider consists of 2 independent rings of structural superconducting magnets. Each ring has its own power system. The power supply circuit of the first Collider ring is shown of Fig. 2.

The main powerful PS1 source of the power supply system generates the required current with a given field growth rate in all sequentially connected structural magnets. The PS2 source of lower power allows one to simultaneously change the field gradient in the focusing and defocusing lenses, and the PS3 is only for the defocusing lenses.

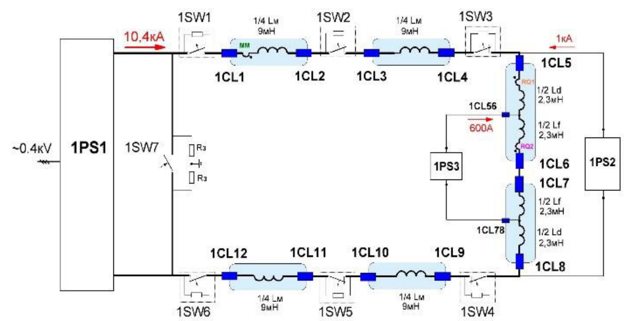

Figure 2: Schematic diagram of the power supply.

To evacuate the energy stored in magnets in the event of a breakdown of superconductivity, SW1…6 switches connected in series with a chain of magnets are used. They are controlled by an external signal from the detection system for the appearance of a normal phase in a superconductor. When a signal occurs, the energy evacuation switches (SWs) open, and the energy stored in the magnets is dissipated in the field quenching resistors connected in parallel to the switches. The SW7 shunts the power supply at the energy evacuation (EE).

Table 1: Parameters of the Main Current Sources

	PS1 PIT 11-50	PS2 PIT 01-40	PS3 PIT 0.6-30
Supply voltage Un	3f~50 Hz 380/220 V		
Peak power, kW	600	45	25
Source voltage, VDC	+/−50	+/−40	+/−30
Maximal current, kADC	11	1	0.6
Current stability at dI/dt not equal to zero	$2 \cdot 10^{-4}$		
Minimal duration of the rise/fall of the field, s	18		
Current stability at dI/dt=0	$2 \cdot 10^{-5}$		
Maximal duration of the field table, hour	24		

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The connections of the superconducting magnets with "warm" devices are carried out by means of current leads CL1...12, CL56, CL78.

In the measuring magnets MMs and the lenses RQ1 and RQ2, induction magnetic field sensors are installed, the signal from which enters the diagnostic and control devices.

THE MAIN POWER SOURCES

The Collider's power system includes three main sources and a number of additional ones. The parameters of the main sources are given in Table 1.

The powerful PS1 source consists of 7 cabinets, an introductory one and six cabinets with PWM converters connected in parallel. To ensure nominal modes, 5 cabinets with PWM converters are sufficient; the sixth cabinet is a backup. The carrier frequency of the conversion of the PIT11-50 source is several tens of kHz. The general view of the cabinet with PWM converters and the converter itself are shown in Fig. 3.

The PS2 and PS3 sources are identical, built on the same principles as PS1, and differ only in the nominal parameters given in Table 1. Each source is made in the form of a separate cabinet. All three sources are controlled from a single center with allowance for mutual influence on each other.

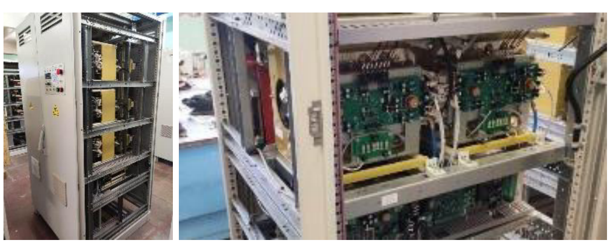

Figure 3: PIT11-50, general view of the PWM converter cabinet and the PWM converter power module.

The sources were developed and manufactured by the scientific and production enterprise LM Invertor (Moscow).

ENERGY EVACUATION SUBSYSTEM

Basic requirements for the EE subsystem:

- energy output from superconducting magnets with a time constant of 160 ms,
- with EE, the maximum voltage on the current leads relative to the potential of the "earth" should not be more than 500 V.

Based on the specified parameters, the field quenching resistance should be 0.29 Ω, and it is necessary to apply 6 groups of SWs.

The diagram of the potential distribution relative to the "earth" on the structural magnets during the evacuation of the maximum current of 10.4 kA for one of the Collider rings is shown in Fig. 4.

A high-speed automatic switch of the VAB-49 type with parameters should be taken as the basis of the SW: the current is 6.3 kA, the voltage is 1000V, the shutdown time is 8 ms. The block diagram of the Collider SW is shown in Fig. 5.

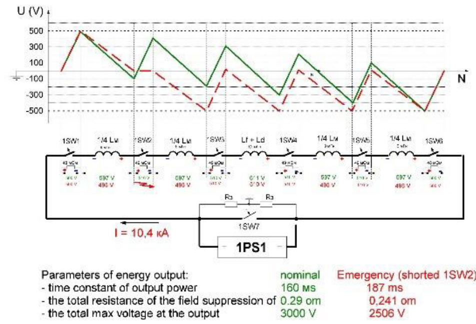

Figure 4: Plot of the potential of the structural magnets during evacuation of 10.4kA current: the normal mode is the green solid line, the emergency mode due to a defect of SW2 is the red dotted line.

The SW consists of 4 unit VAB-49 connected in series and parallel, resistor field quenching units, current sensors, connecting buses and cables, and a control subsystem.

The main technical parameters of the SW: switching current 10.4 kA, voltage 1000 V, shutdown time 12 ms, number of shutdowns up to revision 500, dimensions 1.6×1.0×2.4 m, weight 2.5 t. In total, 12 energy evacuation keys are involved in the power supply system of both Collider rings.

ADDITIONAL SOURCES

To ensure the modes of mixing and dilution of charged particle beams in the zones of the MPD and SPD physical installations, it is necessary to form fields in the superconducting magnets BV1, BV2 (inductance 200 mH). Precision current sources IP500-15 (current 500 A, voltage 15 V, stability $2 \cdot 10^{-5}$) for these magnets are being developed by the LM Invertor enterprise (Moscow). A total of 12 such sources are needed.

Additional sources of the current of the unbalance of the structural lenses of the rectilinear and final focus sections provide a change in the current in the range of +/−3% of the main one. Inductance of structural lenses are in the range of 100-300 μH. A source from DELTA ELEKTRONIKA (The Netherlands) of the type SM 15-400 (15 V, 400 A, current accuracy $2 \cdot 10^{-4}$) with a series-connected energy evacuation device EED300-70 (300 A, 70 V) was tested, Fig. 5.

Figure 5: Testing a source with an EED (from right to left SM 15-400, EED300-70, and test bench).

An additional source consisting of SM 15-400 and EED300-70 satisfy the technical requirements.

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The layout of the additional sources in racks of 4 elements is being developed. In total, 106 additional sources and, accordingly, 26 racks will be required.

CONTROL EQUIPMENT

To control the equipment of the Collider power system, electronic hardware is being developed that connects all segments of the system into a single whole: power sources, SWs, superconducting magnet protection devices, cycle-setting equipment, automated control system (ACS), current monitoring system, etc.

Figure 6: Control racks with a crate of the electronics of the Nuclotron power system.

The rack and the electronics will be an improved version of the existing similar systems built to control the Booster and Nuclotron power supplies. Figure 6 shows the control stand and the electronics crate of the Nuclotron power supply system.

A SYSTEM FOR MEASURING PRECISION CURRENTS

The current measurement system (CMS) is designed for high precision measurements in a wide range from 0 to 11000 A of magnet currents. The system includes LEM-type ultra-precision current sensors with a measurement accuracy of $6.5 \cdot 10^{-5}$ and a bandwidth of 20 kHz, a current meter control (CMC) unit, and software.

The appearance of the CMC units and the main measurement board are shown in Fig. 7.

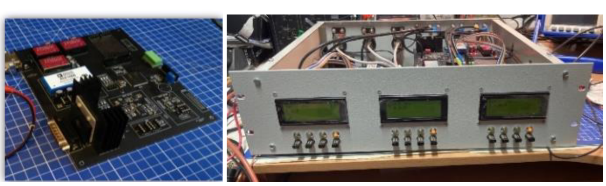

Figure 7: CMC measuring card and the view of the CMC unit.

An example of the program interface for the operator of the Collider power supply system is shown in Fig. 8. The interface displays the functions of the reference (green beam), the measured current (blue beam) and the error signal between them (red beam) (data are given for a proven similar CMS of Booster sources).

The SMC equipment will allow measuring currents in real time in the range from 0.1 to 10000 A, with an accuracy in dynamics mode up to $1 \cdot 10^{-4}$, static mode $2 \cdot 10^{-5}$, with a frequency of 800 Hz, and archiving the received data.

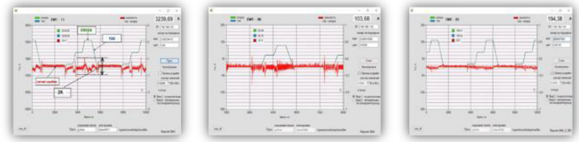

Figure 8: The interface for displaying currents on the example of a Booster CMS (from left to right PS1, PS2, PS3).

PLACEMENT OF EQUIPMENT

All elements of the power system are located in the Collider bldg. 17. Figure 9 shows a fundamental wiring diagram related to the 1st ring.

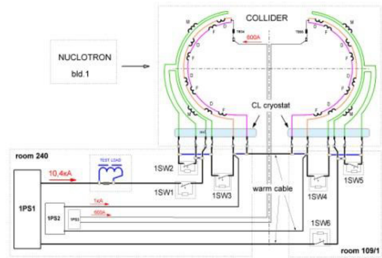

Figure 9: The basic wiring diagram of the power supply of the 1st ring of the Collider. The blue color shows the equivalent load and its connection circuits.

The equipment of the Collider power system is grouped into 2 zones:

- room 240 houses power supplies, some of the SWs, a control center for the system;
- room 109/1 houses the rest of the SWs.

Power and control cables are laid between rooms 240 and 109/1 along the technological channel of the inner radius of the bldg. 17, see Fig. 10.

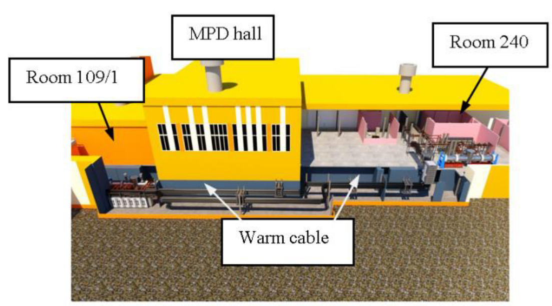

Figure 10: General view of the power system equipment layout in bldg. 17.

CONCLUSION

Installation and commissioning of the power supply system is planned for summer-winter 2022. A technological run at the Collider will be at the middle of 2023, and a beam run will be in end on 2023.

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