

# UP-GRADATION OF RADIOFREQUENCY SYSTEM FOR THE K130 ROOM TEMPERATURE CYCLOTRON

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## Abstract

The radio frequency system of 224 cm room temperature variable energy cyclotron ( $k=130$ ) consists of one quarter-wave ( $\lambda/4$ ) resonant cavity placed horizontally. The cavity is made of with one-end short-circuited coaxial transmission line (dee-stem) terminated by the accelerating electrode (Dee). A Burle 4648 water-cooled tetrode-based high power final RF amplifier (250kW), driven by a wideband 1 kW solid-state driver amplifier, is used to feed power to the RF cavity. There are four DC power supplies namely Filament, grid, anode and screen power supplies, for biasing the Burle 4648 tetrode. After several years of operation, recently all DC power supplies have been replaced with new power supplies and Programmable Logic Controller (PLC) based interlocks has been incorporated in place of previously used relay-based interlocks for the RF system of k130 cyclotron. The RF interlock system takes care of systematic on/off of the power supplies and driver amplifier, water flow, air flow, vacuum and other interlocks for the safe operation of the RF System. In addition to that EPICS based RF operating console and data logging/monitoring system has been added and the system has been operating successfully round-the clock with beam.

## INTRODUCTION

The radio frequency system of 224 cm room temperature variable energy cyclotron ( $k=130$ ) has operational frequency between 5.5 MHz to 16.5MHz. The rf cavity is made of with one-end short-circuited ( $\lambda/4$ ) coaxial transmission line. It is single Dee system, where Dee is placed horizontally between the two ground planes (liner). The Dee is extended with Dee stem and finally terminated at short-end. The change in frequency is done with the movement of upper and lower panel which is placed horizontally above and lower to the dee stem. To compensate thermal and other instability in frequency, there is a adjustable trimmer capacitor. The trimmer capacitor is formed between the dee stem ground planes. The dee, dee stem, panels, trimmer capacitor are located inside the vacuum section of the cavity. The RF power is fed to the cavity from a 4648 tetrode based RF amplifier. The rf signal from signal generator is fed to the Dee voltage regulator and then it is further amplified at solid state driver amplifier and fed to the 4648 based 250kWatt final rf amplifier. The Dee voltage regulator works in a closed loop to maintain constant dee voltage within 100 ppm stability. Trimmer drive unit receives phase

information from grid pick-up and anode pick-up signals to drive trimmer capacitor. The water-cooled final rf amplifier is directly coupled to the cavity.

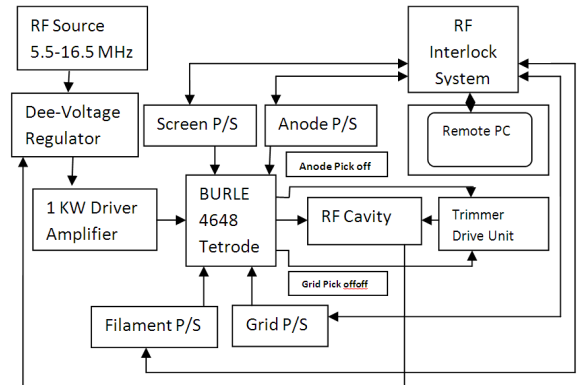


Figure 1: Block diagram of RF system of K130 cyclotron.

## RF INTERLOCK SYSTEM

The Interlock system is maintaining necessary interlock for water flow, door interlock, air flow, power supply interlocks, voltage and current monitoring for safe operation of RF system of the room temperature cyclotron. Due to ageing of relays and wiring it was in urgent need to revamp the entire RF interlock system. During up gradation, relay based interlock system for RF is replaced by PLC based interlock system [1]. The basic control logic remains unchanged. Earlier multiple flow switches were connected in series due to problem of space, now each flow switches are changed to individual channels for input to the PLC.

## RF POWER SUPPLY

Filament, grid, anode and screen power supplies are upgraded and installed at vault/Pit. Filament power supply is of 4 Volt, 2000A, Grid power supply is of -150V to -50V, Anode power supply is of 20kV, 20A and screen power supply is of 1.5kV, 1A. There are fast crowbar protections (within 2  $\mu$ s) in anode and screen power supply for the protection of the very costly Burle#4648 tetrode apart from over current and over voltage interlocks. Filament power supply is unregulated one, whereas grid, anode and screen are regulated power supplies. Filament power supplies has soft start unit associated with it. It ramps up voltage slowly to take care of low initial resistance. As the current built up, resistance

of the filament increases, with increase in temperature. During installation low frequency oscillation is observed in the system even in absence of rf. A low value resistance in series with anode power supply reduces this effect. Power supplies are tested separately and interlocks are thoroughly tested before installation. Adequate diagnostics is added for fault finding and voltage and current readings are monitored.

### SAFETY ASPECT

The RF amplifier, resonant cavity, and RF power supplies are located at vault where entry of human beings is prohibited during normal operation. Vault Doors are interlocked with ion source which inhibit entry of personals when both ion source and rf are in ON condition. All interlocks are implemented in PLC using STL languages maintaining machine safety aspect. It maintains failsafe mode. All four power supplies on and off sequentially for the safety of the Tetrode of the RF amplifier, which is implemented in PLC. In addition, over-current interlocks as well as absolute over voltages are implemented in individual rf power supplies and status is monitored by PLC. All voltages and current are measured and displayed in operating terminal. The PLC has range of setting to ensure safe operating region of the RF amplifier and to obtain optimum gain and power. Over voltage and under voltages are related to operational purpose and safety of the Tetrode tube. In case of failure of these measurement or any abnormal situation RF amplifier trips and logs the data. Hence safety of tetrode tube resonator and power supplies are ensured.

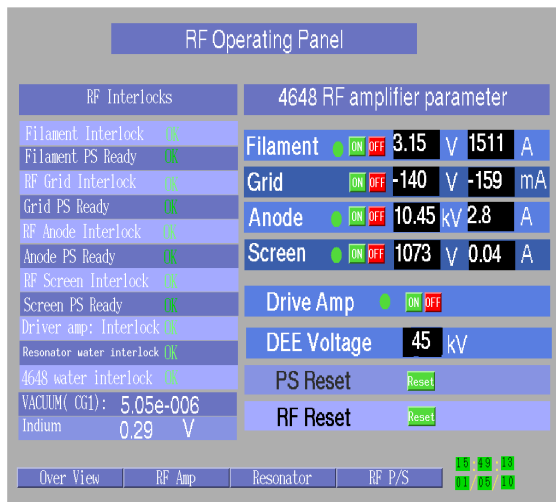


Figure 2: Use interface for rf operation.

### EPICS BASED CONTROL SYSTEM

The supervisory software architecture is based on EPICS, and it is standard well tested open source software. There is an IOC (input output controller) running in Linux platform that works between user and PLC. Both user and PLC are connected in VECC control LAN. Again user interface is built using Medm in EPICS

platform. The s7plc driver[2] is used as EPICS driver to the Siemens S7 CP 315-2pn/dp having integrated ethernet CPU. One data block stores transmitted data and another data block store received data at the PLC terminal. The individual data between PLC memory and IOC is mapped. TCP based communication is established to transfer the data between IOC and PLC. PLC individually handles all the critical data where as user command and data communicated to PLC thought Ethernet interface.

### CONCLUSIONS

The newly installed power supplies enhances the reliability and stability of the rf operation and has significantly reduced the failure rate which in turn increases the availability of the rf system and total beam hour of the machine. Replacement of the old power supplies with highly stable supply also enhances dee voltage stability. RF interlock system is accomplished with Siemens PLC and EPICS. After one year of up-gradation no major failure is found. Utilization of PLC and EPICS provides us quick development, reduce wiring. Standard EPICS tool significantly enhances the speed of deployment. In addition, there is seamless integration to the machine control system as they are also running on EPICS platform. Fanless, battery less PLC offer more reliable operation compared to relay based system. Continuous data logging helps in operation and diagnostics.

### REFERENCES

- [1] S.C. Lay, et al., "The selection, development and application of plc solutions for the diamond light source",
- [2] <http://epics.web.psi.ch/style/software/s7plc/s7plc.html>