DESIGN CONSIDERATIONS FOR DEVELOPMENT OF DISTRIBUTED DATA ACQUISITION AND CONTROL SYSTEM (DDACS) FOR RADIO-ACTIVE ION BEAM (RIB) FACILITY

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Abstract

The Radioactive Ion Beam (RIB) facility is being constructed by the Department of Atomic Energy (DAE) of India at Variable Energy Cyclotron Centre (VECC), Kolkata. The RIB facility at VECC consists of various subsystems like Electron Cyclotron Resonance Ion Source (ECR-IS), Radio Frequency Quadrupole Linear Accelerator (RFQ LINAC), Rebunchers, Inter-digital H-mode Linear Accelerators (IH LINACs) etc., which are required to produce and accelerate the energetic beam of radioactive ions for different experiments. In technical collaboration with VECC, Kolkata, a unique system called " Distributed Data Acquisition and Control System (D-DACS)" was developed. This paper is indented to bring out the design considerations in developing distributed control systems and qualification requirements with reference to functional, environmental and Electromagnetic Compatibility (EMC) standards.

RIB FACILITY – AN OVERVIEW

The RIB facility (Fig. 1) at VECC is an ISOL type RIB facility. Radioactive isotopes are first produced in a target from nuclear reaction with the primary beam. Radioactive atoms diffusing from the target are ionized initially in an integrated 1^+ ion-source and then in ECR ion-source. After mass separation, the low energy RIB is accelerated from 1.75 KeV/u to about 100 KeV/u in a RFQ LINAC. Three IH LINAC modules raise the energy up to around 415 keV/u. Subsequent LINAC modules are to be used to achieve the final beam energy of 1 to 5 MeV/u [1].

The RIB beam line is equipped with state of the art systems to produce and accelerate Radio-active Ion Beam. The major systems are broadly listed below:

- Linear Accelerators (LINACs)
- RF Quadrupole (RFQ)
- Rebunchers
- Faraday Cup, Vacuum Pump, Gate Valve systems etc., and theses beam line systems are powered with:
- Klystron High Power Amplifier (KHPA)
- High power RF Transmitters
- High voltage sources
- High current power sources

Majority of the systems used in the RIB are potential sources of Electromagnetic Interference (EMI). to meet the functional, environmental and Electromagnetic Compatibility (EMC) standards in development of systems for RIB facility need expertise on multiple domains, covering data acquisition, instrumentation and control system.

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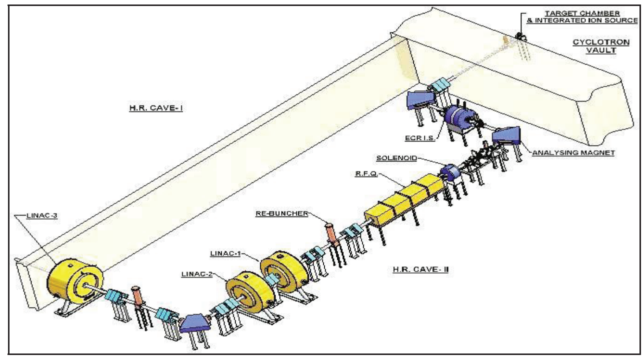

Figure 1: Layout of RIB facility with subsystems.

NEED FOR DDACS SYSTEM

The RIB facility integrates many Electronics Sub-systems procured from different international sources. Each system has its own interface for remote controlling the system parameters. Some of the systems like RF Transmitters do not have provision for remote control. Hence, the DDACS system is aimed to develop all necessary systems, sub-systems and interface circuits to monitor and control the RIB systems. The software developed for DDACS system helps an easy way of controlling the parameters at sub-system level and system level with necessary Graphical User Interface (GUI). An Embedded Controller planned at the Control Room (CR) shall control all the RIB systems and associated equipments [2].

DDACS SYSTEM DESIGN APPROCH

The RIB beam line systems and associated control parameters are shown in Fig.2. The design approaches followed are detailed below.

- The DDACS System is required to control all the equipments of RIB beam line systems and also to monitor the status of the systems continuously.
- The design is planned to support Distributed Data Acquisition considering the physical locations and number of associated RIB systems
- Entire RIB beam line systems are divided in to eight sections depending on the process flow and the equipments connected to it.
- Each section will have one Data Acquisition Front end module with all necessary interface circuits to

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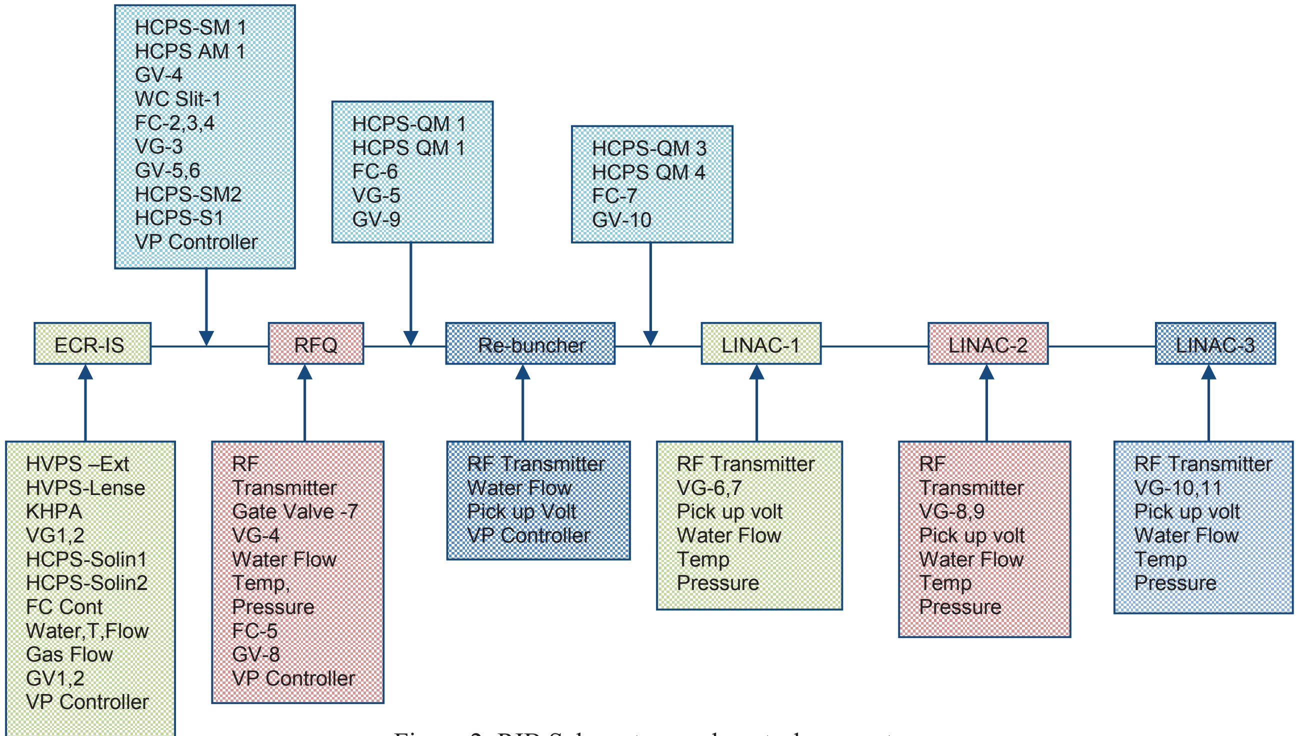

Figure 2: RIB Sub-system and control parameters.

control and monitor the RIB-Sub-system in standalone mode.

- There are eight such Data Acquisition and Interface modules called "Equipment Interface Module (EIM)" which covers all the RIB Systems
- Each EIM modules independently collects the data, monitors and control their respective RIB systems
- There are two RIB Controllers, one positioned near RIB beam line and other in the Control Room. Control and monitoring the status of the RIB systems are possible from both the RIB Controllers depending on the operational requirements.
- The EIM modules and the RIB Controllers are connected through Fibre Optic Interfaces for EMI free operation
- The DDACS system is planned with three layer architecture, i) Equipment Interface Layer ii) Supervisory Control Layer iii) Operator Interface layer [3].

DEVELOPMENT OF DDACS SYSTEM

RIB beam line systems are broadly divided and classified in to eight sectors covering the following sub-systems.

a) Electron Cyclotron Resonance Ion source (ECRIS)
b) ECRIS -to- RFQ Beam Line
c) Radio Frequency Quadrupole (RFQ)
d) RFQ-to-Rebuncher Beam Line
e) Rebuncher
f) Rebuncher-to-LINAC-1 Beam Line
g) LINAC-1, LINAC-2 and LINAC-3

Each section covers group of sub-systems of RIB beam line systems and equipments connected to it. A dedicated Data Acquisition module, the "EIM module" is connected with necessary hardware interface.

Equipment Interface Module (EIM)

The EIM module commands and collects data from each RIB sub-system. There are eight EIM modules connected in a distributed manner to acquire data from all the RIB systems. The data collected from each EIM module are transferred to the RIB controller through the Fiber optic interface. The EIM Modules with an integrated graphical touch screen display are shown in Fig 3. A sample view of the GUI developed for EIM module is shown in Fig 4.

Figure 3: EIM modules.

RIB Controller

The RIB controller is a rugged Control Console aimed to collect the data from all the EIM modules. The

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application software is developed with GUI for easy monitoring and control of selected parameters or sub-systems. The RIB Controller is shown in Fig. 5 and the sample of GUI panel is shown in Fig. 6.

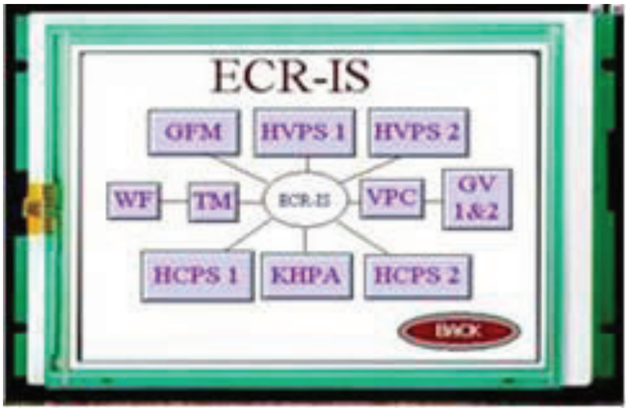

Figure 4: Graphical User Interface in EIM Display.

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Figure 5: RIB Controllers.

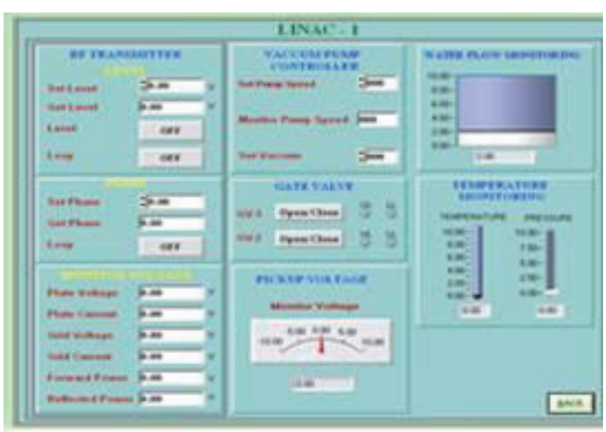

Figure 6: Sample GUI panel display.

Other DDACS Controllers

The Faraday Cup (FC) Controller, which switches and measures the current through the Faraday Cup, is shown in Fig.7. The Slit Controller which controls the slit position in the RIB chain is shown in Fig. 8. The RF Transmitter Remote Interface Module (RIM) and Gate Valve (GV) Controller are shown in Fig. 9 and Fig. 10.

Figure 7: FC Controller.

Figure 8: Slit controller.

Figure 9: RF Tx- RIM.

Figure 10: GV Controller.

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RIB System Simulator

The RIB System simulator is developed as a Test Jig, which can provide test data in the prescribed format for evaluation of the D-DACS System. The RIB Simulator is shown in Fig. 11

Figure 11: RIB System Simulator.

SYSTEM QUALIFICATION ASPECTS

The DDACS system is designed and developed considering the end application and operating environment. The following three aspects were addressed during the system design and implementation phase.

a. Functional specifications and operational requirements
b. Environmental specifications
c. Electromagnetic Compatibility(EMC) requirements

Functional Specifications

The Functional and operational requirements are based on the system specifications provided by the end user. The DDACS system design is based on the parameters to be controlled and monitored in each RIB sub-systems. A Critical Design Report (CDR) was prepared with the details of System Specifications, Configuration, Data Communication Protocols and Software development plan. An Acceptance Test Procedure (ATP) document was submitted with the details of functional tests.

Environmental Specifications

The DDACS system is meant for operation in the RIB facility and hence the system should be qualified for operation at elevated temperature. Hence, the system was designed and tested for limited environmental specifications, like continuous operation at high temperature at 60 deg C, low temperature at 0 deg C, Dry heat test at 45 deg C, 90% Relative Humidity (RH).

EMC Specifications

As the System should operate in the Interference prone environment due to simultaneous operation of high voltage/high current sources, magnetic sources, high power RF Transmitters, it is mandatory that the DDACS system shall be qualified for EMC standards.

As the DDACS System can be a potential victim of Electromagnetic Interference generated from the RIB systems, the following EMC tests were carried out as per IEC Standards and the system was qualified.

i. Radiated Susceptibility (RS) test – IEC 61000-4-3
ii. Power Frequency Magnetic Field test IEC 61000-4-8
iii. Conducted RF Immunity test –IEC 61000-4-6

SYSTEM EVALUATION AND INTEGRATED TESTING

The DDACS system was qualified for functional specifications, environmental specifications and EMC standards before installation of the system in the RIB facility. Next, the system was installed and interfaced to all the RIB Systems as shown in Fig.12. The integrated testing was carried out as detailed below:

a. System control operation from EIM modules
b. System control from the RIB Controller positioned in RIB Room
c. System control from the RIB Controller positioned in the Control Room.

CONCLUSION

The DDACS is an indigenous system developed by Society for Applied Microwave Electronics Engineering & Research (SAMEER), Centre for Electromagnetics, Chennai in technical collaboration with the VECC, Kolkata. The system was developed, qualified for functional, environmental and EMC specifications. The system was installed and interfaced to the RIB systems and integrated tests were carried out. The system is being used in the RIB facility at VECC, Kolkata.

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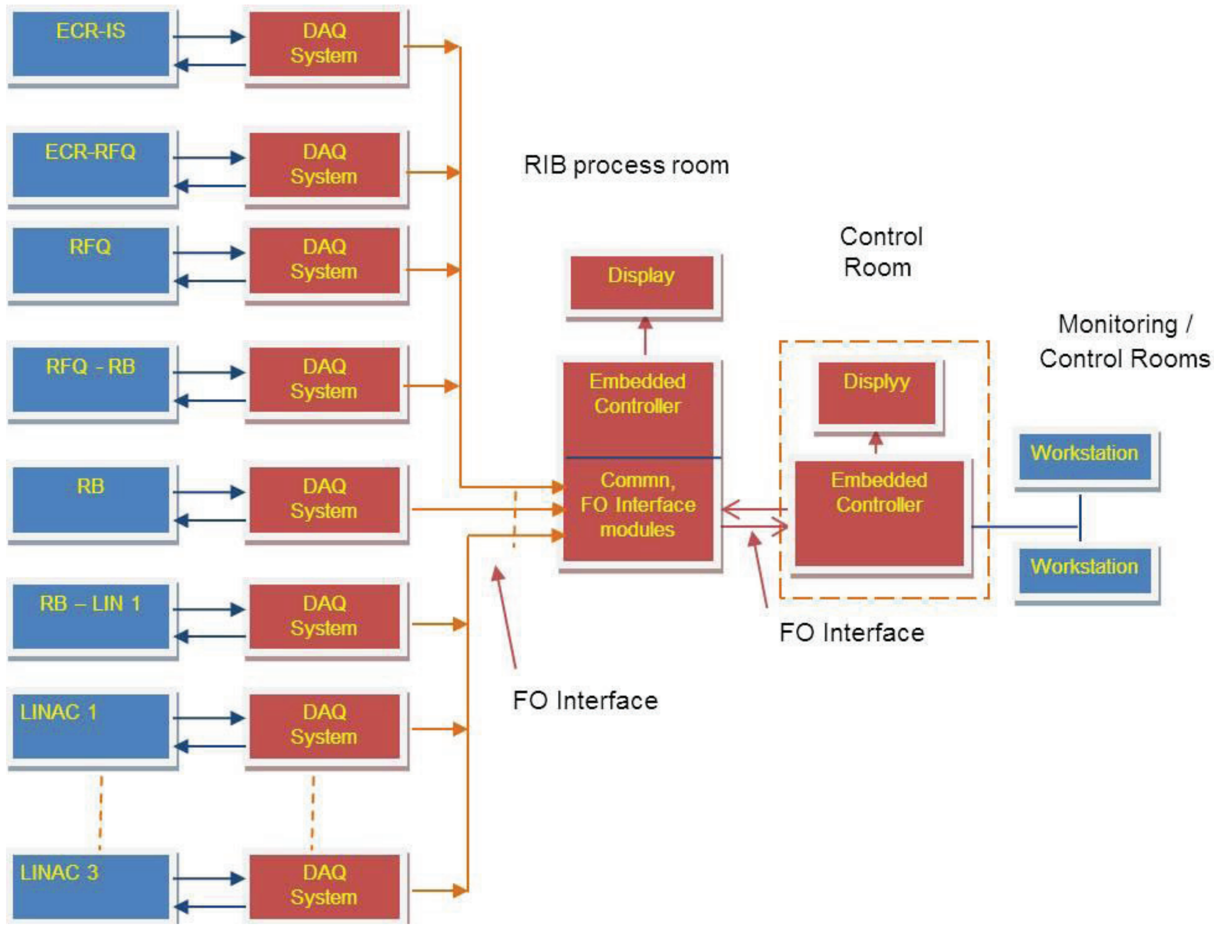

Figure 12: D-DACS system Integration.

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