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A Novel Zero Voltage Transition (ZVT) Technique Based Closed Loop Control of Boost Power Factor Correction (PFC) Converter with EMI Filter

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Abstract: A novel Zero Voltage Transition (ZVT) technique based closed loop control of Boost Power Factor Correction (PFC) converter with Electro Magnetic Interference (EMI) Filter is presented in this paper. It operates at a fixed frequency while achieving zero voltage turn-on of the main switch and zero current turn-off of the boost diode. This is accomplished by employing resonant operation only during switch transitions. During the rest of the cycle, the resonant network is essentially removed from the circuit and converter operation is identical to its non-resonant counterpart. A prototype of 500W is built to test the proposed topology. The input voltage is from 170 to 230 Vrms. The output voltage is 400V. The operation frequency is 100 KHz. This technique increases the efficiency to 95% and power factor to 0.99.

Key words: Power factor correction, electro magnetic interference, zero voltage transition, common mode, differential mode, quality

INTRODUCTION

The demand for power, which is increased tremendously over the last few decades, has forced the power engineers to establish reliable network in order to supply quality power to the consumers. Power factor, which is defined as the cosine of the phase angle between the voltage and current signals, plays a key role in delivering quality power to the consumers[1].

Over the years lot of research has been carried out for the control of the power factor. This research got a tremendous boost with the strides made in the miniaturization of the electronic industry. The component of input current normal to voltage across the load resistance wastes power in the resistance of the source generator. In power supplies with a capacitor filter across the input bridge rectifier, the input line current consists of very narrow spikes with the fast rise and fall time. These current spikes have a high rms value, waste power and give rise to RFI/EMI problems. Power supplies with such input line currents have poor power factor. Power Factor Correction seeks to eliminate such line current spikes and force input current to be sinusoidal, in phase with input voltage and to generate a fairly well regulated DC output voltage somewhat greater than the peak of the incoming sine wave[2,3].

Generally EMI problems arise due to the sudden changes in voltage ($dv\ dt^{-1}$) or current ($di\ dt^{-1}$) levels in a waveform. In diode rectifier, the line current can be pulse of short duration and the diode recovery current pulse can generate transient voltage spikes in the line inductance. A conductor carrying $dv\ dt^{-1}$ wave acts like an antenna and sensitive signal circuit and appear as noise. The EMI problems create communication line interference with sensitive signal electronic circuits.

ZERO VOLTAGE TRANSITION (ZVT) TECHNIQUE

The power stage of proposed PFC converter with ZVT technique based boost topology is shown in Fig. 1 and the ZVT timing diagram is shown in Fig. 2. The capacitive turn-on losses can be theoretically eliminated and the overlap of non-negligible active switch voltage and current can be avoided at turn-on, by using the Zero Voltage Switching-ZVS technique. Basically, this technique consists of forcing to zero the active switch voltage, prior to its turn-on, by creating a resonance between an inductor and a capacitor. The inductor also limits the rate of variation of the diode current, so losses due to the reverse recovery are reduced as well[4].

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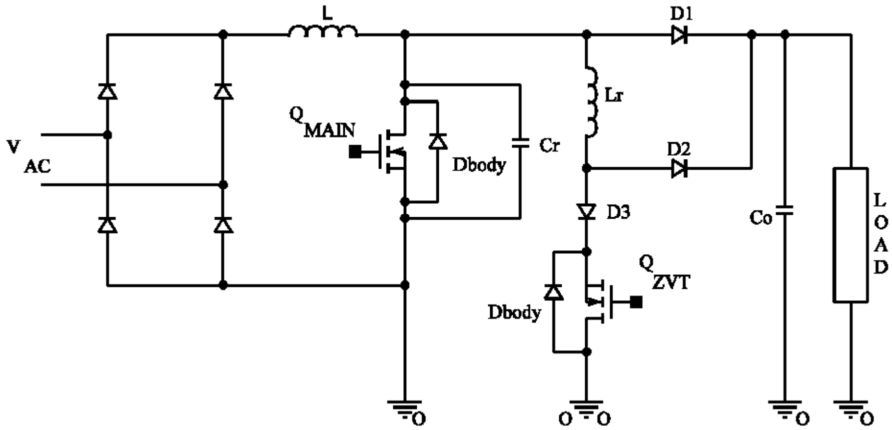

Fig. 1: Power circuit of ZVT based boost PFC converter

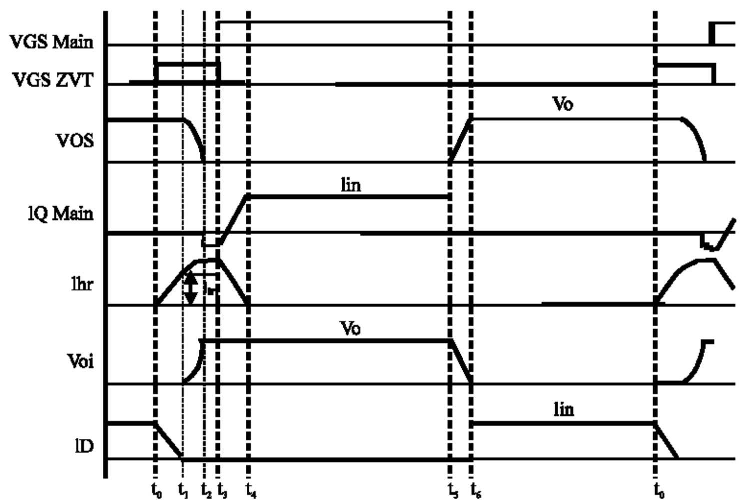

Fig. 2: Timing diagram of ZVT technique

However, better characteristics are obtained in Zero Voltage Transition-ZVT topologies, at the expense of increased complexity. Here, to achieve ZVS, switch voltage and current waveforms are changed only during commutation intervals, the behavior of the ZVT converter being otherwise identical to that of the hard-switching converter. In converter topologies having only one active switch, the ZVT technique is implemented with an auxiliary circuit, which consists of an additional active switch, an auxiliary inductor, for the resonant process that discharges the drain-source capacitance of the switch and for limiting the rate of change of the diode current at turn-off, as well as a few other passive components[5,6].

The auxiliary switch is turned on before turning on the main active switch. This initiates a resonant process, which creates zero voltage switching conditions for the main active switch. The time intervals where the auxiliary

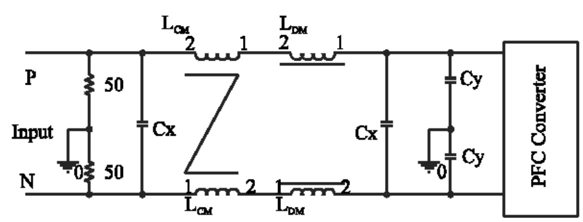

Fig. 3: EMI filter for boost PFC converter

circuit is active are very short when compared to the switching period; hence, except for the commutation intervals, the waveforms of the ZVT Boost converters are the same as those of the hard-switching Boost converter[7].

Electro Magnetic Interference (EMI) filter: The Electro Magnetic Interference can be transmitted in two forms:

radiation and conduction. The switching converters supplied by the power lines generate conducted noise into the power lines that is usually several orders of magnitude higher than the radiated noise into free space. Metal cabinets used for housing power converters reduce the radiated component of the electromagnetic interference. Conducted noise consists of two categories commonly known as the differential mode and the common mode. The differential mode noise is a current or a voltage measured between the lines of the source that is line-to-line voltage. The common mode noise is a voltage or a current measured between the power lines and ground that is line-to-ground voltage[8]. An EMI filter is needed to reduce the differential mode and common mode noises. The EMI Filter for Boost PFC converter is shown in Fig. 3.

For CM Noise,

$$f_{R,CM} = 1/(2\pi\sqrt{(2Cy*L_{CM})}) \quad (1)$$

$$L_{leakage} = 0.5\% \text{ to } 2\% \text{ of } L_{CM} \quad (2)$$

For DM Noise,

$$f_{R,DM} = 1/(2\pi\sqrt{(2L_D C_X)}) \quad (3)$$

$$L_{DM} = (L_D - L_{leakage})/2 \quad (4)$$

First, the prototype of Zero Voltage Transition (ZVT) technique based Boost Power Factor Correction (PFC) Converter is built. The power rating of converter is 500 watts. The input voltage is from 170 Vrms to 230 Vrms. The output voltage is 400V. The operating frequency is 100 Khz. The PFC converter has the predicted noise level and EMI which includes total noise, common mode and differential mode noises. The corner frequencies of EMI noises in the PFC circuit are found as 28 KHz for CM noise and 20.5 KHz for DM noise. The designed values are L_{CM} is 4.9mH and L_{DM} is 40 μH.

RESULTS

Simulation results: Figure 4 shows the simulated input current waveform without EMI Filter. In this figure, there is more noise and more spikes. Figure 5 shows the simulated input current waveform with EMI filter. Here, the noise and spikes are reduced because of Filter. Figure 6 shows the simulated input voltage and current waveforms. Here, the power factor is around 0.99 and the noise and spikes are also reduced.

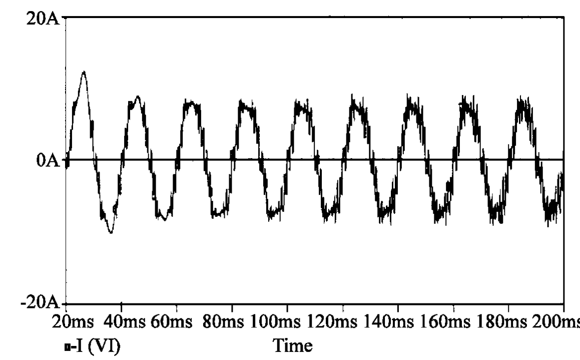

Fig. 4: Input current waveform without EMI filter

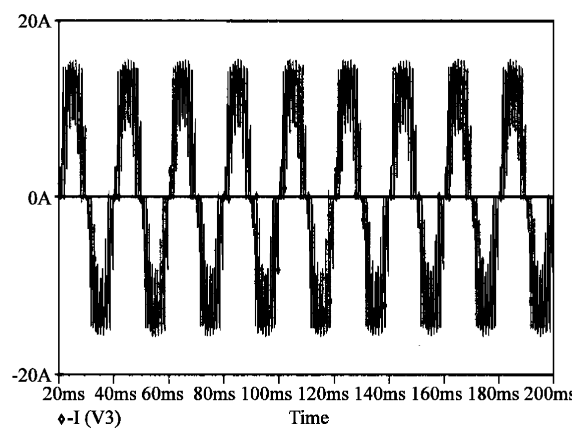

Fig. 5: Input current waveform with EMI filter

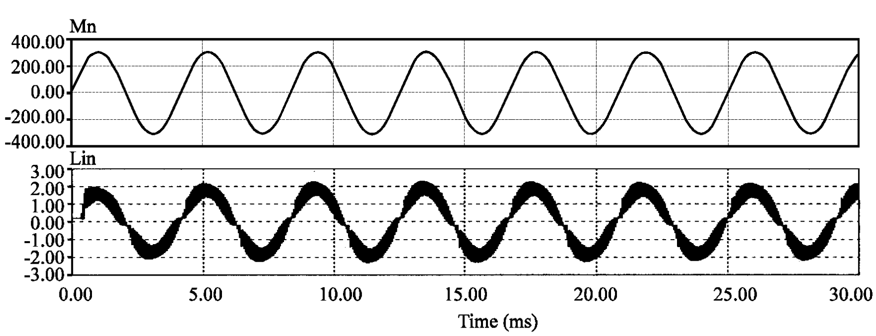

Fig. 6: Input voltage and current waveforms

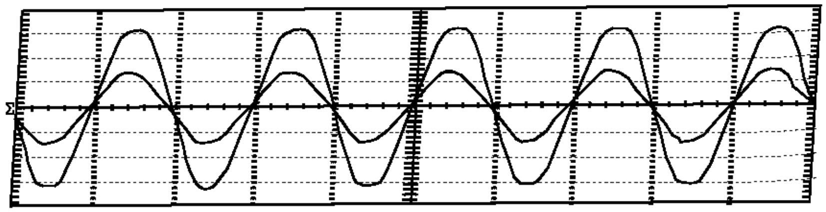

Fig. 7: Experimental result of input voltage and input current waveforms

Experimental results: The control signals for the two switching devices are ZVT based PWM signals. The ZVT technique based IC with name UC 3855 provides the PWM signals to the two MOSFETS. The experimental setup has been done using the above IC. Figure 7 shows that the power factor at the input side of Power Factor Correction (PFC) Converter is around 0.99 and the efficiency is near 95%.

CONCLUSION

A Boost Power Factor Correction (PFC) Converter with EMI Filter employing Zero Voltage Transition (ZVT) technique is proposed. Power factor is improved upto 0.99 (lag) without compromising the efficiency because of the active snubber. The experimental and simulation results are correlated. There is scope for further improvement of the power factor and as well as the converter efficiency using an auxiliary resonant source along with ZVT Boost converter. Here, the drawback is only CM noise and DM noise are considered in Electro Magnetic Interference. The work can be extended by considering different other noises such as IDM, NIDM, mixed mode EMI noise etc.

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