A.5: Development of 100 kV, 20 A, 1 ms solid state Marx modulator

A 100 kV, 20 A, 1 ms Marx modulator has been designed and developed. The important parameters of the Marx modulator are summarized in the Table A.5.1. In a Marx modulator, stack of capacitors are charged in a parallel manner to a specified voltage by the use of solid state charging switches. The capacitors are then discharged in series by the use of discharging switches to generate a high voltage pulse output. The voltage of output pulse is equal to the individual capacitor voltage times the number of capacitors. The Marx modulator is composed of two units that are main Marx unit and corrector Marx unit. The main Marx unit generates 100 kV base pulse while corrector Marx unit compensates the droop of the base pulse by staggered triggering of its modules. Main Marx unit is composed of 34 main modules which operates at 3 kV. It comprises of an energy storage capacitor, a charging IGBT and a discharging IGBT. Figure A.5.1 shows the schematic of the 100 kV Marx modulator.

Table A.5.1: Specifications of the Marx modulator

Parameter	Value
Maximum output Voltage	100 kV
Maximum output current	20 A
Output peak power	2 MW
FWHM pulse width	1 ms
Rise Time	1.4 µs
Fall time	9.7 µs
Droop without correction	16%
Droop with correction	<1%
Peak to peak Ripple in output voltage	1%

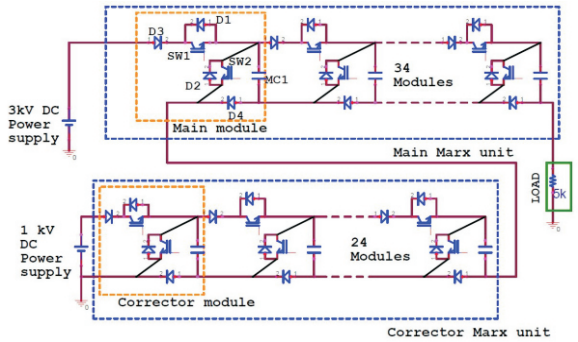

Fig. A.5.1: Schematic of 100 kV Marx modulator.

The diodes D1 and D2 have been used for reverse voltage protection of charging and discharging IGBTs, respectively. During pulse generation, in case discharging IGBT of any module is unable to turn ON, entire high voltage pulse appears across that IGBT. To avoid this high voltage across IGBT, a bypass diode D4 is used in a Marx module. In the above situation, the bypass diode gets forward biased and full pulse current is bypassed through the diode and voltage across the IGBT is limited to the module voltage. Four number of diodes of 1.2 kV, 30 A rating are connected in series to realize the diode.

The corrector unit compensates the overall droop in the main Marx unit. It is composed of 24 corrector modules. The corrector module is a lower voltage version of main module and operates at 1 kV. The corrector modules are charged to a lower voltage and are bypassed at the starting of the pulse. As the pulse progresses, there is droop in the output pulse. When the output pulse drops below an acceptable value of droop, first corrector module is added to the main Marx unit by turning ON its discharging IGBT and so on.

Fig. A.5.2: Photograph of the experimental setup.

Figure A.5.2 shows the experimental setup of 100 kV, 20 A Marx modulator. The modulator performance has been studied on resistive load of 5 kΩ. The output voltage pulse has 16% droop without activating droop compensation. Figure A.5.3 shows the 100 kV, 1ms output pulse with compensated droop. The droop in the output is less than 1%. Corrector unit output is also shown in Figure A.5.3, which increases in steps to compensate the droop. The output The rise time and fall time of the output pulse are 1.4 µs and 9.7 µs, respectively.

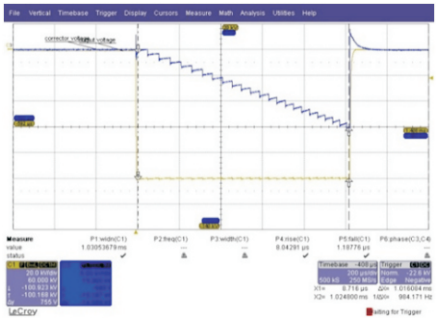

Fig. A.5.3: 755 V droop in 100 kV, 20 A, 1 ms output voltage waveform with droop compensation.

Reported by:
Mahesh Acharya (macharya@rrcat.gov.in) and Purushottam Shrivastava