A PROGRAMMABLE BIPOLAR SAW-TOOTH CURRENT POWER SUPPLY FOR SCANNING MAGNET OF 10 MEV LINAC AT RRCAT

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Abstract

A RF electron linear accelerator capable of delivering a maximum beam energy of 10 MeV is coming up at Agricultural Radiation Processing Facility(ARPF), Indore under RRCAT. The beam delivered by the accelerator will be scanned over the product under irradiation through a titanium window by applying a time varying periodical magnetic field. A programmable bipolar saw-tooth current controlled power supply has been developed at RRCAT which will excite the scanning magnet in order to generate the required magnetic field. The paper presented here describes the design and developmental aspects of this power supply.

INTRODUCTION

Food and agricultural products are treated with ionizing radiation to accomplish different objectives like reduction of pathogenic bacteria and parasites that cause food borne diseases and lengthening the shelf-life of fresh fruits and vegetables by minimising the normal biological changes associated with growth and maturation processes, such as ripening or sprouting. Radiation processing of food has become important due to mounting concern over food born diseases, and growing international trade in food products that must meet stiff import standards of quality and quarantine. ARPF is planned to be a facility where apart from regular radiation processing of agricultural products, various issues like proper irradiation techniques, packing, handling and storage on large scale and economics of radiation processing will be studied and optimized. The facility will be operated in electron (10 MeV) as well as photon mode (5 & 7.5 MeV). The above accelerator will deliver pulsed electron beam of 10 µs with a peak current up to 300 mA at various repetition rates up to 300 Hz. The product handling system is designed to process the products in different packing size with thickness varying up to 50 cm (electron and X ray modes) and to deliver dose up to 10 kGy. The dose delivered to the product can be controlled by controlling the scan rate of the beam over it. So it was required to have variable ramp-up time for the magnet field. Also to have a control over scanning width of the product the amplitude of the magnet current must be controlled, hence a variable current control was required.

In order to achieve above objectives a programmable bipolar power supply with saw-tooth current wave-shape has been developed for scanning magnet coil (L= 44 mH & R= 0.24 Ohms) of 10 MeV electron beam LINAC. Magnet can be subjected to a maximum current reversal of +10 A to -10 A in 5 ms. Its ramp-up time, ramp-down time and current peaks can be programmed through a microcontroller (C8051F040) based reference generator as described below. Major specifications of the power supply are indicated in Table 1.

Table 1: Major specifications of the power supply

S. No.	Parameter	Min. Value	Max. Value	Resolution
1	Current Peak	±3 A	±10 A	0.1 A
2	Ramp Up Time	50 ms	1000 ms	1 ms
3	Ramp Down Time	5 ms	1000 ms	1 ms

SWITCHING AND CONTROL SCHEME

The output voltage requirement across the magnet coil ranges from +0.25 volts(ramp up time of 1000 ms for 6 Ampere current reversal) to -180 volts(ramp down time of 5 ms for 20 Amps current reversal). The programmable power supply uses a bipolar PWM switching scheme developed using discrete digital ICs. It gives better flexibility of achieving any shape of current, if required in future, within the capability of loop bandwidth and software code. Single phase input line is rectified to get unregulated DC input for PWM inverter wherein an IGBT based H-bridge converter switches it to high frequency square wave, modulated with required low frequency saw-tooth current signal. The output of the H-bridge converter is filtered with a damped LC filter and fed to the scanning magnet coil to get the required saw-tooth current through it. Figure 1 shows the schematic of the power converter. Feed forward(scaling) and dual loop control system with inner loop controlling the voltage across the magnet coil and the outer loop controlling the current through the coil provide faster response and better tracking.

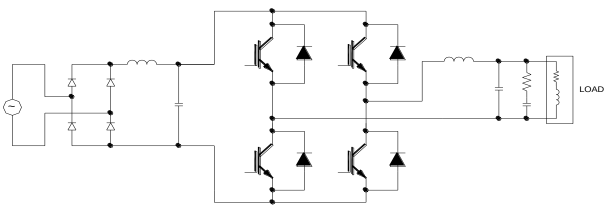

Figure 1 : Power Converter Basic Scheme

Figure 2 shows the basic control loop scheme. Major dissipative components like IGBT, filter chokes etc. are air cooled. The power components are housed in a 19 inch

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6U rack and control electronics is assembled in a 4U-rack.

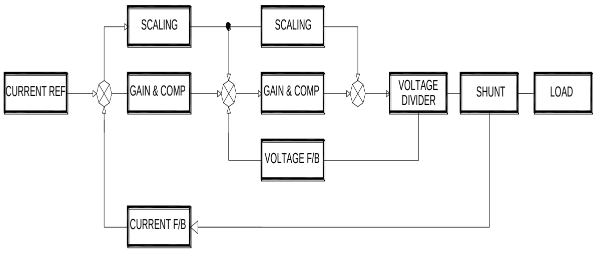

Figure 2 : Feedback Control System

REFERNCE GENERATOR

A bipolar saw-tooth current reference is needed for driving the supply. A C8051F040 microcontroller based programmable reference generator has been developed for this purpose. The magnet current parameters like ramp-up and ramp-down times and current peak values can be programmed through a 4 by 4 keypad matrix using a user friendly menu displayed over 20 by 4 alphanumeric LCD display. Microcontroller C8051F040 has two numbers of unipolar 12 bit DACs. Both DACs have been used to get a bipolar sawtooth reference signal. The required software for embedded controller has been written in “C” language using Keil Cx51 cross compiler. Timer Interrupt is used to generate the required ramp rate and external interrupt is used to read the keypad. The code is so written that it protects the user from entering the data beyond specified limits. The reference generator is integrated on the front fascia of the control rack.

LOCAL/REMOTE OPERATION

The power supply is capable of being operated from local fascia panel or in remote mode from central computer interface via a 15-pin sub-D connector provided on back fascia plate. In remote mode, the power supply operation can be controlled by ON, OFF and RESET commands, which have been isolated using control relays. The readback for the status of the supply with regards to its control ON & TRIP status is provided through opto-isolators and relays. The bipolar analog reference voltage sets power supply output current.

PROTECTIONS

Power supply is protected against over-currents in load, line or IGBT switches and DC or under current in load. To protect the IGBTs against over current (which can either be due to over-setting or control loop failure) , an over current protection circuit is incorporated that senses the IGBT current through a high frequency CT and blocks the firing gate pulses of the IGBTs. A fuse and a MCB in series with ac mains is used for protection against short circuit faults. Common mode and differential mode filters have been employed for protection against conducted EMI.

RESULTS

The power supply has been successfully developed and tested to confirm all intended parameters and functionalities. All the critical parameters of the power supply, namely current peaks, ramp up time and ramp down time were varied to their maximum and minimum ranges and corresponding currents were fed into the prototype magnet. The power supply parameters were measured and found within specified limits. Figure 3 below shows the image captured over a DSO of the actual current flowing through the magnet.

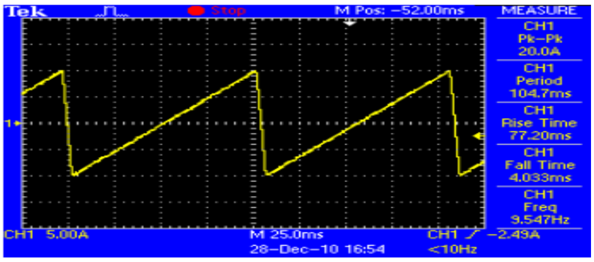

Figure 3 : Current through magnet

Figure 4 : Front fascia of the power supply

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