A.7: Development of 110kV, 24 A, solid state bouncer modulator for CERN

CERN is building a 352.21 MHz., 3 MeV RFQ based test stand as first part of LINAC 4. CERN approached DAE to design and develop a prototype high voltage pulsed modulator for 1 MW LEP klystrons, planning their reuse. RRCAT proposed three design schemes out of which an all solid state bouncer compensated long pulse modulator was chosen for follow up development work. The main considerations for the design were to avoid gas tube crowbar on the HV side, to have low rise and fall times and to realize high voltage stability of the flat top. The output voltage and current are rated up to 110kV/24A, with pulse duration 800µs, repetition rate of 2Hz, <1% droop and <0.1% ripple on pulse top with energy dissipation in klystron restricted to 10 J in case it arcs. Based on the design, the all solid state bouncer compensated modulator has been developed by PHPMS/RRCAT. The modulator has achieved rated specifications and has been accepted by CERN team after rigorous testing at RRCAT. Table A.7.1 presents the main specifications of the bouncer modulator

Table A.7.1: List of main parameters of the modulator

Parameter	Design Targets	Achieved results
Klystron modulator type	Bouncer	Bouncer
High Voltage pulse amplitude	-10 kV to -110 kV	-10 kV to -110 kV
High Voltage pulse width measured at 70% to 70 % of peak.	800 µsec	800 µsec
Minimum Flat top available	600 µsec	600 µsec
Maximum current during pulse	24A	24A
Pulse repetition rate	2Hz	2Hz
Acceptable voltage drop	≤ 1.0 %	≤ 1.0 %
Allowed ripple on flat top (≥10 kHz)	≤ 0.1 %	≤ 0.1 %
Rise time/fall time	<100 µsec	<80 µsec
Energy dissipated in klystron during klystron arc	<10 J	<10 J

RRCAT has designed and commissioned several modulators for klystrons in past based on the PFN topologies with step up pulse transformers, which have peak pulse power up to 15 MW and average power up to 90 kW. Few solid state switched modulators were also developed using RRCAT built stacked MOSFET/IGBT solid state switches, operating at 5 kV/0.5 A@10 µsec/1 Hz and 50kV/2A@10µsec/300Hz for pulsing driver klystrons and LINAC electron gun respectively. Large reservoir of experience gathered on development of modulators with various topologies helped completion of the present effort.

During this endeavour many key technologies were developed indigenously. These include optical trigger circuits, high voltage solid state switch, high voltage automatic safety relay, energy storage capacitors, bouncer circuits, bouncer switches, arc protection circuits and damping networks. Fig.A.7.1 shows the inside of bouncer modulator cabinet. Fig.A.7.2 shows evaluation testing of bouncer modulator on a dummy load. Fig.A.7.3 shows the test results of bouncer modulator on resistive load

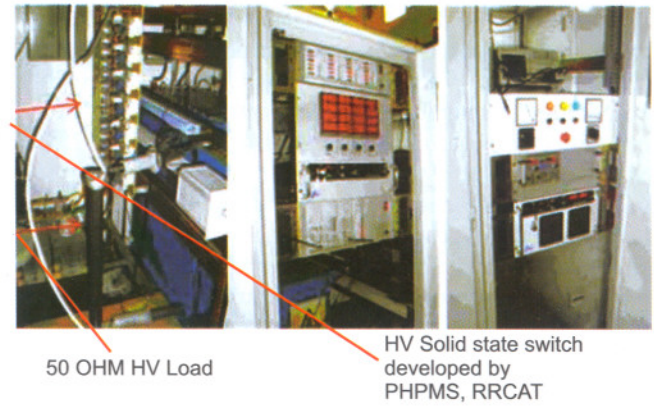

Fig.A.7.1 Modulator Testing on dummy load in primary side with Main & Bouncer IGBT switches

Fig.A.7.2: Evaluation testing of the modulator on a 5kohm, 110kV resistive load

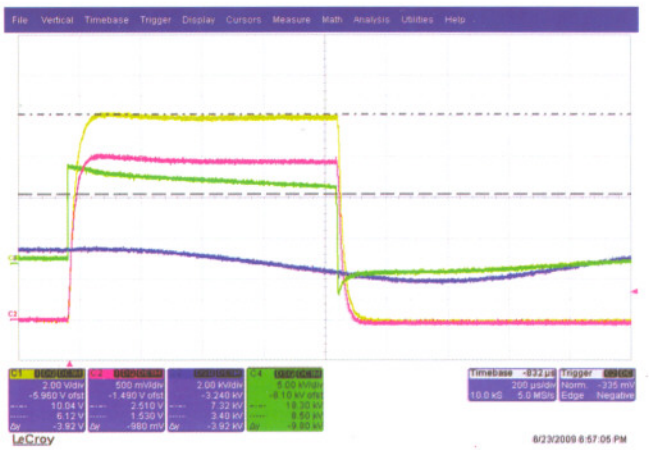

Fig. A.7.3: Testing of modulator at resistive load. Waveforms from top indicate output voltage 104kV@20kV/div, output current@5A/div, primary voltage referred to ground, and bouncer voltage respectively.

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A.8: Development of 1.3 MW, 352.2 MHz Pulsed Test Stand at RRCAT

At RRCAT, several research and development activities are being persued towards realisation of high power pulsed RF technologies for contributions towards the international collaboration projects (like DAE CERN Collaboration in NAT Projects) as well as the domestic projects like H⁻ ion injector LINAC for future SNS at RRCAT. In order to qualify the subsystems, electronics and components, RRCAT has built a pulsed 1.3 MW, 352.2 MHz test stand. It is built around the LEP klystron obtained from CERN under India CERN Collaboration. The overall test stand consists of a signal generator, a 300 W solid state pulsed driver amplifier, the 1.3 MW LEP klystron, 110kV solid state bouncer pulse modulator and output WR 2300 waveguide system. The waveguide system consists of harmonic filter, dual directional coupler, three port circulator, flexible waveguides, magic tee power divider chain and RF loads.

The other auxiliary power supplies for the klystron like the filament power supply, solenoid power supply and the ion pump power supply are also incorporated. The major specifications of test stand are listed in Table 1. Fig.A.8.1 shows the photo of the test stand constructed at RRCAT. Fig.A.8.2 shows the modulator and control system, Fig.A.8.3 shows the wave guide components developed at RRCAT. Fig.A.8.4 shows the test results.

Table A.8.1. Specifications of the 1.3 MW Test Stand at RRCAT

Parameter	Value	Unit
Peak Output power max.	1.3	MW
Operating Frequency	352.21	MHz.
-1dB Bandwidth	±0.8	MHz.
High Voltage pulse width measured		
at 70% to 70 % of peak.	800	µsec
Waveguide System	WR 2300	
Energy dissipation limited in klystron		
during klystron arc	<10	J

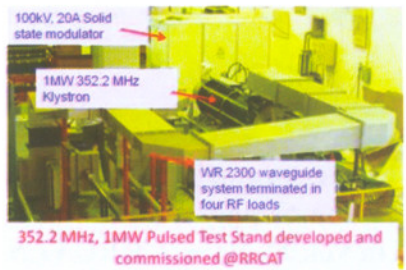

Fig. A.8.1: 352.2MHz, 1MW pulsed test stand commissioned and tested at RRCAT.

Fig.A.8.2: Modulator and controls for test stand

Fig.A.8.3: Some of the WR 2300 waveguide components viz., straight FH and HH sections, coaxial to waveguide transitions, F/H taper transitions, developed at RRCAT.(courtesy Mr. A.K. Jain, Mr. S.D. Sharma, Mr. V. K. Bhatnagar, ACEPD).