OVERVIEW OF DEVELOPMENT OF HIGH POWER RADIO FREQUENCY (RF) SYSTEMS FOR ION ACCELERATORS IN BARC

Manjiri Pande, N.R. Patel, S.D.Shrotriya, S.V.Sharma, J.K.Mishra, B.V.Rao, Sherry R, Shiju A., K.R.Shinde and V.K.Handu
Technical Physics Division, Bhabha Atomic Research Centre, Mumbai 400085, INDIA

Abstract

Bhabha Atomic Research Centre (BARC) is developing proton, deuterium and heavy ion accelerators for its own scientific program. These accelerators require radio frequency (RF) power for their beam acceleration. So, various RF power systems are being developed for this purpose. For low energy high intensity proton accelerator (LEHIPA) (20 MeV, 30 mA), three klystron based RF systems will be developed and for 400 KeV, deuterium accelerator, a tetrode based rf system has been tested. For heavy ion accelerator, as a first step, a rf amplifier has been tested and will be integrated with it soon. For rf ion source of 14 MeV neutron generator, a solid state rf amplifier has been developed and integrated with it to generate deuterium plasma. As a technology development XI plan program, high power solid state rf amplifier development at 350 MHz has been taken up. A modest beginning up to 700 watt level has been made. This paper gives an overview of details and current status of these different high power rf systems.

INTRODUCTION

For the overall optimised system design of an RF power source (inclusive of its cost factor), the fundamental RF criteria's are; RF power range, wall plug efficiency, reliability and maximum voltage standing wave ratio (VSWR) that it can withstand. Other important criteria's are operating frequency, bias parameters (which consume maximum energy), RF transmission line design and gain of final power stage. RF sources can be designed and classified in terms of their class of operation, configuration of the power source and overall system power gain. The choice of RF power device depends upon a range of parameters like high reliability, size, long life, easy replacibilty, possibility of modulation and proven feasibility. Using such criterias, we have developed RF systems which are described below in detail.

KLYSTRON BASED RF SYSTEM (1 MW AT 352 MHZ) FOR LEHIPA

As a part of accelerator driven sub-critical system (ADS) program [1] LEHIPA is being developed As per the accelerator physics design, its RFQ requires about 530 kW of radio frequency (RF) power, DTL-1 require around 665kW and DTL-2 requires around 677 kW. Each accelerating cavity will be driven by a one- megawatt (CW) klystron based RF system at 352.21 MHz. The RF system [2] has been designed around five cavity klystron tube TH2089F, (Thales make) capable of delivering 1 MW continuous wave power at 352.21 MHz. The RF system comprises of a low power driver (~ 100W), klystron tube, associated HV and LV bias supplies, harmonic filter, directional coupler, Y-junction circulator (AFT make) and WR2300 wave guide based RF transmission line. It includes other subsystems like interlock and protection circuits, dedicated low conductivity water-cooling, pulsing circuitry / mechanisms etc. This proton accelerator will be operated initially in pulsed mode and then will be gradually switched to continuous (CW) mode. The required pulse parameters are, Pulse repetition rate (PRR) (Hz): 1, 10, 100 and Pulse width (PW): 20 microseconds. Hence, the RF system is being designed to operate in above-mentioned mode. The performance and reliability of klystron depends on performance of the power supplies connected to it, specially its DC bias supplies. So the essential features like tight voltage regulation, low ripple voltage, better voltage stability, low stored energy and high efficiency are included in all the bias supplies.

TETRODE BASED RF SYSTEM (35 KW AT 350 MHZ) FOR 400 KEV RFQ

A 400 KeV deuterium RFQ based 14 MeV neutron generator is being developed to study neutronics behaviour before going for ADS. This RFQ requires about 70 kW of RF power.

Figure1: Photograph of 35 kW RF system.

Hence, two 35 kW RF power amplifiers [3] are being developed to feed the RF power to this RFQ at two ports. Each RF system comprises of a high power tetrode TH 571B, its driver amplifier, dual directional coupler, rigid coaxial transmission line (6 1/8", 50 ohm), other bias supplies, air and water cooling set up. All the bias supplies, RF driver and cooling circuits are being switched ON/OFF in a predefined time sequence to prevent damage to the high power RF devices by a suitable interlock and protection circuit. This RF system operating in class A and grounded cathode configuration has been tested up to 14 kW and with 49 % efficiency and 18.5 dB power gain.

PENTODE BASED RF SYSTEM (75 MHZ, 1 KW) FOR HEAVY ION RFQ

This RF system has been developed for testing prototype heavy ion RFQ that is being developed. Because of non availability of circulator at this frequency and power range, a pentode based power stage has been designed and developed. Its solid state driver (200 watt) comprises of pre driver and final stage is based on MRF 141G. The entire RF amplifier has been tested up to 1008 Watt with 51.7 % efficiency and 63dB overall system power gain. One more identical solid state driver has been developed and coupled with prototype RFQ (without vacuum). In the coupled stage, it has achieved 0.4 W of reflected power and 80 W of forward power.

Figure 2: Photograph of 1 kW RF system.

SOLID STATE RF SOURCE (100 MHz, 256 W) FOR NEUTRON GENERATOR

14 MeV neutron generator uses a RF coupled ion source for deuterium plasma generation.

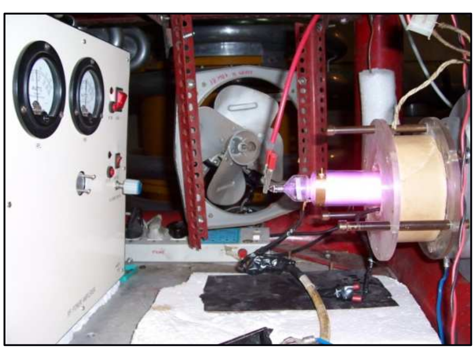

Figure 3: Photograph of RF source with D^+ plasma.

For this purpose, a solid state RF source operating at 100 MHz has been developed. It is capacitively coupled with the ion source to generate deuterium ion beam current of the order of 170 microampere on Tritium target which in turn generates 14 MeV neutrons from DT reaction. This RF source consists of a driver (18 Watt) designed around transistor BEL S 12-28, a power amplifier based on MOSFET MRF 141G biased in class 'C', input / output matching networks, a circulator and biasing techniques. This RF source has achieved an overall efficiency of 63.5 % and 13.7 dB of power gain.

HIGH POWER SOLID-STATE RF AMPLIFIER

As a technology development under departmental XI plan program, high power solid RF amplifier at 352.21 MHz is being developed. The overall configuration of amplifier includes basic 300 watt modules based on LDMOSFET, a no. of power splitters / combiners with different configurations depending upon various power stages, compact DC supplies and an interlock and protection circuit. An attempt has been made to combine four such modules and has been tested at a total of 700 watt power level. Based on this experience, 300 Watt amplifiers have been redesigned and its testing is in progress. Another approach based on single 1000 watt RF device has been tested upto 800 W.

Figure 4: Photograph of 1 kW solid state RF system.

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