INTEGRATED CONTROL SYSTEM FOR LEHIPA

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Abstract

The Low Energy High Intensity Proton Accelerator (LEHIPA) is a 20 MeV 30 mA proton accelerator which will be achieved in multiple stages [1]. LEHIPA consists of several sub systems/devices located at different positions of the beam path which includes ION source, RF Power, RF Protection Interlock System, Low Conductivity Water plant, Low Level RF control Systems, Vacuum System, Beam Diagnostics & Beam Line Devices. All these subsystems have their own local control systems (LCS) which will coordinate the operation of the corresponding subsystem. The control system for LEHIPA is thus being designed as a Distributed Control System with different teams developing each LCS. The control system will assist the operator to achieve a beam of desired characteristics by interacting with various sub systems of the accelerator in a seamless manner, protect the various parts of machine by generating the necessary interlocks, keep track of various parameters monitored periodically by suitably archiving them, alarms annunciation and trouble shoot from the control room. This paper describes approach to system design of ICS.

SYSTEM DESCRIPTION

The Low Energy High Intensity Proton Accelerator (LEHIPA) is a 20 MeV 30 mA proton accelerator. An overall design of the LEHIPA is given in Fig. 1. Electron Cyclotron Resonance (ECR) ion source gives DC proton beam of energy 50 keV and current of 30 mA. The low-energy beam transport (LEBT) system will consist of a magnetic system comprising of two solenoids that will transport the beam from the ion source, and match the beam into the acceptance of the RFQ. It will also have various beam diagnostic systems. For the acceleration of the proton beam at low energy, a four-vane RFQ (3 MeV, 30 mA, 350 MHz) is used. A Drift-Tube Linac (DTL) structure will accelerate the beam up to 20 MeV. The DTL is preceded by medium-energy beam transport (MEBT) section. The MEBT section will consist of four magnetic quadrupoles and a rebuncher cavity that will transport the beam from the RFQ to the DTL structures that follow, and match the beam into the acceptance of the DTL. For both the RFQ and the DTL high-power CW klystrons are used to generate the CW power of around 2 MW CW, at 350 MHz, along with high-power microwave lines to transport the RF to the accelerating structures.

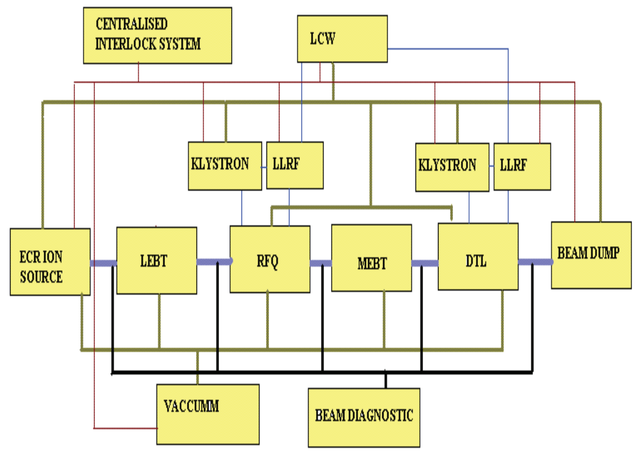

Figure 1: LEHIPA subsystems.

INTEGRATED CONTROL SYSTEM (ICS)

The integrated control system is designed as a 3 tier architecture depicted in Fig 2. The OWS layer hosts the presentation applications and run manager which is used by operators for machine run. The middle layer is the server layer where command control, parameter and configuration servers are hosted. The command control server is responsible for permitting commands to the equipment server depending upon macro level machine state logic. Parameter server is a data concentrator which collects data from different equipment servers, arrange data as per properties and present it to OWS layer. The equipment layer is the lowest layer. It is presented to the server and OWS layer through standard interface, it receives commands from higher layers and multicast its parameters to OWS layer. It hosts the access to the hardware. At the equipment level, the various actuators, sensors and measurement devices are interfaced to the control system through three different types of front-end computers.

CPCI computers dealing with high performance acquisitions and real-time processing; these employ a large variety of I/O modules. Typically, the LEHIPA beam instrumentation, RF Electronics System and the LEHIPA beam interlock systems use CPCI front-ends.

Systems like LCW System, ECR Injector uses PC based gateways interfacing systems as a large quantity of identical equipment is controlled through field buses.

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Programmable Logic Controllers (PLCs) are used to drive various sorts of industrial actuators and sensors for systems such as the Klystron System or the Vacuum system.

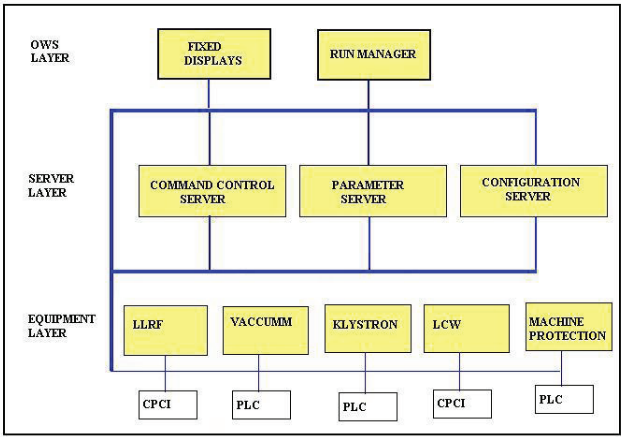

Figure 2: ICS Architecture.

INTERLOCK FOR ICS

Interlocks are needed for the protection of the machine and personnel where, during an unexpected event a safety action has to be implemented. The action taken will depend on the subsystem. The worst case scenario will include shutting of the beam and all the relevant power supplies. The interlocks will be of two types for each subsystem: an interlock generated by the subsystem and an interlock which is supplied to the subsystem. Each system will define the significance of the interlock generated by that system. These interlocks are made available to other subsystems through the ICS, which will monitor and process the interlocks and activate the various interlocks which are connected to individual subsystems, as required. The processed interlocks are then distributed to each sub systems. Subsystems will decide what action has to be taken on the activation of interlock provided to it from the ICS.

A search and secure operation philosophy will also be provided for personal safety and the status of search and secure system will be given to ICS. Depending upon various searches and secure status appropriate operation permission will be decided by ICS. The interlock operation will depend upon mode of the accelerator viz with beam, without beam. Also interlock system has to be programmable as during commissioning stages a reduced set of interlock operations will be required.

An emergency shutdown command generated from emergency console, in absence of loss of connectivity with the OWS, will be part of the global interlock in which case all the systems are expected to shutdown as an emergency shutdown. The 'beam hall open' condition will provide input to the ICS as well as a hardwired interlock directly to the Ion Source Subsystem for shutting down the beam.

TIMING AND PULSING FOR ICS

One of the major requirements for the Accelerator operation is the pulsed beam operation. LEHIPA, being a high current accelerator, will not be operated in Continuous Working (CW) mode in the initial stages of operation and also during start-up of the accelerator. For this purpose, beam will be operated in pulsed mode whenever required with facility to switch over from one mode to another mode which can be set from the OWS. In the initial phase of commissioning and also during each start-up after a shut-down, LEHIPA will work in a pulsed mode. During the pulsed mode a sequence of actions takes place. During the initial phase of the 'on' period, RF is set-up and stabilized in different resonators of the linac. A timing signal is provided to the LLRF and high power RF system, which perform the action of setting-up and stabilizing of the RF field in different resonators. After stabilizing the fields, the beam is injected into the resonators. After a predetermined time, signalled by a trigger, the beam is removed and after this RF is removed from the Resonator. The beam diagnostic system also receives suitable timing signals to provide beam parameters during the beam on period. This operation is repeated for each cycle of pulsing. Before going to the continuous mode of operation the average beam current is slowly increased by changing the duty cycle. All this action sequence is managed by a pulsing system which emits timing pulses to different sub-systems (ion-source, LLRF and RF power systems of different resonators and beam diagnostic system) of the linac. This pulsing system is essentially a number of programmable pulse generators, where the parameters of pulse sequences are under operator control.

In addition to the pulsing system a RF master signal is distributed to different subsystems. In order to work as an accelerator, the RF field in different resonators of the LEHIPA has to be phase locked with this RF reference signal. This reference phase line is provided to the LLRF system, which stabilizes the field in the resonators with respect to it. The phase of the beam at any point in the LEHIPA is obtained by comparing the phase of the beam induced RF in the pick-up type of monitors along the LEHIPA, with respect to the RF phase reference. Phase information from two pick-up helps to determine the energy of the beam. In addition to serving the phase reference for the LLRF and beam pick-up devices, this reference phase also constitutes the basic clock from which other clocks for example, for down/up conversion, sampling are derived. The ICS will provide this RF reference phase signal for the LEHIPA.

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ALARMS ANNUNCIATION

Each subsystem will be monitoring a large number of parameters, the important parameters and operation condition will be announced as alarms to draw the operator attention. Whenever a parameter which is monitored is not in limits (low, high, very low and very high) then alarm has to be announced by the ICS. All the necessary interlock actions local to the subsystem will be taken care of by the subsystem. Thus all the parameters which are monitored for alarm annunciation should be made available to the ICS. ICS will annunciate the alarm condition generation and removal on dedicated display. Also at a later stage the alarm annunciation process has to provide intelligent conclusions which may lead to revision of the requirements. Also the time sequence of alarm generation/removal has to be archived for future analysis.

DATA ARCHIVING FACILITY

Data servers have to be provided as many of the sub systems will keep their periodically monitored parameters for diagnosis and design improvement purpose in the archives. Also parameters which are used for alarm generation will also be available in the archives. Sequence of alarm generation and removal, diagnostic messages and operator logs will be parts of the archives.

OWS PROTOTYPE

The operator workstation should provide a facility that operator can easily operate the accelerator and focus on important jobs for operation the OWS prototype has been developed. The LEHIPA simulator which displays parameters of accelerator of different subsystem and provides operational parameter change facility has been developed. This simulator along with OWS prototype was tested with Server software which connects to different subsystem and fetches parameters. This prototype has provided as design inputs for software design phase.

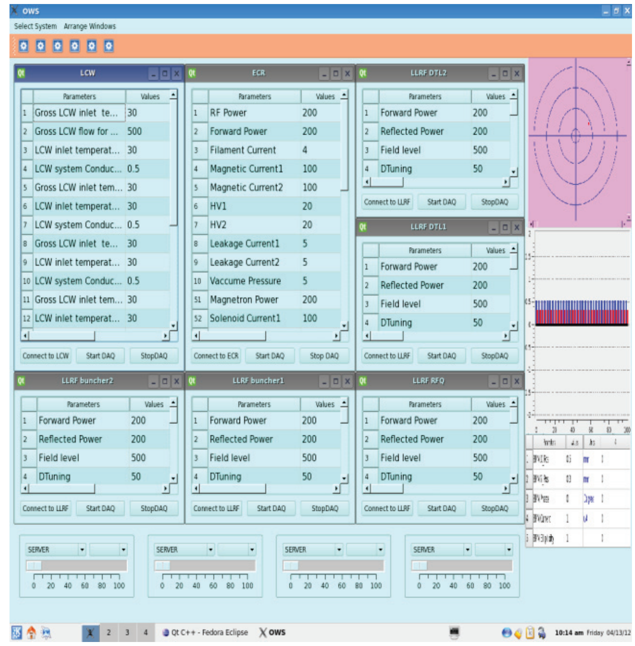

Figure 3: OWS Prototype.

REFERENCES

[1] P. Singh et al, "Accelerator development in India for ADS programme," Indian Academy of Sciences, Vol. 68, No. 2, Journal of Physics. p 331 (2007) ; http://repository.ias.ac.in/15620/1/333.pdf

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