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THE HIGH VOLTAGE POWER SUPPLY SYSTEM FOR THE ELECTRON COOLER FOR CSRe

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Abstract

The high-voltage power supply system for upgrade of the electron cooling system of CSRe ring in the IMP, was developed at the BINP in 2014 - 2019. The main features are - maximum voltage is 300 kV, stability - 10ppm, with the ability of quick changing of voltage in range ±10% of nominal voltage for a time not more than 500 μs. The key points of this design are presented in this article.

INTRODUCTION

In 2014 – 2019 upgrade of the electron cooling system of CSRe ring in the IMP (Lanzhou, China) was carried out. The high-voltage power supply system for upgrading was developed at the BINP. The power supply system consists of 10 controlled modules, distributed by the high voltage potential. Each module has a precision controlled voltage source. All the systems are controlled through the wireless network interface. System was installed and tested at CSRe ring in IMP at May – June of 2019.

High voltage system of such a modular structure already was created in BINP earlier for an high voltage electron cooler for heavy ions, which was installed on the COSY accelerator (Jülich, Germany) [1, 2]. New system has essential differences from old one. It does not have current sources for solenoids, but it has additional circuits for detuning mode. This mode allows change the energy of electron beam within 10% range from mean level. The main parameters of the cooler are as follows: the electron energy is from 5 keV to 300 keV and the current is up to 2 A. The energy instability of the new supply system will not exceed 10 ppm. Main limitations for installation is the need to fit into an existing vessel installed on an already-existing electron cooling system.

The main parameters of the accelerator column of the cooler are presented in Table 1.

Table 1: Main Parameters of the Power Supply System

Parameter	Units	Value
Supply voltage	kV	5 - 300
Voltage instability, less than	ppm	10
External power supply	V	400 - 500
Carrier frequency	kHz	20
Power consumption	kW	3-5
Total height of the column	m	1

Designed power supply system along with precision output parameters should have high reliability and resistance to high voltage discharges.

STRUCTURE OF THE POWER SUPPLY SYSTEM

The structure of the power supply system is shown in Fig. 1.

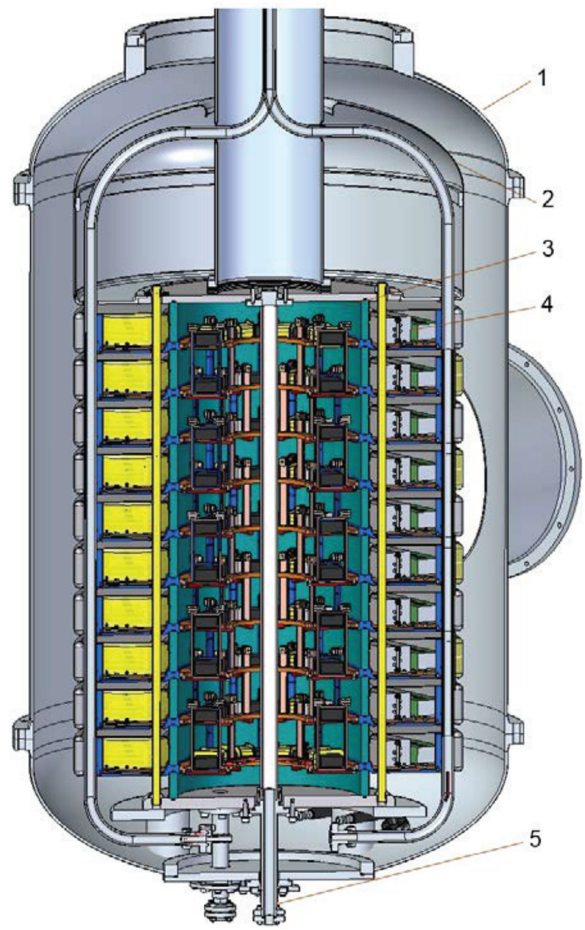

Figure 1: The structure of the high voltage column. 1 – SF_6 tank; 2 – shielding cover; 3 – high voltage cascade transformer; 4 – high voltage section; 5 – isolating and cooling oil tubes.

The high voltage column is placed in the tank, filled with SF_6, and contains high-voltage sections, cascade transformer, oil tubes for high voltage terminal, and communication circuits.

The SF_6 tank already exists in the cooling system, so dimensions of sections are determined by the tank dimensions and high voltage clearances. The cascade transformer provides required power for the high voltage sections and high-voltage terminal. The high voltage

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sections provide a voltage required for electron beam acceleration.

Requirements to high voltage in the accelerator column are pretty tough: the ripple and long-term instability shall not exceed 10^{-5}. A full voltage is generated by 10 high-voltage sections with a maximum voltage of 30 kV each. Additional requirement to high voltage section is ability of quick changing of accelerating voltage in range of ±10 % for the time of 500 µs.

The general view of the section is shown in Fig. 2.

Figure 2: The general view of the high voltage section.

The high-voltage section is powered from the power-takeoff winding on the corresponding section of the cascade transformer. Externally, the section looks like a disc 80 mm high of 750 mm in diameter, with a cascade transformer in center, closed with screens from above and below. The bottom screen is also a load-bearing element and supports the entire structure. Along the perimeter, the section is shielded with metal bands. A section comprises two aluminum support plates with electronic installed on them.

KEY POINTS OF DEVELOPING

From a user's point of view, the electronics of the high-voltage section is a high-precision regulated high-voltage power supply (1 mA, 30 kV), integrated into a shielded housing. One section consumes no more than 300 W: about 50 W for generation of high voltage, 20 W for thermal stabilization of precision divider, and the rest for providing fast energy changes. Acceptable supply voltages vary from 100V to 250V.

The essential part of electronics unit is precision high voltage divider. This part is enclosed in isolating box and has thermal stabilization for providing precision measurements of output voltage and feedback in the high-voltage stabilization circuits. A general view of the divider is shown in Fig. 3.

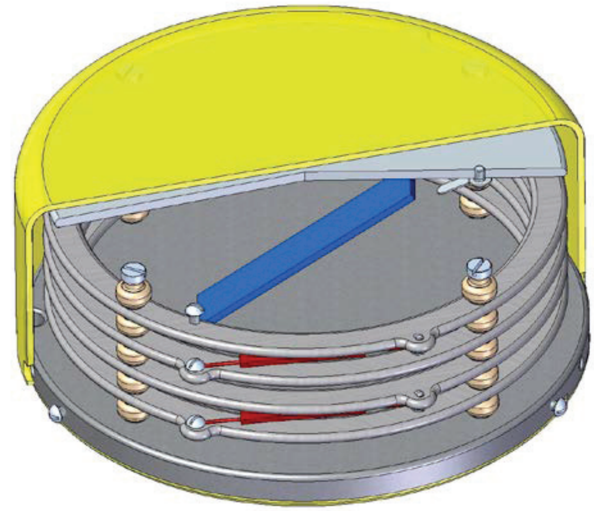

Figure 3: General view of the precision high voltage divider.

Key difference from earlier COSY cooler supply system is detuning operation mode. In this mode energy of electron beam changes in the range of ±10 % from mean value. So as load for the supply system is high voltage terminal, relatively high current needed to charge high voltage terminal capacitance during this energy changes. To have ability to change energy in 500 µs, peak current should be about 300 mA. Taking into account voltage up to 300 kV, peak power during this changes should be up to 100 kW (10 kW per section). Special high voltage amplifier designed to supply this power and provide accuracy.

Section also contains auxiliary power supply for the electronics, filtering elements, controller board, and a transceiver for communication with the controlling server by the radio frequency channel.

The control interface is realized in a ZigBee self-organizing network based on Telegesis transceivers [3]. This network operates in the 2.5 GHz radio frequency band, which allows to communicate without a large number of optical lines and simplifies the mounting and maintenance of the system. The structure of the section is shown in Fig. 4.

Prior to developing main high voltage supply system, we developed a prototype of high-voltage section, on which we made preliminary tests of all systems of the section and debugged the feedback of the power supplies. In addition, we tested resistance to electrostatic discharges. This prototype was designed in 19 inch rack and used as power supply for electrostatic plates. This part of power supply system was delivered to IMP one year earlier than main high voltage column, tested as main power supply for the low voltage cooler at CSRm, and used in recombination experiments [4].

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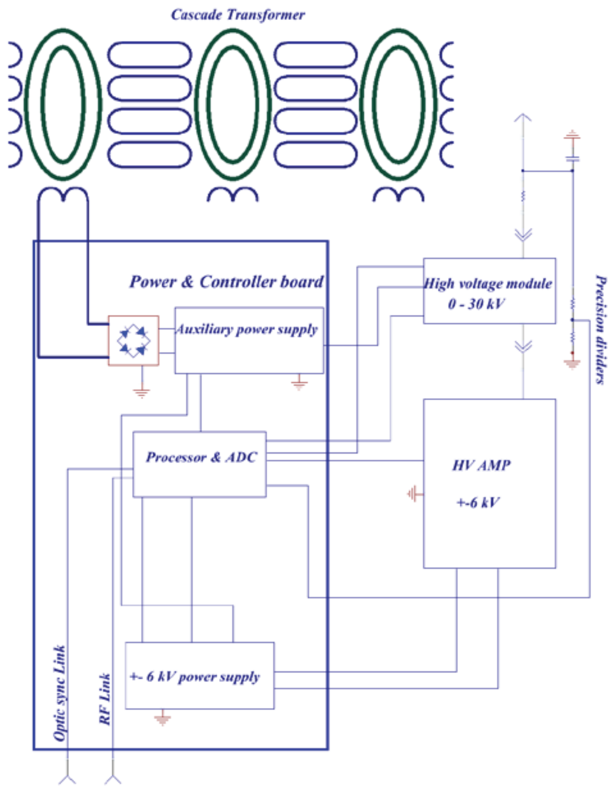

Figure 4: The structure of the high voltage section.

A set of programs with graphical interface were developed for control and monitor of the high voltage power supply system. A screenshot of the graphical interface of the program is shown in Fig. 5.

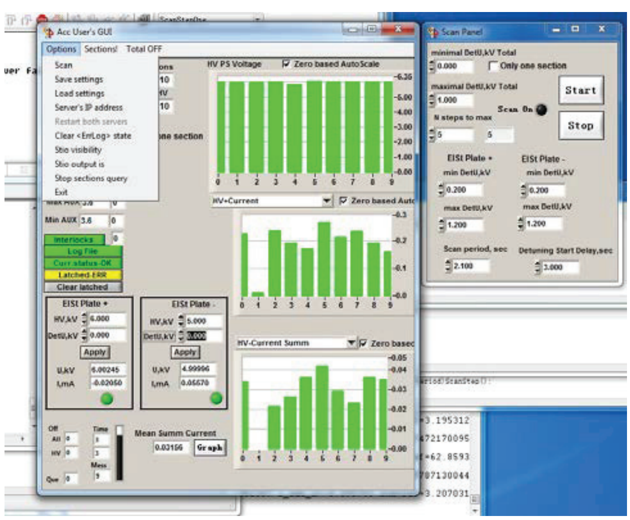

Figure 5: A screenshot of the graphical interface of the supply system control software. An accelerating voltage of 60 kV, a high voltage of about 250 μA presented.

The entire power supply system and individual units of the installation were tested at BINP in the summer and autumn of 2018. High-voltage tests were carried out at voltages in the column of up to 120 kV and detuning voltage up to ±20 kV. Numerous high-voltage breakdowns at voltage of 100 kV in air allowed us to identify and eliminate trouble spots in the power supply system. At the spring of 2019 power supply system was shipped to Lanzhou, and at summer was installed and tested on the CSRe ring.

CONCLUSION

High voltage power supply system for CSRe cooler was designed and produced in BINP. First testing electronic units and all system carried out in BINP before shipping to IMP. The final high-voltage tests of the power supply system and cooler system as a whole performed in IMP after installation on CSRe at summer of 2019 showed that the power supply system of the high-voltage column in general meets all the requirements of the electron cooler.

ACKNOWLEDGEMENTS

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