

RF DISTRIBUTION AND CONTROL SYSTEM FOR ACCELERATORS OF THE VEC-RIB FACILITY

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Abstract

RIB facility at VECC has several heavy ion linear accelerators like RFQ, two IH-LINACs and one buncher cavity operating at 37.8 MHz and two IH-LINACs with one buncher cavity at 75.6 MHz. Some more RF cavities are being designed at the third harmonic of 37.8 MHz and will be added in the RIB beam line [1]. All the cavities have separate RF power amplifiers with proper amplitude, phase and resonance frequency tuning and control system for efficient and stable operation. The Low Level RF control system has been operational for the power amplifiers of the existing RF cavities and improved design and development is carried out. An embedded controller based data acquisition and processing system is being used for control and local/remote operation. The RF distribution system as well as the design details of RF control system and remote control system will be presented in this paper.

RF DISTRIBUTION SYSTEM

The RF sources for the RIB accelerators consist of three 30 kW RF transmitters operating at 37.8 MHz, one 2 kW RF transmitter operating at 37.8 MHz and a 5 kW RF transmitter operating at 75.6 MHz [2]. A single oscillator at 37.8 MHz drives all the RF power amplifiers of the RIB facility. This is done using a 6-way power splitter

which divides the RF signal to the respective power amplifiers. For LINAC 3, which operates at 75.6 MHz, a frequency doubler is used to convert the 37.8 MHz signal to 75.6 MHz [3]. The forward and reflected power samples and pick-up signal from each of the RF accelerator cavities are fed to the low level RF control modules of the RF amplifiers. The schematic diagram for RF distribution is shown in Figure 1.

LOW LEVEL RF CONTROL

The Low Level RF (LLRF) control system regulates the amplitude and phase of the RF cavity voltage through fast electronic feedback mechanism. The frequency of the cavity is regulated through mechanical movement of a tuner loop in appropriate direction by sensing the frequency deviation. At present the control is based on the conventional amplitude and phase loop method. The scheme of the LLRF control is shown in Figure 2.

Amplitude Control

The important components in amplitude control comprises of the amplitude detector (realized with Schottky diodes HP5082-2835), PI controller and voltage controlled attenuators (realized with pin diodes based π configuration circuitry).

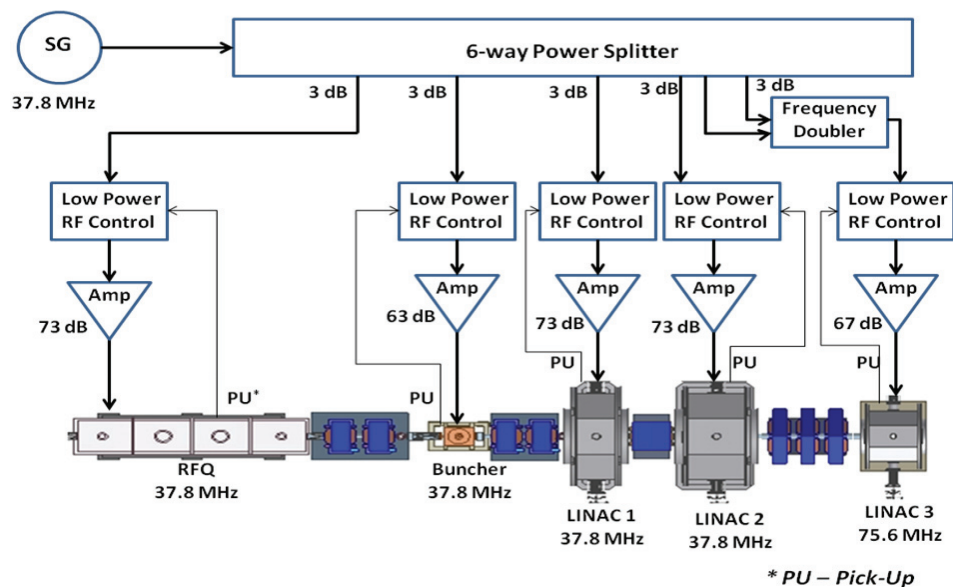


Figure 1: RF Distribution scheme for VEC-RIB accelerators.

The amplitude detector senses the level of the feedback signal (the power sample obtained from pickup port of cavities) and then it is compared with the reference level signal to produce the error signal which is fed to a PI controller. This low-cost ultra stable amplitude control circuit for each RF transmitter has been designed and tested. The measured performance of amplitude stability of the control circuit is $\pm 0.5\%$.

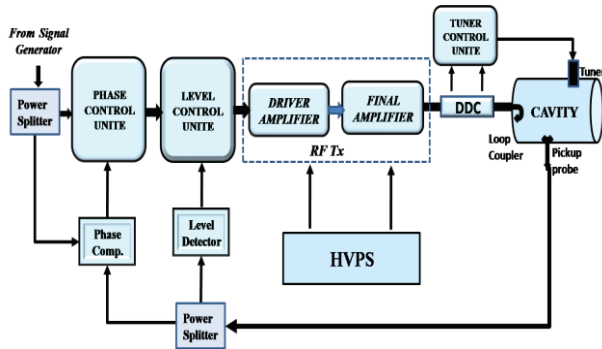


Figure 2: Block diagram of RF feedback control unit.

Phase Control

The important components in phase control comprises of the phase comparator (realized with double balanced mixer configured in phase comparator mode), PI controller and voltage controlled phase shifter (realized with two 0-180° varactor diode based phase shifters in cascade). The phase detector senses the phase difference between the RF input signal and the feedback signal (the power sample obtained from pickup port of cavities) to produce an error signal which is fed to a PI controller which provides an appropriate control voltage. The control voltage is input to a phase shifter which brings the phase of the RF signal to the desired value. For accurate measurement of phase difference, the high frequency RF and feedback signals are mixed with a LO signal to produce an IF signal at 455 KHz. This IF signal is converted to TTL signal and the phase difference is detected using a flip flop based digital phase detector. This stable phase control circuit for each RF transmitter has been designed and tested. The measured performance of the phase satiability is $\pm 0.5^\circ$ and phase control range is 360°.

Resonance Frequency Control

In the resonance frequency control, the frequency deviation of the RF cavity is sensed by measuring the phase difference between the forward power sample obtained from a dual directional coupler and the pick-up signal from RF cavity. The phase difference is converted to proportional output voltage using a phase detector (AD8302). The output of the phase detector is fed to a microcontroller (ADuC841) wherein a control logic program generates corrective output signals (direction and/or stepping sequence) which drive a stepper motor

holding the tuner loop. The motor rotates the tuner in an appropriate direction until the RF cavity is brought back to resonance. The resonance frequency controller operates only when the VSWR in the input transmission line exceeds a particular value, during which, it switches the level controller to open loop state to prevent two loops from operating at the same time.

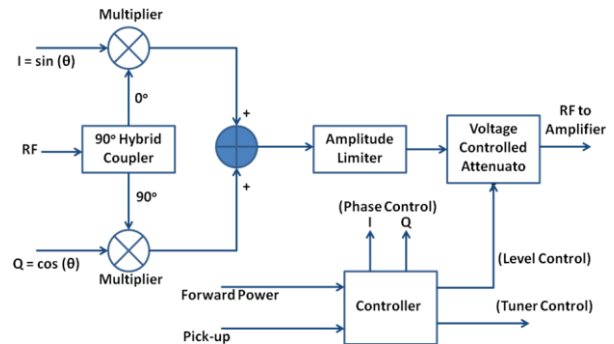


Figure 3: Schematic of the planned LLRF control.

It is planned to upgrade the present control system to analog/digital IQ based LLRF control system. A schematic diagram of the low level control unit is shown in Figure 3. To this end, the simulation studies of the analog IQ based LLRF control has been carried out, the details of which are presented in another paper in this conference.

REMOTE CONTROL FOR RF SYSTEM

The remote control system is designed to control and monitor all parameters for the RIB beam line components including the RF transmitters at RIB Facility. This unique system “Distributed Data Acquisition and Control System (DDACS)” has been developed and installed at VECC. The details of DDACS are presented in another paper in this conference. For reliable and fast RF operation, the data acquisition and control system has a 3 layered design as shown in Figure 4, namely: a) Equipment Interface Layer b) Supervisory Layer and c) Operator Interface Layer [4-6].

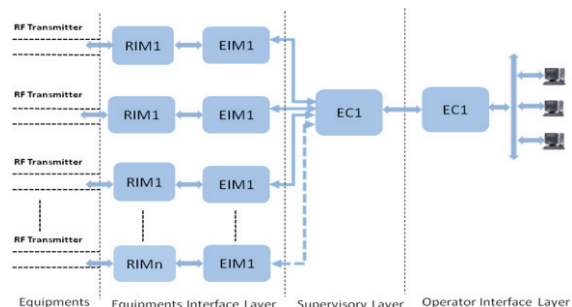


Figure 4: Schematic diagram of control system.

Equipment Interface Layer

The Equipment Interface Layer consists of Remote Interface Modules (RIM) and Equipment Interface Modules (EIM). The main controller used in RIM is 32-bit LPC 2478 ARM7TDMI with analog/digital front-end

electronics (ADCs, DACs, Optoisolators, Multiplexers etc.) and RS232 line driver. It also consists of a touch-screen display from which equipments, connected to it, can be locally controlled and monitored. RIM is directly connected to the different analog and digital input/output signals and the local controller for the RF transmitters. The local controller of the RF transmitter is equipped with 8 bit microcontroller, relays, buffers etc. All interlock systems are checked by the local controller. It takes the necessary actions and sends the status of the interlocks to the RIM for display as well as transmission to the Equipment Interface Module (EIM). Some screenshots of the RIM display is shown in Figure 5.

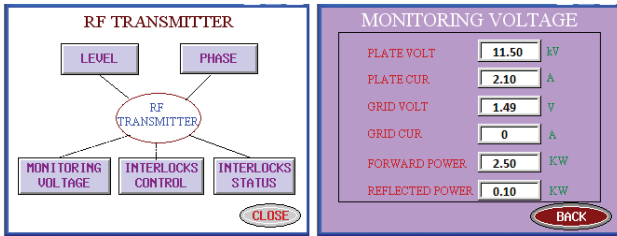


Figure 5: Snapshots from the RIM.

The RIM is interfaced to the EIM through RS232. Each EIM controls a specific RIM along with a specific section of beam line support subsystems. EIM also supports multiple analog/digital input/output channels and RS232/RS485 ports.

Supervisory Layer

The Supervisory layer has been realised using Embedded Controllers (EC1) designed around Single Board Computer (SBC) with Embedded XP operating system. This controller, interfaced with EIMs through fiber optic cables, performs supervisory task of continuously sending command and acquiring data from lower level EIMs and reporting to the operator interface layer as and when requested. The EC1 has higher priority as compared to the EIMs.

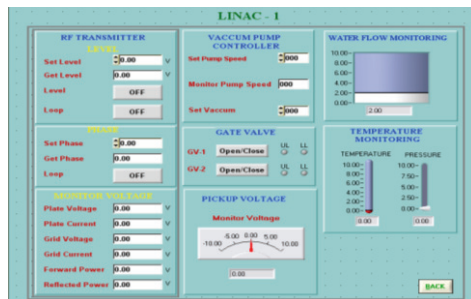


Figure 6: GUI interface at operator console.

Operator Interface Layer

Operator interface layer consists of operator console formed with another embedded controller (EC2) and high performance PCs/Workstations for controlling and monitoring machine parameters. The data acquired and analysed at the supervisory layer can be displayed at the operator console and operators can control the whole

facility from user friendly graphical interfaces shown in Figure 6. EC2 has higher priority as compared to EC1 and EIMs.

Remote Setting of Control Parameters

The important controlling parameters of the RF transmitter are level controller and phase controller. In the level controller the RF switch and voltage variable attenuator are the main controlling parameters which are used to vary the RF power of a transmitter. The phase controller consists of phase shifter and phase comparator module. The digital signals are used to control the level and phase controllers ON/OFF and a 10-bit DAC output is used to set the level and phase of the transmitter. The corresponding output values are read back using 10-bit ADC in the RIM module. The snapshot of the level control and phase control are shown in Figure 7.

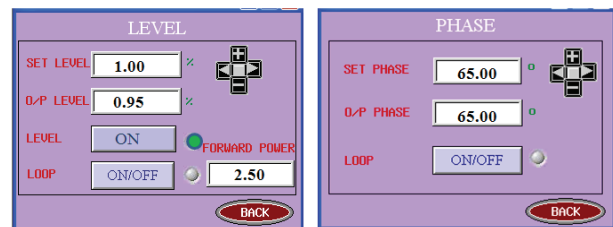


Figure 7: Snapshots of Level/Phase Controllers in RIM.

SUMMARY

The RF distribution scheme and a remote control scheme for RF transmitters have been presented. The remote control system for the RF transmitters has been tested and further tests and refinements are in progress. The present low level RF control system for the RF transmitters are described in this paper. The design of the LLRF system is being improved to IQ based LLRF control.

ACKNOWLEDGMENT

The authors are grateful to Mr K. Mourougayane and his teams from SAMEER, Chennai for their efforts to development of remote control for RF system.

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