DESIGN AND DEVELOPMENT OF PULSED MODULATORS FOR RF ELECTRON LINACS

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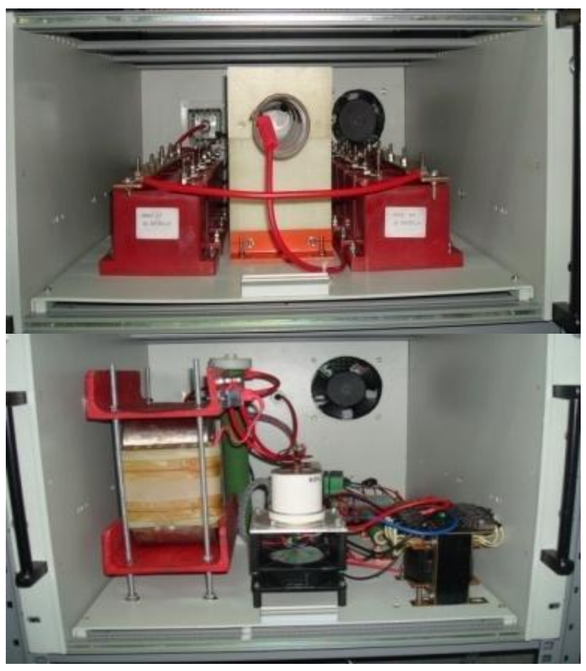
Industrial electron RF linacs, including the 10 MeV RF Linac and 3 MeV DC Accelerator, have been indigenously designed and developed at Accelerator & Pulse Power Division, BARC, India. Several industrial applications such as plastic modification, semiconductor irradiation have been demonstrated with these accelerators. 6 MeV and 9 MeV linacs as x-ray sources for cargo-scanning and radiography have been built and characterized. These linacs operate in the pulsed mode, which requires the use of pulse modulators for the RF source as well as the electron guns.

MODULATORS FOR E-GUNS

- Pulse electron guns are injectors to RF linacs and are powered by modulators
- Ratings 40-85kV, Peak current ranging from 1-4A. Pulse width varies between 3-10µs, with a pulse repetition rates between 250-400 Hz
- Both line-type and solid-state modulators have been designed and developed indigenously.

Line Type modulators

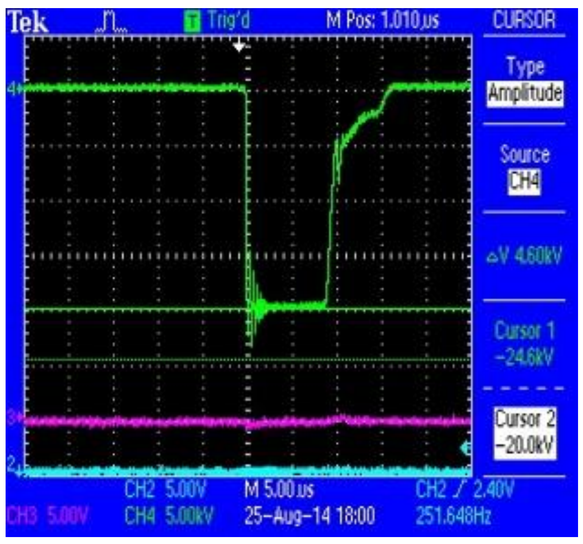
- For Electron Gun of 6 MeV Compact linac
- Rated for 4 A with 6 µs pulse width and 250 Hz repetition rate
- 10-stage PFN capacitor (72 nF) charged resonantly through charging choke of 20 H
- PFN impedance 50Ω
- 18 kV/4 kA hydrogen thyratron as switch
- 1:20 pulse transformer to obtain 85 kV at its secondary

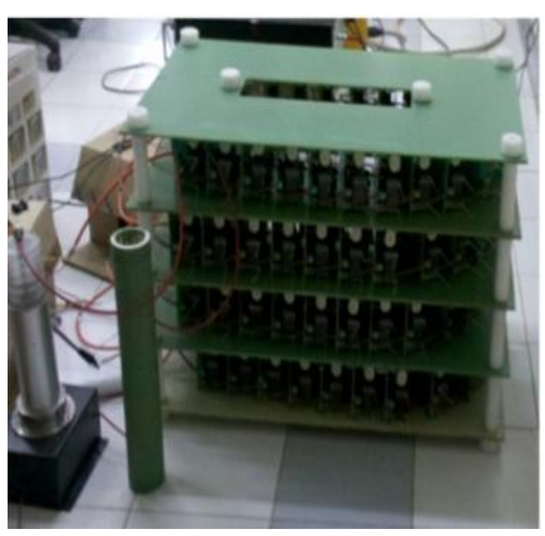


Primary circuit of 85 kV e-gun modulator

Solid-state e-gun modulators

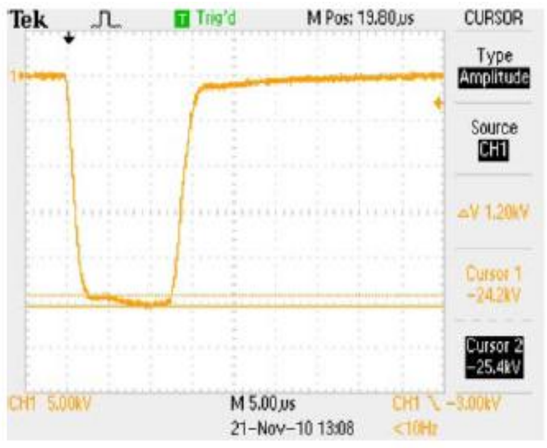
- **84-stage Marx adder transformerless configuration**
- **40 kV, 10 µs pulse at 250 Hz with rise time of <250 ns achieved**





Marx adder (84-stage) and output of 40 kV on resistive load

- **Solid-state modulator for e-gun with single-stage IGBT-based system**
- **At primary pulse of 1 kV, output pulse of 90 kV achieved with 1:90 pulse transformer**



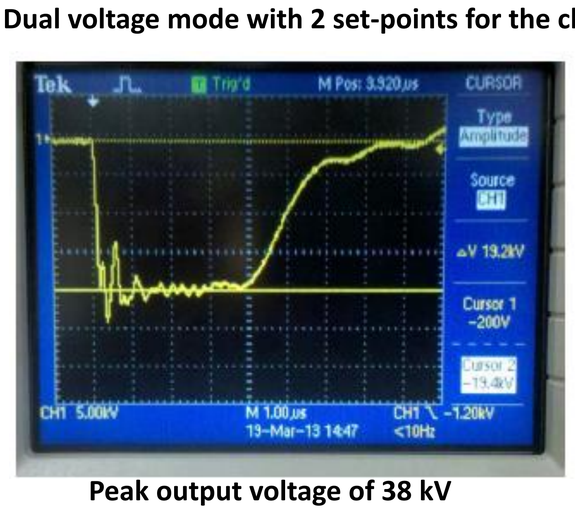
IGBT-based modulator with 90 kV output pulse

MAGNETRON MODULATORS

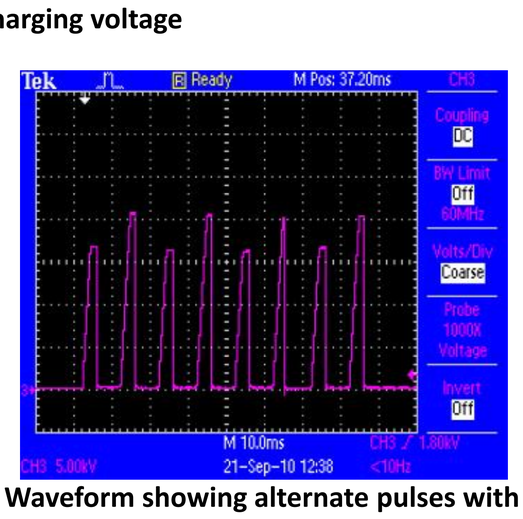
- **For 6 MeV compact linac**
- **Ratings of 38 kV with 4.5 µs pulse at 250 Hz**

Line Type Modulator

- **7-stage PFN, 16.6 ohm 25 kV/ 2 kA thyratron as switch**
- **1:3.7 pulse transformer with amorphous cut-C cores**
- **Dual voltage mode with 2 set-points for the charging voltage**



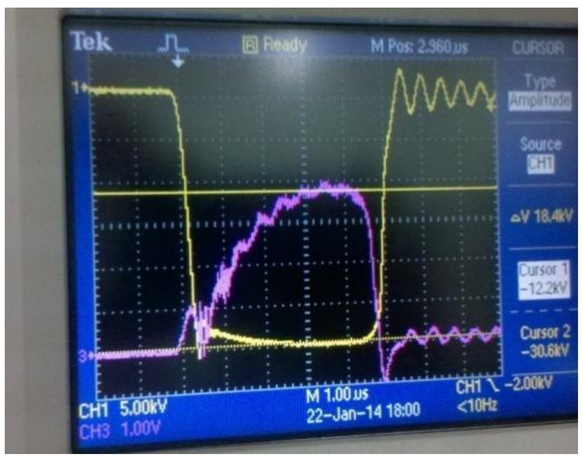
Peak output voltage of 38 kV (rise time <350 ns)



Waveform showing alternate pulses with different peak voltages

Solid-state modulators

- Output voltage of 38 kV with 4.5 µs pulse at 300 Hz
- Tested on Magnetron (MG5028)
- Based on 1 kV IGBTs with fractional-turn windings



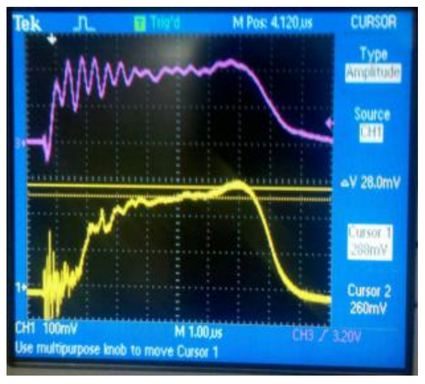
Output pulse of 30 kV (yellow) and magnetron current of ~80 A (pink)

KLYSTRON MODULATORS

- **Line type Pulsed modulator of 150kV/110A/7µs/250 Hz**
- **Peak RF power of 7.5 MW has been achieved with klystron as load**

Modulator with single-beam klystron on test

Pulse transformer (1:10.7) for 150kV/110 A klystron modulator



RF Output pulse of 7 MW & klystron peak current of 102A

CONCLUSION

Indigenous design and development of line-type and solid-state modulators has been successfully demonstrated. Design standardization for production of line-type modulators for various linac systems is under way. Prototype solid-state modulators have been successfully developed and will be tested with their respective loads