ASPECTS OF THE CONTROL SYSTEM FOR THE ELECTRON LINEAR ACCELERATORS BUILT IN ROMANIA

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Abstract

The paper presents the control system for the electron linear accelerator ALID-7 of 5.5 MeV and 0.7 kW, built in Romania. The PC-based control methods are used in parallel with classical techniques in order to increase the personnel and accelerator safety.

1 INTRODUCTION

ALID-7 linac was designed and built in the Accelerator Laboratory of the National Institute for Lasers, Plasma and Radiation Physics, Bucharest, to carry out the research in the radiation processes field. To develop new electron beam technologies and to provide small-scale commercial irradiation services such as: polymeric flocculants preparation for wastewater treatment, sterilization of some medical products and high power semiconductor recovery characteristic improvement. Also, we have been attracted, during the last few years, to the concept of microwave energy addition to electron beam energy. In view of these arguments, the electron linear accelerator ALID-7 was completed with a special designed facility which permits the simultaneous electron beam and microwave irradiation of monomer mixtures, microbial cultures, gas mixtures containing SO_2 and NO_x and rubber mixtures. Our research results demonstrated that required absorbed dose for micro-organisms sterilization, polymeric flocculants preparation, rubber mixtures vulcanization as well as for sulfur dioxide removing is about 2 - 10 times smaller by simultaneous electron beam and microwave irradiation than for electron beam irradiation only, at the same processing efficiency. Thus, the use of simultaneous electron beam and microwave treatment, the ionizing radiation costs could be much decreased and the application of low intensity electron sources, which are less expensive, will be extended.

2 ALID-7 CONSTRUCTION AND PHYSICAL CHARACTERISTICS

ALID-7 is a piece of industrial equipment having a rotating acceleration structure [1, 2].

Fig.1 shows the ALID-7 system configuration, including the main blocks of ALID-7 control system. ALID-7 is a travelling-wave type linac, driven by EEV M 5125-type magnetrons operating in S-band and delivering 2 MW power in 4 μs pulses. The electrons are injected from a diode type gun in the acceleration structure operating in the $\pi/2$ mode. The first part of the acceleration structure (iris-loaded circular guide) is a variable phase velocity buncher and the remainder has an uniform section, for a phase velocity equal to light speed. An axial magnetic field produced by several separate focusing coils placed around the accelerator tube was used to compensate the radial forces tending to disperse the electrons, which are travelling through the acceleration structure. During and after acceleration, electrons are subjected to a succession of electromagnetic devices for beam focusing and sweeping in a horn-shaped vacuum chamber. In the output arrangement, ahead of the sweep electromagnet, the electron beam (EB) passes through a current monitor consisting of a ferrite ring pulse transformer (induction monitor). The dose uniformity on the swept surface is ensured by specific current waveforms of the scanning electromagnet. ALID-7 is provided with a circular conveyor (325 cm average diameter, 50 cm width) driven by a servomotor. Direct collection of part of the scanned electron beam is used as a monitoring method by sampling during the irradiation process.

Another facility, referred to here as simultaneous electron beam and microwave irradiation facility (SEBMIF), was specially designed to be used together with ALID-7, in order to permit simultaneous accelerated electron beam and microwave irradiation. The microwave power is coupled to the MRC (microwave rectangular cavity) upper-end plate (as in Fig. 2) via a slotted waveguide system (a structure based on five inclined series slots cut at $\lambda_g/2$ apart in the broad wall of a WR430-waveguide). The following beam physical characteristics are important at the end of the accelerating process: electron beam output power P_B (the basic processing capability of a given electron source for a "required dose") and electron beam energy E_B (which determines the electron beam penetration depth). The values of the maximum beam power P_B and the optimum values of peak beam current I_B and electron energy E_B are as follows: $P_B = 670$ W, $E_B = 5.5$ MeV and $I_B = 130$ mA.

3 ALID-7 CONTROL SYSTEM

The ALID-7 control system (ALID-7-CS) is of critical importance to ensure personnel and sensitive devices are protected against dangerous events, efficient energy utilization, reliable operation and beam parameter stability.

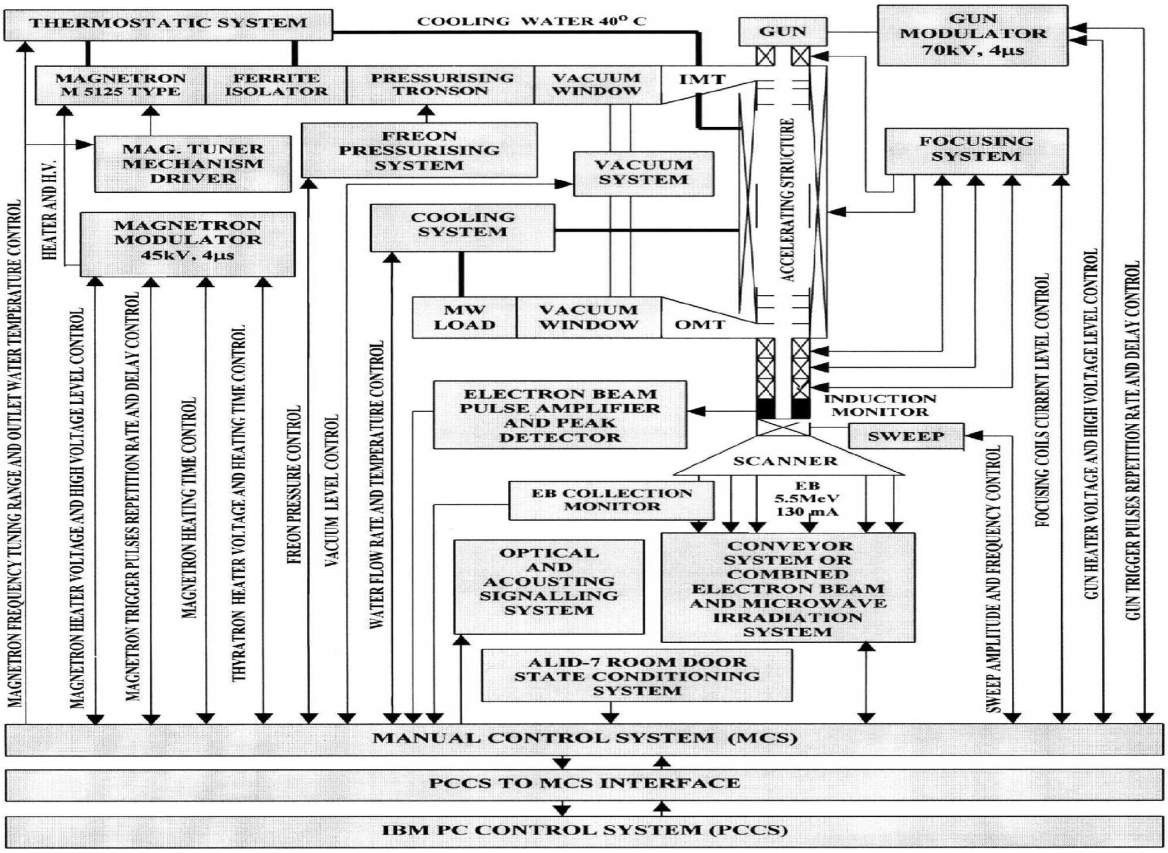


Figure 1: ALID -7 system configuration.

In order to provide these functions, the following two main solutions have been adopted:

- The use of classical control techniques in parallel with PC-based control methods in order to increase the personnel and accelerator safety.
- The use of the original ALID-7 triggering method for obtaining programmed beam single shots and beam pulse trains with programmed pulse duration, number and repetition frequency, from a diode gun linear accelerator. This is by discrete pulse, temporal position modulation of the gun electron pulses and magnetron microwave pulses. The method eliminates the lack of flexibility of the diode gun types. It combines the unsophisticated construction of diode guns and better temporal flexibility of the beam, generally available when using triode guns. It is particularly useful for automatic control of absorbed dose rate level, irradiation process control as well as in pulse radiolysis studies, single pulse or pulse train dose measurement and for research experiments where pulse-to-pulse reproductibiliy is required.

3.1 ALID-7-CS working principles

ALID-7-CS ensures the automatic operation of the whole experimental assembly shown in Fig.1. An IBM compatible PC (486, 100 MHz, 16MB RAM) control system (PCCS) and manual control system (MCS) simultaneously govern the irradiation process evolution by strict hard and soft interlocking in parallel.

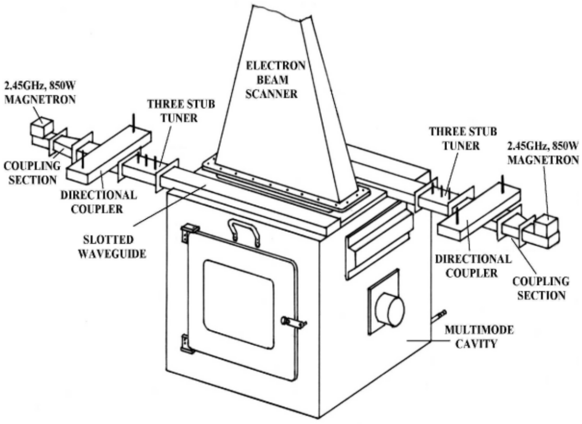


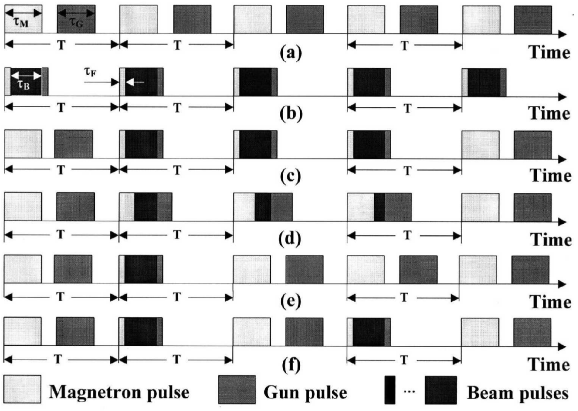
Figure 2: Simultaneous electron beam and microwave irradiation facility (SEBMIF).

Moreover, the main subassemblies may be controlled from their local control panel, as well as from their dedicated modules in the central control panel. A general-purpose control and acquisition interface (Keithley DAS 1600), installed in the PC, has been programmed to acquire process parameters and generate linac control signals. Before the start of the experiment the operator has to introduce by means of the PCCS keyboard, in an interactive way, or by means display potentiometers, digital selector switches on the MCS front panel, the experimental parameters and the operating mode (completely automated or sequential). In the completely automated operating mode, the operator commands only the start of the experiment, the system operation being software and hardware controlled afterwards. The evolution of the experiment is continuously presented on the PC display, every experimental phase providing the operator with a set of commands, which he could use in case of system malfunction. In the sequential mode, the operator from the system keyboard or MCS front panel commands both the start of the experiment and also the evolution from one phase to the other. The system displays continuously each phase of the experiment, the measured values of the main device parameters, as well as a set of commands for operator intervention in case of malfunction. Both operating modes provide the operator with the possibility of interrupting the experiment at a certain sequence, in order to change the experimental parameters that have previously been introduced. At the end of experiment, the operator has the possibility of adding his observations regarding the evolution of the experiment. He also decides whether the experiment data is to be stored on the PC as experimental data files. The main measured and/or controlled operational parameters are represented in Fig. 1. Other parameters, such as peak forward microwave power and peak reflected microwave power (detected at the bi-directional coupler) are also acquired and used to control the 2.45 GHz CW microwave power source when SEBMIF is in operation. The speed of conveyor travel is controlled according to the doses required to be applied. The beam sweeping over the material to be irradiated is controlled by monitoring the sweep frequency and amplitude.

The programs have been written in the C language. They have been designed around a real-time kernel and have a modular open structure allowing further development in accordance with new application requirements.

3.2 ALID-7 triggering method

ALID-7 triggering method allows the beam deliverance as single shot or pulse trains with the desired pulses number, pulse repetition time and pulse duration. The linac beam is determined by the electron gun and magnetron pulses overlapping. The method consists of controlling the above condition in order to deliver the beam in the desired sequence. This control is implemented by a discrete pulse temporal position modulation of gun and/or magnetron pulses. A schematic diagram of this kind of modulation applied to the gun pulses and some temporal distributions of the electron beam are presented in Fig. 3. In order to implement the mentioned triggering technique two separate modulators are provided: a gun modulator and a magnetron modulator. ALID-7-CS, which synchronizes all the system units, delivers trigger pulses at a programmed repetition rate (up to 250 pulses/s) to the gun modulator and magnetron modulator via the gun and magnetron thyratron drivers, respectively. When no gun and magnetron pulses overlap no accelerated electron beam results at the output (Fig. 3a). The instabilities of the gun and magnetron transitory regimes are avoided by operating the accelerator with no accelerated beam for a certain time.



T = repetition period of magnetron and gun pulses; τ_M = magnetron pulse duration; τ_G = gun pulse duration; τ_B = beam pulse duration τ_F = accelerating structure filling time

Figure 3: A schematic diagram of the discrete pulse temporal position modulation applied to the gun pulses and some electron beam temporal distributions.

At the operator "beam start" command, ALID-7-CS, controls electron gun and magnetron pulses overlapping and the accelerated electron beam is generated (Fig. 3b). The pulse-to-pulse absorbed dose variation is thus considerably reduced. The proportion of filling-time electrons and thus electrons energy dispersion, may be reduced to some extend by arranging the electron gun to trigger at some optimum time (accelerating structure filling time τ_F) after the commencement of each magnetron pulse (Fig. 3b). Also, an accelerated electron beam with a controlled number of pulses (three in Fig. 3c and single pulse in Fig. 3e) or with a controlled repetition period (2T in Fig. 3f) may easily be obtained by this electron gun and magnetron triggering method. Programmed absorbed dose, irradiation time, beam pulse number or other external events may interrupt the coincidence between the gun and magnetron pulses and the irradiation regime. The beam pulse duration may be continuously adjusted from 0.25 μs to τ_M-τ_F, where τ_M is the magnetron pulse length and τ_F is the acceleration structure filling-time (Fig. 3d). The short pulse duration is limited only by the values of the gun pulse leading edge and of the magnetron pulse trailing edge. Slow absorbed dose variation is compensated by the control of the triggering pulse repetition frequency as well as by magnetron and gun pulses overlapping.

4 REFERENCES

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