

FULL RANGE ZVS DC-DC CONVERTER

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Abstract

A 500 V, 24 Amp DC-DC converter with digital signal processor (DSP) based control and protection has been designed, fabricated and tested. Its power circuit consists of IGBT based single phase inverter bridge, ferrite transformer and diode rectifier. All IGBTs in the inverter bridge are operated in zero voltage switching (ZVS) mode to minimize switching losses thereby increasing the efficiency of the converter significantly. The efficiency of this converter is measured to be greater than 97% at full load. In a conventional full bridge inverter, typically ZVS is achieved under full load condition while at light load ZVS is lost. An auxiliary LC circuit has been intentionally incorporated in this converter to achieve ZVS even at light loaded conditions. Detailed simulation of the converter circuit is carried out and crucial waveforms have been presented in this paper. Microchip make dsPIC30F2020 DSP is employed to provide phase shifted PWMs to IGBTs in the inverter bridge. All the crucial parameters are also monitored by this DSP and in case of any unfavorable conditions, the converter is tripped off. Suitable experiments were carried out in this DC-DC converter under different loaded conditions and a close match between the simulated and experimental results were obtained. Such DC-DC converters can be connected in series or parallel for the development of solid state modular power supplies for various applications.

INTRODUCTION

Full bridge inverter based DC-DC converters are quite popular and widely used for high power applications. High efficiency, high power density, and high reliability are of prime importance in such high power conversion. Generally Phase shifted Pulse Width Modulation is used in such converters to achieve Zero Voltage Switching (ZVS) of the switches which reduces the switching losses significantly and hence increases the overall efficiency of the system. Normally to achieve ZVS, an inductor is connected in series or parallel across the transformer. However the converter with series inductor loses duty cycle as well as ZVS near light load while the one with parallel inductor loses ZVS under load short circuit condition. The switches on the lagging leg are the first ones to lose ZVS followed by the leading leg switches. The loss of ZVS leads to increased size of heat sink due to high switching losses, higher EMI thereby reducing the reliability of the system. Several techniques have been proposed to extend the range of ZVS operation [1]. In this paper, a 500 V, 24 Amp DC-DC converter which incorporates an auxiliary

LC circuit to achieve ZVS in the full operating range [2] is presented along with Pspice simulation waveforms and the experimental results.

POWER CIRCUIT

The 500 V, 24 Amp DC-DC converter employs IGBT based single phase inverter bridge operating in ZVS at 18 kHz followed by ferrite transformer and diode rectifier. An auxiliary circuit comprising of an inductor is connected at each of the legs of the inverter bridge to achieve ZVS over full operating range. The desired output of the converter is a PWM waveform with minimum overshoot at resistive load. Microchip make dsPIC30F2020 has been programmed in assembly language to provide phase shifted PWM pulses to the IGBTs in the inverter bridge. Various protection features like the input DC under voltage, over voltage, output over current, IGBT short circuit monitoring have also been implemented with the help of this DSP. In case of any unfavourable situation, the IGBT gate pulses are withdrawn and the converter is tripped off. By incorporating suitable ripple filters, this PWM output can be converted into a perfect DC if required. Depending on the input DC voltage, the IGBT duty cycle is varied to maintain 500 V average PWM DC at the output of the converter.

SIMULATION RESULTS

Pspice simulation of the 500 V, 24 Amp DC-DC converter circuit shown in Figure 1 was carried out. Initially the simulation was done without incorporating the auxiliary circuit. The waveform of the lagging leg IGBT switch losing ZVS under light load condition (20 % of full load) is shown in Figure 2. Thereafter the auxiliary circuit was added and their values suitably optimized for achieving ZVS in the full operating range i.e. 20 % to 100 % of full load. Figure 3 shows the waveform for a lagging leg IGBT switch operating in ZVS at 20 % of full load. Output voltage waveform at full load is also shown in Figure 4.

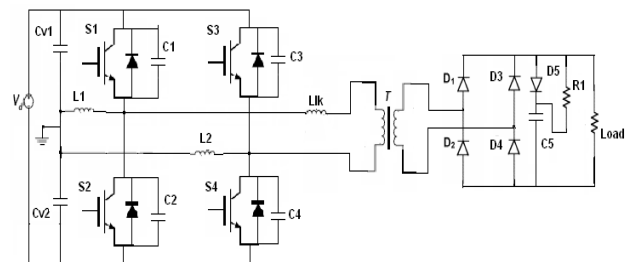


Figure 1: Pspice simulation circuit for 500 V, 24 Amp DC-DC converter

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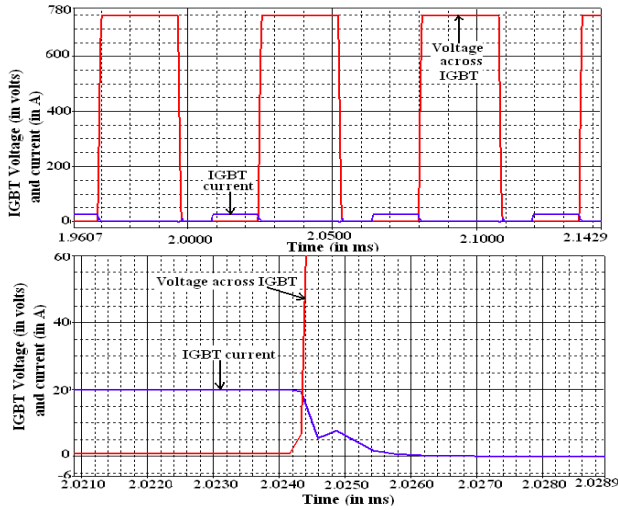


Figure 2: IGBT voltage and current at 20 % load without auxiliary circuit

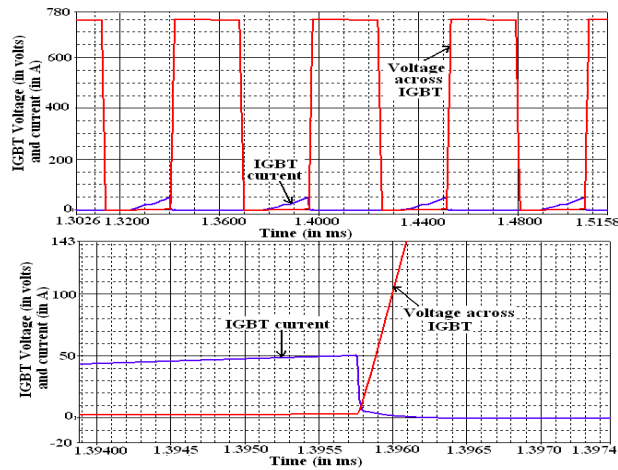


Figure 3: IGBT voltage and current at 20 % load with auxiliary circuit

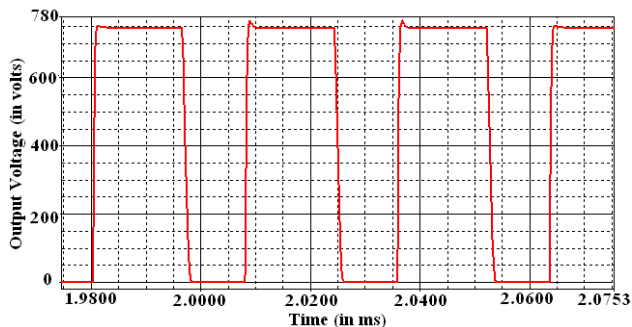


Figure 4: Output Voltage at full load

EXPERIMENTAL RESULTS

The experimental test set up consisted of a 3-phase auto transformer followed by rectifier, filter arrangement which provided DC input to 500 V, 24 Amp DC-DC converter. The converter was tested at resistive load varying from light load to full load. All crucial waveforms including the IGBT voltage, gate pulse, transformer secondary voltage, final output voltage, auxiliary inductor currents were observed. It was found

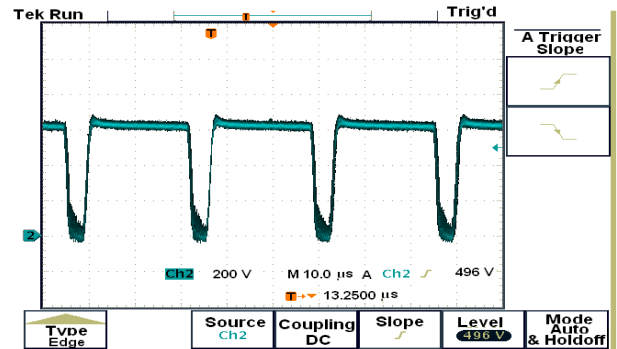


Figure 5: Output Voltage at full load

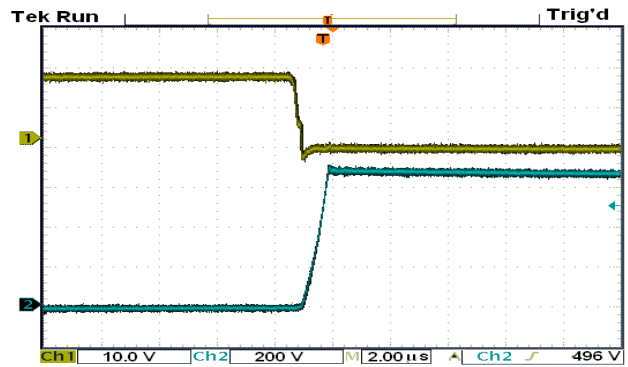


Figure 6: IGBT Voltage and gate pulse

that the IGBTs operated in ZVS mode in the full operating range. The final output voltage waveform and IGBT switch voltage along with the gate pulse are shown in Figure 5 and Figure 6 respectively.

CONCLUSION

PSpice simulation waveforms along with the experimental results of 500V, 24 A DC-DC converter are presented in this paper. A close match between the simulated waveforms and experimental results is obtained. It is observed that the IGBTs employed in the inverter bridge of this DC-DC converter operate in ZVS mode in the full operating range. The efficiency of this DC-DC converter is measured to be greater than 97% at full load. Such DC-DC converters can be connected in series or parallel for the development of regulated high voltage or high current power supplies. Series connection of such DC-DC converter power modules is a prospective candidate for the development of solid state modular klystron bias power supplies for advanced particle accelerators.

REFERENCES

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