IOP Conf. Series: Materials Science and Engineering **199** (2017) 012048 doi:10.1088/1757-899X/199/1/012048

Control system of mobile radiographic complex to study equations of state of substances

O V Belov, R V Valekzhanin, D V Kustov, O A Shamro and T V Sharov

Russian Federal Nuclear Center – VNIIEF, 37 Mira Ave., Sarov, 607188, Russia

Roman.Vlzh@gmail.ru

Abstract. A source of x-ray radiation is one of the tools to study equations of state of substances in dynamics. The mobile radiographic bench based on BIM-1500 [1] was developed in RFNC-VNIIEF to increase output parameters of the x-ray radiation source. From automated control system side, BIM-1500 is a set of six high-voltage generators based on the capacitive energy storage, technological equipment, and elements of a blocking system. This paper considers automated control system of the mobile radiographic bench MCA BIM 1500. It consists of six high-voltage generator control circuits, synchronization subsystem, and block subsystem. The object of control has some peculiarities: high level of electromagnetic noise, remoteness of the control panel from the object of control. In connection with this, the coupling devices are arranged closer to the object of control and performed in the form of a set of galvanically insulated control units, which are combined into a net. The operator runs MCA BIM using the operator's screens on PC or by means of manual control on the equipment in the mode of debugging. The control software provides performance of the experiment in automatic regime in accordance with preset settings. The operator can stop the experiment at the stage of charging the capacitive storage.

1. Introduction

A source of x-ray radiation is one of the tools to study equations of state of substances in dynamics. The electrophysical benches based on small-sized, ironless betatrons (BIM) [1] provide the needed power, spectral composition, and time characteristics of radiation. The mobile radiographic bench based on BIM-1500 [2, 3] was developed in RFNC-VNIIEF aimed to increase output parameters of the x-ray radiation source.

2. Description of the automation object

Electrophysical benches of BIM type consist of:

- ironless betatron accelerating an electron beam;
- injector performing generation, preliminary acceleration and electron beam entering the betatron;
- systems of fast and slow dumping which are necessary for the shift of the accelerated electron beam on the target and hereby, x-ray radiation generation.

From automated control system side, BIM-1500 is a set of six high-voltage generators based on the capacitive energy storage (CES), technological equipment, and elements of a blocking system.

Generators based on the capacitive energy storage are intended for forming high-voltage pulses and represent complex electrophysical facilities (EPF) consisting of several subsystems that operate according to the setup algorithm. The general structural scheme of such generator is provided in Figure 1.

IOP Conf. Series: Materials Science and Engineering **199** (2017) 012048 doi:10.1088/1757-899X/199/1/012048

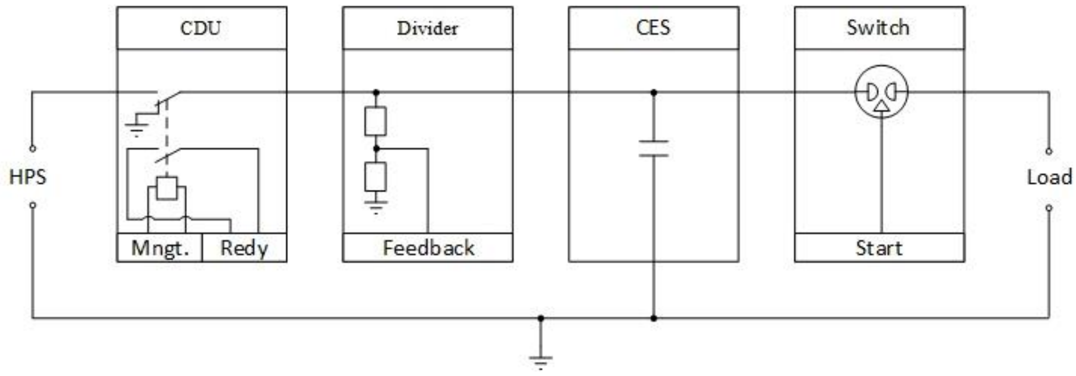

Figure 1. Structural scheme of the generator with capacitive energy storage

The high-voltage generator consists of the capacitive energy storage, switch for transferring energy of CES into the load, resistive voltage divider for voltage control on CES and charging - discharge unit (CDU) for connecting to the high-voltage power supply (HPS), discharge and shorting of CES to the ground. Such a generator often operates into the inductive load that is a source of electro-magnetic fields of broad spectrum of frequencies. The electro-physical bench can contain a set of generators of this type distributed in space.

3. The structure of the control circuit high-voltage generator

Automated control system (ACS) is one of the subsystems of the electrophysical bench; its main functions are defined according to the assignment and generator scheme:

- charge and charge voltage stabilization of CES on the fixed level;
- discharge and shorting of CES in case of emergency;
- switch starting according to the given time algorithm.

The control system of high-voltage generator allows fulfilling of the indicated functions completely. Its structure is shown in Figure 2.

The object of control has some peculiarities: high level of electromagnetic noise, remoteness of the control panel from the object of control. In connection with this, the coupling devices are arranged closer to the object of control and performed in the form of a set of galvanically insulated control units (CU), which are combined into a net.

Connection with CU and triggering signals transmission are performed along a fiber-optic communication line. Thus, control circuits of EPF are galvanically insulated from each other and the central control panel. Galvanic separation of the circuits is a radical solution of the most issues connected with grounding. Actually, its application became a standard in systems of industrial automation [4, 5].

The control unit forms commands of energizing to the operation units, fixes the level of voltage HPS setting, controls the switching of “high voltage” HPS, performs the digitization of a feedback signal and transmission of discrete signals of operation units condition to PC (response ON HPS, response ON CDU, response Ready BING).

Starting of the block pulsed voltage generator (BING) [6] is performed with the usage of the channel of the programed synthesizer of time intervals (SVIP) and receiving optical module (PROM). BING performs the starting of the generator switch.

IOP Conf. Series: Materials Science and Engineering **199** (2017) 012048 doi:10.1088/1757-899X/199/1/012048

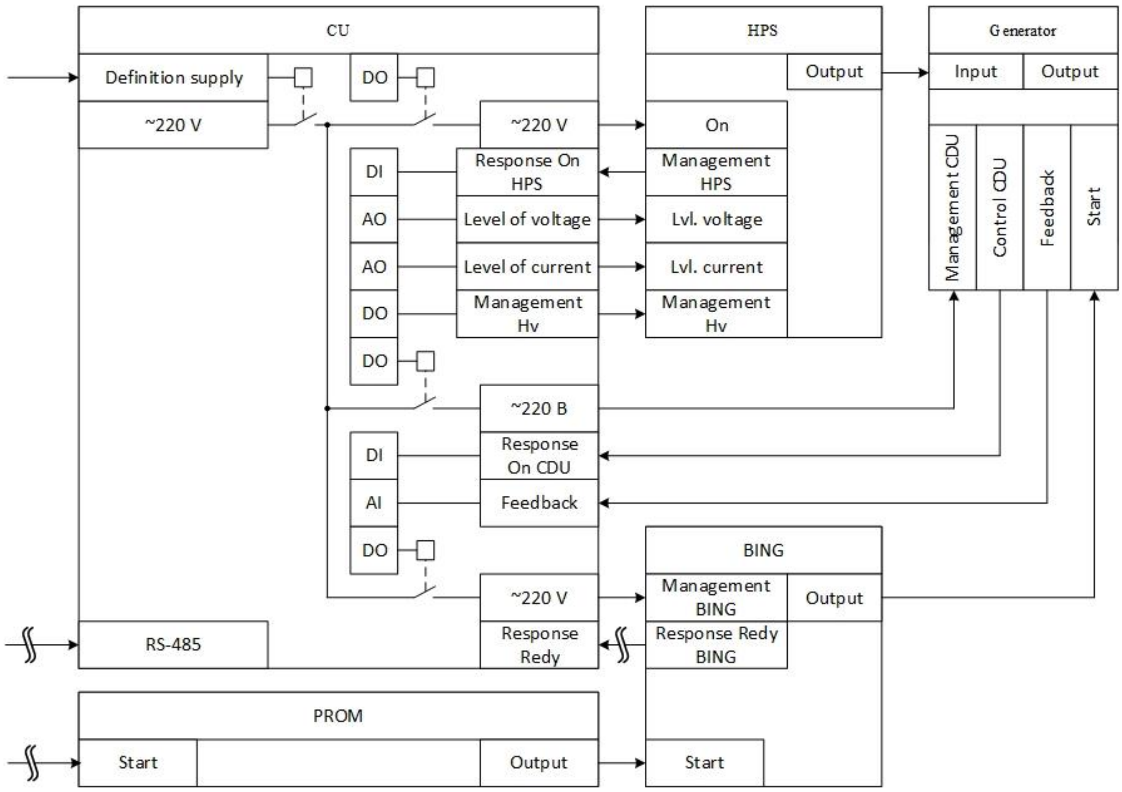

Figure 2. The general structural scheme of control system of high-voltage generator

4. The structure of the automated control system of the mobile radiographic bench MCA BIM1500

It is possible to design a reliable, cheap, and scaled control system of the electrophysical bench from the typical control circuits of the high voltage generator. The automated control system of mobile electrophysical bench BIM-1500 contains six control circuits of high-voltage generators, industrial computer, synchronization system, blocking system, and optical blocking system. The general structural scheme of the ACS is presented in Figure 3.

The electromagnet starting device (UZEM) starts the magnet switch, thus beginning the accelerated cycle.

The programed synthesizer of time intervals is a sixteen-channel generator of optical pulses; it forms the optical pulses in every channel with a programed time delay relative to the starting signal. The blocking system provides a hardware security from the voltage supply on the high-voltage devices in case if the staff is in the rooms of danger area, and if there are no requests from the control program or the operator's blocking of high-power voltage.

The optical blocking unit (OBU) provides the γ-radiation rate prediction according to the synchronized radiation of the electron beam that is registered in the process of electrons acceleration by the synchrotron radiation sensor (SRS). It makes the commands for starting of the studying process in case if the intensity of the synchronized radiation is higher than the fixed low threshold value. In case if the predicted radiation intensity is lower than the minimal threshold value, the experiment is stopped and the information about the interruption causes is provided.

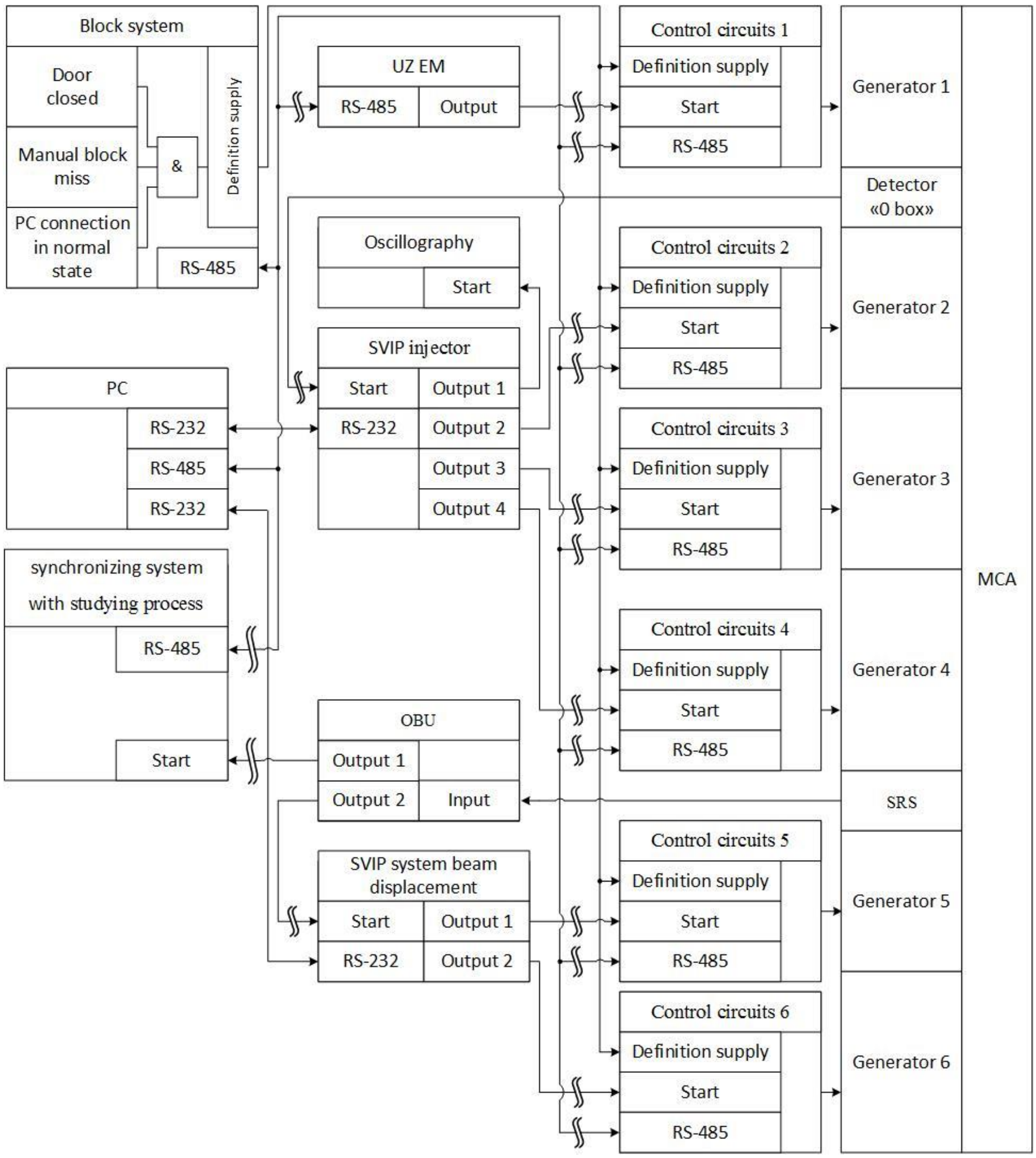

Figure 3. The general structural scheme of the automated control system MCA BIM BIM-1500

5. Software description

The operator runs MCA BIM using the operator's screens on PC or by means of manual control on the equipment in the mode of debugging.

All the necessary information about the accelerator condition is presented on the operator's screens in friendly and comfortable way; control elements and ACS parameters for tuning are provided. The screenshot of the remote control screen is illustrated in Figure 4. It is intended for the operation of the electrophysical bench by the qualified operator at some subsystems tuning.

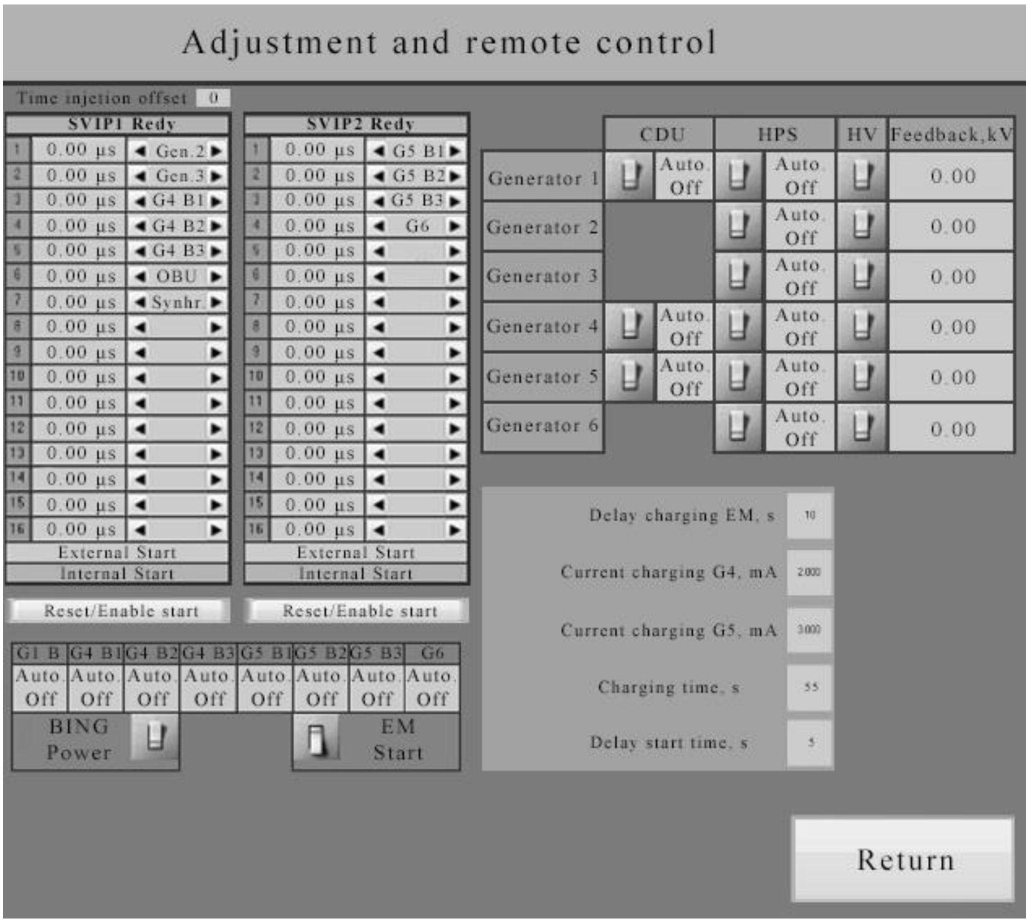

Figure 4. Remote control screen

The screenshot of the automated control screen is illustrated in Figure 5. It is intended for the operation of the electrophysical bench in the automatic mode.

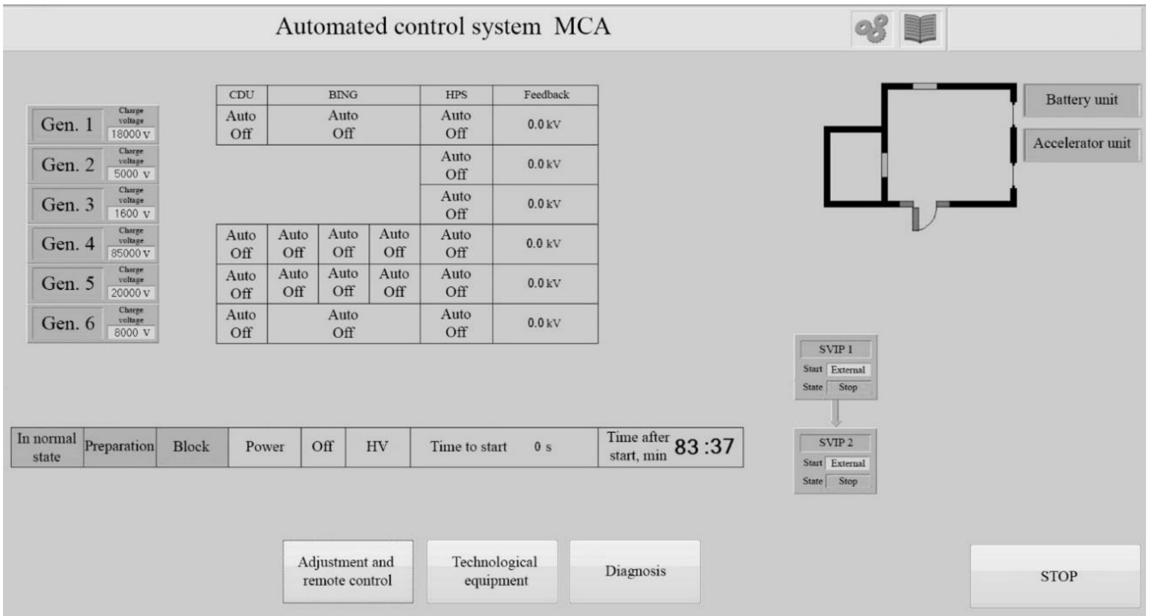

Figure 5. The screenshot of the automated control screen

IOP Conf. Series: Materials Science and Engineering **199** (2017) 012048 doi:10.1088/1757-899X/199/1/012048

The automated control screen contains the selection field of the experiment revision, information field of the units conditions of EPF, track plan of the perimeter condition and synchronization system.

The software algorithm is the following: all the devices operating in the experiment are switched on after the command "Start". If all the devices are ready, CES begins charging: the signal comes "high on" for HPS, the signals are formed to fix the level of output voltage of high-voltage power supplies, feedback and facility mismatch is controlled. The accelerated cycle starts with the help of UZEM after charging time is up. The accelerated cycle control is performed only in the automated mode and defined by the SVIP and OBU tunings. When the accelerated cycle is over, all the high-voltage devices are off; there are "shorting" of the capacitive energy storage, all settings and stop reasons (in case of emergemcy) are recorded into "EPF log".

6. Conclusion

Developed automated control system ensures optimal functioning of mobile radiographic bench MCA BIM 1500 at any stage of the preparation and conduct of the experiment. Modularity and the availability of spare channels of the synchronization system allows easy expansion to cover additional devices required in the experiment.

Acknowledgments
The authors are thankful to V.M. Zaitsev and Yu.P. Kuropatkin.

References

[1] Gerasimov A I, Kuropatkin Yu P and Tarasov A D 1996 *Ironless betatron – narrow-pulse generator radiation for radiographic high-speed processes* (Moskow Atom **2**), pp 32-37.
[2] Zenkov D I, Kuropatkin Yu P, Nizhegorodtsev V I, Selemir V D and Shamro O A 2015 Patent 2548585 C1 RU MPK G03B 42/02. *Mobile radiographic complex and betatron type radiation source for radiographic complex,* **11.**
[3] 2013 *Main achievements of RFNC-VNIIEF 2013* (Sarov) pp 34-35
[4] Alferov V N 2008 *Control system electrophysical facility* (Moskow: MEPhI) p 184
[5] Denisenko V D 2006 STA *Grounding* in systems of industrial automation (Moskow STA **3**), pp 76-78.
[6] Kudasov B G, Pavlov S S and Tananakin V A 1997 *Proceeding of the 11th Pulsed Power Conf.* (Baltimore) p 465.