L.9: Development of 1200V, 6kJ/sec constant current capacitor charging power supply for pulsed discharge excimer laser

A solid state pulse modulator for excimer laser, need to charge initial storage capacitor accurately to a set value. Therefore a constant current capacitor charging power supply was designed developed and tested to energize solid state pulse modulator at Laser Systems Engineering Division of RRCAT. This power supply can charge a 72 μF capacitor to 1200 V at 120 Hz. The total charging rate is 6 kJ/sec. This is based on a LLC based variable frequency, half bridge resonant dc to dc converter as shown in fig. L.9.1. The pulse energy output of laser was 150 mJ/pulse.

The capacitor charging requires operation over a wide range of load conditions varying from nearly short circuit to nearly open circuit. This kind of performance can be best achieved by supplying a constant charging current through a multimode controller. This controller will work in burst mode when there is no load or light load. The variable switching

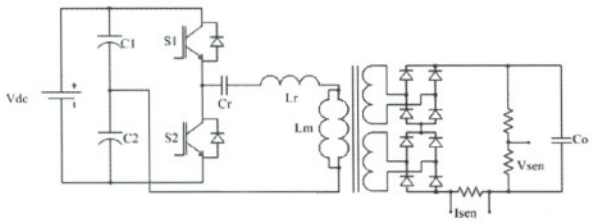

Fig.L.9.1: Capacitor charging power supply circuit diagram based on LLC dc-dc converter.

frequency (similar to variable duty cycle in conventional fixed frequency PWM) modulates the output voltage/current. When the input voltage is low, the switches will operate in boost mode by reducing the frequency below the natural resonant frequency. When the input is high it operates in buck mode by increasing the switching frequency above the resonant frequency.

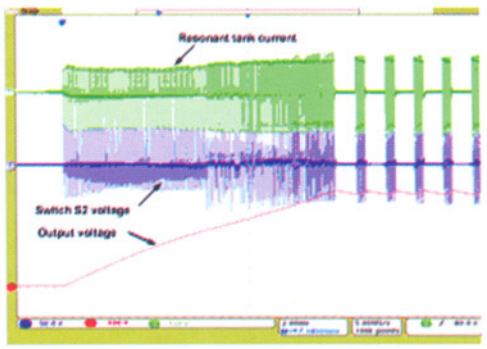

Fig.L.9.2: Output waveform during resistive load test, Ch1: resonant tank current, (50A/div.) Ch_2: shows the output voltage, (400V/div.) and Ch_3: voltage waveform across the switch S_2 (200V/div.).

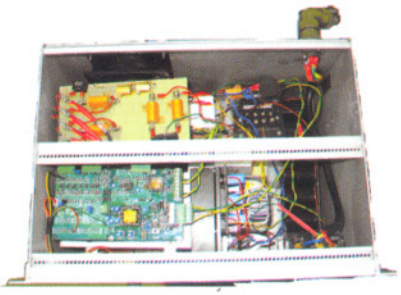

Fig.L.9.3: Capacitor charging power supply prototype.

The switches S_1 and S_2 operate ~ 50% duty cycle at variable frequency from 25 kHz to 40 kHz. The half-bridge switches together with two series voltage divider capacitors C_1 and C_2, resonant inductance L_r (transformer leakage inductance), magnetizing inductor L_m (transformer), and resonant capacitor C_r form the resonant tank, which is connected between the centre point of half bridge and the centre of series capacitors C_1 and C_2. A step up core type transformer with a turn's ratio of 1:5.3 is used to get the required 1200V. Compared to the configuration of the earlier power topology with the traditional half-bridge converters, no filter inductor is included on the secondary side in this LLC series topology, hence the output rectifier diode rating is same as that of maximum output voltage. The switches S_1 and S_2 are driven by complementary control signals generated using variable frequency resonant controller NCP1395A.

The prototype was developed using CM150DY-24H IGBT as main switch, series inductor L_r= 27μH, L_m=120 μH and series capacitance C_r=1100 nF. The high frequency isolation transformer is made using 2 pair of UU-93X30X26 ferrite cores material grade 3C80 from Philips. There are two primary and two secondary windings. The primary windings are connected in parallel and each of the secondary is rectified using full bridge ultra-fast rectifier and connected in series after rectification. The high voltage rectifier was made using DSEP60-12A diodes from IXYS 8 nos. The power supply was tested initially with a thyristor triggered pulse discharge R-C circuit load. Fig.L.9.2 shows the waveforms of the power supply in pulsed discharged mode. The Ch_3 shows the resonant tank current, Ch_2 shows the output voltage and Ch_1 shows the voltage waveform across the switch S_2. The controller works in constant current mode while charging the storage capacitor, from 2msec to 14msec. When the capacitor charged to a set value at 14 msec it enters in burst mode of operation. Hence it maintains constant voltage against self discharge of energy storage capacitor. The power supply was tested with resistive load at 6kW. After the resistive load test, the power supply was tested with actual load by charging a 72 μF/2kV capacitor up to the repetition rate of 120Hz with solid state pulse modulator. The measured output ripple was ± 2.5%.

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