SIMULATION ANALYSIS OF ANALOG IQ BASED LLRF CONTROL OF RF CAVITY

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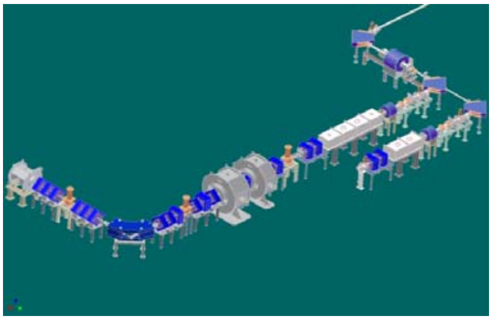
Abstract

This paper presents the simulation work and results in Matlab Simulink for the analog Inphase-Quadrature (IQ) based Low Level Radio Frequency (LLRF) control of RF cavity voltage. The RF cavity chosen here is the Radio Frequency Quadrupole (RFQ) cavity in our RIB project. All the subsystems in the IQ based RF control were modelled using the Simulink blocks/components. The simulation graphs showing the time evolution of the RF cavity voltage with a step changes of the input reference signal is presented. The simulation results showing Nichols plots of the control loop and the gain and phase margin values obtained from them are presented, which are good enough for stability considerations.



Schematic of RIB Facility at VECC

INTRODUCTION : An ISOL type RIB facility is presently being developed at VECC. At present the RIB facility comprises of a RFQ (3.4m), three rebunchers and three Linacs. The RFQ, first rebuncher, and first two Linacs operate at 37.8 MHz, while the third Linac and the other two rebunchers were designed to operate in the second harmonic at 75.8 MHz. For proper beam acceleration it is essential to regulate the RF cavity voltage at proper amplitude and phase. At present the RF cavity voltage are controlled in the conventional amplitude and phase loop control method and it is planned to upgrade the LLRF control to analog / digital IQ method.

SIMULATION OF IQ METHOD OF LLRF CONTROL

RFQ (3.4m) Photograph

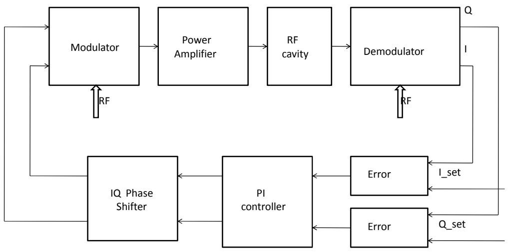
Parameter	Value
Frequency	37.83 MHz
Q_o (measured)	5393
R_{sh} (measured)	42 KΩ
Input energy	1.68 keV/u
Output energy	95.7 keV/u

RFQ (3.4m) Parameters

IQ description of RF Cavity

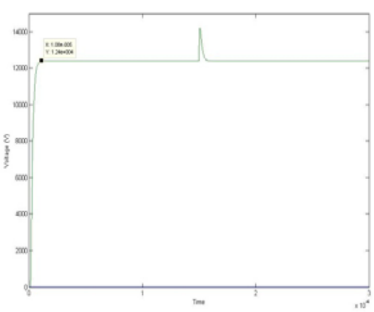
$$\frac{dV_r}{dt} + \omega_{1/2} V_r + \Delta\omega\, V_i = \omega_{1/2} R_L I_r$$

$$\frac{dV_i}{dt} + \omega_{1/2} V_i - \Delta\omega\, V_r = \omega_{1/2} R_L I_i$$

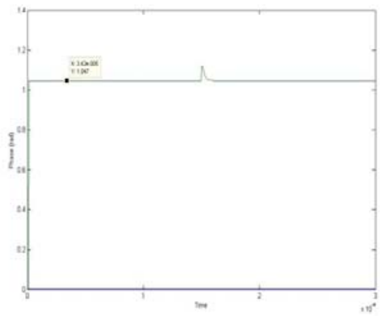


Schematic of analog IQ LLRF control

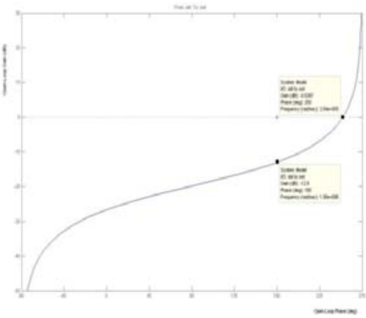
Simulation of RFQ cavity voltage control is presented for a test voltage of 12.4 KV and for RF phase of 60°. The beam loading effects are neglected in the simulation. The cavity is operated at resonance in usual 50 Ω system. The PI controller parameters are adjusted for the getting the desired response. The desired cavity voltage and phase is set by two I and Q parameters namely I_set and Q_set. The graphs showing the time evolution of RF voltage and the suppression of disturbances are presented below. The gain margin and the phase margin are almost 13 dB and 70° respectively.



RF cavity voltage amplitude versus time



RF cavity voltage phase versus time



Nichols plot of the control system