STATIC ELECTRON GUN POWER SUPPLIES FOR 3MeV DC ACCELERATOR

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Abstract

A DC accelerator is designed to operate with beam energy of 1MeV-3MeV and beam current of 0-10mA. The electron beam is generated by a thermionic emission electron gun. The gun is floating at 3 Million Volts and requires regulated and controllable power supplies for its Anode and Filament respectively. This requires generation of about 400W on the 3 MV terminal and conditioning it to the desired voltages and power levels with remote control facility as per beam requirement. The paper describes briefly about the design aspects and test results.

INTRODUCTION

A 3MeV, 10mA DC Industrial Electron Beam Accelerator is being developed at Electron Beam Centre, Kharghar, Navi Mumbai. Typically electron gun and associated power supplies in DC industrial accelerator floats at the accelerating potential, so as to facilitate the acceleration of the electrons and irradiation of objects at ground potential. This requirement can be realized by extracting power from the high voltage system itself. The power supplies should be designed to handle wide input voltage range, should withstand unique environmental conditions like vacuum during gas transfer to the pressure vessel and 6kg/cm^2 SF_6 environment with temperature up to 60^{o}C during normal operation. The supply is designed to withstand electromagnetic interference conditions occurring inside the high voltage dome during transients. While the anode voltage decides injection voltage, the filament power sets the beam current. To fine tune the beam parameters, these supplies are remotely controlled using a fibre optic link from the control room. The specifications are summarised in table 1.

Table 1: Specifications for gun power supplies

Isolation	3MV
Operating environment	SF_6@6kg/cm^2 Pressure
Storage environment	1mbar to 6kg/cm^2
Operating temperature	20 - 60^{o}C
Filament supply	0-15V, 20A
Anode supply	0-5kV, 10mA
Control power supply	15V/1A
Control	digital control by fibre optic

POWER EXTRACTION SCHEME

The high voltage system employed in this machine is based on the parallel coupled multiplier scheme. The multiplier employs 74 corona guards to harness RF power from the feeder electrodes which are subsequently rectified in adder mode to obtain the accelerating potential. Two corona guards closer to the high voltage terminal are used only for the gun power extraction, which is described elsewhere. Studies done on the extraction scheme suggest output voltage in the range of 150-600V. Anticipating maximum deviation of 20% from the projected figures, the operating range of the supplies are fixed to 120-600V.

POWER PROCESSING SCHEME

Due to wide input voltage range of the power supplies, two stage processing is adopted as shown in Figure 1. The first stage employs a chopper to stabilise the voltage to an intermediate level of 100V. This intermediate voltage is fed to the anode and filament supplies for further processing. The control power supply which is required to be active from 70V onwards is connected to the unregulated DC so that the monitoring scheme can be active from 500kV onwards. The control supply involves IGBT based series regulator followed by a fly back converter. The series regulator clamps the maximum operating voltage of the flyback converter to 300V. The flyback converter is realised using TOPSwitch family of integrated PWM switch from Power Integrations.

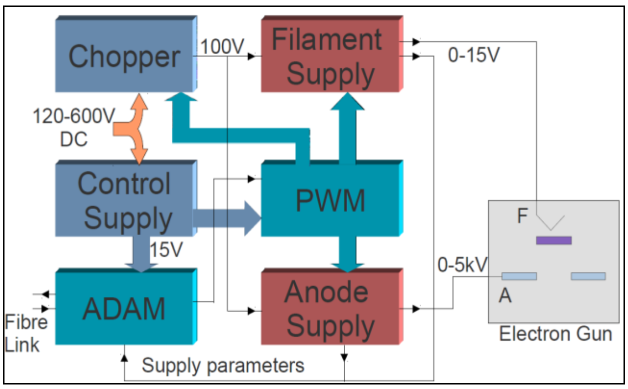

Figure1: Block Schematic of the Gun power supplies

The anode and filament supplies employ half bridge inverters running at 100 KHz. For the anode supply the inverter is followed by a step up and a 2 stage multiplier. The filament supply employs step down transformer and rectifier scheme ahead of the inverter. In the filament power supply only inductive filter is employed. The closed loop operation is done using SG1525 PWM controller.

CONTROL AND MONITORING

The supplies are not readily accessible during normal course of operation. The parameters of the supply required to be monitored to evaluate its performance and for verification of the design parameters. The control and monitoring system is based on industrial data acquisition modules wired together on a RS-485 bus locally in the high voltage dome. The operating levels of the supplies were set using a 4 channel analog output module. The local parameters were monitored using a 8 channel analog input module. A thermocouple module is used to measure the dome ambient. Communication to the floating RS-485 network is achieved using a pair of fibre optic trans-receiver modules.

THERMAL MANAGEMENT

Ambient temperature in the high voltage terminal can increase due to the dissipation in the electron gun and the power supplies inside the dome. Dissipation from the power supplies are estimated at 65 W. The maximum temperature inside the dome is estimated to reach 60^{o}C maximum for continuous operation at full power. As the power supplies are provided with an internal aluminium shield for electromagnetic protection, the power devices are mounted to the shield with isolating silicon rubber pads. The thermal resistance of the shield is brought down to 0.1^{o}C /W by welding aluminium heat fins to the shield. The shield is provided with 6 mm diameter breathing holes for cooling of other components not mounted to the heat sink.

COMPONENT SELECTION

The supply is subjected to vacuum in the order of 1mbar for a period approximately 100 minutes during SF_6 filling operations to remove moisture traces in the pressure vessel. During normal operation the operating environment will be SF_6 at 6 kg/cm^2. The component selection should be based on long term reliability, ability to with stand vacuum and pressure and high operating temperature. For vacuum compatibility and reliability, it is desired to avoid electrolytic capacitors. For unavoidable cases, solid tantalum capacitors are used. All other capacitor requirements are managed by poly propylene capacitors or ceramic capacitors.

ELECTOMAGNETIC COMPATIBILITY

In the event of a high voltage breakdown in the system, the supplies are subjected to electromagnetic interference. Conducted noise can enter the supply either through the power extraction transformer or through the electron gun. To minimise these effects the supply is protected by using common mode and differential mode filters in both the power input side and output side. The entire supply is enclosed in aluminium shield to minimise radiated interferences. A view of the power supplies assembled in the high voltage terminal is shown in figure 2.

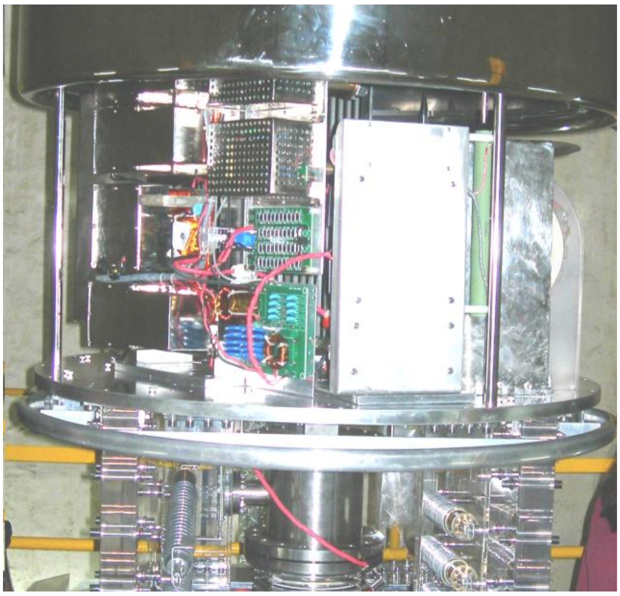

Figure 2: Gun power supplies assembled inside HV Dome

EXPERIMENTAL RESULTS

The supply has been extensively tested for electromagnetic compatibility and thermal performance. The supply has been subjected to electric fast transient immunity test as per IEC/EN61000-4-2 and RF conducted susceptibility test as per IEC/EN61000-4-5. To simulate expected surge conditions, the supplies were tested with custom designed pulse generators at 40 kV level. To simulate the actual operation, a test setup has been made using 6 sets of corona guards to replicate the power extraction side capacitance network. The supply has been tested and qualified with this setup before employing in the actual system. The supply has been tested for 24 hours with the electron gun as load. The test has been conducted by keeping the power supplies inside the high voltage terminal and powering it with an external DC supply. The results are presented in Figure 3.

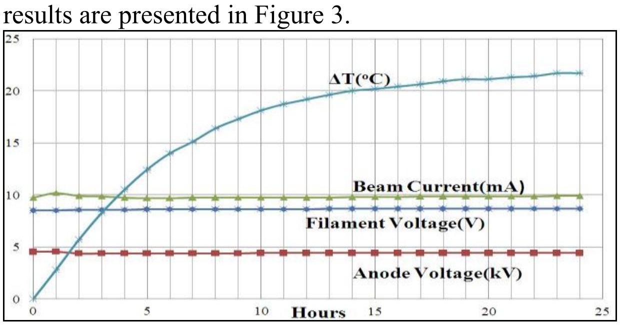

Figure 3: Heat run test results

CURRENT STATUS

The accelerator has been operated with these supplies. The gun controls get energised from 560kV onwards. The supplies successfully withstood large number sparks in the system. Currently the accelerator is being tested at 1.5 MeV with 4mA beam current.