CONTROL SYSTEM IN THE TECHNOLOGICAL ELECTRON LINACS

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In recent years in the Science Research Complex "Accelerator" in NSC KIPT the power current technological electron linacs are developed and put into operation. Their energy varies from 8 MeV to 30 MeV [1], the pulse current does not exceed 1A and the operating frequency is 150-300 Hz. The one- section linacs, KUT and LU-10, and two- section linac EPOS are used primarily for technological aims. The technological object zone irradiated by accelerated electrons is created with the magnet scanning system [2].

1. AUTOMATIC CONTROL SYSTEM

The special system has been developed for linac control. It controls the electron beam current [3,5], the energy [4] and the position, protects the accelerating and scanning systems from the damage caused by the beam; blocks the modulator and the klystron amplifier in the case of intolerable operating modes; regulates the phase and power of the HF signals in the injecting system and also regulates the source power currents in the magnetic system. Besides, the radiation dose of the technological samples is controlled and the target devices are operated. The program & technical complex comprises: PC equipped with CAMAC crate or measuring channels in PC standard (Fig. 1), synchronization unit (S), microprocessor-operated complexes (MC) to monitor the klystron amplifier operation, thermostating system (t°C), magnet power supplies (MPS, target equipment (TE).

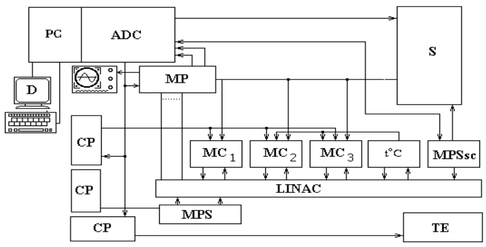

Fig. 1. Functional layout of the EPOS linac control system

The multiplexer (MP) and the analog- to -digital converters (ADC) with 8 digits receive the signal from the analog pulse sensors with the 50 or 100 nsec discreteness by two or four switching channels simultaneously. The information of the linac system state and the beam parameters is shown on the local unit terminals (CP) and on the color graphics display (D) in the form of the triple-screen control panel (Fig. 2-4). The operator can monitor the linac work from the PC keyboard and from the local control panels. The program units can provide the momentary or repeated control of system parameters or give operating commands. Simultaneously the parameters of several systems can be controlled and only one of them is regulated.

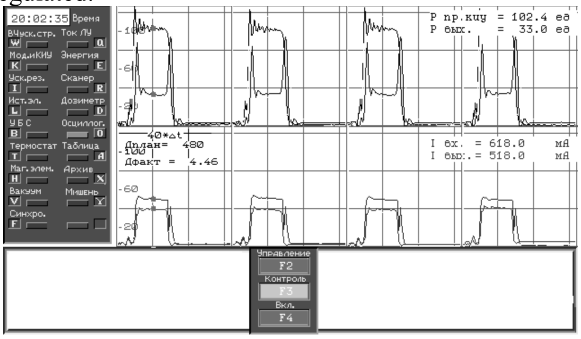

Fig. 2. Videogram of the process of signal monitoring the HF and current of an electron beam on an input and output of an accelerating section on the linac KUT.

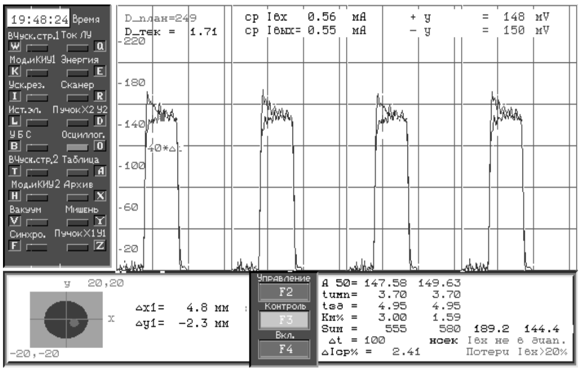

Fig. 3. Videogram of the process of controlling the position of the center of electron beam at the output of the linac EPOS accelerating section

2. THE OPERATIVE CONTROL OF THE ELECTRON ENERGY

All linacs are equipped with magneto inductance transducers established on an input and an output of accelerating sections for measurement of the value and the form of a beam pulse current [7,8]. The signals from transducers are used in the control system for the rating amplitude and the average current value. (Fig. 3). The calibration of sensors is carried out periodically with the test pulse trains from a special current generator as well as with the Faraday cylinder [9,10]. The EPOS linac also is equipped by four winding position sensors [11]. These sensors allow one to measure the center beam position with a 0.5 mm error (Fig. 4).

The wide-aperture (50 × 200mm) magneto-induction position transducer is used for the energy and position control of the sweeped electron beam on the linac exit [6]. One of the program modules provides the simultaneous signal measurement from the sensor winding and the scanning magnet excitation current (Fig.4). Using the results of the measurements of several

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scanning cycles we calculated the maximum Y_{max} and minimum Y_{min} values of the electron beam center deviation and determined the value $2R= Y_{max} - Y_{min}$. It is shown in [7,8] that the scanning electromagnet equipped with a beam position sensor may be used for the on-line control of the electron energy. For the small angles of the beam deflection ($\varphi \le 20^{\circ}$) the practical formula for the maximum probable average energy of the electron beam is used:

$$E_k = \sqrt{E_0^{\,2} + \frac{k^2 I^2}{\sin^2 \varphi}} - E_0,$$

where k is the constant determined by bench testing the magnet. In this case $\varphi = arctg(R / h)$ where h is the distance from the magnet center to the plane of the beam position control. With the inductive transduser or another method the current value R is evaluated, the amplitude of the electromagnet excitation current I is determined, and then the value E_k is calculated with an error of about 5%. The videogram of the process of electron beam energy control is shown in Fig.4.

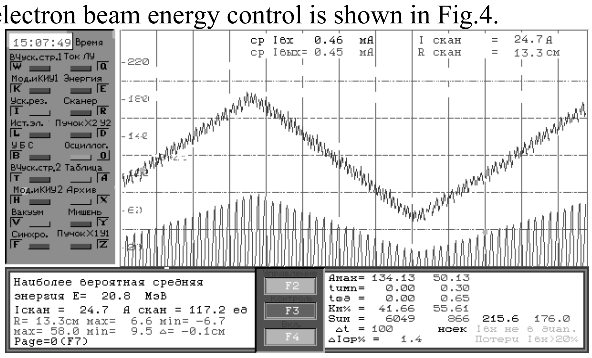

Fig. 4. Videogram of the process of the electron beam energy control on the linac EPOS.

The evaluation of value R and the electron energy is performed without a denormalization of the accelerator operation regime and taken about 2 sec.

3.THE SYNCHRONIZING SYSTEMS

In connection with the specific requirements to the synchronizing systems there is an own system for each linear accelerator. The data on main technical system as well as their comparison characteristics are shown. The frequencies of the synchronizing pulses of our linacs are different.

The most wide frequency range is used by the synchronizing system of the linac EPOS. Initially, this system was designed for the upgrading of the LU-2000 linac. The KPA modulator startup frequency f_0 may be given at a range of 50…. 1500 Hz with a step of 50 Hz. It is synchronous with the supply frequency (50 ± 0.5 Hz) and is tuned at a phase in the range of 1100 μs with a step of 10 μs for the choice of the most static mode of the KPA modulator. The startup frequency of the electron gun modulator (EGM) is equal $f_0/2^n$ *(n=0, ... 6)*. The operation delay of this pulse falls within the wide range between *0 μs* and *9.9 μs* with a step of *0.1 μs*. The startup pedestal frequency of EGM f_0 determines a standard regime for the high voltage and control beam systems. The startup pulse of the KPA modulator firing block and of the control device deflector have the 100 V amplitude (for the protection of the interference) and regulated delay at the range of *0.... 9.9 μs* with a step of *0.01 μs*. The precise delay tune is needed for getting the monochromatic accelerated beam. The change of value delay is realized by the operator during the process of a manual or PC control. The pulses of EGM startup circuit delay in addition for *10 μs* with receiving alarm signals “Beam switching off” from accelerator systems. The beam is switched on by the operator at the front of the synchronizer unit after accelerator tune. There is the regime with the limit quantity of the current beam pulses at the range of *1 ... 9999* for the repair operations. When the linac operator changes the startup frequency of EGM the corresponding code is passed to to PC.

Synchronizing system of the accelerated technology complex KYT forms the frequency scale of the pedestal pulses $f_0 =600/n$, where n=1, 2, 3, 4, 6, 12, 24. The operation startup frequency of EGM and KPA modulator are f_0. A lower operation frequency of EGM may be equal *6.25, 3.125 or 1.562 Hz*. The synchronizer has *10* channels. Pulse amplitude is not more than 15 V, the pulse width is *2.5±0.5μs*, the delay range is from *0 to 10 μs* with the step *0.1 μs*. When alarm signals “Beam switching off” are received from the accelerators systems the electron beam turns off with the additional delay of EGM startup pulses on *11 μs*.

Synchronizing system of the laser injector complex [13] forms the scale of lower frequencies from *0.0625 to 50 Hz* with step 50/n (n=1, 2, 4, 8, 16, 50, 100, 150). If the generated startup frequency is no more than *1 Hz*, KPA modulator triggers with the double pulse. In so doing the high frequency pulse amplitude of KPA increases on near of 10%.

Synchronizing systems of the LU10 and of LU40 accelerators practically are the same and form the scale of the frequency from *3.125* to *300 Hz*. The startup frequency of KPA modulator and EGM may be chosen independently of one another.

4.THE TERMOSTABILIZATION SYSTEM

The thermostabilization system is designed for the temperature stabilization. Each linac has unique optimum temperatures of the accelerating section and of the high frequency resonators.

The thermostabilization system of the accelerator KUT ensures the termostabilization of an accelerating section, of the grouping and stabilization resonators in the KPA self-excitation system. The thermostabilization system consists of 25 detectors for a temperature measurement and 30 detectors in the water cooling system. The 60-channel measuring transformer analyzes the detector signals and for the temperature stabilization the regulative programmable microprocessor devices are used. The information from the tested devices through RS232C interface is transmitted to the control PC, the lock signals by 10 channels come in the alarm system.

5. ALARM SYSTEM

The alarm system tests more than 60 discrete state signals of the accelerator systems. It allows to turn on and gives the command to turn off the high voltage

local control panel and is transmitted to the microprocessor complex [12].

6.TARGET DEVICE OPERATION

Special target devices are set up in the accelerator bunker for the transfer of irradiated samples. There are manual and automatic modes for its operation. The technological file is created for each sample; target position number and corresponding exposure doze are written there. The microprocessor complex changes the irradiated sample position with an electromotor if PC command passes. When necessary doze is received by sample the operator is informed about it.

of modulator supply if the equipment failure occurs. The information about system is represented on the

REFERENCES

[1] A.N.Dovbnya et al. Electron Linacs Based Radiation Facilities of Ukrainian National Science Center "KIPT / Bulletin of the American Physical Society, May 1997, V.42, No.3, p.1391."

[2] A.N.Dovbnya, et al., "The Output Beam Scanning and Forming in the Multipurpose Electron Accelerators of KIPT", VANT, Series: Nucleic Physics, 1997, vol. 1(28). p. 114-121.

[3] V.N.Boriskin et al. Control system for a linear resonance accelerator of intense electron beams / Nucl. Instr. and Meth. in Phys. Res A 352 (1994) 61-62.

[4] V.N.Boriskin, A.E.Tolstoy, V.L.Uvarov et al., "Automatic Control of the Electron Energy in the Technological Linear Electron Accelerators", Digest of the XIV Meeting on the Accelerated Particles, Protvino, Russia, 1994, vol.2, pp.97-98.

[5] V.Boriskin. Control System for Technological Linacs /Proc.EPAC98, Stockholm,1998.

[6] V.N.Boriskin, A.N.Savchenko, V.I.Tatanov. Monitoring of the Electtron Beam Position in Industrial Linacs/Proc. PAC99, NY, 1999.

[7] V.N. Boriskin et al. The System of the Linac LUE-2000 Beam Parametres' Measurement/ Didest of the XI Meeting on the Accelerated Particles, Dubna, Russia, 1989, v.1, p. 61-63.

[8] Uj.V.Avdeev, V.N.Boriskin, et al Metrological Research of Measurement Facility Parameters of Electron Radiation LU-10 и LU-40 KIPT/ Pre-print KIPT 91-6,Kharkov, 1991.

[9] V.L.Uvarov et al. A Beam Monitoring & Calibration System for High-Power Electron Linacs/ Bulletin of the American Physical Society, May 1997, V.42, No.3, p.1367.

[10] S.P.Karasyov et al. System for testing of the magneto inductance converters of electron beam pulse current / VANT, Series: Nucleic Physics, vol. 1(28), Kharkov, 1997, p.93-97.

[11] V.N. Boriskin et al. Channel of the Control of the Beam Position in the High-Current LEA / Didest of the XV Meeting on the Accelerated Particles, Dubna, Russia, 1996.

[12] Yu I.Akchurin et al. Linac failure diagnostic/VANT, Series: Nucleic Physics, Kharkov, 1999.

[13] V.A.Kuchnir et al. Scanning of the Vent Beam and Operative Control of Electrons Energy of the Technological Accelerators / VANT, Series: Nucleic Physics, vol. 4, 5 (31, 32), Kharkov, 1997, p.78.