PLC-BASED CONTROL SYSTEM FOR LINEAR ACCELERATOR (LCS) AT EBC KHARGHAR, BARC

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Abstract

Currently the 10MeV Linac is being used for different research and industrial applications. The control system in operation was developed using CAMAC based Data Acquisition System (DAS) and Hard-wired Interlock System. It is proposed to replace the CAMAC system with a state-of-the-art indigenously developed Programmable Logic Controller (PLC) that is verified to the level of a Class IB computer-based system used in nuclear power plants. A PLC node comprises of two VME bus based CPU boards (PowerPC MPC7447, 600MHz) working in redundant mode. The inputs and outputs are common to both CPUs. The I/O boards are hot swappable and intelligent. An intelligent Ethernet board is used for communication with a PC running the SCADA software and industry standard communication protocols drivers. The PLC hardware and software has undergone rigorous verification and validation. A user-friendly 'Application Development Environment' is provided to the process engineer for building the application using pre-defined function blocks. The LCS developed using PLC is to be used for operating the Linac irradiation facility, remotely as well as locally in a fail-safe mode, with sequential start-up and sequential shut-down. Apart from system status monitoring, data archiving, alarm generation and setpoint adjustments, it monitors the important parameters and trips the Gun Modulator High Voltage (GM HV), the Klystron Modulator High Voltage (KM HV) and the Electron Gun Power Supply (EG PS) on fault conditions.

INTRODUCTION TO LINAC [1]

The 10 MeV Linac Irradiation Facility consists of the RF Linac and conveyor system. It is housed in a two-storied building with 2.6 meters thick concrete shielding walls. The Linac structure with electron gun, RF cavity, gate valves, Sputter Ion Pumps (SIP), and beam transport line is at the first floor as shown in figure 1, whereas scan magnet, scan horn, titanium foil, SIP for scan horn and conveyor system for material handling is at ground floor. The Electron beam at 50 KeV is generated in electron gun

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*retired

with LaB_6 cathode and injected into the on-axis coupled cavity Linac which accelerates the electrons to 10 MeV. A 2856 MHz, 6MW Klystron based RF Power source is used to establish the required electric field of 18 MV/m inside the Linac. After acceleration, the magnetic sweep scanner deflects the beam in the scan horn and is taken out to the atmosphere through a 100 cm X 7 cm X 50 µm titanium foil exit window for irradiation jobs. The Linac up to titanium foil is maintained at 10^{-7} torr vacuum with the help of rotary-backed turbo molecular pump and sputter-ion pumps.

Linac can be operated in various modes like RF Conditioning Mode, Vacuum System Maintenance Mode, Beam Trial Mode and Job Irradiation Mode using the LCS.

Figure 1: 10- MeV LINAC.

SYSTEM REQUIREMENTS

The main function of the system is to trip the GM HV, the KM HV and the EG PS against unhealthy conditions of various digital and analog inputs. The system is also used by the operator for operating the subsystems of Linac during various modes of operation. Fail-safe operation, with sequential start-up, sequential shut-down and tripping of

Linac is the main requirement of LCS in all modes of operation.The system checks a programmed (but modifiable) set of interlocks at every stage of the startup and shutdown sequence.

LCS is capable of processing approximately 150 analog inputs, 200 digital inputs and generating 108 digital outputs. LCS also receives commands from operator to operate the pumps, cooling compressors, cooling fans, power supplies etc and generates a 200 msec pulse output signal to operate the equipment. Whenever any command is received from the operator, the LCS operates the corresponding sub-system and subsequently checks the status by scanning the corresponding digital input signal and communicates the status back to the operator. Whenever a command to operate the equipment is unsuccessful, an error message is generated and sent to the operator.

SYSTEM DESCRIPTION
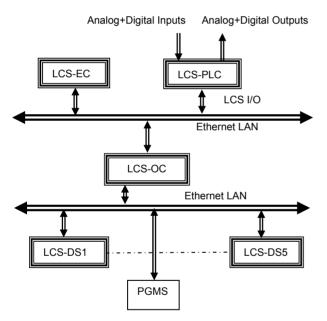
The configuration of the system is given below:

Figure 2: System Configuration.

The LCS is being developed using PLC as DAS and COTS SCADA package for data storage and data display in different formats. The in-house developed PLC has PowerPC based CPU cards and real- time operating system (RTOS) for managing the CPU resources.

Personal Computers are used for Operator Interface. The system has one Operator Console named as "LCS – OC" at the control room G-14A at ground floor. From this OC the Linac operations are controlled. To view the Linac sub-system data, additional Display Stations (DS) are

provided at 122A Power supply room, Scan Horn area, Linac shell area, and Project Manager Room. No control operations are possible from these additional Display Stations.

The embedded software running on PLC samples all the digital and analog signals every 100 ms and communicates with SCADA software running on OC and DSs on a 100Mbps LAN. PLC sends the current values of all signals to the OC on the Ethernet link periodically. PLC also sends the alarms and trips generated along with time stamp to the OC as and when they are detected. The OC saves the important signals at regular configurable intervals and sends the user commands to PLC.

The LCS works as a stand-alone system. The safety interlocks are built at the software level and backed by an independent stand-alone hard-wired interlock system.

The LCS-OC communicates with Pulse Generation and Measurement System (PGMS) comprising of oscilloscope, function generator, RF driver. Pulse signals of 10 µs pulse width like klystron current, reflected RF power, forward RF power, Beam Energy, Beam Current etc. are monitored using an oscilloscope and sent to OC for storage and display.

The PLC is programmed using the Engineering console (EC). Both system configuration and application configuration need to be carried out before the PLC can be deployed as a DAS. System configuration along with application configuration are compiled together and downloaded to the PLC. Changes to the configuration can be made by authorized personnel.

On every start up, the system carries out self-diagnostics immediately before it starts scanning the inputs. Further diagnostics is carried out periodically at user-defined interval. If any of the cards of the system is detected faulty, the self-diagnostics is repeated and only on confirmation of the fault, it is annunciated. The system also checks for the Real Time Clock (RTC) on the CPU boards on start up.

The PLC software executes on the node configuration data. During initialization, PLC software reads system configuration data and configures itself. It reads application configuration data and interprets it for cyclic execution of the configured application.

MODES OF OPERATION

LCS is used in all the modes of Linac operations to check and ensure sequential safety interlocks at start-up, trip interlocks while in operation and sequential shut-down interlocks at the time of shutting down. LCS trips the Linac in case any trip related parameter crosses its limit. The various Linac modes of operation and the role played by LCS are described below briefly.

RF Conditioning Mode

In this mode Beam is not energized (GM and EG PS is not energized). RF Power is fed to cavity by energizing the Klystron and Klystron Modulator. Conveyor system, Ozone

Removal System, and Foil Blower Cooling System are not energized. LCS checks the vacuum level, water flow, human safety interlock before feeding the RF power to the cavity. LCS does not allow operating other sub-systems in this mode.

Vacuum System Maintenance Mode

Linac has to operate in this mode when the vacuum of the order of 10^{-7} torr has to be generated from atmospheric pressure. In this mode LCS ensures that only vacuum related systems can be turned ON. It ensures that SIPs can not be turned ON till rotary backed Turbo Molecular Pump (TMP) is operated to achieve the vacuum of the order of 10^{-5} torr in Linac. After achieving vacuum of 10^{-5} torr, LCS allows operator to turn on SIPs to achieve and sustain the vacuum of the order of 10^{-7} torr for beam generation and operation.

Beam Trial Mode

Linac has to operate in this mode before declaring the facility ready for the user's application. In this mode, Linac is energized for normal beam operation. LCS carries out start-up and shutdown as per the accepted sequence. Parameters like Beam Energy, Beam Current, Beam Power, conveyor speed and radiation dose for the irradiation job are validated using LCS.

Job Irradiation Mode

Linac enters into this mode of operation after successfully completing the start-up interlocks. In this mode of operation Linac is energized as per the job's requirement. After successfully completing the irradiation job, LCS checks shutdown interlocks for smooth shutdown of Linac. For ex. LCS ensures that Mobile Shield door and Room 121 door remain closed till ozone level falls below 100 ppb.

HARDWARE DETAILS [2]

The PLC hardware is designed around in-house developed modular electronic hardware boards that use proven and widely used components. VME32 (A24, D16) and a proprietary I/O bus are used as the two system buses.

The boards in the system are arranged in two 19" bins (CPU bin and I/O bin). The CPU bin contains two 7-slot VME backplanes. Each VME backplane accommodates one CPU board, one Ethernet board with dual media (ENET-DM) and one Protocol translator board (PTB).

The CPU board is based on PowerPC 7447A microprocessor running at 600 MHz. The PTB provides a bridge between VME bus in the CPU bin and I/O bus in the I/O bin. The ENET-DM board provides 100-Mbps Ethernet connectivity that is used to establish communication interface with OC.

I/O bin accommodates all the required sixteen I/O boards and two IO Bus eXtender (IOX) boards. The I/O boards are accessed by both the CPUs in the CPU bin. The I/O board access is facilitated by PTB and IOX board connection through flat cable.

The LCS uses five Analog Input Output Boards, seven Digital Input Boards and four Digital Output Boards.

OPC SERVER FOR PDCP

For data transfer between the LCS-PLC and LCS-OC, Packed Data Communication Protocol (PDCP) is used at the application layer. TCP/IP is the base protocol. An OLE for Process Control (OPC) Server for PDCP is used for data communication. PDCP is a rugged protocol capable of handling data of various sizes like bit, word, float and double. It can also handle alarms, messages and diagnostics data.

GRAPHICAL USER INTERFACE (GUI)

EC provides the GUI required for creating the node configuration. The system configuration details like no of input / outputs, no of cards, type of signals, their names and other details are configured using the 'Application Development Environment' software package on EC. The application is configured using pre-defined function blocks as the building blocks.

The SCADA package on DSs is configured to display the current data and events/alarms in a tabular format. Last event/alarm is added at the bottom of the list. Historical data is also available for viewing. The operator can print selected data and transfer the desired data to CD/DVD on demand.

CONCLUSION

Since the control system is designed using an in-house developed PLC, long term maintenance, support and upgradation will be possible. The control logics of the system are built in the form of function block diagrams and are easily modifiable. The process engineers can carry out changes in the control logics without consulting the PLC developer. State-of-the-art hardware has gone into building the system and so obsolescence of component will set in late in life of the system.

REFERENCES

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