International Journal of Advanced and Innovative Research (2278-7844) / # 26 / Volume 4 Issue 1

EFFICIENT ZVS OPERATION OF BOOST CONVERTER WITH LOAD VARIATION

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Abstract: **A new kind of step-up converter is hereby presented. It consists of a diode, an auxiliary switch, and a coupled winding to the boost inductor as in the conventional boost converter. By transferring the boost-inductor current to the coupled winding in a time of very short period, the negatively built-up I_{po} current of the boost winding guarantees the zero-voltage switching (ZVS) operation of the boost switch in all the load conditions. Further, since the negatively built-up I_{po} current is minimized after the zero voltage of the boost switch is achieved, the unnecessary current build-up and the conduction loss are minimized. Therefore, efficient ZVS operation with load variation is achieved and the operation principle, design and simulation results of the boost converter are presented.**

Index terms: **Boost Converter, Power Electronics, ZVS-Zero Voltage Switching.**

NOMENCLATURE:

L_r	Leakage inductance
L_b	Boost winding inductance
S_x	Auxiliary switch
S_b	Boost switch
C_s	Switch capacitance
C_o	Output capacitance
I_{Lr}	Leakage inductor current
I_{Lb}	Boost winding current
I_o	Output current
I_x	Coupled winding current
I_{Dx}	Diode Dx current
I_{sx}	Switch Sx current
I_{sb}	Switch Sb current
I_{Db}	Diode Db current
V_{in}	DC Input voltage
V_o	Output voltage
V_{Lr}	Leakage inductor voltage
V_{Lb}	Boost winding voltage
V_{Db}	Diode Db voltage
n	Duty ratio

I. INTRODUCTION

The step-up power-conversion technique is using in power sources (microprocessors, battery chargers, LED drivers, solar-power regulators) and for these applications the high power density, high efficiency, and low noise is required in power converter.

- Since magnetic and capacitive elements are in small sizes in high frequencies the high power density can be achieved by increasing switching frequency.
- However, by increasing switching frequency switching power dissipation increases due to the hard switching of the power switch in conventional converters and also increases switching noise.
- Therefore, the soft-switching technique is suitable in modern switching converters, to achieve high power density with high efficiency and low noise. The choice of the soft-switching technique depends on the type of switching device.
- For this, the zero-voltage switching (ZVS) technique is more preferable in MOSFET switches since it eliminates the capacitive loss of a power switch during the turn-on transition.

The circuit diagram and operation of step-up converter with efficient ZVS operation is from [1]. Many types of ZVS converters have been presented like the resonant type, active resonant tank type, by coupled-inductor converter but these converters well utilized the parasitic components of the power switch with additional resonant components which induce higher voltage and current stresses, conduction loss in these converters.

By resonating the current between the interleaved inductors and the parasitic capacitors of the switches ZVS is achieved in [2] which conduction loss in the auxiliary inductor occurs all the time, which reduces the efficiency of the converter since the reduced current is delivered to output during the on time of the auxiliary switch, this converter increases the dc value of the boost inductor and therefore increases its conduction loss. The other ZVS converters presented in [3], [4], [5] which have their own good characteristics and drawbacks, since the large number of components, increased device stress, circulating current, complex structure, and so on.

In this project, a new kind of step-up converter is hereby presented. It consists of a diode, an auxiliary switch, and a coupled winding to the boost inductor as in the conventional boost converter. By transferring the boost-inductor current to the coupled winding in a time of very short period, the negatively built-up I_{po} current of the boost winding guarantees the zero-voltage switching (ZVS) operation of the boost switch in all the load conditions.

Further, since the negatively built-up I_{po} current is minimized after the zero voltage of the boost switch is achieved, the unnecessary current build-up and the conduction loss are minimized. Therefore, efficient ZVS operation with load variation is achieved and the operation principle, design and simulation results of the boost converter are presented in this project.

II. OPERATIONAL PRINCIPLE

The circuit of the proposed converter is based on the conventional boost converter. However, to achieve the ZVS operation of the power switch during the turn-on transition, the proposed converter uses an additional switch S_x, a diode D_x, and a coupled winding on the original boost inductor, as shown in Fig. 1.

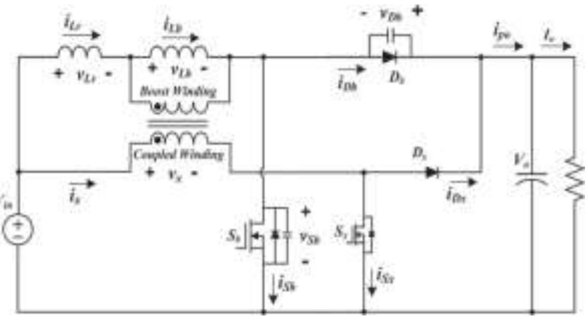


Fig.1. Circuit diagram of boost converter.

Fig. 2 shows the gating pulses for the switches and key operation waveforms of the proposed boost converter in a steady state. In order to simplify the analysis of the steady-state operation, all parasitic components except for those specified in Fig. 1 are neglected. It is assumed that the output capacitors of switch S_b and diode D_b have the same capacitance as C_s for simple analysis. Moreover, the output current Io, output voltage V_o, and input voltage V_{in} are assumed constant during the switching cycle.

In Mode 1 (t_0–t_1) begins when the current i_{po} reaches the boost-inductor current i_{Lb}. Since boost switch S_b is in the ON state, the difference between the input voltage V_{in} and output voltage V_o is applied in boost inductor L_b with the assumption of $L_b >> L_r$. V_{SX} and V_{DX} are positive and the output diode of switch S_x and diode D_x

remains in the OFF state since n >1 and V_{in}> V_o,. This mode ends when switch S_b is turned off.

In Mode 2 (t_1–t_2) diode D_b is in the ON state and the boost-inductor voltage $v_{Lb} = -V_o$. V_{SX} and V_{DX} are positive and the output diode of switch S_x and diode D_x remain in the OFF state since n >1 and V_{in}> V_o,. This mode ends when switch $S_x$is turned on.

In Mode 3 (t_2–t_3) switch $S_x$is turned on, the coupled winding voltage v_x becomes V_{in}– V_o. Since n >1, the leakage inductor voltage v_{Lr} has a large negative value. Then, the leakage inductor current i_{Lr} decreases to zero since leakage inductor L_r has a very small value. The time interval of this mode is short and the current difference between i_{Lb} and i_{po} is transferred to the coupled winding and flows through switch S_x and the output capacitor, as shown by the powering current i_{Po} in Fig. 2, the transferred current is not circulating but powering to output which does not induce the additional conduction losses, increase the dc value of the boost-inductor current. The voltage of diode D_x and switches S_b is V_{in} during this mode. This mode ends when the current i_{po} reaches zero.

The Mode 4 (t_3–t_4) has a very short period compared with Mode 3. After the current i_{po} reaches zero, it flows in the negative direction and to the charge and discharge output capacitors of diode D_b and the output capacitor of switch S_b in a resonant manner. The voltage across the boost inductor remains the same since switch S_x is still in the ON state. The voltage across the leakage inductor is always negative during t_3–t_4, which forces the current Ipo to flow in the negative direction always in this mode.

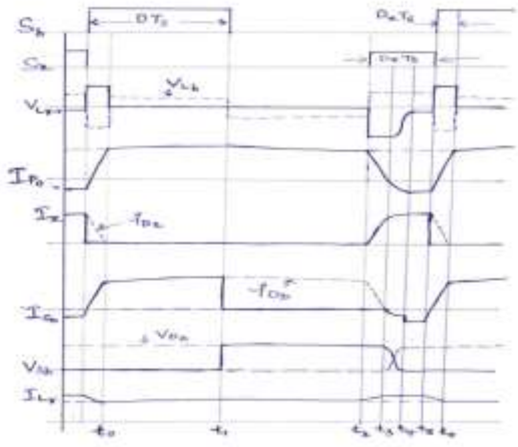


Fig.2. Mode analysis of boost converter.

Therefore, the ZVS of switch S_b is always achieved only if switch S_x is not turned off before v_{Sb} reaches zero since the leakage inductor L_r and output capacitor C_s have very small values and the time interval within which switch voltage v_{Sb} decreases from V_{in} to zero is very short, switch S_x is never turned-off before v_{Sb} reaches zero. Therefore, the ZVS of switch S_b is already guaranteed.

Mode 5(t_4–t_5) begins when v_{Sb} reaches zero voltage, the output diode of switch S_b is turned on and maintained in its ON state during this mode since the voltage of the leakage inductor v_{Lr} remains negative which maintains that the current Ipo still flows in the negative direction. Since n>1, the voltage across the leakage inductor v_{Lr} has a very small negative value and the current i_{po} increases negatively in a very slow slope, as shown in Fig. 2 during t_4–t_5. Therefore, the unnecessary current increment after the zero voltage of the power switch is minimized. This is an advantage of the boost converter since minimizes the unnecessary current increment after the zero voltage of switch $S_b$is achieved. Mode 5 ends when switch S_x is turned off.

In Mode 6 (t_5–t_0) as switch $S_x$is turned off, switch S_b is turned on with a zero-voltage condition since the output diode Db of switch S_b is in ON state and the transferred current to the coupled winding flows through diode D_x. The voltage across boost inductor v_{Lb} and leakage inductor v_{Lr} is large positive voltage and the current i_{po} increases rapidly up to the boost-inductor current i_{Lb}(t0). This mode ends when the current i_{po} reaches the boost-inductor current i_{Lb}.

III. DESIGN AND SIMULATION RESULTS:

To validate the characteristics of boost converter, the converter is designed and tested with the following specifications in Table-I.

Table-I

PARAMETERS	RATINGS
Input voltage V_{in}	100 V dc
Output voltage V_o	250 V
Max.output power P_o.(max)	8.75 KW
Switching frequency f_s	125 kHz
Coupled winding turn ratio n	1.5
Leakage inductor L_r	4.2 μH
Buck inductor L_b	250.66 μH
Capacitance C_o	0.1931 μF
Capacitance C_s	0.1931 nF
Resistance R_o	8 Ω

The following shows the simulation circuit diagram and output waveforms of boost converter.

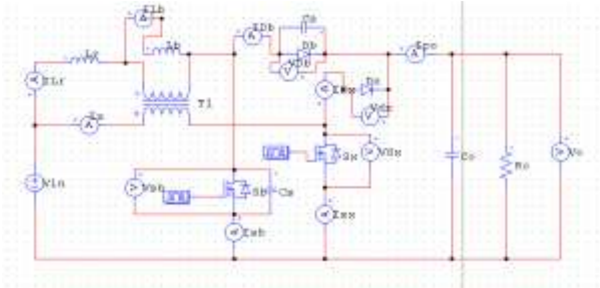
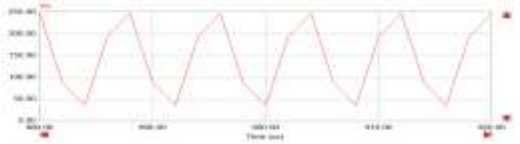
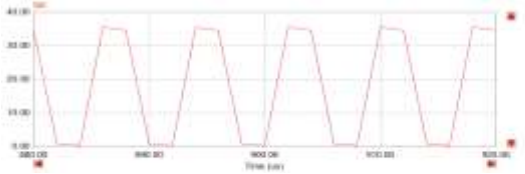


Fig.4.1: Circuit diagram of boost converter.

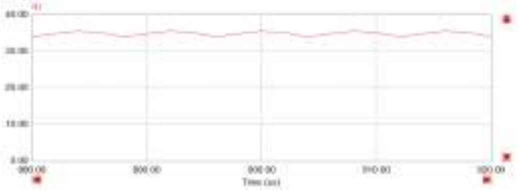
Output voltage (V_O):



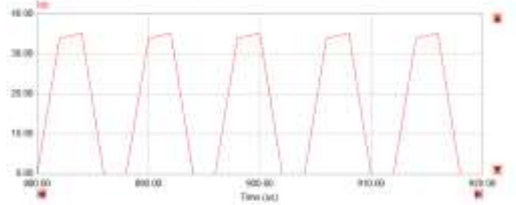
Output current (I_{po}):



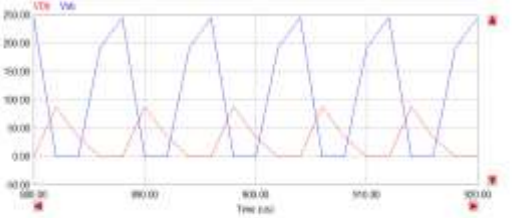
Output leakage inductor current (I_{Lr}):



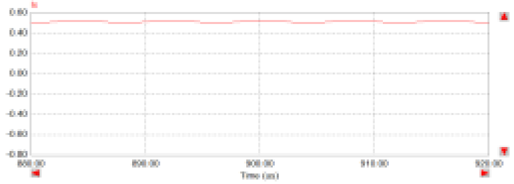
Output boost switch current (I_{Sb}):



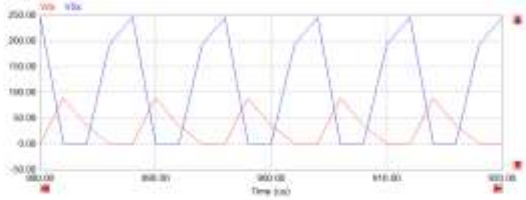
Output boosts switch S_b and diode D_b voltages:



Output current (I_x):



Output switch S_x and diode D_x voltages:



IV.CONCLUSION:

This project has operational principle, analysis, design and simulation results of the boost converter with a coupled winding, shows the efficient ZVS operation of the power switch from R-load condition. Since the boost-inductor current is transferred to the coupled winding in a very short period when the auxiliary switch is in the ON state, the negatively built-up current Ipo of the boost winding guarantees the ZVS operation of the boost switch. Furthermore, since the negatively built up current Ipo is minimized after the zero voltage of the boost switch is achieved, the unnecessary current and the conduction loss is minimized. The basic operational principle has been presented in the mode analysis and key characteristics, such as the ZVS operation and the dc values have also presented and the simulation results and characteristics of the boost converter observed in R-load condition.

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