IMPROVED CHARACTERISTICS OF HV PULSE MODULATORS FOR TECHNOLOGICAL ACCELERATORS

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The new modulator series intended to provide a pulse power supply of MI-451, MI-456 microwave magnetrons is described. The main feature of this modulator series, as compared with the existing national counterparts, is the storage charging power supply. The offered modulators with improved charging power supplies have the substantially better efficiency and high operation stability and reliability.

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1. INTRODUCTION

A great quantity of technological linear electron accelerators (LINACs) are produced in the last years for nondestructive checking, activation analysis, sterilization, radiochemistry, medicine [1,2]. The requirements for these LINACs have been raised. It regards their stability, operate reliability, efficiency, ease and compliance of operation mode change, overall dimensions and mass. All this involved also the appearance of new requirements for pulse modulators that serve to provide the power supply of LINACs [3].

The LINACs for the energy from 5 to 15 MeV are successfully used as radiation sources for quite a number of radiation processes. The MI-451, MI-456-type magnetrons or their foreign counterparts being used as microwave devices. The new pulse-modulator series with improved characteristics intended to provide the power supply of mentioned magnetrons was designed in "TIRA Corporation" (former "Komintern"). The main parameters of the modulators are given in Table.

Parameters	'"MAGNETIT" modulator	"PIRIT" modulator
Magnetron	MI-451	MI-456
Peak pulse power, MW	4.2	5.5
Peak pulse voltage, kV	45	50
Peak pulse current, A	95	110
Peak pulse current control limits, A	60-95	60-110
Flat top duration, μs	4.5	6
Pulse top Ripple, at most	±1%	±1%
Current instability from pulse to pulse, at most	±0.75%	±0.75%
Maximum pulse repetition rate (PRR), Hz	300	225
Maximum charging Speed, kJ/sec	10	15

The pulse modulators of this series are pulse generators with a store's full discharge and a step-up pulse transformer. They can be functionally divided into the following devices: charging power supply (CPS), pulse-forming device (PFD), pulse transformer unit (PTU).

The simplified diagram of the modulator is given in Fig.1.

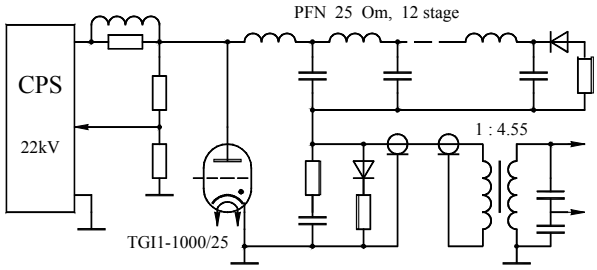

Fig.1. Simplified diagram of the "MAGNETIT" modulator

2. PFD AND PTU

The modulator output pulses are formed by the twelve-section PFN using the K75-74-type capacitors. The trimming of a pulse shape can be made off-line by changing the turns on PFN coils.

The TGI1-1000/25 thyratrons are used as switch in modulators. The "MAGNETIT" modulator uses one thyratron, the "PIRIT" modulator – two thyratrons operated in turns. The thyratron average current was reduced due to this approach that will permit to increase in future the pulse-repetition rate to more than 225 Hz.

The additional circuits that ensure the modulator reliability operation at load breakdowns, as well as the circuits intended to reduce the pulse overshoot at leading edge and backswing, are provided in the modulator.

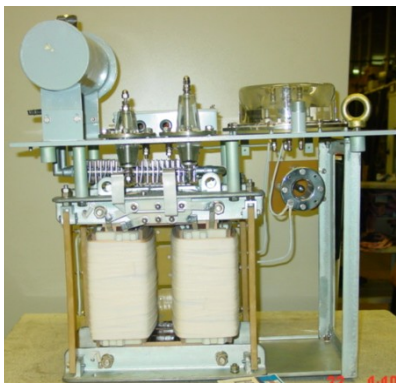

Fig.2. PTU

PTU (see Fig.2) provides, in addition to load matching, the power supply of the magnetron filament circuits and gun.

The matching circuit, that permits to work with a cable up to 20 m long, is provided at the PTU input. The pulse transformer is demagnetized on its primary winding.

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The capacitance voltage divider and shunt for monitoring the voltage shape and load current are installed at the PTU output. The modulator voltage pulse shape is shown in Fig.3.

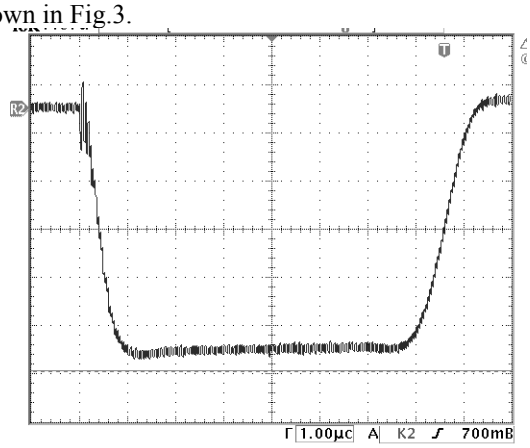

Fig.3. Modulator output voltage oscillogram (10 kV/div, 1 μs/div)

3. CPS

The main feature of this modulator series is the charging power supply. It represents the power supply without an input line transformer and with intermediate frequency conversion. Such sources are produced in full-scale by a number of companies, but the optimum solution and reliable operation (reliability operation at high-pulse powers, reliable thyratron switching off, low cost) can be obtained only at the complex design of the modulator on the whole for specific parameters.

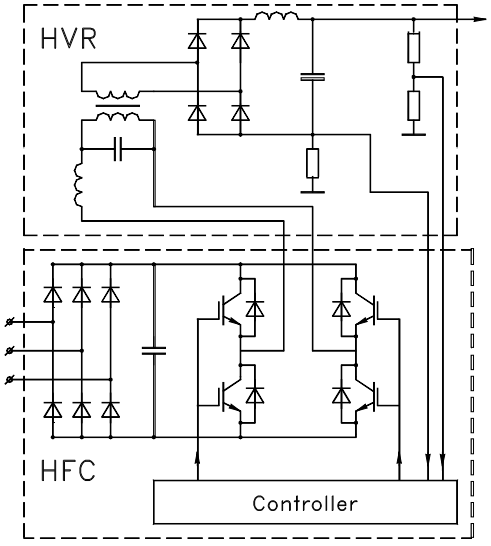

Fig.4. CPS simplified diagram

The simplified diagram of the charging power supply that contains two packaged products: HF converter (HFC) and HV rectifier (HVR) - is shown in Fig.4. The HFC represents the ac-line rectifier and bridge resonance voltage converter based on IGBT transistors with accessory circuits. It provides the conversion of a three-phase ac-line voltage applied to its input to 15...40 kHz single-phase sinusoid voltage. The HF voltage is applied to HVR unit that includes the step-up transformer and the single-phase bridge rectifier with a filter. The CPS output current and voltage control is provided at the expense of frequency control of converter operation mode.

The PFN voltage oscillogram is shown in Fig.5. As it can be seen on this oscillogram, there is a pause between the thyratron switching on moment and beginning of the next charging cycle. It allows one to ensure the reliable thyratron switching off. The duration of this pause can be adjusted, but, as the studies have shown, 200-250 μs are sufficient for reliable TGI1-1000/25 thyratron switching off for any operation mode.

After the pause has been finished, the storage charging begins, while the charging power supply is practically operated in constant-current source mode. The charging current value is chosen so that the PFN voltage has time to increase up to 20...22 kV value during the pause between the pulses, even at minimum ac power line voltage (-15%) and maximum PRR. When the PFN voltage runs into the specified value, the control system provides the CPS transfer to the voltage stabilization mode in which the device can remain during long time, while compensating the PFN leakage currents. The stabilizing voltage value can be adjusted on-line manually or remotely by means of the analog signal within 50% to 100% of the peak value.

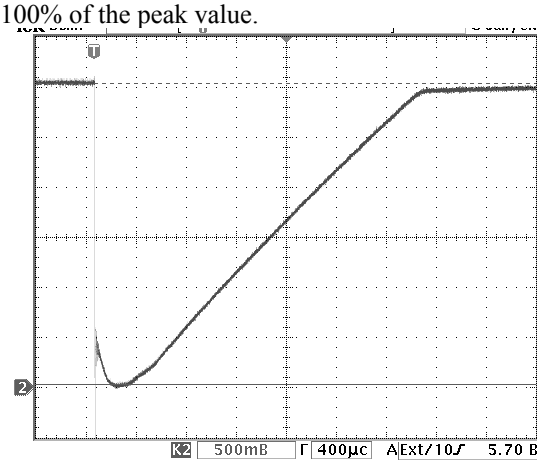

Fig.5. Charging voltage (3.5 kV/div, 400 μs/div)

This control method has a substantial advantage over the de-Q systems [4] because there is no extra energy overflow into the absorbing resistors. This permits to obtain the charging process efficiency of 92%, at least, at total control range of charging voltage, ac power line, PRR. The "PIRIT" modulator CPS outward view is shown in Fig.6. The PFN voltage oscillograms illustrating the CPS system operation at ac power line voltage change within ± 15% are shown in Fig.7,a, and at charging voltage level control – in Fig.7,b.

Fig. 6. CPS

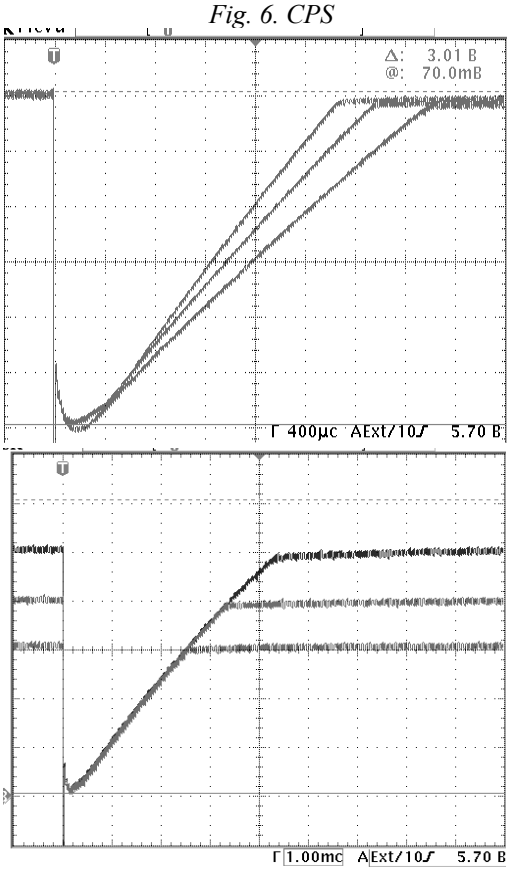

Fig.7. Charging voltage: a) at ac power line voltage change within ± 15% (3.5 kV/div., 400 µs/div.); b) at charging voltage level control change (4 kV/div, 1ms/div)

4. CONSTRUCTION

As for the design, the modulators differ from each another, that was resulted from not only the different output power but also from the design task put before the designers. The main task of "MAGNETIT" designing was minimizing of the modulator mass-dimensions parameters. The modulator elements are placed in the common cabinet with other devices comprised in LINAC structure. As a result, this modulator is placed in the "Ritall" cabinet being the size of 600x800x1200 mm.

The main task of "PIRIT" designing was to provide an easy access to any elements and to simplify the construction. The modulator is placed in the "Schroff" cabinet having the size of 600x800x1800 mm. In addition, the modulator construction permitting to divide the cabinet into two parts has been developed, that provides its easier transportation. The modulators are made with a separate PTU that is connected by means of the KPV1/60 cable 20 m long. The PTUs represents the oil tanks having the overall dimensions of 360x580x300 mm ("MAGNETIT"), 600x350x590 mm ("PIRIT").

5. CONCLUSIONS

The described modulators at improved storage charging power supplies have a substantially better efficiency and high operation stability, providing a substantial increase of the consumer properties of all the technological system with LINAC.

The designed charging power supply allows one to provide:

1. Controlled pause after a pulse for reliable thyratron switching off;
2. Modulator output voltage control and stabilization at ac power-line voltage variation without an energy outflow into absorbing resistors;
3. Modulator output voltage control and stabilization with PRR rate variation, down to single pulses;
4. Improved mass and overall dimensions;
5. The charge efficiency not worse than 92%.

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ВВ ИМПУЛЬСНЫЕ МОДУЛЯТОРЫ С УЛУЧШЕННЫМИ ХАРАКТЕРИСТИКАМИ ДЛЯ ПРОМЫШЛЕННЫХ УСКОРИТЕЛЕЙ

А.Долгов, О. Килдишева

Описан новый ряд модуляторов, предназначенных для питания импульсной мощностью магнетронов MI-451, MI-456. Предлагаемые модуляторы имеют существенно лучшую эффективность, высокую стабильность в работе и надежность.

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Описано новий ряд модуляторів, призначених для живлення імпульсною потужністю магнетронів МІ-451, МІ-456. Запропоновані модулятори мають істотно кращу ефективність, високу стабільність у роботі і надійність.

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