POWER SUPPLIES FOR THE RF-SYSTEM OF K=130 CYCLOTRON AT VECC, KOLKATA

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Abstract

The K=130 room temperature variable energy cyclotron at Kolkata has been operating for the last three decades. The radio-frequency (RF) system of the cyclotron designed at the early stage of its evolution was based on self excited RCA-6949 shielded grid triode. Later the RCA-6949 has been replaced to an amplifier based system using Burle-4648 tetrode tube. As a part of the modernisation programme (2007-2009) of the VEC technical systems, renovation of all the dc bias power supplies of the RF tube has been done replacing the old and obsolete components with newer ones and modifying the sub-systems with upgraded technologies for improved performance.

This paper describes the present design and the technology adopted for the diversely rated RF power supplies of the cyclotron basically for providing the DC bias to the Anode, Screen, Grid and Filament of the Burle-4648 tube.

INTRODUCTION

The resonator cavity of the K=130 cyclotron at VEC, Kolkata is made up of one end short-circuited quarter wave coaxial transmission line (Dee-Stem) followed by the accelerating electrode (Dee). The RF transmitter system feeding power to the resonating cyclotron cavity consists of a RF signal generator (5MHz-16MHz) to set the RF frequency for specific beam energy. This reference signal is fed to the Dee-Voltage-Regulator unit which in turn is fed to a Solid State Driver Amplifier. The amplifier output drives the 250kW, Burle-4648 tetrode based Final Amplifier operating in Class-B to couple the output power to the cavity. Four dc power supplies designed to provide the required bias to operate the high power Tetrode is given in Table-1.

Table-1 Specification of the DC Bias Power Supplies

Filament Power Supply	0 to 4V Adjustable, 2000A max. Motorized Variac Control.
Grid Power Supply	0 to -160V Adjustable, 0.5A max. Voltage Regulated – Series Pass. Long Term Stability ~ 50ppm.
Anode Power Supply	0 to 20kV Adjustable, 20A max. Voltage Regulated - Series Pass. Crowbar with Recycling.
Screen Power Supply	0 to 1.2kV Adjustable, 0.5A max. Shunt Active Filter. Motorized Variac Control. Crowbar with Recycling.

DESIGN AND TOPOLOGY

Filament Power Supply

The filament power supply (Fig. 1) consists of a 3-phase water-cooled transformer (28kVA) in Y/y0y6 configuration that is connected to a half-wave rectifier assembly in common-cathode configuration. The feedback signal derived from the power supply output voltage is compared with a set reference voltage and the error signal is used to drive the input motorized variac.

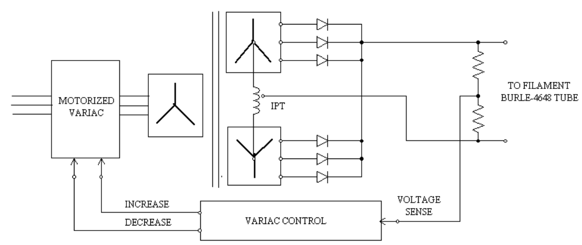

Figure 1: Schematic of Filament Power Supply.

Grid Power Supply

The power circuit for the continuously varying voltage controlled grid power supply (Fig. 2) uses step down transformer followed by rectification and filter. Final control of the output is achieved by series pass transistor operating in the linear region, thus having a large control bandwidth. Output voltage regulation is achieved by an inner fast voltage control loop in the regulation module for cancellation of supply ripple and provides line regulation for short term stability. The outer slow voltage loop ensures the long term stability of the power supply.

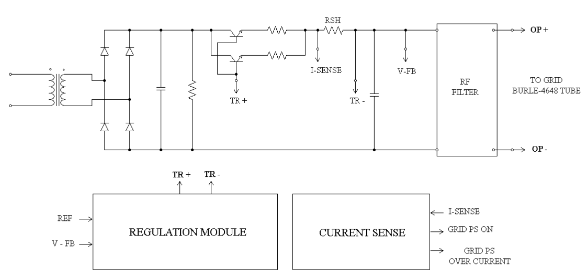

Figure 2: Schematic of Grid Power Supply.

Anode Power Supply

The high power, continuously variable, voltage regulated anode power supply (Fig. 3) consists of four epoxy cast water-cooled transformers (96kVA, 415V / 5kV), rectifier stack (oil-cooled), filter capacitor bank

(3x3.75mfd / 35kV) that generates the necessary unregulated voltage. The output voltage control is achieved using a high power water-cooled triode ML-7560 as the series-pass element. The output feedback from the voltage divider after comparing with a reference source is fed to the compensated error amplifier along with associated electronics to produce 1MHz amplitude-modulated signal transmitted through a pulse transformer which isolates the low power regulation module with the series-pass tube floating at high voltage. The AM signal after demodulation is used to drive the series-pass tube through BEL-135 pre-driver and EIMAC 3CW5000 driver tube. A fast acting crowbar system designed to operate within 3 µsec is required to protect the RF tube in case of an overload. For this purpose a crowbar module [1] having fast switching power MOSFET with its high current driver has been designed. This deliver a high quality trigger pulse with adequate power to turn on the 5C22 Hydrogen Thyratron to trigger the series pass tube to go to the cut-off region.

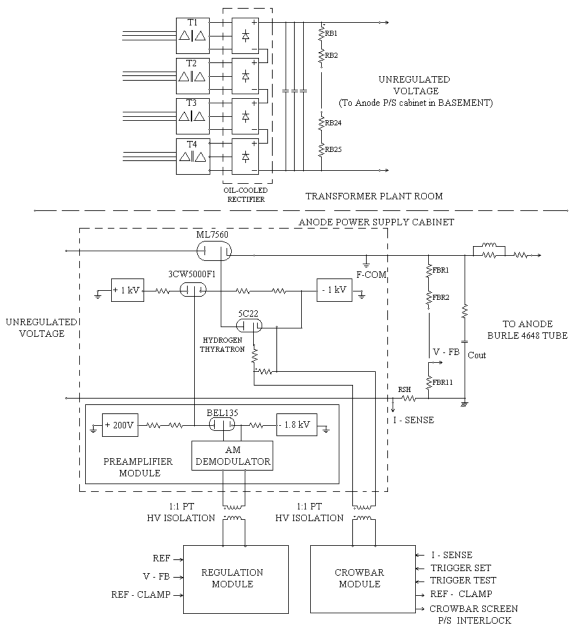

Figure 3: Schematic of Anode Power Supply.

Screen Power Supply

The screen power supply (Fig. 4) has been implemented using primary voltage regulation topology with a motorized variac. The utility input voltage is step-up using a 3-phase 4kVA transformer having Delta-Wye configuration and is then rectified and filtered to get the output dc voltage. A shunt active filter using EIMAC 4CW2000 tetrode tube has been utilized for the output ripple rejection, which in turn also reduces the capacitor filter requirement and thus the stored energy. Crowbar protection scheme with 6 µsec operating time has been designed and implemented using thyristors to divert the energy from the screen electrode in case of an overload in screen or anode power supply.

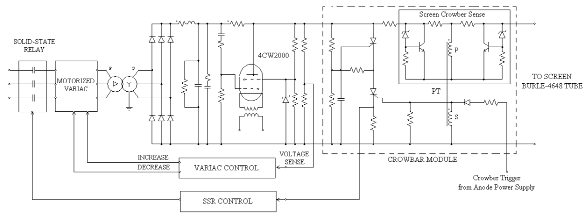

Figure 4: Schematic of Screen Power Supply.

Figure 5: clockwise from left (a) Filament and Screen Power Supply, (b) Anode Series Pass Triode, (c) Transformer Plant Room, (d) Anode Power Supply.

CONCLUSION

All the power supplies were tested for their specifications and integrated with the RF system. These are currently in operation to develop the required Dee voltage for proper beam dynamics. A PLC based system is used for full coordination of each of these sub-systems with sequential power up and down, fault handling and ensuring safe and reliable operation.

ACKNOWLEDGEMENT

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REFERENCES

[1] Chen-Yao Liu et al, “Design and Implementation of the High Performance Thyratron Tube Driver”, Proc. of EPAC 2002, Pages: 2646-2648.