THE NG-10 NEUTRON GENERATOR FOR PRODUCTION OF NEUTRON FLUXES IN CONTINUOUS AND PULSE MODES

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Abstract

The neutron generator is designed for a neutron yield of 1x1011 n/s in the continuous operation mode. It consists of an ion accelerator with an accelerating voltage continuously adjustable in the range of 120-150 keV and beam current of atomic deuterium ions up to 2 mA and a set of target devices, in which Ti-T and Ti-TD targets of different diameters are used. In addition to a high and stable in time yield of neutrons when operating continuously, the generator also provides the pulsed mode over a wide range of pulse widths and repetition rates. By modulating the discharge current of the ion source, the neutron generator is switched into the pulsed mode. A unique system of the discharge power supply allows operation both in continuous and pulse modes. In this case, a smooth adjustment of the pulse width and repetition rate is possible. Switching from the pulse mode to DC can be promptly made from the host computer.

A wide range of available neutron sources and instruments for measuring neutron flux parameters calls for creation of systems of apparatus for calibration and certification of such products. The NG-10 neutron generator designed in NIIEFA can be used as an apparatus producing reference neutron fluxes in such systems. In addition to a high and stable in time neutron yield in the continuous mode, such a generator will ensure the pulse operating mode when pulse durations and repetition rates vary over a broad range.

This generator can be widely used for the neutron-activation analysis in different fields of science and engineering as well as in highly efficient systems intended for control of fissionable substances, detection of explosives, toxic substances and drugs. The NG-10 neutron generator is designed for a neutron yield of 1x1011 n/s in the continuous operating mode. It includes an ion accelerator with an accelerating voltage continuously adjustable in the range of 120-150 keV and beam current of atomic deuterium ions up to 2 mA and 4 target devices, in which Ti-T and Ti-TD targets of different diameters are used.

An ion beam produced by a duoplasmatron - type source is accelerated up to 150 keV in a sectionalized accelerating tube, separated in mass with an electromagnetic mass-separator and then is focused to a target with a doublet of quadrupole electromagnetic lenses. General view of the ion accelerator is shown in Fig. 1.

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The power supply system of the ion source is installed in a high-voltage terminal and consists of a unit for data receive and transfer, hv sources of extraction and focusing voltage and power supply unit housing power supplies of the discharge, electromagnet, cathode filament and Pd leak valve.

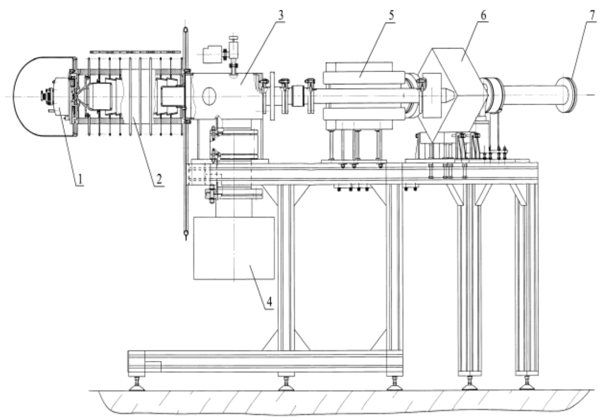

Figure 1: Ion Accelerator. General View. 1-ion source, 2-accelerating tube, 3-vacuum chamber, 4- ion pump, 5-electromagnetic mass-separator, 6- quadrupole lens, 7-target device.

All power supply systems are stabilized and operate at a frequency of 40-50 kHz, which allows its overall dimensions to be reduced and the ion beam current stability of about 1% to be attained. Power supplies under high potential are controlled through fiber-optic communication lines.

By modulating the discharge current of the ion source the neutron generator is switched into the pulse mode. For this purpose a unique system of the discharge power supply was designed, which allows operation both in continuous and pulse modes. In this case smooth adjustment of the pulse width and repetition rate is possible. Switching from the pulse mode to DC and vice versa can be promptly made from the host computer. The structural diagram of the discharge power supply is shown in Fig. 2.

The discharge power supply is a serial pulse current controller based on V1, V3 components and operating at a frequency of 40 kHz. Choke L1 serves to smooth current ripples and to store energy. The current from the controller output enters a load through the connector X1.Transistor V4 is connected in parallel with the current controller output. In the continuous mode of the power supply this transistor is cut off and does not affect its operation. When switched into the pulse mode, the

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transistor V4 is modulated in frequency and duration with pulses applied from the generator through a light guide.

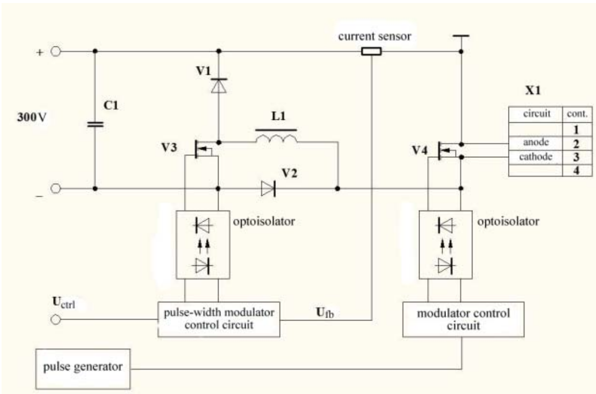

Figure 2: Structural diagram of the discharge power supply.

When the transistor is on, the power supply output is short-circuited, and the output voltage is 0. During the pulse, the transistor moves into the cut-off mode, and an energy stored in the choke L1 is transferred to the load as a current pulse. Diode V2 limits the load voltage to be not higher than the supply voltage by delivering the rests of the energy stored in chokes to an input capacitor C1. Power transistors V3 and V4 are controlled via optical drivers A1 and A2, which generate voltages pulses of necessary amplitude and growth rate and ensure galvanic isolation between power and control circuits. Pulses controlling the power transistor V3 of the pulse controller are generated with the control card A3. The width of these pulses is proportional to an error signal obtained by summing a reference signal arriving to the control system input with a feedback signal from the current meter D1. Pulses controlling the modulator transistor V4 are generated with the card A4of the optical receiver.

To supply power to devices under high voltage, a compact isolation transformer was designed. The secondary winding of the transformer consists of 4 turns of a hv cable with an insulation designed for 160 kV placed inside ferrite cores located uniformly around the winding perimeter. The transformer operates at a frequency of 50 kHz, and its design allowed its overall dimensions and weight to be significantly reduced. Photo of a high-voltage structure of the neutron generator at a test-facility in NIIEFA is shown in Fig. 3.

The vacuum system of the generator is based on the НМД-0,4ion pump. A dry forevacuum pump is used for preliminary pumping. The НМД-0,4pump is separated from the vacuum volume of the accelerator with a fast gate valve. The target device is connected to the accelerator vacuum system through a fast vacuum valve, which allows replacement of targets without the vacuum break in the accelerator. All vacuum valves are pneumatically driven; the process is controlled from the host computer. Necessary pressure in the pneumatic line is provided with a compressor, a part of the facility.

A set of targets devices, in which targets with diameter less than 10, 16, 18, 23 mm can be used, was designed for the generator. Targets with the 45mm diameter, which can be used at a high beam power, are installed in a special target device, which performs circular travel of a target relative to the ion beam.

Figure 3: High-Voltage Structure of the Neutron Generator.

The automatic control system made on the basis of an industrial computer is intended for the acquisition of the data on the status of the neutron generator and its separate devices and systems and its visualization on the display as well as for solving routine tasks of choosing and setting operating modes of the accelerator and tuning the working parameters of separate devices. The automatic control system consists of a control cabinet, units for data receiving and transfer and operator workstation. The control cabinet houses controller blocks with expansion modules, input/output analog modules, transmitter-receiver of the optical channel for data transfer and power supply units for electronics. The unit for data receiving and transfer houses a controller with an expansion module, galvanic isolations of analog signals and transmitter-receiver of the optical communication link. The operator workstation consists of an industrial computer with 2 monitors. The automatic control system allows the generator interaction with systems for measuring the neutron flux parameters.

The automatic control system of the NG-10 neutron generator is built on the basis of the Fastwel CPC109 controller, three Fastwel IO CPM704 controllers and the Advantix panel-type industrial computer. The software of the automatic control system consists of the five following programs:

- program of the host controller (Fastwel CPC109);
- program to control the injector (Fastwel IO CPM704);
- program to control the vacuum system of the neutron generator (Fastwel IO CPM704);
- program to control the neutron generator (Fastwel IO CPM704);
- host computer program (Advantix)

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The Fastwel CPC109 controller program functions under an operational system compatible with the MS-DOS 6.22, and CPM704 controllers' programs function in the Fastwel IO special environment. The host computer functions under the MS Windows7. Fig. 4 shows the structure of the automatic control system.

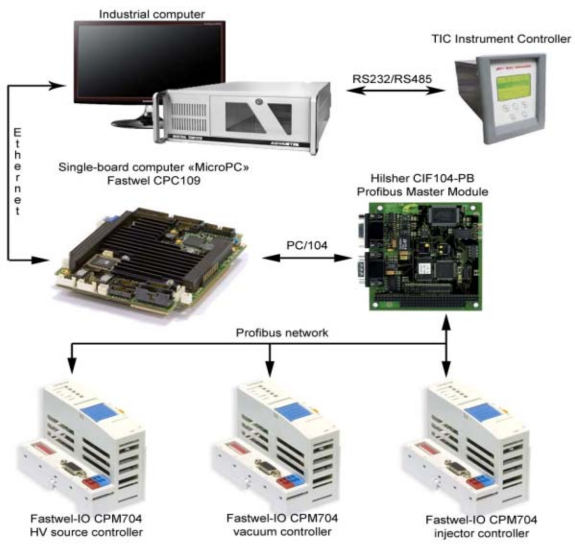

Figure 4: Structure of the Automatic Control System.

Controllers' programs are automatically loaded and are not directly controlled by the operator. Information about their states and control commands are transmitted in the network based on the Ethernet and Profibus protocols via the host computer program. A DB Viewer program is provided for viewing analog parameters of the system.

The host computer program is intended for:

- setting the operation mode of the neutron generator;
- control and preventing of accidents when the neutron generator is brought to its operating conditions and in the process of operation ;
- keeping constant input parameters of the neutron generator in the process of operation;

The program is loaded automatically after the loading of the computer operational system or, if necessary, by an icon located on the desktop of the MS Windows 7. General view of the user interface is given in Fig. 5.

The main window of the program consists of two sections. In the upper part of the window there are a panel to change-over pages of the control systems, setting buttons, unlocking buttons, button for logbook and the exit button. In the lower panel are located digital indicators of the main parameters of the neutron generator and indicators of the door, water and oil interlocks (1).The most part of the window is occupied by the panel with switched-over pages of the NG sub-systems (2).

Figure 5: Main window of the program.

As a result of an experimental tryout and optimization of the neutron generator and its separate systems, we successfully solved problems of generation and forming of 2μs - 100 ms pulsed ion beams with a smooth regulation of the pulse width. The pulse repetition rate can be changed from single pulses to tens of kHz. In the process of the accelerator tests, a beam of atomic ions with a current of up to 2 mA and beam diameter of 5-10 mm was formed on target.

So, in recent years in NIIEFA have been designed 4 modifications of neutron generators [1, 2], which produce neutron yields from 1010 up to 2×1012 n/s in the continuous mode and are equipped with pulsed mode systems allowing production of pulse neutron fluxes both in microsecond and nanosecond ranges of the pulse width.

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