FREE ELECTRON LASER FOR SIBERIAN CENTRE FOR PHOTOCHEMICAL RESEARCH: THE CONTROL SYSTEM FOR THE MAGNET POWER SUPPLIES[1]

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Abstract.

A control system for the magnetic system of the free electron laser (FEL) is described. The characteristics and structure of the power supply system are presented. The control system is based on embedded intelligent controllers with the CAN-BUS interfaced. The control software structure and capabilities are described. A possibility of connection of the control software to the integrated control system using the Epics Channel Access protocol is also discussed.

INTRODUCTION

A high-power FEL, based on the accelerator-recuperator, [1] is under construction now at the Budker Institute of Nuclear Physics. The first phase of the project - the terahertz FEL - was commissioned recently [2].

This article discusses the control system for power supplies for the FEL magnetic system. The magnetic system consists of bending magnets, quadrupole and solenoid lenses, undulators, buncher, and steering coils, about 60 elements in all. All these elements are fed from controllable DC sources, which were developed and manufactured by the Budker INP. All power sources are controlled by a computer, via digital-analog converters. Current and voltage on elements of the magnetic system are measured with the help of analog-digital converters.

POWER SUPPLY SYSTEM

The DC power supplies of different types were used. They can be divided into four groups in dependence on current and power consumption. The first group, consisting of power sources of the lowest power, with the current range ±3A and power up to 40 W, feeds windings of the steering magnets, additional (correcting) windings of the bending magnets and focusing quadrupoles. Power sources with the current range ±20A and power up to 200W, which feed the main windings of the bending magnets and focusing lenses, can be referred to the second group The third group includes two higher-power sources for 165-degree magnets with output current up to 1000A and power up to 10 kW. The power source for two serially-connected undulators, with output current up to 2500 A and power up to 120 kW belongs to the fourth group.

Power sources of the first and the second group are power amplifiers fed from direct voltage sources. They are devices with deep negative feedback and provide across a low-resistance shunt a voltage that is proportional to the input one.

The technical characteristics of the power sources of the first and the second groups are listed in the Table 1.

Table 1: Parameters of the low-power current supplies

	gr. 1	gr. 2
Nominal load current	± 3A	± 10A
Voltage of the buffer power source	12V	20V
Gain determination error (output current/input voltage)	± 1%	± 1%
Output current instability	± 6mA	± 6mA
Output voltage ripple level (100 kHz)	0.1V	0.1V
Control voltage at the nominal load current	± 6V	± 6V

The high-power sources of the third and fourth groups (the bending magnets and undulators) are made on the base of three-phase thyristor voltage regulator [3]. The technical characteristics of the power sources of the third and the fourth groups are shown in Table 2.

Table 2: Parameters of the high-power current supplies.

	Bending magnets	Undulator
Max output voltage	12V	48V
Max output current	1000A	2500A
Output voltage pulsation amplitude at the output current and output voltage making 80% from the maximal one	10 mV	0.4 V
Relative output current instability	0.02%	0.01%
Relative power source efficiency	80%	92%
Cooling system	water	water
Max power consumption	15 kW	130 KW

The tolerances for instability of magnetic field in elements of the magnetic system were defined from the consideration of the effective emittance growth [4]. If no more than twice-increased emittance is allowed, then the

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maximal allowed field instability values are defined for different elements and thus the value of current stability of the power sources for the magnetic system is also defined. It was shown, that the 1% current stability is necessary for quadrupoles and steering coils, and 0.1% current stability is required for bending magnets and undulators.

CONTROL HARDWARE.

By the time of design of the control system for the power supplies, the BINP has developed the microprocessor controllers with the CAN-BUS interface [5]. Comparative analysis of possible configurations of control systems for power supplies revealed significant advantages of the scheme on the base of CAN-BUS devices, which has determined the choice of the system. The main characteristics of the devices, used in the automation of the magnetic system, are presented in Table 3.

The whole power supply system for the FEL magnetic system includes 4 low-power racks, 2 high-power racks for the bending magnets and a power rack for the undulators.

Table 3: Parameters of DAC and ADC.

Parameter	Candac16	Canadc40	Cdac20
DAC resolution	16 bits	-	21 bits
DAC accuracy	0,05%	-	0,005%
DAC channels	16	-	1
ADC resolution	-	23 bits	23 bits
ADC accuracy	-	0,03%	0,003%
ADC channels	-	40	5
Scale (input/output)	10 V	10 V	10 V

The scheme of communication of all controllers with the central computer and arrangement of the power racks are shown in Fig. 1.

Each low-power rack (racks 3A and 10-17A) has 3 sections. Each section is controlled by a **Candac16-Canadc40** couple and can contain up to 16 independent current sources (channels). Correspondingly, there can be up to 192 channels in 4 racks. By now, about 150 channels are in use. Each high-power rack is controlled by **Cdac20** controller.

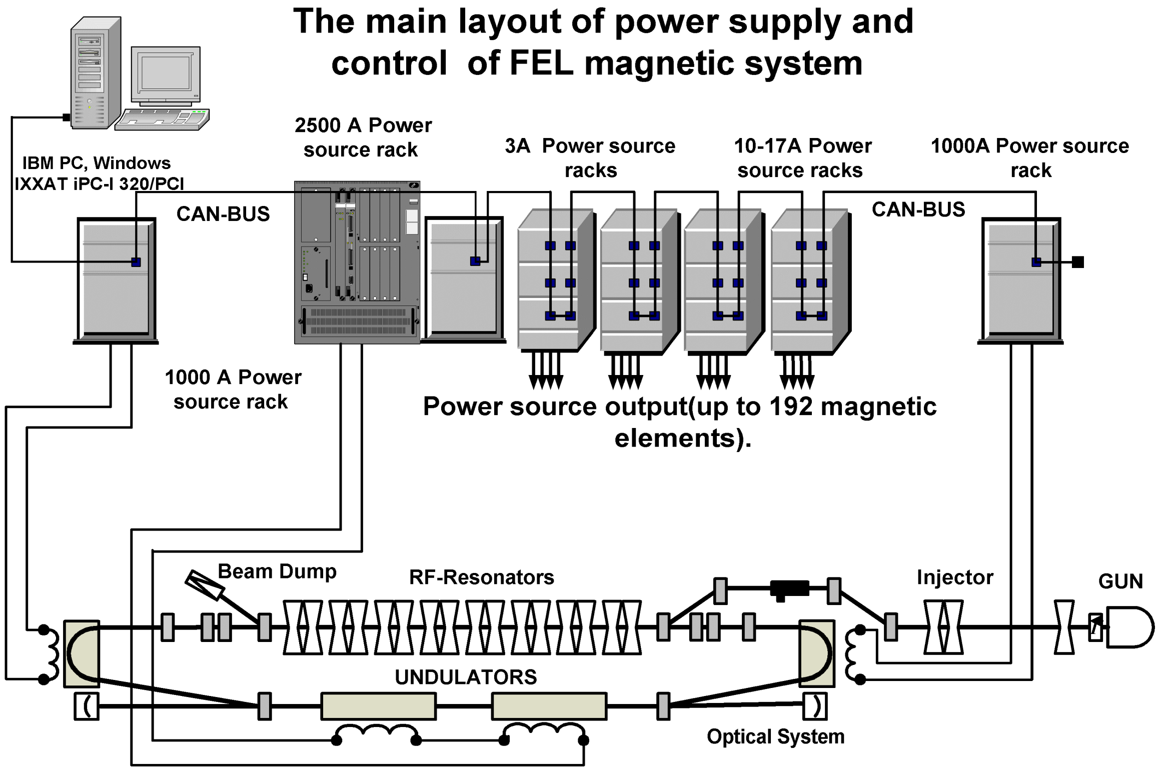

Figure 1. Control and power supply scheme for elements of the magnetic system.

SOFTWARE

The control program for power supplies of the magnetic system was developed on the MS Windows 2000 platform. The C++ language was used for control codes. The CAN-to-PC interface is provided by the PCI-board iPC-I 320/PCI of IXXAT. Interaction with this board at the program level is performed using the set of functions called VCI (Virtual CAN Interface).

An approximate internal structure of the program is shown in Fig. 2.

The main features of the program are:

1) Ability to save the values of all currents in all elements to a file (working regime) at any time, and load a regime from the file.

2) Continuous control of deviations of the measured currents from the set values. If the difference is too large (violation of the user-set limit), that element is indicated by color in the main window of the program.

3) The remote control over all elements of the system using Epics Channel Access Server, i.e., one can set and check currents of elements from any other computer in this local network.

4) Demagnetization of all elements of the system via applying to an element the current of an alternate polarity, and amplitude damping from the maximal source current to zero.

5) Possibility of single-channel measurements of any selected element with measurement time down to 1ms.

6) Cyclic measurements of all used ADC channels in the single-channel mode, sequentially for all power sources. This allows one to indicate possible voltage and current instabilities in a power supply with the bandwidth up to 300Hz.

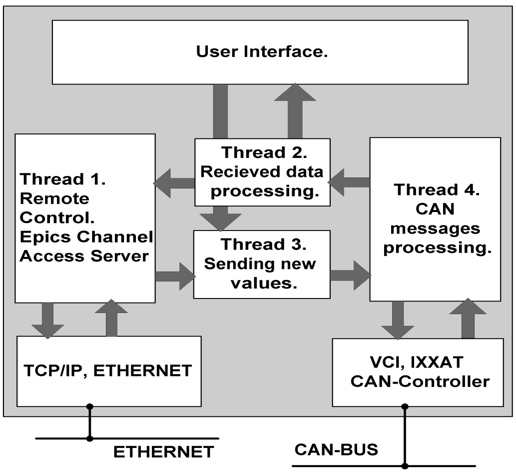

Figure 2. Structure of the control program.

The main window of the program is shown in Fig. 3.

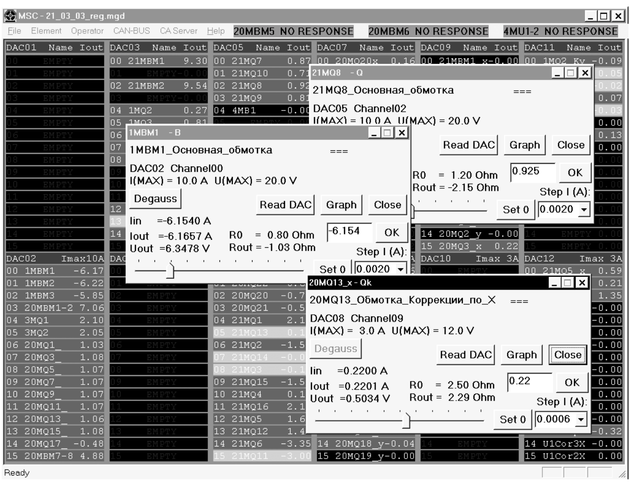

Figure 3. The main program window.

The front panel of the program depicts schematically with cells of different colors all the power sources in the four low-power racks. The text and the background colors of cells represent the status of power source. Content of the cells indicates the number of the power supply channel in the section, name of the magnetic system element controlled by this source, and the value of the set current in it. Then, after clicking by left mouse button on the cell, the individual dialog window for this power source appears (see Fig. 3).

Cells of elements are grouped in columns by 16 items (according to the number of channels in a section) and the columns are numbered in correspondence with the common number of this section in the racks: DAC01–DAC12 – 12 sections in 4 racks.

Remote control over the magnetic system is performed via the Epics Channel Access interface. So, the program meets the main requirements of EPICS, and may be integrated into distributed control system.

CONCLUSION

By now, the first phase of the free electron laser is in operation. We have reached generation of coherent radiation at near wavelength of 150 micron. During the operation, the magnetic system demonstrated high reliability. This realization makes it possible easily to add, remove, and change power supplies for the elements of the magnetic system, as well as to replace power sources and controllers. That can be made without reloading of the control program. Examination of the power source operation allows quick detection and investigation of failures of individual channels and the supply system as a whole. The possibility of remote control via the Epics Channel Access interface makes it possible to integrate it into the general control system of the FEL.

Architecture of the supply system is scalable, which allows its easy extension for the second phase of the FEL without modifications of the software.

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