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DEVELOPMENT OF AN AUTOMATED SYSTEM FOR THE OPERATION OF AN ELECTROM BEAM ACELLERATOR

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ABSTRACT

Electron beam accelerators are used in many applications, such as basic physical research, chemistry, medicine, molecular biology, microelectronics, agriculture and industry, among others. The majority of the accelerators have electrons from a hot tungsten filament and their energy is increased as it passes through an electric field in the vacuum chamber. For industrial purposes, the most common model is Dynamitrons®. At IPEN-CNEN/SP, there is an electron beam accelerator Dynamitron® Type (Manufactured by RDI- Radiation Dynamics Inc., 1978) model DC1500/25/4. The technology applied was available in the 60´s and 70´s, but, nowadays is obsolete. Moreover, there are not original spare parts for this equipment any longer. The aim of this work is to develop a nationalized automated operation system for the accelerator, to replace the old equipment.

1. INTRODUCTION

Ion accelerators are sophisticated and expensive equipment used to accelerate electrically charged particles such as electrons, protons and ions, besides less common particles, like positrons. The equipment and process are the result of years of research and dedication of dozens of thousands of professionals, in many countries. Its various applications range from industry, medicine, basic physical research, molecular biology, chemistry and agriculture, among others. At the end of the 1920´s, it became clear that natural radioactive sources were not enough anymore and the ion accelerators were necessary in the development and research of nuclear physics. At the beginning of the 1930´s, different types of accelerators started to be developed, almost simultaneously: the Linear high frequency accelerator, the Circular and the Direct Current accelerator. Cockroft and Walton built their first generator of 600 KeV,cascade type, in 1932. Almost at the same time, Robert Van de Graaff built his 1.5 MeV machine. All the electron beam accelerators have an electron source, a vacuum acceleration chamber and a device to extract and distribute the electrons over the product surface. The majority of the accelerators have electrons from a hot tungsten filament and their energy is increased as it passes through an electric field in the vacuum chamber. For industrial purposes, the most common model in the market is Dynamitrons® [1,2]. At IPEN-CNEN/SP, there is an electron beam accelerator Dynamitron® Type (Manufactured by RDI- Radiation Dynamics Inc., 1978, model DC1500/25/4 [3,4]. This accelerator is used to reticulate the insulation of electric cables and wires, polyethylene blankets and retractable tubes, besides medical products radio sterilization, composites and polymeric materials modification and food treatment [5-8]. The technology applied to this accelerator was available in the 60´s and 70´s, but, nowadays is obsolete. Moreover, there are not original spare parts for this equipment any longer. The aim of this work is to develop a nationalized automated operation system for the accelerator, to replace the old equipment. The project started with an economic and technical feasibility study and industrial dosimetry study. The safety standards from the IAEA and CNEN were used to guide the project. Several studies have been conducted and major development has been reached, including printed circuit boards construction, mechanical solutions, CLP automation, software for the automation and process parameters. In this work, the services of the industrial dosimetry laboratory, at IPEN-CNEN-SP Radiation Technology Center (CTR), were used. The main results are the development of an automated control system, signal converting boards, electron beam intensity and sweep system, safety system, overall control system and a device to simulate the electrical signals of the accelerator, allowing the whole system to be tested. This work will permit a considerable amount of money to be saved, once the complete new system from the manufacturer could reach as much as US$400,000.00.

2. MATERIALS AND METHODS

The facilities used were the Laboratory of High Intensity Radiation Sources (LFIR) and the Laboratory of Irradiation Process Dosimetry (LDPY), in the Radiation Technology Center (CTR) of IPEN-CNEN/SP. The control panels of the Dynamitron® DC1500/25/4 Cockroft-Walton type accelerator, with energy of 1.5 MeV are shown in FIG.1 (command panel) and FIG. 2 (electrical protection and safety).

FIG.1: Command panel

FIG.2: Protection and safety

The panel for control of the electron beam, emergency stop, video cameras and the accelerator power control are showed in FIG.3 (electron beam control) and FIG.4 (power control).

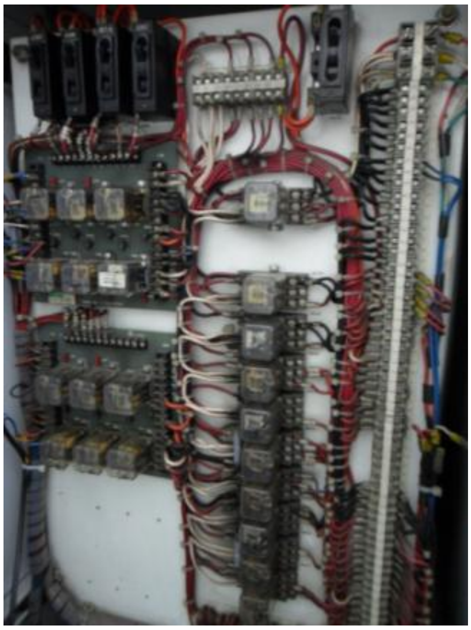


FIG.3: Electron beam control panel **FIG.4: Power control**

The panel of electron beam sweep is showed in FIG.5 and the indicators of the electron beam electrical parameters are showed in FIG.6.

FIG.5: Electron beam sweep panel **FIG.6: Electrical parameters indicators**

With this scientific work an operating software and men machine interface were designed, allowing work in automated conditions. This development includes a Programable Logic Controller design (PLC) and the correlate software. The design was, previously, based on the flowsheets of power management, showed in FIG.7, and process control, showed in FIG.8.

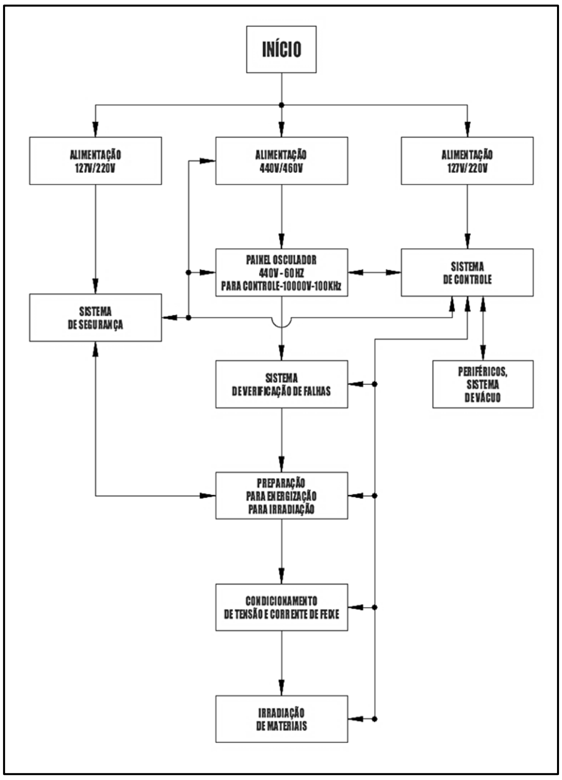


FIG.7: Flowsheet of power management.

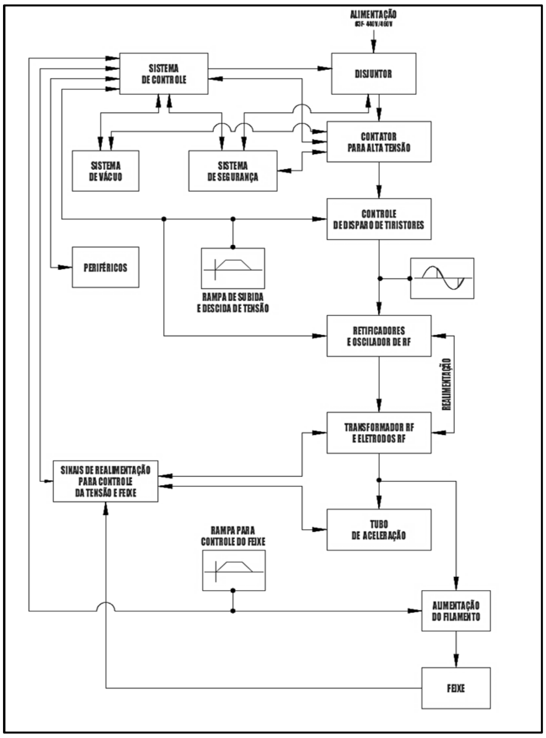


FIG.8: Flowsheet of process control.

The resulting electrical diagram of the Dynamitron® DC1500/25/4, used to develop the electrical devices and the automation software is showed in FIG.9 and the signal feedbacks of the controlled parameters in the accelerator are showed in FIG. 10.

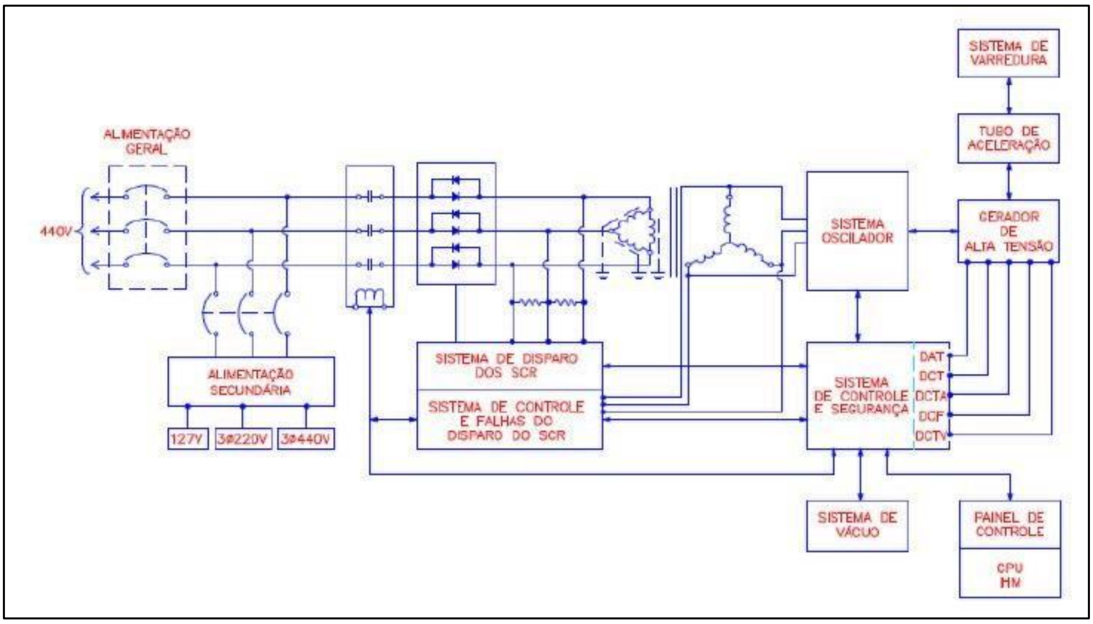


FIG.9: Electrical block diagram of the accelerator.

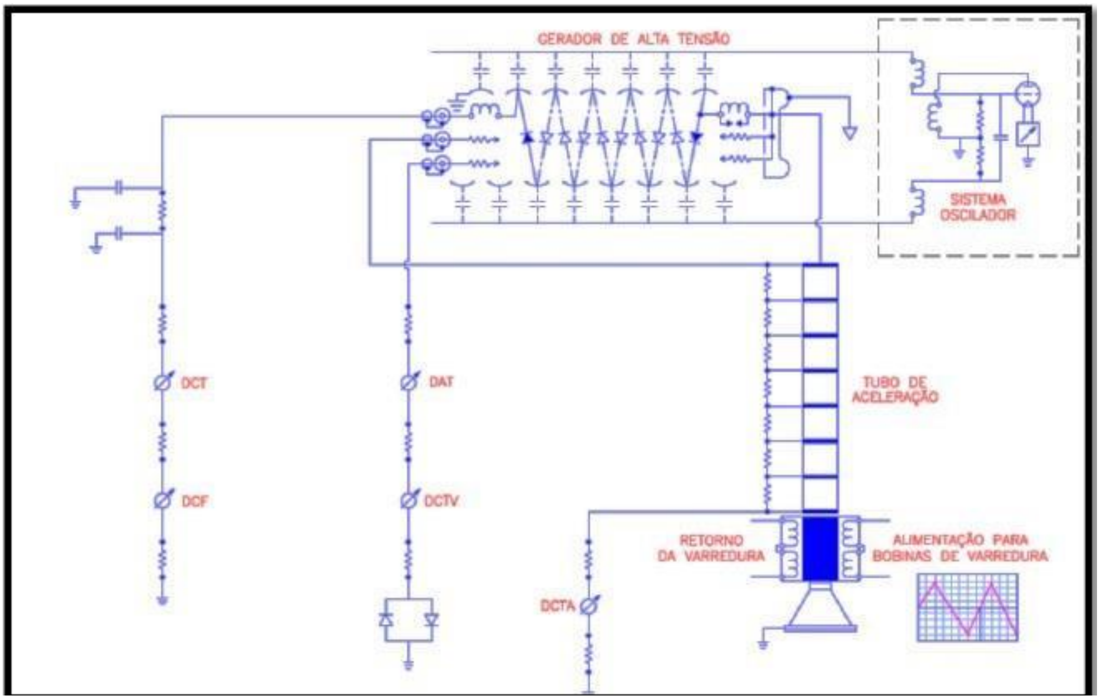


FIG.10: Signal feedbacks of the controlled parameters in the accelerator.

3. CONCLUSIONS

The design of the new automated system for the accelerator consists of:

Hardware - microcomputer; Programable Logic Controler (PLC); drivers for communication; step motors; sensors; communication interfaces; electronic and pneumatic devices. An electronic interface board was constructed to take analogic feedback signals and feed it to the automated system. The board is showed in FIG.11.

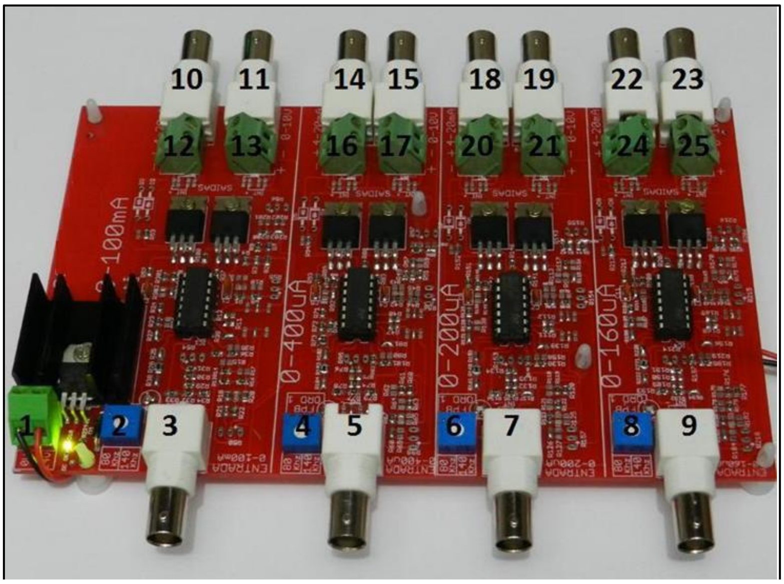


FIG.11: Analogic signals electronic feedback board.

Software – operational control software; vacuum, electron beam sweep drivers; PLC programming using Step S7-1200, from Siemens; man-machine interface programming (Web Studio 8.0, from Indusoft. The various functions were integrated in the supervisor system running in the man-.machine interface software. The beam electron sweep control is showed in FIG. 12.

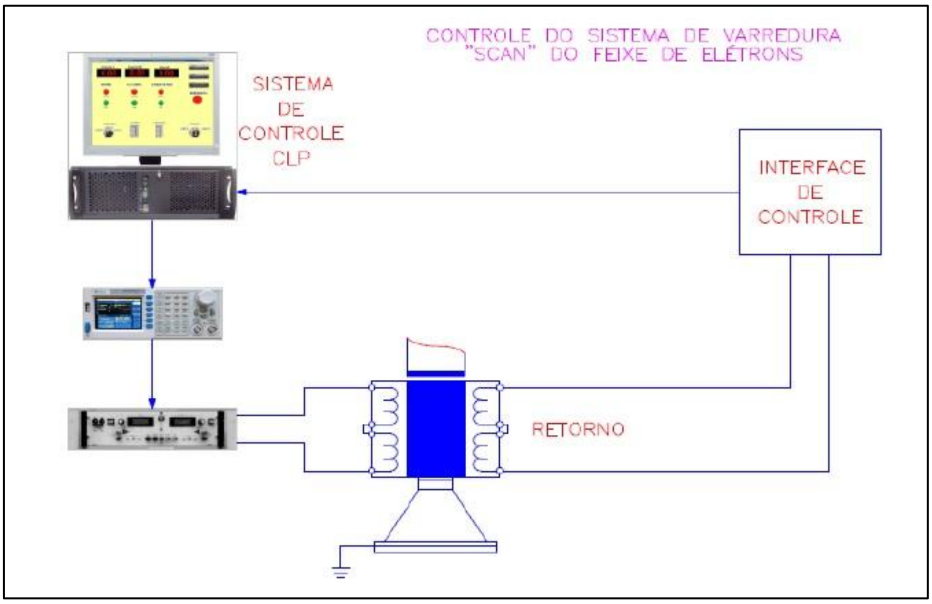
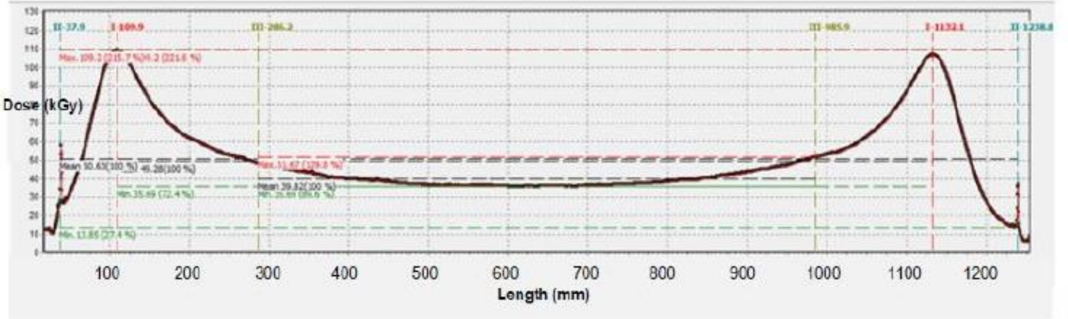


FIG.12: Electron beam sweep control.

The resulting spectrum of the electron beam was measured and is showed in FIG. 13.



Label	ROI Mode	ROI-L (mm)	ROI-R (mm)	Centre (mm)	Width (mm)	Mean dose (kGy)	Min dose (kGy)	Max dose (kGy)	Min at (mm)	Max at (mm)	UCTY (kGy)	Min UCTY (kGy)	Max UCTY (kGy)
Ebeam	Manual	109.9	1132.1	621.0	1022.2	49.28	35.69	109.2	604.3	109.9	5.01	4.00	9.81
Pos. mark	Manual	37.9	1238.8	638.4	1200.9	50.63	13.85	109.2	1235.3	108.0			9.81
	Manual	286.2	985.9	636.0	699.7	39.82	35.69	51.67	604.3	985.9	4.28	4.00	5.15
Tolerance L				20 mm	950mm								
Tolerance H				20 mm	1050mm								

FIG.13: Electron beam resulting spectrum.

As expected, the scan width is measured to be about 1.02m long. Irradiation uniformity across the tray (70cm) of the conveyor is evaluated to be -10% to +30% from the average delivered dose. Those results show that the products to be irradiated must be placed in the center of the tray where the surface dose is the most homogeneous. For products larger than 35cm, one can expect a surface dose variation higher than +/- 5% (minimum to maximum).

To make it possible to operate the system using a computerized digital control for all functions of the accelerator, some screens with commands and displays were created for activating and adjusting the operational parameters. FIG. 14 shows one operational screen for command and parameter adjustment.

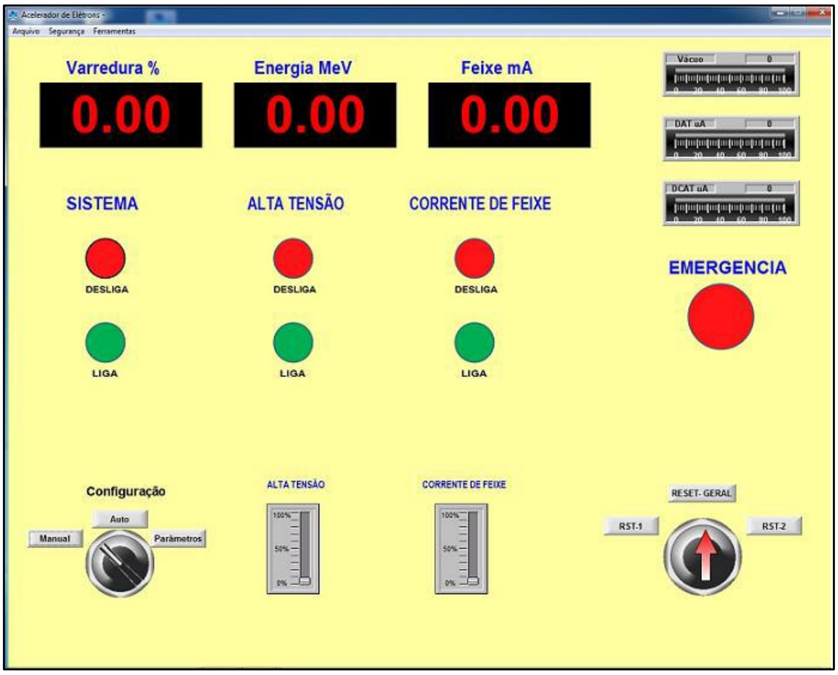


FIG.14: Computer screen for command and parameter adjustment.

REFERENCES

1. E. Cottereau, Tandetron, *DC accelerator* – CNRS/CEA, Bat 30 Ave de la Terrasse, F-91198 Gif sur Yvette Cedex, France. Disponível em : https://cas.web.cern.ch/cas/Pruhonice/PDF/DC-accel-DB1.pdf> Acesso em: 22 julho 2014.
2. Radiation Dynamics, Inc – RDI. *General Dynamitron manual of electron beam accelerator*.
3. Calvo, W. A. P. et al. *Electron beam accelerators - trends in radiation processing Technology for industrial and environmental applications in Latin America and the Caribbean.* Radiation Physics and Chemistry, v.81 (2012), p.1276–1281.
4. Duarte, C. L. et al. *Electron beam combined with hydrothermal treatment for enhancing the enzymatic convertibility of sugarcane bagasse.* Radiation Physics and Chemistry, v.81 (2012), p.1008–1011.
5. Somessari, S. L. ; Silveira, C. G.; Paes H.; Somessari, E. S. R. – *Electron beam accelerator facilities at IPEN-CNEN/SP*. In: International Nuclear Atlantic Conference (INAC 2007). Proceeding… Santos, SP, Brazil, September 30 to October 5, 2007.
6. International Atomic Energy Agency (IAEA). *Radiation Processing: Environmental Applications* –ISBN 92-0-100507-5 – IAEA – Library Cataloguing Publication Data - Vienna – 2007.
7. International Atomic Energy Agency (IAEA). *Radiation treatment of gaseous and liquid effluents for contaminant removal* – Proceeding… of technical meeting held in Sophia – Bulgaria – 07-10 Sept, 2004.
8. International Atomic Energy Agency (IAEA). *Radiation Technology series 1 – Use of mathematical Modelling in Electron Beam Processing: A Guidebook* - Vienna – 2010