TESTING OF INDUCTIVE OUTPUT TUBE BASED RF AMPLIFIER FOR 650 MHz SRF CAVITIES

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Abstract

A 650 MHz IOT based RF amplifier has been developed in VECC. It can be used to power several cavity modules in high energy high current proton linear accelerator to be built for ADSS programme in India and in Project-X at Fermilab, USA. The IOT based amplifier requires different powers supplies, water cooling and forced air cooling for its operation. A Programmable Logic Controller (PLC) based interlocks has been incorporated to take care of systematic on/off of the power supplies and driver amplifier, water flow, air flow 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.

INTRODUCTION

IOT based high frequency amplifier has been developed in VECC to power several 650 MHz high beta (β=0.61) RF cavities in ADSS programme and Project-X at Fermilab, USA. The amplifier uses the TH 793-1 Inductive Output Tube that delivers an output power of typically 85 kW in CW operation [1]. Specifications are given in Table 1. In addition to this, the amplifier is equipped with various impedance matching and biasing networks and two resonant cavities for input and output tuning. This water cooled amplifier requires five different power supplies naming filament PS, ion-pump PS, Grid PS, Collector PS and focus Coil PS. Among these auxiliary power supplies filament, ion-pump and grid are floating are in high voltage potential, i.e. collector/beam voltage (36 kV) and therefore mounted in an isolated frame in a separated cabinet called high voltage deck. The whole scheme is shown in Figure 1. The mains inputs of High voltage deck are electrically isolated by means of an isolating transformer. The amplifier is cooled by low conductivity water (<2 µS) and forced air. Water flow switches and air flow switches are installed at proper locations to have safety interlocks. In addition to that a PLC works as main control device. It acquires and controls all the analogue and digital readings and settings, supervises and interlocks the slower signals and handles the interfaces to the remote interlocking unit and the local control consol.

Table 1: IOT Specifications

Output Power	70	kW
Frequency Range	650	MHz
Bandwidth	6	MHz
Beam Voltage	36	kV
Beam Current	3.4	A
Body Current	50	mA
Grid Current	-40	mA
Filament Current	24	A
Focusing Current	18	A
Efficiency	69.4	% typ
Gain	23.2	dB typ

CONTROL SYSTEM OVERVIEW

Control architecture of our IOT based amplifier test system is a three layer architecture comprising of device layer, IOC server layer and user Interface layer. The device layer consists of PLCs which controls the automatic process sequence operations. The PLCs and the process components are configured to satisfy fail-safe operation. The user interface layer consists of the control computers where the operators issue the set points and the mode of operation commands. The system is controlled by means of Siemens S7-300 PLC which is handling all the field I/Os. PLC takes care of all safety interlocks of the amplifier like over-voltage, over-current, water flow and airflow. The PLC is programmed using Simatic manager Step7 [2]. All PLC programmes are written in STL (Statement List) i.e. the program consists of a sequence of mnemonic codes of the commands executed one after another by the PLC. Three auxiliary power supplies for the amplifier are located at high voltage deck floating at 36 kV. These power supplies and other instruments located at high voltage deck are powered through an isolation transformer (isolation: 40 kVolt). An ethernet to optical and optical to ethernet channel is used to navigate the control signals from HV deck to PLC. Two ethernet-optical fibre media converters and a 3 meter fibre optic cable are used to have the isolation between HV deck and PLC located at ground level. A siemens distributed I/O module (ET200) with ethernet takes care of all the I/Os at HV deck. The scheme used for HV isolation is given in Figure 2.

SUPERVISORY CONTROL

Supervisory control is the user interface layer part. In this layer the PLCs are being monitored and controlled

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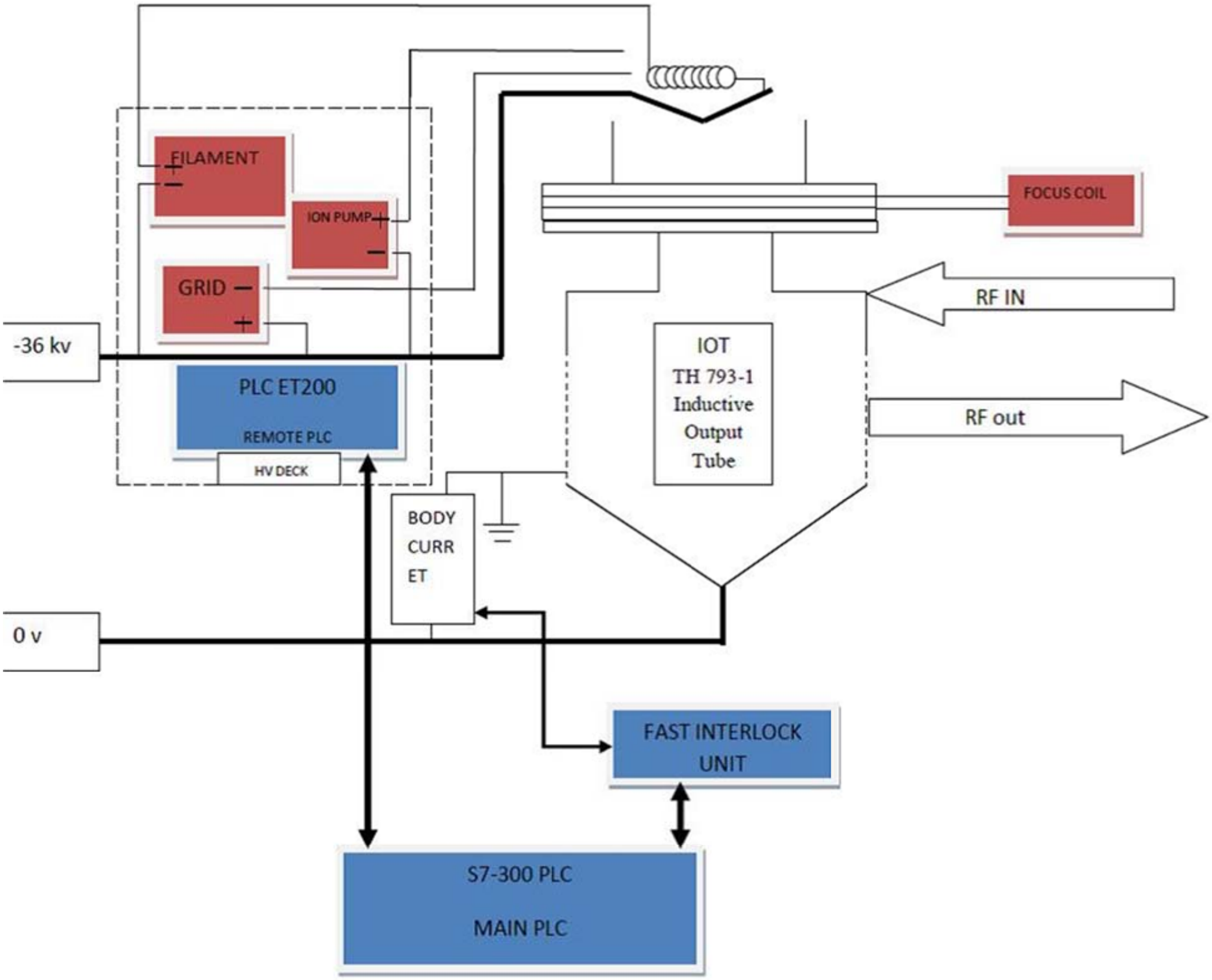

Figure 1: The IOT Amplifier: Schematic overview.

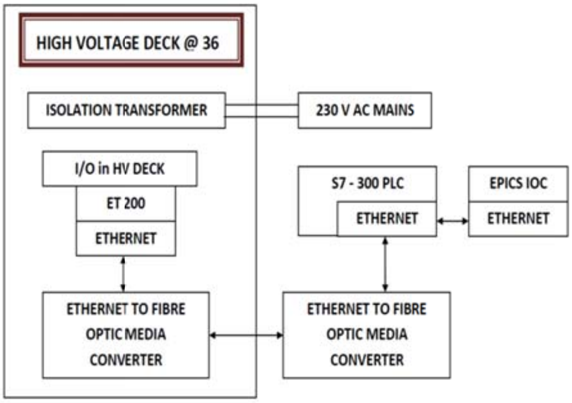

Figure 2: HV Isolation scheme.

through Ethernet based control LAN.We felt the requirement of a common platform as well as exchange data between systems. Also the user interface computers were required to be put at different locations for system integration. After evaluation of requirements, we selected Experimental Physics Industrial Control System (EPICS) [3] as suitable system which fulfil our need. Experimental Physics and Industrial Control System (EPICS) is a set of open source software which provide a software platform for building distributed control systems to operate devices such as Particle Accelerators, Large Experiments and major Telescopes, and is used worldwide for such applications. EPICS is free, hence there is no license fees, no new payment to be made for every upgrade. EPICS architecture shown in Figure 3 has primarily three parts, the operator interface (OPI), the IOC (input-output controller) and the communication network (LAN) which allows the IOCs and OPIs to communicate.

After testing successfully we implemented this in a linux PC in our network to run the IOC to communicate with Siemens PLC with TCP communication. The Graphical User Interface (GUI) is made by using EPICS Motif Editor and Display Manger (MEDM) tool. All the process parameters of all the systems are displayed here for monitoring with a proper navigation. Same GUI can

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Filament (V) 12 V
Filament (I) 23.8 A
Ion Pump (V) 3.2 kV
Ion Pump (I) 10 uA
Grid (V) 60 V
Grid (I) 30 mA
Focus Coil (V) 4.0 V
Focus Coil (I) 15.9
Collector (V) 23.0 kV
Collector (I) 0.9 A

Ion Pump Voltage Set 0.470
Ion Pump Max Current Set 0.030
Filament Voltage Set 8.000
Filament Max Current Set 50.000
Grid Voltage Set 0.330

APPLY INTERLOCK SETTINGS

Filament Under Volt Lt 0.000
Filament Over Volt Lt 15.000
Filament Current Lt 36.000
Ion Pump Under Volt Lt 2500.000
Ion Pump Over Volt Lt 4000.000
IonPump Current Lt 20.000
Grid Under Volt Lt 100.000
Grid Over Volt Lt 360.000
Grid Current Lt 3.000
Collector Over Volt Lt 360.000
Collection Current Lt 0.500
Focus Coil Over Volt Lt 18.000
Focus Coil Current Lt 20.000

Figure 4: GUI for Remote operation.

be run in different PCs so that different systems can be monitored together. In our standalone test setup IOC and remote computer where MEDM based GUI is running, is in the same computer. Operators use the GUI shown in Figure 4 to turn on the system step by step.

CONCLUSION

We had operated the system continuously round the clock delivering power to a RF dummy load. Presently total control system is running undisturbed and without any change. The amplifier has delivered up to 14 kW of RF power. Going to higher power levels is restricted due to crowbar problem in main collector power supply. The amplifier system can be easily integrated with other EPICS based system. In future we are looking forward to power SRF cavities with this amplifier.

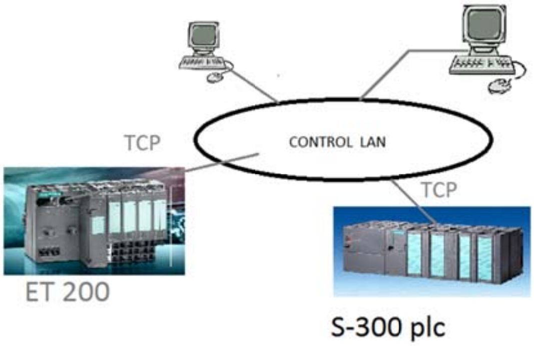

Figure 3: EPICS control architecture.

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[2] Working with STEP 7, https://moodle.dce.fel.cvut.cz/file.php/17/Manualy/S7gsv54_e.pdf
[3] EPICS: http://www.aps.anl.gov/epics