ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

Single-Phase Power Factor Correction Circuit Using Zero-Voltage-Transition Technique

A .Dhanumjaya Apparao
Assistant Professor,
Department of Electrical and Electronics Engineering,
ANITS College, Sangivalasa, Andhra Pradesh, India.

V. Anil Kumar
Assistant Professor,
Department of Electrical and Electronics Engineering,
ANITS College, Sangivalasa, Andhra Pradesh, India.

Abstract:

This paper presents a Zero-Voltage-Transition Technique (ZVT-Technique) in single phase active power factor correction circuit based boost converter topology and operated in a continuous-inductor-current mode with peak current control method. An additional circuit for reducing the turn-off switching loss of the auxiliary switching circuit was applied. The results showed that the efficiency was improved from 95 Percent to 98 percent with power factor 0.99.

Index Terms:

Boost converter, zero-voltage-Transition, dc-dc converter, power factor correction, soft-swatching, peak current control.

I. INTRODUCTION:

The growth of consumer electronics has meant that the average home has a plethora of mains driven electronic devices and not just television sets. Invariably these electronic devices have mains rectification circuits, which is the dominant cause of mains harmonic distortion. Therefore, the problems caused by the harmonic currents become more important. International regulations goveming the amount of harmonic currents (e.g. EC1000-3-2) became mandatory and active power factor correction (PFC) circuit became inevitabIe for the ac dc converters. Generally, the solution for harmonic reduction and PFC are classified into passive approach and active approach. The passive approach offers the advantages of high reliability, high power handling capability and easy to design and maintain. While the active approach remains the best choice in many high power applications, the active approach dominates the low to medium power applications due to their extraordinary performance (unity power factor and efficiency approach to 100%), regulation capabilities and high power density. [1]-[3].Today's harmonic and PFC technique to improve distortion are still under development. Power supply industries are undergoing the change of adopting more and more PFC techniques in all off-line power supplies. Moreover, with the residential and defense industries continuously demanding for even higher power density, switching mode power supply operating at high frequency is required because at high switching frequency, the size and weight of circuit components can be remarkably reduced. However, with the increasing of switching frequency, the switching loss becomes intolerable, resulting in very low conversion efficiency [4].Soft-switching techniques have been widely used in reducing the switching losses and EMI noises of switching mode power converter.

Soft-switching techniques, especially zero-voltage-transition (ZVT) have become more and more popular in the power supplies industries. The boost PFC converter employing the ZVT technique was first introduce in [5]. This converter provides ZVS condition for the main switch without increasing voltage stress of the active switches. However, it has a disadvantage such as the auxiliary switching circuit is turned off with hard-switching which deteriorates the overall efficiency and increase EMI noises [6].This paper proposes a ZVT PWM boost PFC converter using additional capacitor. PWM converters that use an active auxiliary circuit to allow the main switch to turn on with zvs are generally referred to as zero-voltage-transition converter in the power electronic literature.The auxiliary switch is turned off while it is conducting current. Switching losses and EMI can be generated by this hard turn off, which offsets the benefits of the using the auxiliary circuit [7]. Active auxiliary circuits in ZVT PWM converters can be categorized as belonging to one of two basic types: non-resonant and resonant[8].

The circuit shown in fig-1 is a non- resonant type ZVT PWM converter. In this converter the auxiliary switch is turned off while it is conducting current. Switching losses and EMI can be generated by this hard turn off which leads to a reduction in converter efficiency.The proposed converter achieves zero voltage or zero current urn-on and turn-off for the active switches as well as the soft-switching for the passive switches. A 500 W, 10 kHz ZVT PWM boost PFC converter has been simulated.

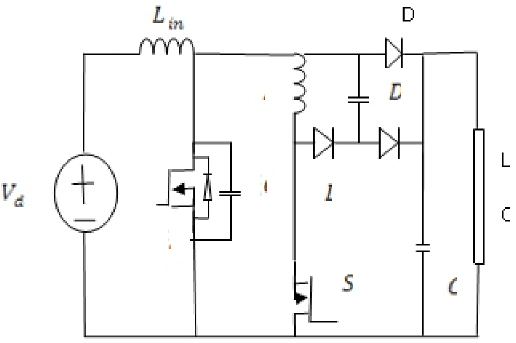


Fig-1 ZVT-PWM boost converter with non resonant auxiliary circuit.

II. ZVT-BOOST CONVERTER

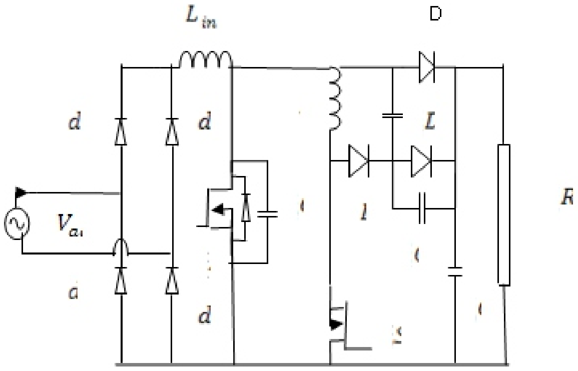


Fig-2 Proposed ZVT-PWM boost converter with additional capacitor C1 across diode D2

Fig.2. shows the circuit of the converter is consisted of switches, including auxiliary switches, are only turned-on and off at soft switching a diode (D1) and two capacitors. (C1 ,C2) The converter operates in a continuous inductor current mode (CICM).The proposed converter has eight operating modes. The ideal waveform and equivalent circuit of each mode are shown in fig shown below.

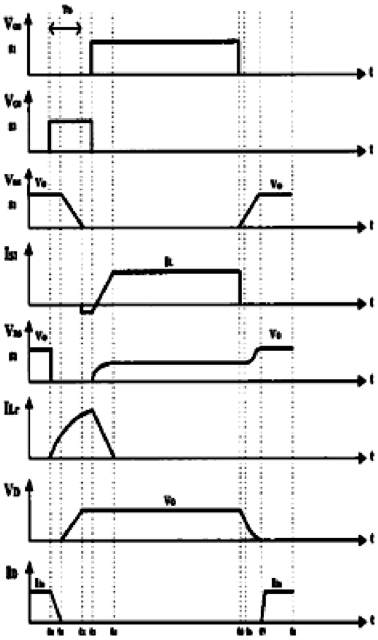
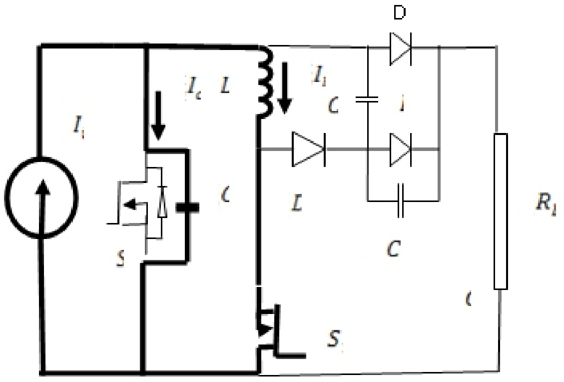


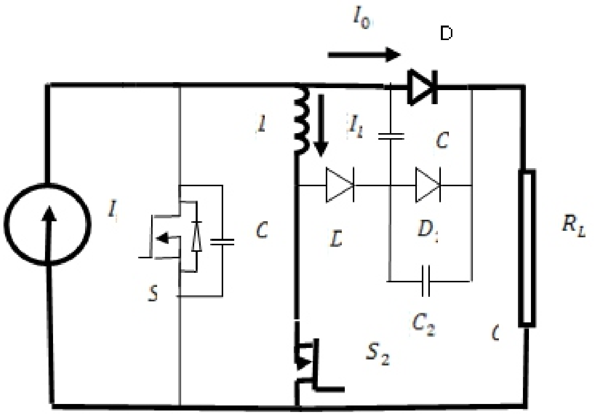
Fig-3 Theoretical waveform of proposed converter

Modes of Operation:

The operations of each mode are explained as follows:

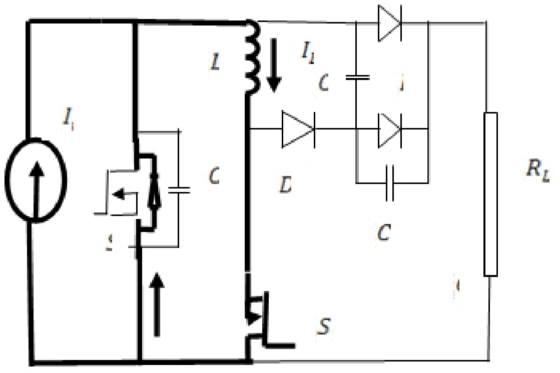


Mode-1

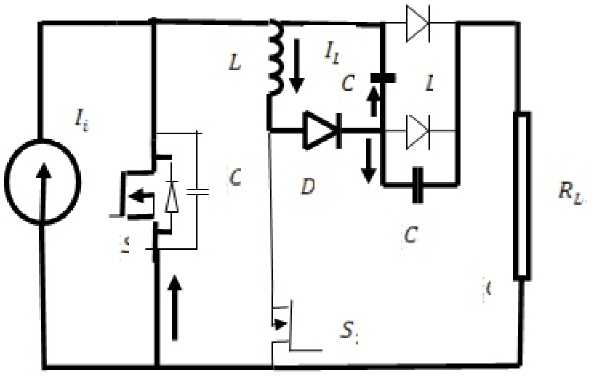


Mode-2

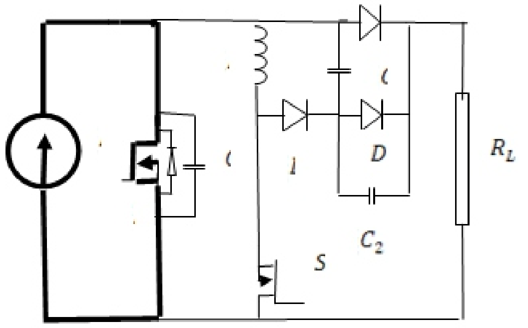
ISSN No: 2348-4845
International Journal & Magazine of Engineering,
Technology, Management and Research
A Peer Reviewed Open Access International Journal



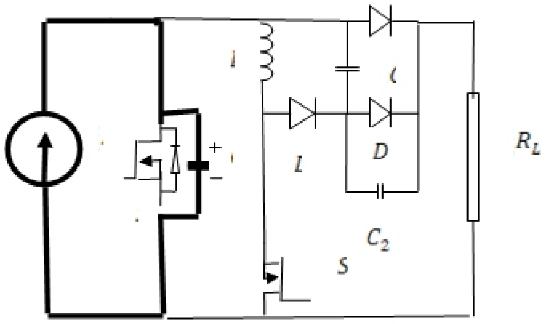
Mode-3



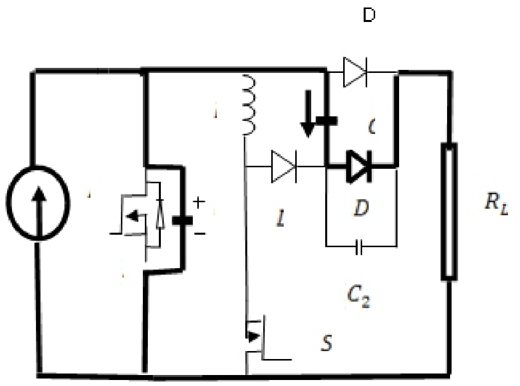
Mode-4



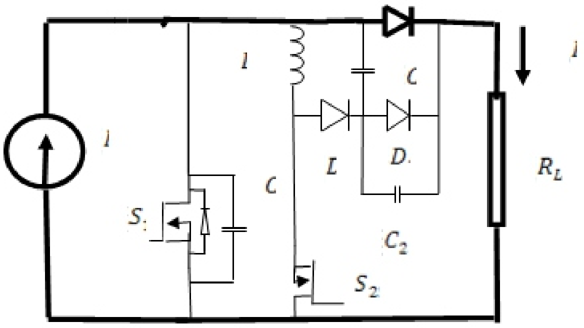
Mode-5



Mode-6



Mode-7



Mode-8

Mode 1 [to-t1]:

Prior to t = to, the main switch S1 and the auxiliary switch S2 are turned-off, and main diode D is conducting. At t = to, S2 is turned-on, the resonant inductor current nearly ramp up until it reaches at I, where main diode D is turned-off with soft-switching. The voltage and current expressions which govern this circuit mode are given by:

$$i_{Lr} = \frac{V_0}{L_r}t \tag{1}$$

$$V_{cr} = V_{Lr} = V_0 \tag{2}$$

Mode 2[t1 - t2]:

At t1, the resonant inductor current iLr reaches Iin, Lr, and Cr begin to resonate. The resonant capacitor voltage VCr is equal to V0 The voltage and current expressions are given by:

$$I_{Lr} = I_{in} + \frac{V_0}{Z_n}\sin\omega_{n(t-t_1)} \tag{3}$$

$$V_{cr} = V_0\cos\omega_{n(t-t_1)} \tag{4}$$

Where $Z_n = \sqrt{\frac{L_r}{C_r}}$ and

$$\omega_n = \frac{1}{\sqrt{(L_r C_r)}}$$

Mode 3 [t2 – t3]:

When VCr reaches zero the body diode DS1 of the main switch conducts providing a freewheeling way for ILr. At this instant, main switch S1 can be turned on at zero voltage. The current IDS1 is given by

$$I_{DS1} = \left[I_{in} + \frac{V_0}{Z_n} \right] - I_{in} = \frac{V_0}{Z_n} \qquad (5)$$

Mode 4 [t3 – t4]:

Auxiliary switch S2 is turned off with near ZVS at t=t3. The energy stored in the resonant inductor Lr is transferred to the capacitor C1 to C2. Then the voltage polarity of the capacitor C1 is reversed to negative. During this period, the capacitor C1 is acting as a turn-off snubber of the auxiliary switch. The energy stored in the capacitor C2 will be recycled and used to suppress the turn-off voltage spike of the main switch S1. The voltage and the current expressions of this mode are given by

$$I_{Lr} = I_{Lr}(t_2) \cos \omega_{n(t-t_3)} \qquad (6)$$

$$V_{c1} = Z_n I_{Lr}(t_2) \sin \omega_{n(t-t_3)} \qquad (7)$$

Where

$$Z_n = \sqrt{\frac{L_r}{C_1+C_2}}$$

$$\omega_n = \frac{1}{\sqrt{(L_r(c_1+c_2))}}$$

Mode 5 [t4 – t5]:

During this period, the inductor L is the converter was designed to operate in a continuous charged the input dc voltage while the main switch , continues to be turned-on and the auxiliary switch S, is turned off.

Mode 6 [t5 –t6]:

At t 5 , the main switch s, begins to turn-off, the inductor L charges the resonant capacitor and the voltage across the capacitor increases. The current in equals zero and the voltage across is given by

$$V_{Cr} = \frac{I_{in}}{C_r} t = \frac{I_l}{C_r} t \qquad (8)$$

Mode 7 [t6 –t7]:

When the increasing voltage across C_r is greater than ($V_0 +$ V_{c1}), the capacitor $c_1$begins to discharge through the diode D_2 .This discharge of c_1, can slow down the rising voltage slope of the rising voltage across C_r, or the main switch S_1. The voltage across C_r is given by:

$$V_{Cr} = (V_0 + V_{c1}) \qquad (9)$$

Mode 8 (t7-t8):

This stage begins when the diode D is turned-on under ZVS. The operation of the circuit at this stage is identical to the normal turned off operation Of a PWM boost converter. It ends at the moment that , is turned on to begin a new switching cycle.

A. Switching Frequency (f_g)

Determination of switching frequency plays a most important role in the design of the power converter. There are many factors influence its proper selection. However, the determination of switching frequency is still a compromise between theoretical analysis and practical implementation.

B. Minimum Duty Ratio (Dmin)

The minimum duty ratio occurs when the input voltage gets the maximum and this is equal to :

$$D_{min} = \frac{V_0 - V_{in(max)}}{V_0} \qquad (10)$$

C. Primary Input Inductor (L)

The primary input inductor must satisfy a constraint governing to meet the requirement on maxi" allowable ripple current. The input inductor (L) is given by

$$L = \frac{V_{in(min)} D_{min} T_s}{\Delta I_{in}} \qquad (11)$$

where $\nabla I_{in}$is the input ripple current and

$$T_s = \frac{1}{f_s}$$

D. output Capacitor (c_o)

The selection of the output capacitor depends on the output ripple voltage (ΔV_0) as follows:

$$C_0 \geq \frac{P_0}{2\omega_s V_0 \Delta V_0} \qquad (12)$$

Where $\omega_s = 2\pi f_{line}$

E. Delay Time (T_D)

The on-time of auxiliary switch (S_2) must be shorter than one tenth of the switching period.

F. Resonant Capacitor (C_r)

The resonant capacitor (C_r) can be expressed as:

$$C_r = \frac{(a-1)^{4} I_{in(max)} T_D}{V_0 [1+\frac{\pi}{2}(a-1)]} \qquad (13)$$

G. Resonant Inductor (L_r)

The resonant inductor is given by

$$L_r = \frac{V_0 T_D}{I_{in(max)}[1+\frac{\pi}{2}(a-1)]} \qquad (14)$$

H. Additional Capacitor (C1, C2)

To guarantee a soft-switching of the auxiliary switch the required capacitance C1 should be selected according to the expression:

$$C_1 < \frac{L_r[I_{in(min)}+V_0\sqrt{\frac{L_r}{C_r}}]^2}{V_0^2} - C2 \qquad (15)$$

Where C1 > C2

The following specifications of ZVT Boost converter is illustrated below.

Input ac voltage V_{in} =230 volt (rms)
Output dc voltage V_0 =400 volt
Output power $P_0 = 500\ watt$
Switching frequency f_s=10 khz
Estimated efficiency=98 %

Components used in the converter is listed as:

Boost inductor L=33.7mH
Resonant inductor $L_r = 80\mu H$
Capacitor C1=4.7nF
Capacitor C2=1.5nF
Output capacitor C_0=470 µF
Resistive load R=500 Ω

IV. SIMULATION RESULTS:

1. Switching of auxiliary switch:

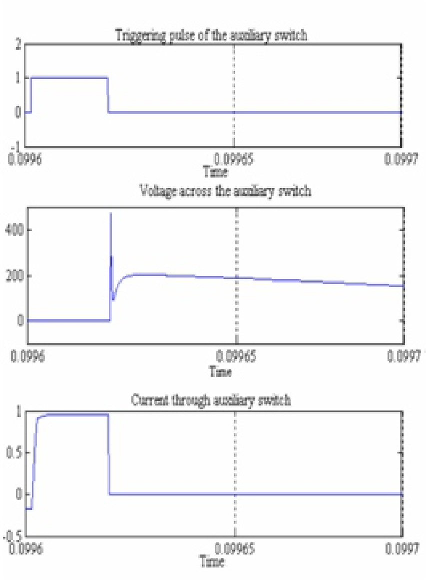


Fig-4 Triggering pulse of the auxiliary switch, the voltage and current across it in the proposed converter during one switching cycle.

2. Swithing of main switch:

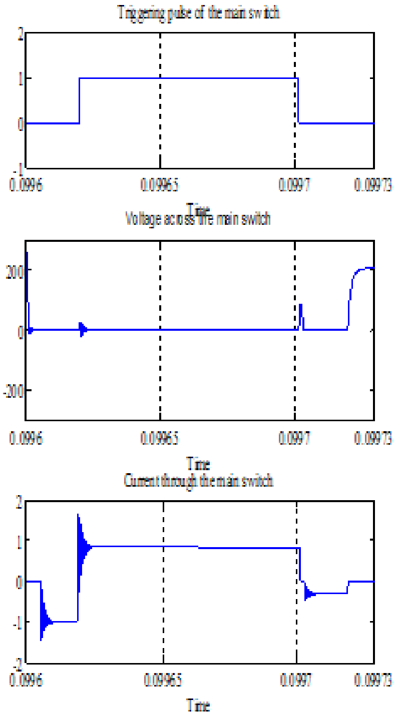


Fig-5 Triggering pulse of the main switch, the voltage across it and the current through the main switch present in proposed converter during one switching cycle.

Figure.4 shows the wave forms of auxiliary Switch .we can clearly observe the zero voltage switching of the auxiliary switch in the ZVT converter. Figure.5 shows the waveforms of main switchwhich turns on and turns off under zero voltage transition.

3. Voltage and current Wave forms :

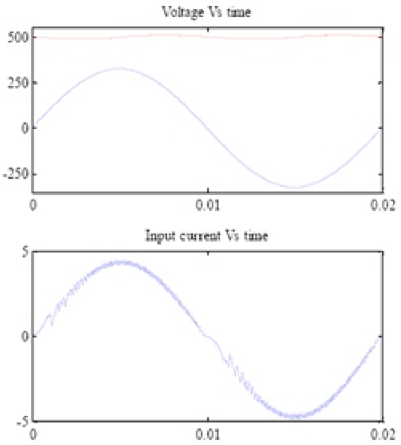


Fig-6 input voltage, output voltage (upper plot) and input current wave forms(lower plot).

4. Soft-Switching of diode:

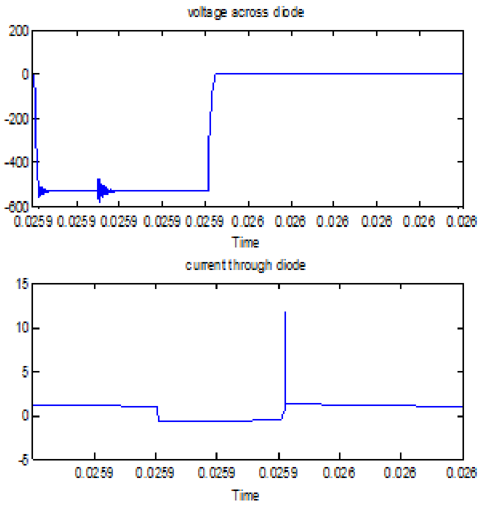


Fig-7 Current through the diode and voltage across the diode during one switching cycle.

Fig.6 shows the waveforms of input current,output voltage and input voltage.The input current is exactly in phase with input voltage and it is nearly sinusoidal. Fig.7 shows soft-switching across diode.

V.CONCLUSION:

Table below shows comparison of different parameters with and without soft-switching:

Parameters	Without ZVT	With ZVT
THD	0.0669	0.0722
KP	0.9978	0.9974
cosΦ	1.0000	1.0000
Power factor	0.9977	0.9974
Pac	575.4819W	510.2205W
Pdc	499.7793W	499.8873W
Efficiency	86.84%	98 %

The switching losses of the auxiliary switch are minimized by using an additional capacitor applied to the auxiliary switch. Besides the main switch ZVS turned-on and turned-off and the auxiliary switch turned-on and turned-off near ZVS. Since the active switch is turned on and turned-off softly, the switching losses are reduced and the higher efficiency of the system is achieved. The results have been compared with the PFC stage with hard switching.

VI. REFERENCES:

[1]B. K.. Bose, "Power electronics- A technology review", in proc IEEE Power Eletron , Spec. Conf1992, pp. 1303-1334.

[2] H. Akagi, 'Trends in active power lin e conditioners" , IEEE Trans Power Electron., vol. 9, pp. 263-268, May 1994.

[3] W. Meacham, "Power electronics in the 1990's; in Proc. IEEE IECON'90, 1990,pp 839-843.

[4]P. Gegner and C. Q. Lee, "Zero –voltage - transition converters using an inductor feedback technique," in Proc, IEEE PESC'94, 1994, pp. 590-596.

[5] G. Hua, C. S. Leu, Y. Jiang, and P.C. Lee, "Novel zero-Voltage-Transition PWM converter,"EEE Trans. Power Electron., vol. 9,pp. 213-219,Mar.1, 1994.

[6] T.W.Kim,H.S.Kim,and H.W.Ahn,"An improved ZVT-PWM PWM boost converter: in Pmc. IEEE Power Electron. Spec. Con$, ZW0,pp. 615- 619.

[7]J.P Noon,'A 250 khz ,500 w power factor correction circuit employing zero voltage transitions',in proc.Unitrode Power Supply Design Sem 1000,1994,pp.1-1-1-16.

[8] Wannian Huang, Gerry Moschopoulos " A NewFamily of Zero-Voltage-Transition PWM Converters With Dual Active Auxiliary Circuits", IEEE Transactions on Power Electronics, VOL. 21, NO. 2, March 2006.