POWER SUPPLY DEVELOPMENT FOR ION SOURCE OF ACCELERATOR MLUD-3

Ye.V. Gussev, O.V. Manuilenko, V.N. Sokol, A.A. Turchin, V.V. Zhiznevsky
National Science Center "Kharkov Institute of Physics and Technology", Kharkov, Ukraine
E-mail: turchin@kipt.kharkov.ua

The paper presents the results obtained during the development of the design of the power supply for a ions source of the douplasmatron type with a hollow cold cathode, which operates in a pulsed mode .The experience of using the existing power supply device is generalized and the need for work on a new power supply device creation is justified. The choice of circuit solutions for the design is discussed, as well as the main parameters of the device.

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INTRODUCTION

The ion source in the MRLU-3 accelerator is a double-chamber plasmatron [1] with a hollow cold cathode. A feature of his work is the need for the existence of a high-voltage (≥400 V) gas discharge in the first chamber. This kind of discharge provides a powerful emission of electrons from the developed inner surface of the cathode. With these discharge parameters, a paraxial electron beam with a current of ~150 A is created, providing a high degree of ionization in the near-axis region in the second discharge chamber [2]. A low-voltage arc discharge in a contracting magnetic field created by an electromagnet makes it possible to obtain in the second chamber of the ion source a high content of the atomic component of the ionized gas H^+_1 or D^+ (75...90)%.

To power supply the ion source for a long time, the mockup of the ion source power supply device (ISPSD) created in the department was used. It consists of modulators supplying the discharge chambers of the ion source and the solenoid valve for the gas inlet, as well as the current source for the electromagnet. The power supply provides the necessary duration and magnitude of the current pulses in the discharge chambers of the source. The device is shown in Fig. 1, it is located in two baskets of the "Vishnja" standard.

The parameters of the power supply corresponded to the requirements that were lodge during the adjustment and investigation of the accelerator characteristics [3 - 5]. During the adjustment process, it turned out that the device does not meet certain requirements required when operating the accelerator as a radiation irradiation setup. In particular, it does not provide the required stability of the currents in the discharge chambers, as there is no stabilization of the charging voltage of the storage capacitors. Regulators of storage capacitors charge voltage are made on autotransformers, which were operated by means of insulating rods. The maximum repetition rate of impulse did not exceed 2 Hz. This is due to the low speed of the modulator's storage capacitors charge circuits and the limited amount of permissible power dissipation on the pulse modulators elements.

Since at the end of the adjustment work on the MLUD-3 accelerator it is planned to use it as an irradiation unit, we have made efforts to create a new ion source power supply device providing the required parameters. Namely, the device should provide a high stability of the proton beam current at a frequency of parcels of at least 10 Hz and a pulse width of 250...300 μs.

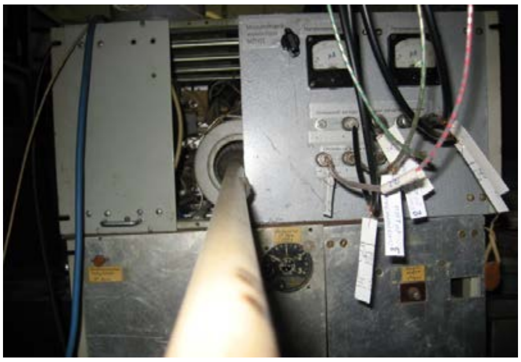

Fig. 1. Model of ion source power supply device

DEVELOPMENT POWER SUPPLY DEVICE OF THE ION SOURCE

During the operation of the accelerator ISPSD is at a high potential of 75 or 150 kV, depending on the operating mode of the accelerator. Therefore, to connect the device to the 220 V/50 Hz network, a separating transformer (220/220 V) is used, designed to operate at a potential on the secondary winding up to 300 kV.

The ion source power supply device is located in the basket of the "Vishnja" standard. Dimensions of the developed ISPSD are 528×263×485 mm. The view of device front panel is shown in Fig. 2.

The ISPSD is created using modern circuit technology solutions and electronic components of a high degree of integration.

The device contains seven blocks, each of which has its own functional purpose. They are located in five modules. The first module is a multi-channel power supply. It provides the generation of voltages necessary for the operation of control devices and monitoring its parameters and also voltage of +300 V for powering the pulse modulators. The two following modules generate a pulse voltage supply for the discharge chambers of the ion source (Arc 1 and Arc 2). In the third module (Arc 2), a block is placed that converts electrical analog signals containing information about the parameters of the operation of pulse modulators to optical analog signals for transferring them to a low potential. The electromagnet power supply block and block of the voltage generation, which controls the duration of the open state of the impulse gas valve, are located in the fourth module. The fifth module provides reception and processing of digital optical signals, which ensure synchronization of the operation and control of pulse devices. Control signals are generated in the ISPSD control module, and the clock pulses are generated by the accelerator timer [6], which are located in the control room.

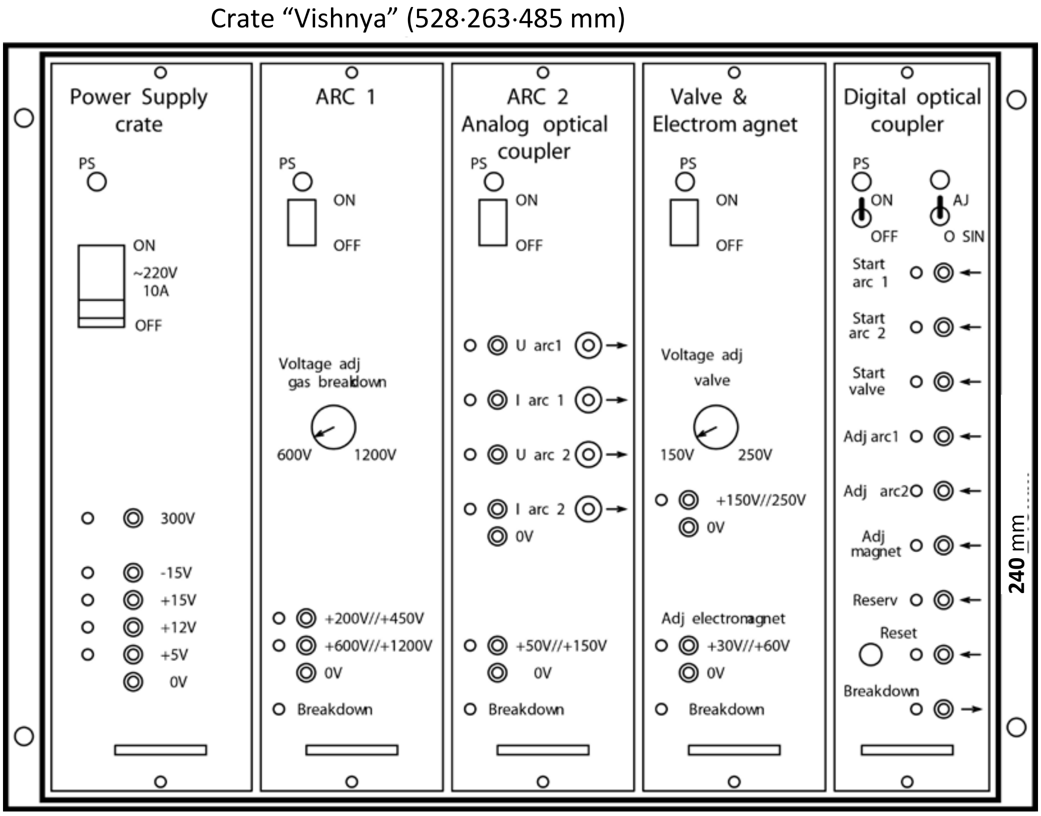

Fig. 2. ISPSD front panel

On the modules front panels there are the organs for switching on the units located in the modules, as well as the operating controls for the operating modes and the block status indicators. On the panel there are checks sockets, on which the voltages produced in the blocks are output. On the front panel of module № 5 there are connectors to which optical fibers are connected, through which digital signals are enter the ISPSD to control the device. On the panel of module № 3 there are connectors through which analog light signals are outputted to the light guides. These signals contain information about the discharges parameters in the ion source chambers.

Voltages necessary for operation of the control and monitoring circuits of ion source power supply device blocks are generated by high-frequency (50…100 kHz) adjustable converters located in the power supply block № 1, Fig. 3 in the upper left. In this block, a constant voltage of +300 V is generated, which is used to operate high-frequency converters providing power to storage capacitors in pulse modulators. The same voltage is used for converters providing power to the electromagnetic lens and the gas inlet valve in the ion source. The use of high-frequency voltage converters made it possible not only to obtain the necessary voltages with high accuracy and stability, but also to significantly reduce the mass-dimensional parameters of the device, as well as improve its efficiency.

Signals that control the parameters of the pulse modulators, of the electromagnet current source, and the gas valve, which are generated in the control unit and the timer, through the cable lines, first come to the transceiver (Fig. 4). The device converts of frequency-pulse electrical signals into light pulses. Then, light pulses through optical waveguide up to 6 m in length are transmitted to the ion source power supply device (see Fig. 3). Optical waveguides provide high voltage isolation (up to 200 kV). The control module of the ion source power supply, located in the control room, generates control signals and checking of the ISPSD operation parameters. The module is made in the «CAMAC» standard. Signals that synchronize the operation of ion source power supply pulse devices and the duration of the open state of the gas valve come from the accelerator timer in a similar way. Light impulses by means of optical waveguides of 6 m length, which provide high voltage isolation (up to 200 kV), are then transmitted to the ion source power supply device on a block of optical digital converters. After converting the light signals into electrical pulses, they are transferred to the corresponding blocks of ion source power supply. The speed of information transmission by digital channels is 1000 kBaud. Adjustment of the charging voltage of the storage capacitors of modulators Arc 1 and Arc 2 and the current of the magnet is effected by changing the frequency of the control pulses. The frequency of the control pulses can vary in the range from 1 to 10 kHz, the stability of the frequency setting is 10^{-4} with linearity not worse than 10^{-4}.

To achieve the required accuracy of adjusting the voltage supplied to the consumers, variable 10-turn resistors are used as regulating elements. The frequency-pulse method of parameters adjustment provides high noise immunity of control circuits in the presence of powerful pulsed and high-frequency fields created by the accelerator systems.

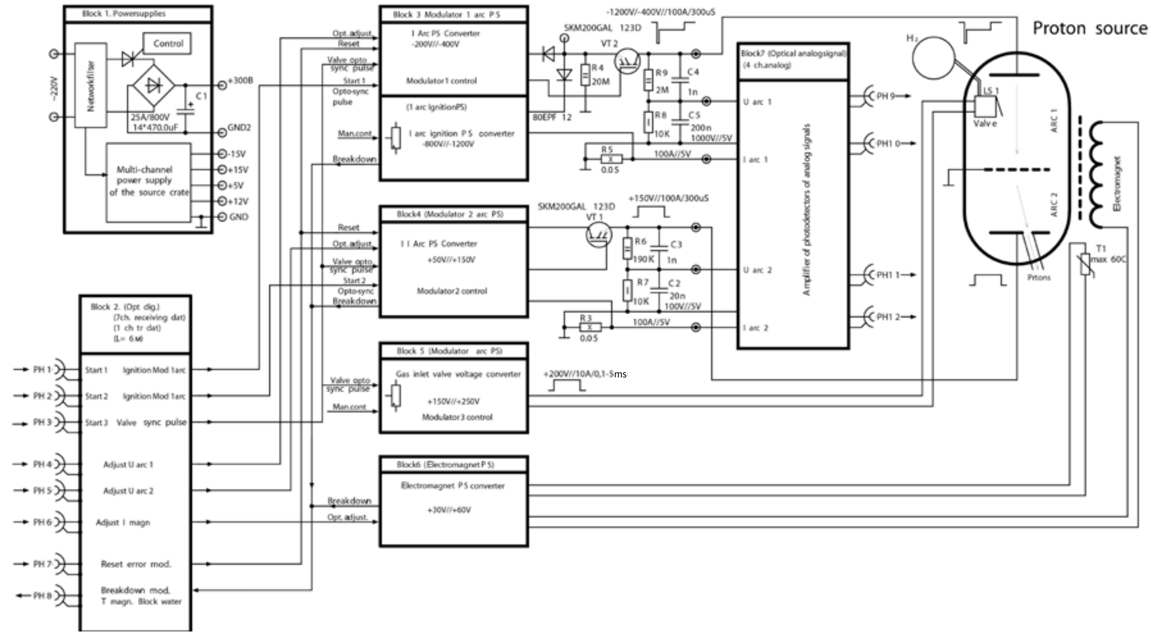

Fig. 3. Block diagram ISPSD power supply device

Fig. 4. Optoelectronic transceiver

Electrical signals characterizing the discharge parameters in the ion source chambers (Arc 1 and Arc 2) and the magnitude of the electromagnet current are taken off from the measuring voltage dividers and shunts. These voltages and currents are supplied to the unit № 7 located in module № 3 (see Fig. 3), in which the electrical analog signals are converted into light analog signals and transmitted to the optical channels. Light signals via an optoelectronic line are transmitted to the transceiver (see Fig. 4), which converts analog light signals into electrical analog signals. In subsequent, these signals are transmitted through the cable lines to the control room to the control unit of the ISPSD and to the measuring equipment. The bandwidth of analog optical channels is not less than 300 kHz, the accuracy of signal conversion in the transceiver is not worse than 3%.

Modulators that produce voltage for feeding the discharge chambers of the ion source (see Fig. 3), are designed according to the scheme with a partial discharge of storage capacitors. Such a circuit solution allows the construct of modulators with a high repetition rate of modulating pulses. With a relatively simple circuit solution, modulators with a partial discharge make it possible to stabilize the voltages and currents in the discharge circuits with high accuracy. The disadvantage of such modulators is the large capacitance of the storage capacitors necessary to achieve high stability of voltage or current in the discharge circuit during the discharge pulse. To achieve the stability of the current in the discharge circuit of the modulator, Arc 1 is not worse than 1% at a discharge current of up to 150 A and pulse duration of 300 μs, as shown by calculations, the total capacitance of the storage capacitors should be ~9000 μF. The storage capacitors in the Arc 1 modulator must withstand a voltage of at least 450 V needed to create a high-voltage discharge. The operating mode of the Arc 2 modulator is less intense, the operating voltage of the storage capacitors does not exceed 100 V, and the discharge current is not more than 100 A. Therefore, the estimated value of the storage capacity is approximately half that of the first case. Modulators with partial discharge have low output impedance, which provides a high efficiency of device.

For switching in the circuits of the modulators Arc 1 and Arc 2, the keys on the IGBT transistors type SKM200GAL123D are used. he selected transistors have a fast-switching commutation and provide switching current up to 200 A at a voltage of up to 1700 V.

To facilitate ignition of the discharge in the first chamber synchronously with the main discharge an additional high-voltage low-power discharge with voltage ~1.5...2 kV is used, which initializes the breakdown of the discharge gap.

The ion source power supply modulators have high-speed protection against breakdowns in the ion source and ISPSD. Response time of protection is not more than 0.5 μs. The protection is disconnected remotely in the ion source power supply control unit.

In Fig. 5 shows the exchange of information between the ISPSD control unit and the timer located in the control room and the power supply device of ion source.

As shown in Fig. 5, from the timer to the power supply of the ion source, the impulses synchronizing the work of the modulators Arc 1 and Arc 2, as well as the signal controlling the duration of the open state of ion source gas valve, are transmitted. The signals controlling the modes of modulators operation and the source of electromagnet current supplying come from the control unit of the ion source power supply. From the power supply device of the ion source to the control unit, a signal of triggering of interlocks in the power device. This signal informs either of a breakdown in the ion source, or the absence of a coolant flow in it, as well as an increase in the temperature of the electromagnet coil above a predetermined value.

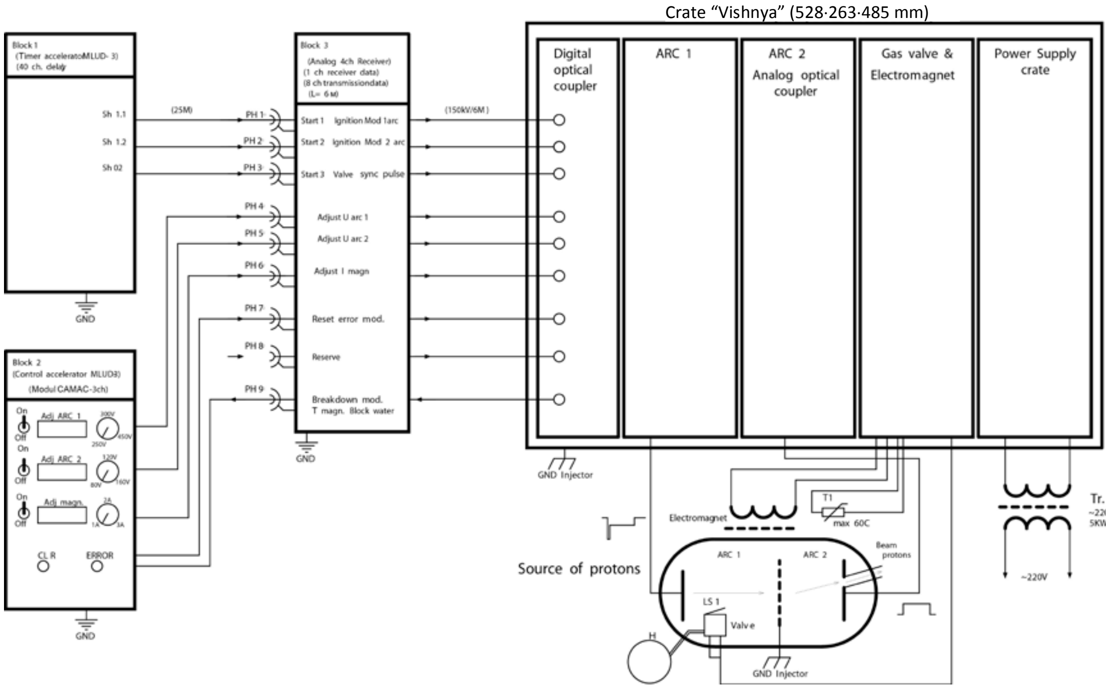

Fig. 5. Block diagram of the ISPSD control

CONCLUSIONS

The presented results of designing and modeling modules and units of the ion source power supply showed that with the chosen approach to creating a power supply, we managed to create a model of the device with parameters that will ensure the operation of the accelerator MLUD-3 as a radiation irradiation installation. The use of modulators with a partial discharge of storage capacitance made it possible to obtain a good stability of the discharge parameters in the ion source chambers. The applied method of frequency-pulse control allowed not only to obtain high accuracy and linearity of adjustment of power supply parameters, but also provided noise immunity of control channels.

It should be noted that the developed principle of creating an ion source power supply is a typical solution. It can be taken as a basis for creating power supplies of ion sources of other types or ion sources with other operating parameters. This device can be used both for electric power supply of ion sources used in accelerator technology, and for ion sources used in other fields of physics and technology.

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РАЗРАБОТКА УСТРОЙСТВА ПИТАНИЯ ИСТОЧНИКА ИОНОВ УСКОРИТЕЛЯ МЛУД-3

Е.В. Гусев, О.В. Мануйленко, В.Н. Сокол, А.А. Турчин, В.В. Жизневский

Приведены результаты, полученные в процессе разработки конструкции устройства питания для источника ионов типа дуаплазматрон с полым холодным катодом, работающим в импульсном режиме. Обобщен опыт использования имеющегося устройства и обоснована необходимость проведения работ по созданию нового устройства питания. Обсуждается выбор схемных решений, положенных в основу разработки, а также приведены основные параметры устройства.

РОЗРОБКА ПРИСТРОЮ ЖИВЛЕННЯ ДЖЕРЕЛА ІОНІВ ПРИСКОРЮВАЧА МЛУД-3

Є.В. Гусєв, О.В. Мануйленко, В.М. Сокол, О.А. Турчин, В.В. Жизневський

Наведені результати, отримані в процесі розробки конструкції пристрою живлення для джерела іонів типу дуаплазматрон з порожнистим холодним катодом, який працює в імпульсному режимі. Узагальнено досвід використання існуючого пристрою живлення і обґрунтовано необхідність проведення робіт по створенню нового пристрою живлення. Обговорюється вибір схемних рішень, покладених в основу розробки, а також наведено основні параметри пристрою.