ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 6, June 2015

A Transformerless Soft Switching Resonant PWM (RPWM) Boost Converter for High Step up Applications

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ABSTRACT: This paper proposes the transformerless soft switched resonant pulse width modulation (RPWM) dc-dc converter with high voltage gain for high power applications. The proposed converter achieves turn on the switches in continuous conduction mode (CCM) with zero voltage switching (ZVS) and reverse recovery losses are negligible due to zero current switching (ZCS) turn of the diodes. The efficiency is increase due to auxiliary resonant components (L_r, C_r).This auxiliary circuit not only increases the output voltage but also zero voltage switching turn on of the switches is achieved. In case of hard switching there are various problems such as conduction loss, high voltage stress across the switches due to this efficiency is degraded but all these problems are reduced by using soft switching operation (ZVZCS).Proposed converter achieves high voltage gain and low duty loss which reduces the diode reverse recovery problems.

KEYWORDS Voltage gain, zero voltage zero current switching (ZVZCS), reverse recovery loss

I.INTRODUCTION

Recently the growth of battery powered applications are increasing for the demand of high step up dc-dc converters. A dc-dc boost converter are used because of high efficiency and easy circuitry. The solar array, fuel array etc. All these applications has low output voltage. So foe these applications high step up dc-dc boost converter with high voltage gain is necessary and boost converter is able to provide high voltage gain. But general boost converter operates at extreme high duty cycle and hard switching operation, increases the diode reverse recovery problems. So in order to compensate all these drawbacks a new Resonant Pulse Width Modulation Technique (RPWM) converter is designed. This proposed converter increases the output voltage and also reduces the diode reverse recovery problems. Early hard switching technique is also used but it increases the voltage stress across the switches reduces the efficiency. So for this purpose soft switching technique is used. This technique consist zero voltage and zero current switching (ZVZCS) operation. This technique reduces the losses across switches and increases the circuit performance.

In recent years non isolation high step up dc-dc converters are proposed. They used coupled inductors to reduce stress across switches and extends the voltage gain. But in this proposed RPWM converter technique, it uses the resonant component L_2, C_1 in auxiliary circuit that increases voltage gain, output voltage and reduces voltage stress across the switches, duty loss. The performances of proposed converter are as follows-

1) Efficiency increases due to resonant components in auxiliary circuits
2) The voltage stresses across the switches are very low
3) Without extremely high duty cycle the high voltage gain is achieved
4) Due to soft switching operation diode reverse recovery problems are reduced
5) The voltage step ratio is achieved due to reduced duty cycle

The capacitance in auxiliary circuit is reduced by 20 fold. Also by using soft switching operation switching losses are greatly reduced and duty cycle reduced resulting increase in output voltage. Experimental prototype hardware along with results are provided in this paper.

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II.RELATED WORK

Dong Cao [1] had presented, input capacitor power losses are minimized using multiphase dc dc converter. This paper proposes, high power density dc to dc converter is made for high voltage gain applications. R.J. Wai [2] had presented the converter can achieve high voltage gain with a single inductor and also deals a problem of leakage inductor and transformer demagnetisation for coupled inductor based converter. Yohan Park etc, [3] had presented by using resonant component in auxiliary circuit high voltage gain can be achieved and also capacitance is reduced by 20 fold. Hyun-Lark Do [4] the use of transformer leakage inductance with controlling changing rate of current reverse recovery characteristics of output diodes are greatly improved. The high voltage gain provided by ZVS half bridge converter. Hyun-Lark Do, etc. [5] had presented by controlling current changing rates of diode with use of coupled inductor reverse recovery problems are removed and also without using high duty cycle the converter provides high output voltage. S. Park, etc. [6] switches are turned on in continuous conduction mode and negligible reverse recovery loss is achieved due to zero current switch turn off of diodes. As compared to conventional boost converter voltage conversion ratio is doubled. Qun Zhao [7] presented, few converters provides high voltage gain but they operates with high duty cycle but converters with coupled winding and diode perform better. Marcos Prudente, etc. [8] had presented to obtain high voltage gain voltage multiplier technique is applied to dc dc converter and diode reverse recovery problems are minimized.

III.PROPOSED SOFT SWITCHED RPWM CONVERTER

Fig 1 shows the proposed RPWM converter for high step up applications. It consists of resonant components L_2, C_1 in auxiliary circuit along with two diodes D_1 and D_2 which acts as resonant PWM converter. By using these two components reduces the switch turn off current. In order to regulate output voltage switch S_1 and S_2 are operates with asymmetrical complementary. As the auxiliary circuit consist of C_1, L_2 and Two diodes D_1, D_2.

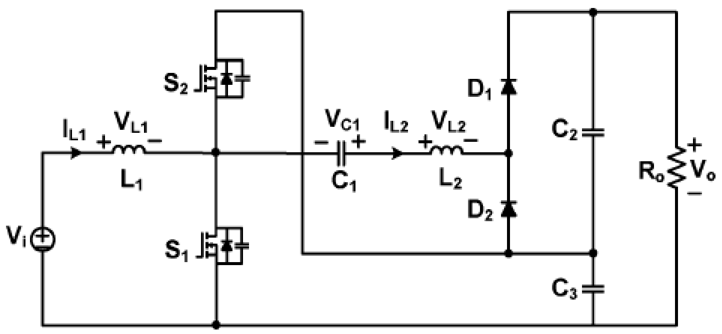

Fig. 1 Proposed RPWM Converter

IV.OPERATING MODES OF RPWM CONVERTER

Operation of proposed converter is divided into five groups Are as follows:

Mode 1

Fig. 2 (a)Shows when auxiliary inductor current i_{L2} reduces to zero and diode D_2 is turned on then this mode starts. Through the lower switch S_1 both auxiliary inductor current iL2 and Input inductor current i_{L1} flows.

Mode 2

When diode S_2 is turned on and switch S1is turned off then this mode starts. During this mode, gate signal for switch S_2 is applied and S_2 is turned on under Zero voltage condition (ZVS) condition. Both auxiliary inductor current i_{L2} and input inductor current i_{L1} reducing when D_1 conducts and i_{L2} changes its direction then this mode ends.

Mode 3

When switch current i_{S2} reverses its direction of flow then this mode ends.

Mode 4

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Auxiliary and input inductor current i_{L2} and i_{L1} respectively are flowing during this mode.

Mode 5

When diode of switch S_1 is turned on and switch S_2 is turned off then this mode begins. Under zero voltage switching (ZVS) condition gate signal for switch S_1 is applied during this mode.

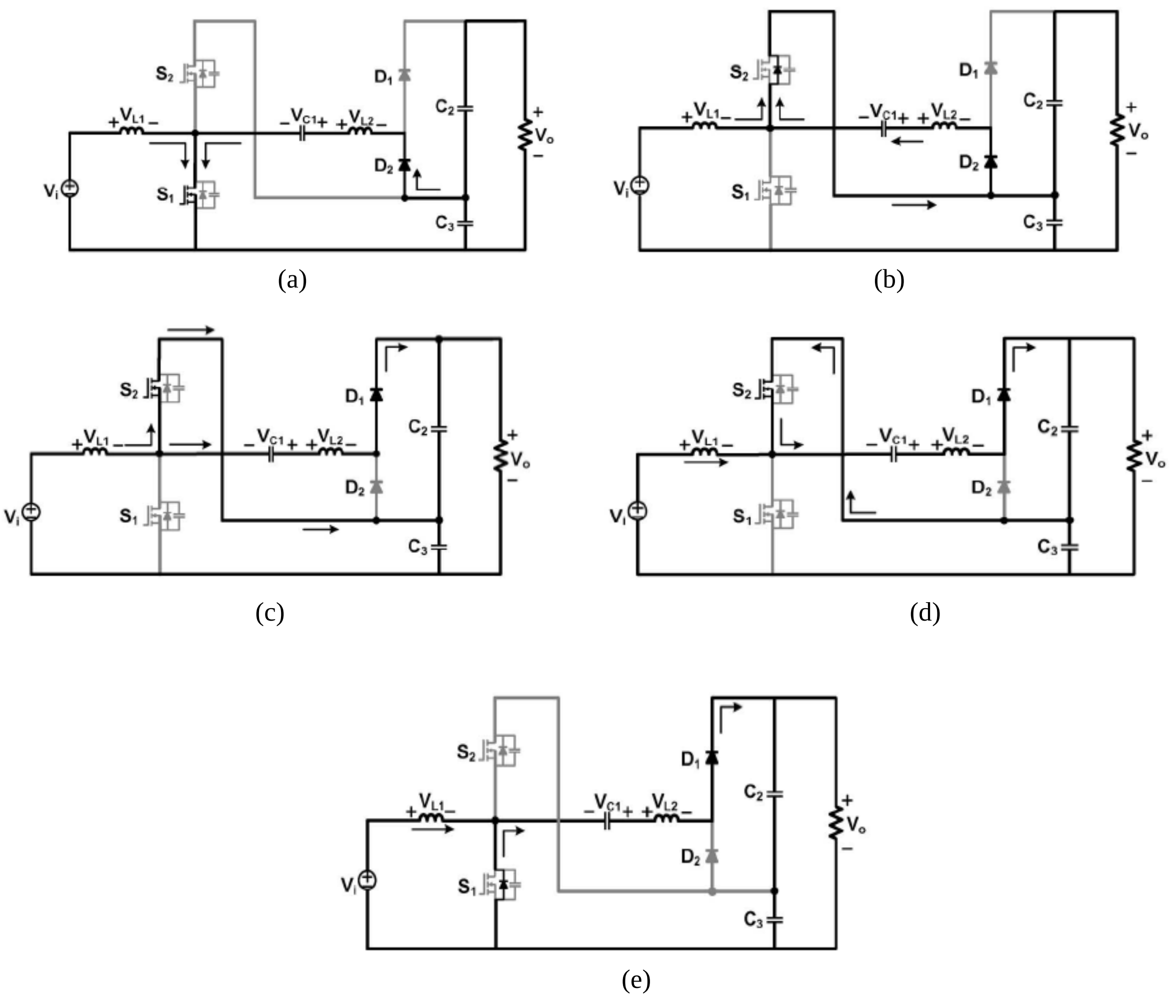

Fig. 2 Operating Modes of Proposed RPWM Converter

V.SWITCHING TECHNIQUES

There are two types of switching techniques are present area s follows,

1) Hard switching
2) Soft switching

1) Hard switching

In hard switching power losses are higher on power semiconductor devices i.e. Power loss =f * Energy loss at each switching. A hard switching refers to stressful switching on power electronics devices. A switching trajectory of power switches is shown in fig.3

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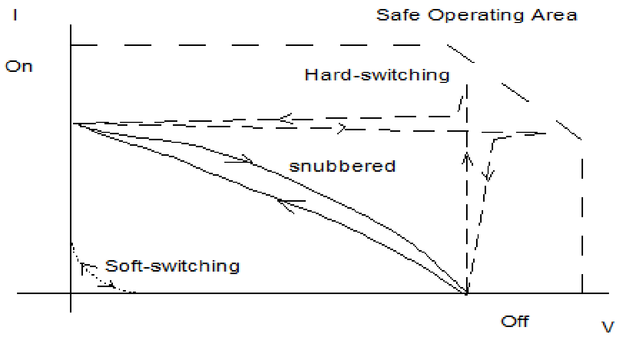
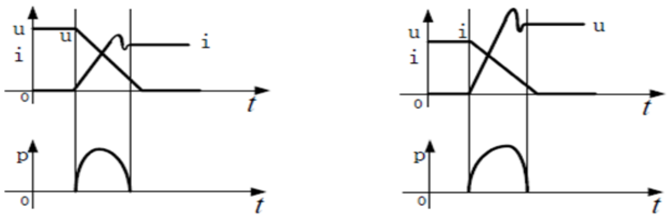


Fig. 3 Switching trajectory of power switches

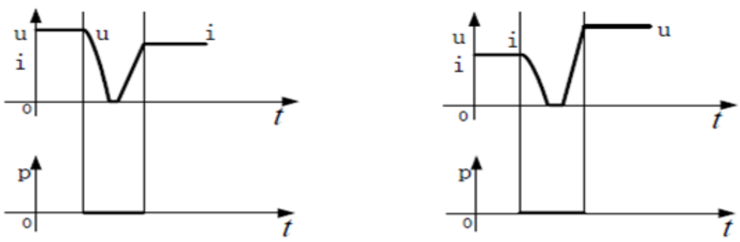
A power device has to withstand high voltage and current simultaneously, during turn on and turn off processes resulting the high switching losses and stress. Fig.4 shows the power semiconductor device hard switching.



a) Turning on b) Turning off

Fig.4 Power semiconductor device hard switching

In order to overcome above drawbacks of hard switching, Soft switching technique is used in proposed RPWM converter. Fig.5 shows the power semiconductor device soft switching.



a) Turning on b) Turning off

Fig.5 Power semiconductor device soft switching

The soft switching converter has some switching waveforms are similar to conventional PWM converter without any transient spikes. An effective solution to suppress Electromagnetic interference (EMI) is provided by Soft switching converters.

VI. COMPARISON BETWEEN ZVS AND ZCS

As Zero voltage and zero current switching comparison shows the losses can be minimised during turn on and turn off. At turn off ZCS can eliminate the switching losses and at turn on reduces the switching losses..ZVS eliminates the

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capacitive turn on loss and suitable for high frequency operation. The ZCS is effective particularly in reducing the switching loss for power devices such as IGBT For both ZCS and ZVS, by variable frequency control output regulation of the resonant converters can be achieved. The ZCS operates with constant on time control while ZVS operates with constant off time control. There are two types of resonant switches are as follows,

A) Zero Voltage (ZV) Resonant switch-

For achieving zero voltage switching, a capacitor Cr is connected in parallel with Switch S as shown in Fig.6. The capacitor Cr can oscillate in both positive and negative half cycle if switch S is unidirectional switch. Thus a resonant switch can operate in full wave mode. The resonant capacitor voltage is clamped by the diode to zero during negative half cycle when diode is connected in anti parallel with the unidirectional switch. The main objective of ZV Switch to use the resonant circuit shape the switch waveform to create zero voltage condition for the switch to turn on.

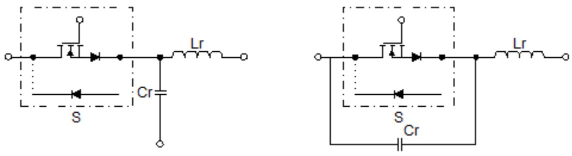

Fig.6 Zero Voltage (ZV) Resonant Switch

B) Zero Current (ZC) Resonant switch-

For achieving zero current switching, an inductor L_r is connected in series with a power switch S as shown in fig.7. The switch current is allowed to resonant in positive half cycle only when the switch S is bidirectional switch. If the diode is connected anti-parallel with the unidirectional switch, the switch current can flow in both directions, in this case resonant switch can operate in full wave mode. The aim of this resonant switch is to shape the switch current waveform during conduction time in order to create the zero current condition for the switch to turn off.

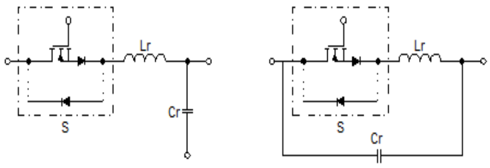

Fig.7 Zero Current (ZC) Resonant Switch

VII. SIMULATION RESULTS

A simulated result of Lower switch current (is_L) and upper switch current (is_U) is as shown below.

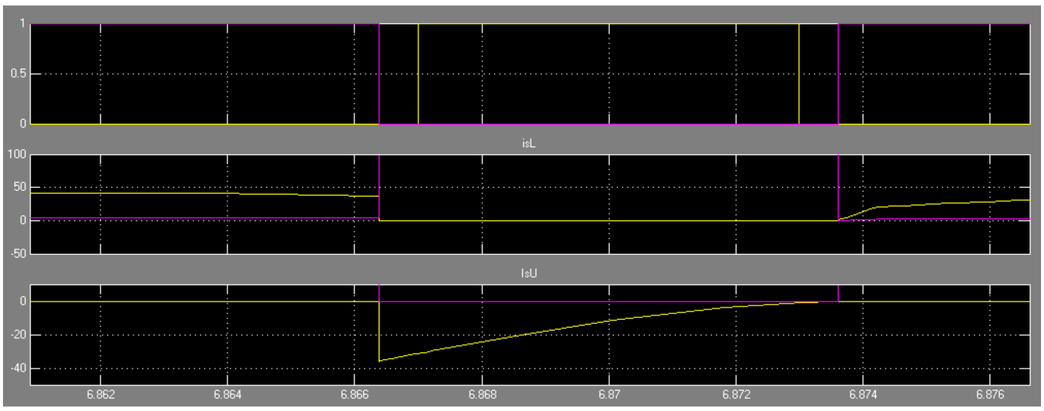

Fig 6 Waveforms of upper and lower switch current (i_{sL} and i_{sL})

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VIII.CONCLUSION

The proposed Resonant pulse width modulation (RPWM) converter is suitable for high power applications. The proposed converter has following features

1) Reduces the voltage ratings of components due to small operating duty cycle.

2) High voltage gain is achieved due to use of resonance components in the auxiliary circuits.

3) Also reduces the conduction loss, due to low voltage stress across the switches

4) By reducing the auxiliary capacitor by $1/20^{th}$ fold which reduces volume and size of proposed converter

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