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CONTROL SYSTEM FOR 30 keV ELECTRON GUN TEST FACILITY

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Abstract

At LINAC Project PINSTECH, an electron gun test facility for indigenously developed 30 keV electron guns is developed to control and monitor various beam parameters by performing electron beam tests and diagnostics. After successful testing, electron gun is then integrated into 6 MeV standing wave linear accelerator. This paper presents the control system design and development for the facility.

INTRODUCTION

At LINAC Project PINSTECH, two RF standing wave linear accelerator prototypes are being developed. One is Medical linear accelerator (*Medical LINAC*) for use in medical applications such as cancer treatment, and the other is Industrial linear accelerator (*Industrial Linac*) for use in Non-Destructive Testing (NDT) applications. Electron source is one of the main components of an RF linear accelerator which provides charged particles to be accelerated by means of radio frequency [1]. Indigenously electron guns developed by Beam Transport and Diagnostics Group (BTDG) of LINAC Project are the electron sources for the linear accelerator prototypes at the project. Low energy 30 keV electron guns are designed and fabricated for integration into the 6 MeV linear accelerators. Characterization, testing and validation of electron gun parameters are important tasks that need to be properly done before integration into the accelerator [2]. For this purpose, Electron Source Operation and Characterization lab is developed at LINAC project PINSTECH that contains test facility. Next section describes overview of the experimental setup at the Lab.

OVERVIEW

The Lab is divided into two main areas: Experimental High Voltage (HV) Area and Control Room Low Voltage (LV) Area. Both of these areas are described in following subsections.

Experimental Area

Experimental Area consists of test bench and high voltage components. It consists of a low energy 30 keV electron gun along with beam diagnostic equipment integrated on a CF-63 based test bench. The designed electron gun is diode type based on thermionic emission which incorporates the modern dispenser cathode. The system is evacuated down to 1e-8 mbar with turbo molecular pump. Cold cathode ionization gauge IMG 300 is used for pressure measurement. A Faraday cup is integrated with transitional feed through to measure the beam current and a Ce doped YAG screen is used to measure the beam profile. The cathode of the gun is powered up with low voltage DC power supply, and beam extraction voltage is applied through high voltage DC power supply. Experimental area is remotely monitored and controlled from *Control Room* by means of a PLC-based control system. The schematic picture of experiment is shown in Fig. 1. Due to presence of high voltages, and for elimination of EMI, *Experimental Area* is completely caged, grounded and isolated.

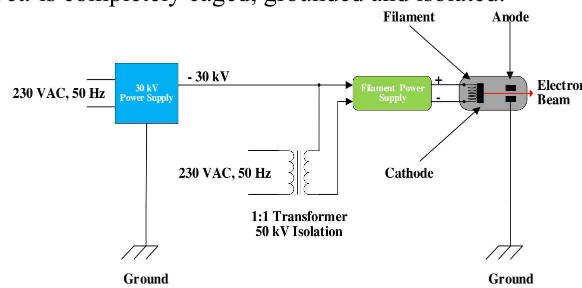

Figure 1: Schematic diagram of experiment.

Control Room Area

Control Room Area consists of two main components: *Operator Computer* and *Control Panel*. Operator computer consists of branded Dell i7 CPU, 24-inch LED monitor, keyboard, mouse and printer. The control panel consists of a C-type rail containing Siemens Simatic S7-300 PLC CPU, input, output and communication modules. The I/O modules allow support for digital inputs, digital outputs, analog inputs, analog outputs and RS-232/422/485 communications. The control panel can be divided into two parts: front panel and back panel. PLC controller along with its power supply, I/O and communication modules, and IPC477D touch panel are installed at the front panel. Circuit Breakers are installed at the back panel which provide protection in case of any short circuit or fault current.

CONTROL SYSTEM DESIGN

Control system acts as brain of the electron gun test facility. It enables operator to remotely monitor and control the complete system in a safe and interlocked environment to avoid any undesirable condition. In order to design the control system, hardware required was to have the following features: modular configuration for scalability, distributed configuration for separating high and low voltage area, Ethernet and serial interfaces for integration of commercial-off-the-shelf equipment, future availability for upgradation, knowledge and expertise for assistance. Keeping in view the above features, Siemens Simatic hardware and TIA-portal software packages were selected to design and develop the control system for electron gun test facility.

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Logical Layout

The idea for development of the test bench control system is same as arrangement of experimental setup i.e. modular configuration divided into two areas: High Voltage (HV) and Low Voltage (LV). We need to monitor and control devices and interlocks inside the experimental area which is at high potential and also monitor and control electronic devices and interlocks from the control panel which is at the ground potential. LV area control module consists of main processing unit i.e. S7-300 CPU placed inside control panel situated in the Control Room Area, and HV area control module consists of slave unit i.e. ET-200M placed inside HV deck situated in the Experimental Area [3]. These two control system modules are connected via optical fiber to provide isolation. To program the PLCs, Ladder Logic programming language is mostly used. Logical layout of the control system is shown in Fig. 2.

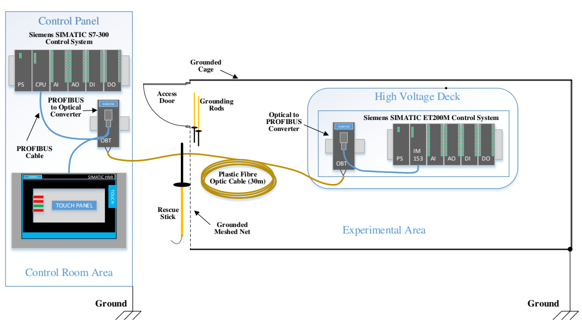

Figure 2: Logical layout of Control System.

Network Layout

CPU, slave module and touch panel need to communicate with one another for data transfer. This communication is achieved by means of a PROFINET-PROFIBUS network. Figure 3 shows the network layout configuration in Siemens TIA-Portal. ET200M based slave module is networked using PROFIBUS interface with the main processing unit S7-300. As PROFIBUS is a copper medium, it can carry EMI. Hence, PROFIBUS is converted to optical network and vice versa using Optical Bus Terminals (OBT) at both ends. ET200M module delivers/collects information to/from the main processing unit. PLC S7-300 CPU, IPC477D based HMI station, and operator computer are networked using ETHERNET interface as shown in Fig. 3.

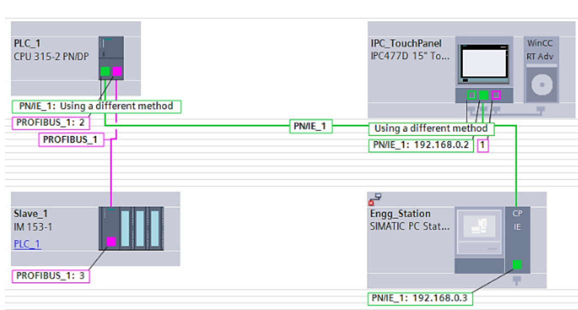

Figure 3: TIA-Portal Network layout.

Equipment

Several signals have been monitored and controlled from different instruments, power supplies, vacuum gauge controllers and faraday cup stepper motor. The brief explanation is given below:

Vacuum and Temperature
Vacuum of electron gun is measured from IMG-300 card of Agilent Technologies Vacuum Gauge Controller XGS 600. This card provide an analog signal corresponding to the vacuum and is acquired in the control system through an analog input module of S7-300. Desired/permissible vacuum window is programmed inside PLC for activating interlocks. Electron gun temperature is measured from K-type thermocouple through Phoenix transducer into the analog input module.

Filament Power Supply
TDK Lamba power supply is used for providing voltage to the filament. It is controlled and monitored through digital and analog input/outputs.

Pico ammeter
Keithley Pico ammeter is used to measure beam current. It contains serial interface (RS-485) for remote monitoring and control. RS-485 communication module is used to interface ammeter with PLC CPU.

High Voltage Power Supply
High Voltage is provided from Glassman High Voltage Power Supply. It is controlled and monitored through digital and analog inputs/outputs.

Solenoid Power Supply
Delta Electronika Power Supply is the solenoid power supply for the electron gun experimental setup. It is controlled from PLC via RS-232 interface.

Faraday Cup Motor
Faraday cup is moved back and forth with the help of stepper motor. Stepper motor driver receives pulse train, enable and director commands from PLC.

Interlocks
Several interlocks are incorporated for machine and personnel safety and protection with the help of PLC.

Human Machine Interface (HMI)

Two HMI stations are deployed in the test facility to remotely monitor and control the system. Both of these stations contain same HMI screens.

- PC based Human Machine Interface
- SIEMENS IPC477D Touch Panel based Human Machine Interface

Figure 4 shows layout diagram of the present deployed control system.

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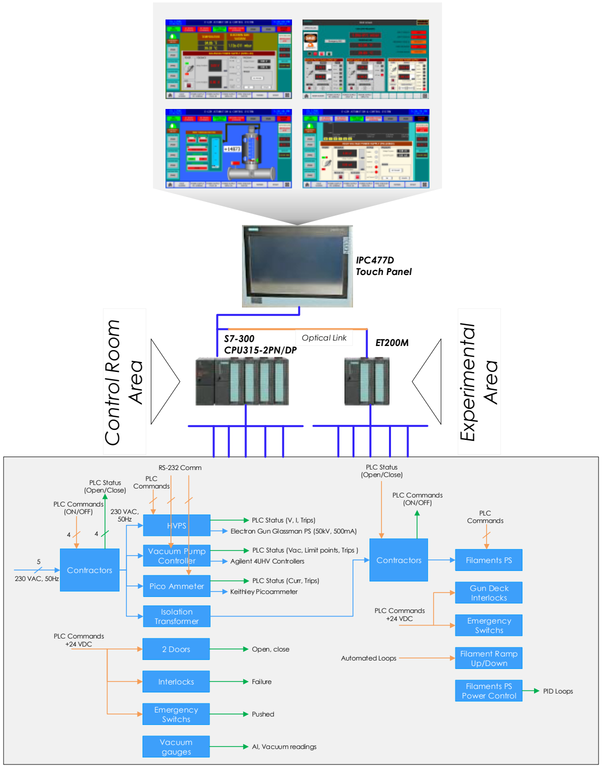

Figure 4: Control System Layout.

PLANNED UPGRADE

The existent PLC based control system is under process of upgradation to EPICS based control system. Operator interfaces currently developed in Siemens WinCC Advanced would be shifted to Phoebus Control System Studio and the existing Siemens PLCs will be interfaced with EPICS using s7nodave support module. Figure 5 shows layout of control system upgrade that will contain following additional hardware and software components:

High Voltage Pulse Modulator

Currently, Glassman high voltage DC power supply is used for extraction of electrons from the electron gun. This is a continuous DC mode power supply whereas the electron gun in RF linear accelerator is operated in pulsed mode. An indigenously developed 48 kV/110 A high voltage pulse modulator is developed for the facility. Control system for the modulator is already developed using S7-1200 PLC. It would be included in the system upgrade after interfacing with EPICS.

Magnet Power Supplies

Magnets are installed along the beamline for beam steering and focusing. Delta Electronika power supplies are installed for these magnets. The power supplies contain serial interfaces (RS-232/422/485) for remote interfacing. EPICS Asyn and Stream Device modules would be used to remotely monitor and control these power supplies via EPICS IOC.

Automated Software Loops

During system startup/shutdown, electron gun filament voltage is increased/decreased in steps to avoid filament damage. It is such a process which can be automated as it is based on a repetitive logic. We would automate this ramp up/down process of the electron gun filament using EPICS sequencer module. Sequencer implements finite state-machine using SNL (State Notation Language) which is a C-type language.

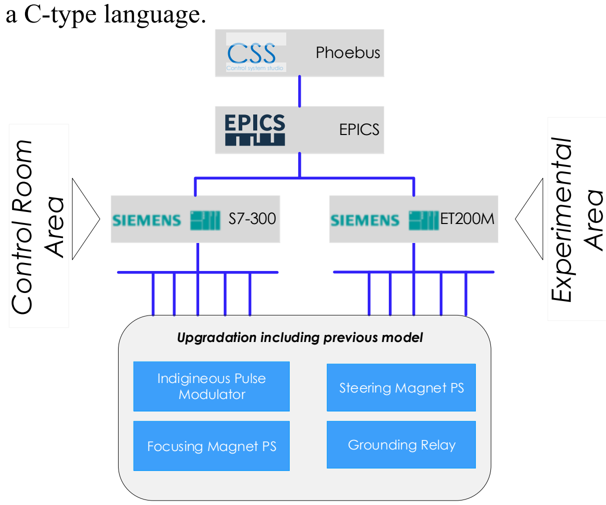

Figure 5: Control System Upgrade Layout.

EXPERIMENTAL SETUP

Experimental setup consists of Experimental Area and Control Room Area. Experimental Area is surrounded by Faraday cage which is grounded to eliminate EMI and provide protection from high voltages. Figure 6 shows the experimental area, Figure 7 shows the Faraday cage and Figure 8 shows the Control Room Area.

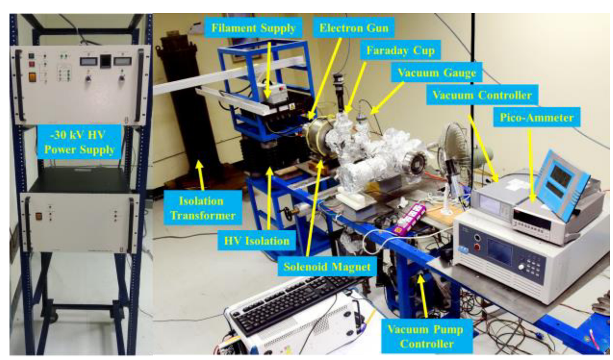

Figure 6: Experimental Area.

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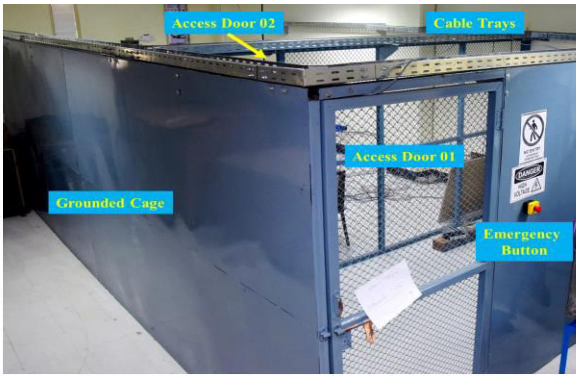

Figure 7: Faraday Cage.

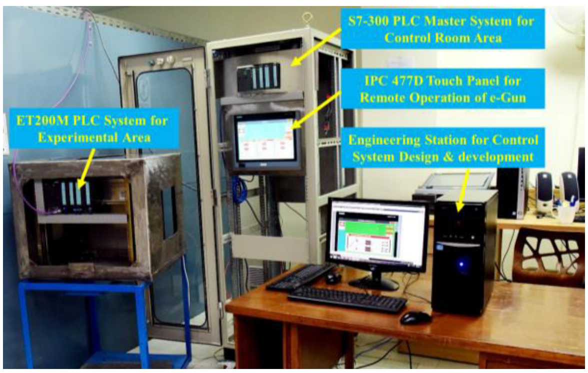

Figure 8: Control Room Area.

CONCLUSION

The automated electron gun test facility is efficiently providing infrastructure to test and characterize indigenously developed electron guns for integration into the RF linear accelerators. The planned upgrade of control system will further enhance the capabilities of the test stand for pulsed beam diagnostics and analysis.

ACKNOWLEDGEMENTS

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