THE ICH15 PROJECT: DESIGN STUDY OF A PROTON ACCELERATOR SISTEM FOR PRODUCTION OF RADIOACTIVE ISOTOPES AND TREATMENT OF UVEAL MELANOMA BY USING IH/CH RF-CAVITIES.

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1. INTRODUCCTION

Radioactive isotopes have been extensively used in medicine since their early applications during the First World War by Marie Curie. At present, they are widely used in Nuclear Medicine both for the diagnosis of many pathophysiological diseases or alterations, and for the therapy of some diseases such as hyperthyroidism or cancer. In the diagnosis they are used to, through SPECT / CT (Single Photon Emission Computed Tomography / Computed Tomography) and PET / CT (Positron Emission Tomography / Computed Tomography), to obtain the diagnostic images.

In therapy they are increasingly used and because of this the need arises to build facilities capable of massively producing radioisotopes for medicine [1]. On the other hand, proton treatment of certain tumours has demonstrated since 1998 its efficiency in the cure of cancer, which in the case of uveal melanoma, has shown a 96% disease-free survival at 5 years, and only 7 % needed enucleation [2].

Proton Accelerator

Most radioactive isotopes for medical use are

accelerator laboratories using nuclear reactions based on the bombardment of targets with high-energy protons. However, due to the obsolescence and high costs of nuclear reactors, they are progressively being closed and decommissioned, and therefore stop producing isotopes for medical use.

Our research group considered the alternative of designing a low-cost proton linear accelerator operating at 200 MHz, based on high performance room-temperature IH/CH cavities. Three beam lines were designed to address the needs for producing "medium-energy" radioisotopes (35MeV), "high-energy" radioisotopes (70MeV) and a dedicated proton therapy facility for irradiating uveal melanoma.

The R&D project was funded with 1.305.110 Euro by the Centre for the Development of Industrial Technology (CDTI), a public entity of the Ministry of Economy and Competitiveness of Spain, under the contract "ICH15: Design of a proton accelerator with CH/IH structures for radioisotope production and tumour treatment", ITC-20151186 (2015- 2018), leaded by the company TTI Norte (Spain). The overall layout of the facility ICH15 is shown in Figure 1.

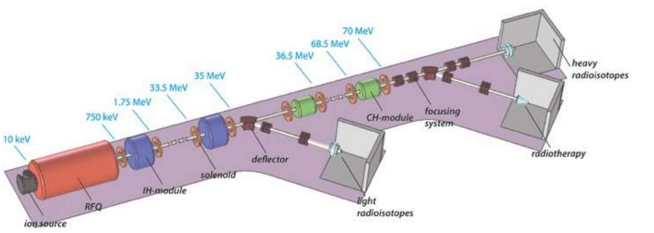

Figure 1. *Overall layout of the ICH15 facility*

Design of the different elements of the

The different parts of the accelerator were designed using dedicated software: COMSOL®, AUTOCAD®, and LISE ++.

RFQ.- A four-rod RFQ (Radio Frequency Quadrupole) was designed to accelerate the protons from the exit of the ion source (10 KeV) to the first accelerating cavity (750 KeV). A prototype was built in collaboration with Huelva local industry (Figure 2).

Figure 2. *The four-vane RFQ*

IH cavity (interdigital H mode) and CH (crossbar H mode). In IH/CH cavities the TE field has no longitudinal component, so the acceleration is produced by electrically connecting the wall surface to a group of drift tubes, which "artificially" create in the inter-gap region the axial electric field used for acceleration. The IH structure uses the "dipole mode" TE110 with a series of radial stems with a single end welded to the cavity surface, at alternating top and bottom locations. The CH structure uses the "quadrupole mode" TE210, alternating vertical and perpendicular diametral stems with both ends welded to the cavity surface. The energy losses are smaller than with TM modes because the maximum magnetic field is reached in the central region, and the minimum near the conductive walls, inducing weaker surface currents and smaller power dissipation. On the contrary, the main losses are produced on the surface of stems of the drift-tubes. The prototype of the IH cavity is shown in Figure 4.

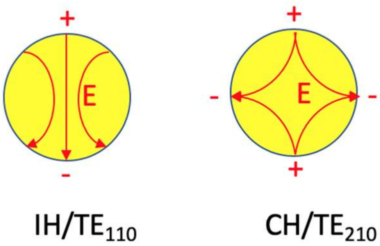

Figure 3. *Working principle of IH and CH cavities.*

Beam deflector magnets.- Due to the multifunctionality of the accelerator, a series of dipoles, septums and fast RF-kickers had to be designed to divert the beam to the different work areas (Figure 1). All the magnetic elements were designed with COMSOL. A prototype of a water-cooled solenoid of 0.6 T, 500 mm length and 10 cm bore was fabricated as part of the collaboration with a local company in Huelva.

70MeV Beam Division.- The design of the beam division is of particular interest to use the high energy beam simultaneously for both the production of radioisotopes and proton therapy. At high energies and frequencies ~ 1 MHz, the construction of a standard capacitive RF-kicker system is difficult and expensive due to the high RF-power needed to drive it. A RF-traveling wave structure was therefore designed, based on metal strips transverse to the direction of beam propagation, connected by coaxial delay lines. The delay is controlled by the length of the coaxial cables. The main advantage of this system is the high coverage factor, close to 100%. The main disadvantage is the space necessary for its installation. An example of such a system is the HIPPI system installed at CERN-SPS (Switzerland). The option of building a micro-strip transmission line implanted on a substrate of dielectric material was also studied. Synchronization between the traveling wave and the beam speed is done by adjusting the width of the microstrip for a specific dielectric permittivity of the substrate. This system has very high rise / fall times, relatively simple and compact construction, but heat conduction and radiation resistance must be considered in detail. A similar system is operating at Fermi Lab (USA).

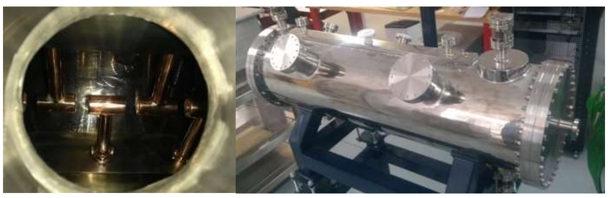

Figure 3. *IH cavity prototype.*

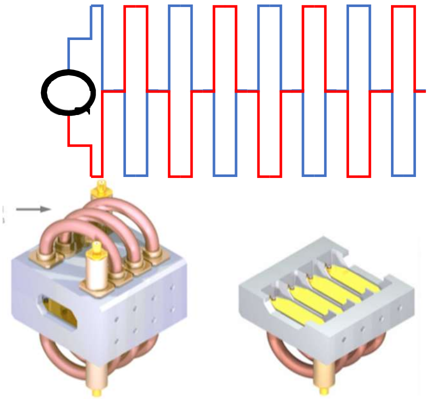

Figure 4. *Travelling wave system HIPPI [3]*

2. CONCLUSIONS:

The design and construction of RF-cavities and magnet prototypes for the production of radioactive isotopes has left an important legacy in accelerator technologies to the companies participating in the R&D project.

3. REFERENCES:

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[2] Dendalea et all. "Proton Beam Radiotherapy for Uveal Melanoma: Results of Curie Institut-Orsay Proton Therapy Center (ICPO)." International Journal of Radiation Oncology Biology Physics.

[3] M.A.Clarke-Gayther. HIPPI Work Package4 (WP4): The RAL Fast Beam Chopper Development Programme Progress Report for the period: July 2005 – December 2006https://cds.cern.ch/record/1087648/files/note-2007-002-HIPPI.pdf.

DC-DC CONVERTER WITH BIPOLAR OUTPUT AND ITS USE FOR CONNECTION OF A DISTRIBUTED GENERATION SYSTEM TO A BIPOLAR DC GRID

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Inventors: E. Durán, S. P. Litrán, M. B. Ferrera

The invention is related to a DC-DC converter capable of generating bipolar voltage with a suitable novel topology for distributed generation connection to a DC bipolar grid. The proposed topology uses only one power switch, unlike other DC-DC converters which employ two or four switches. Thus, the complexity of the converter is reduced. The DC-DC converter with bipolar output has an input for the connection to a monopolar DC source and a bipolar output voltage with a positive terminal and a negative terminal. The DC-DC converter can be applied to bipolar DC grids because it allows the connection of a monopolar DC source to such networks. The present invention is especially applicable in the industrial sector and renewable energies. Mainly this network type is an alternative to classic electric system, currently of special interest in the industry. In this sector, the proposed converter can control the voltage level and possible unbalances of the DC voltage network. On the other hand, in the renewable energy sector, the proposed scheme enables the connection of generation and storage systems to a bipolar DC network in a reliably way. The proposed topology is a solution for these applications with sufficient guarantees of reliability, quality and performance. An experimental prototype based on a combination of SEPIC (Single Ended Primary Converter) and Cuk converter has been implemented to validate the patented system.

Among the different topologies of DC microgrids for low voltage, the bipolar type is the most versatile. In this system, DC power is distributed through three-wire lines, Fig. 1. They are positive wire, neutral wire and negative wire. Loads can be connected to the network at different voltage levels, +V, -V or 2V volts depending on which wires are connected. This topology has a higher technical complexity and cost than others DC microgrid topologies.

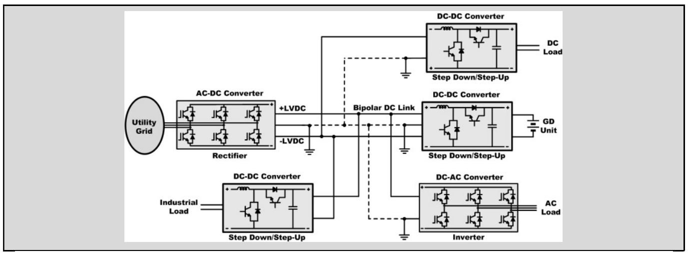

Figure 1. *Bipolar DC microgrid scheme.*

By inspection of single-switch converters, it can be observed that some configurations show an identical front end; this allows to provide multiple-output configurations when some basic topologies are modified or combined. These can be obtained using a single-switch and only an input inductor. In this sense, if SEPIC and Cuk configurations are compared it is observed that both also have identical front end and therefore they can be combined as Fig. 2 shows. The Cuk converter provides a negative-polarity output voltage regarding the common or ground terminal of the input voltage; while the SEPIC is a positive output converter. Both converters provide the same conversion relation.

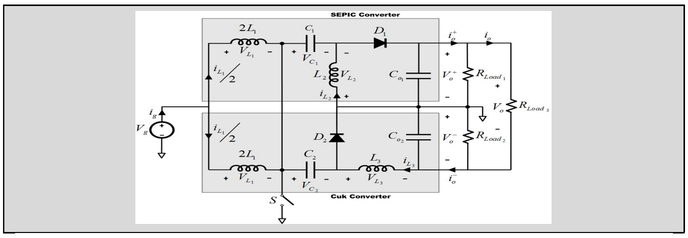

Figure 2. *SEPIC-Cuk combination converter.*

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https://patents.google.com/patent/ES2608255B1/es