Analysis of Interleaved Flyback Converter with Voltage Multiplier Circuit

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Abstract— **The recent growth of battery powered applications and low voltage storage elements are increasing the demand of efficient step-up dc–dc converters. Typical applications are embedded systems, renewable energy systems, fuel cells, mobility applications and uninterrupted power supply (UPS). These applications demand high step-up static gain, high efficiency and reduced weight, volume and cost. Usually, the conventional boost converter cannot realize high voltage gain even with high duty cycle due to the parasitic parameters limitation.**

Keywords— **Interleaved flyback converter, passive absorption circuit, voltage multiplier, high voltage gain.**

I. INTRODUCTION

A lot of high step-up converters are developed which are mainly composed by coupled inductor, switched capacitor and cascaded methods. In order to realize soft switching performance and recycle leakage energy, active clamp circuits are added. However, active clamp circuit needs more MOSFETs and complicated control method.

Furthermore, active clamp circuits rarely contribute to the voltage gain, and the dead time between main switch and clamp switch causes duty loss. Simple passive clamp circuits are also developed in many high step-up topologies, but those circuits have limited contribution to output voltage gain. Therefore it is important to develop a general passive clamp circuit which can clamp spike of MOSFETs, recycle the energy of leakage inductor to output and also have high voltage step-up ability. Non-isolated dc–dc converters as the classical boost, can provide high step-up voltage gain, but with the penalty of high voltage and current stress, high duty-cycle operation and limited dynamic response. The diode reverse recovery current can reduce the efficiency when operating with high current and voltage levels. There are some non-isolated dc–dc converters operating with high static gain, as the quadratic boost converter, but additional inductors and filter capacitors must be used and the switch voltage is high. The output voltage generated by the photovoltaic arrays, the fuel stacks, the super capacitors or the battery sources is relatively low, even lower than 48V. It should be boosted to a high voltage, such as 380V for the full bridge inverter or 760V for the half bridge inverter in the 220V AC grid-connected power system. How to realize high step-up DC/DC converters with high performance is one of the main issues in the renewable energy applications. The limitations of the conventional flyback converter are analyzed and the conceptual solution for high step-up conversion is proposed in this paper.

II. PASSIVE ABSORPTION CIRCUIT

Usually, the conventional boost converter cannot realize high voltage gain even with high duty cycle due to the parasitic parameters limitation. Thus a lot of high step-up converters are developed which are mainly composed by coupled inductor, switched capacitor and cascaded methods. In order to realize soft switching performance and recycle leakage energy, active clamp circuits are added. However, active clamp circuit needs more MOSFETs and complicated control method. Furthermore, active clamp circuits rarely contribute to the voltage gain, and the dead time between main switch and clamp switch causes duty loss Simple passive clamp circuits are also developed in many high Step - up topologies, but those circuits have limited contribution to output voltage gain. Therefore it is important to develop a general passive clamp circuit which can clamp spike of MOSFETs, recycle the energy of leakage inductor to output and also have high voltage step-up ability. The passive absorption clamp circuit which is composed by two diodes and one capacitor. The passive absorption clamp circuits are employed to clamp main switch voltage spike and transfer the leakage energy to output.

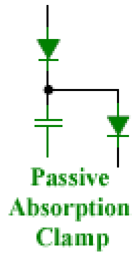

Fig- 1 passive clamp circuit

III. FLYBACK CONVERTER WITH PASSIVE ABSORPTION CIRCUIT

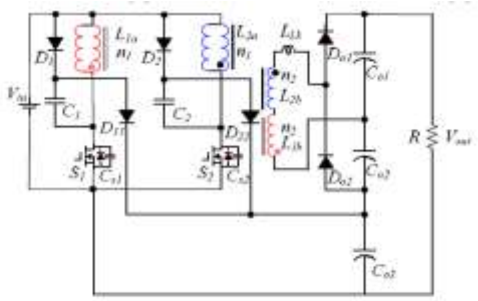

Fig- 2 Flyback converter with passive absorption circuit

The passive absorption clamp circuit consists of two diodes and one capacitor. Fig- 2 shows flyback forward dc-dc converter with passive absorption circuit. Passive absorption clamp circuits are employed to clamp main switch voltage spike and transfer the leakage energy to output. There are two coupled inductors in the proposed high step-up converter, which are named L1 and L2. The primary inductors L1p and L2p with np turns are coupled with secondary inductors L1s and L2s with ns turns. The coupling references are remarked as "*" and ".". The secondary windings of L1 and L2 are in series to achieve boost-type conversion. Llk is the summation of the leakage inductance of the two coupled inductors. D1, D11, D2 and D22 are rectifier diodes, C1 and C2 are self-lift capacitor, Co1, Co2, Co3 are output capacitors. Do1 and Do2 are output rectifier diodes. Capacitors CS1 and CS2 are the parasitic capacitors of S1 and S2 respectively. D1, D11, and C1 compose the passive absorption clamp circuit, thus the leakage energy can be recycled and the spike voltage of main switch S1 can be clamped. Based on the influence of leakage inductance, there are two typical operation modes.

IV. SIMULATION RESULTS

Digital simulation is done by using the elements of MATLAB Simulink and the results are presented here.

A. Interleaved Flyback Converter without Passive Absorption Circuit: The Simulink diagram of flyback converter without passive absorption circuit is shown in Fig-3. The voltage and current measurement blocks are connected to measure the output voltage and output current. DC input voltage and current are shown in the Fig-4. The output current and output voltage is shown in the Fig-5.

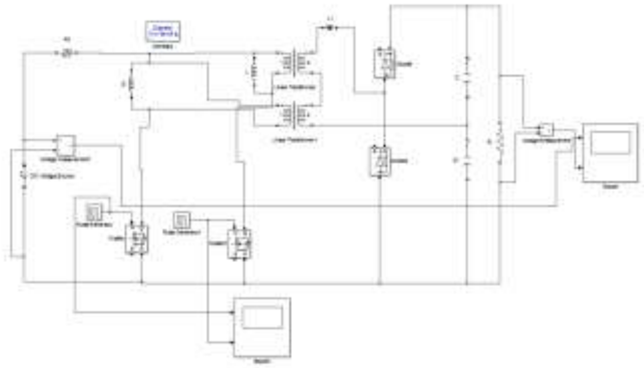

Fig 3- Circuit Diagram of interleaved flyback converter with R-load.

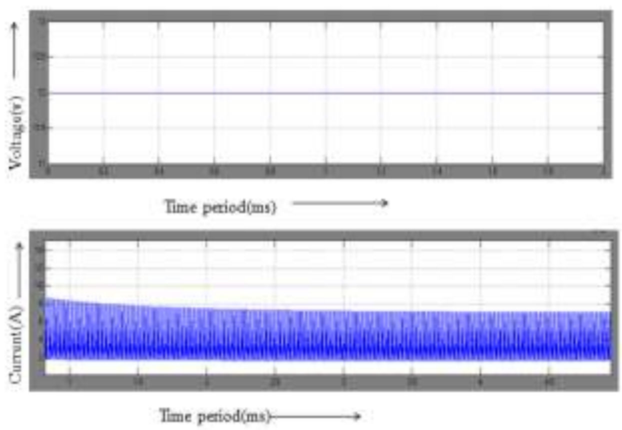

Fig-4 Input Voltage and Input current for the converter

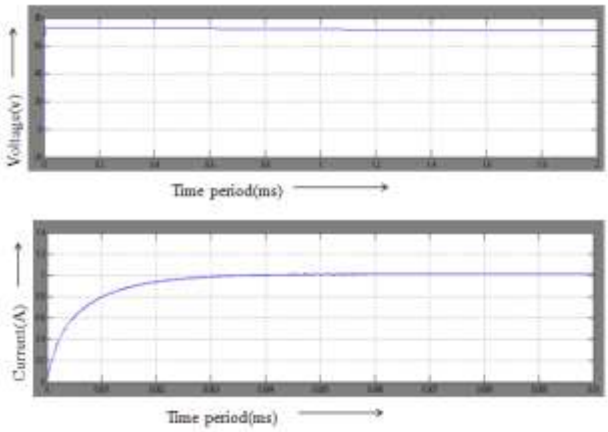

Fig-5 DC output voltage and current

B. Simulation Of High Step-Up Dc-Dc Converter With Passive Absorption Circuit: The Simulink diagram of flyback converter with passive absorption circuit is shown in Fig-6. The voltage and current measurement blocks are connected to measure the output voltage and output current. DC input voltage and current are shown in the Fig-7.Gate pulses for the switches are shown in Fig-8. The output current and output voltage is shown in the Fig-9.

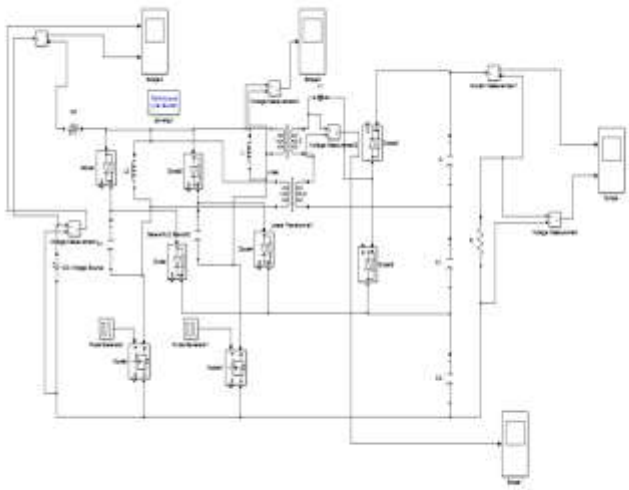

Fig-6 Circuit Diagram of interleaved flyback converter with R-load.

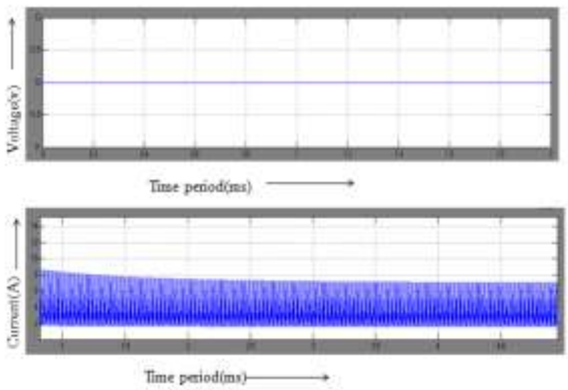

Fig-7 Input Voltage and Input current for the converter

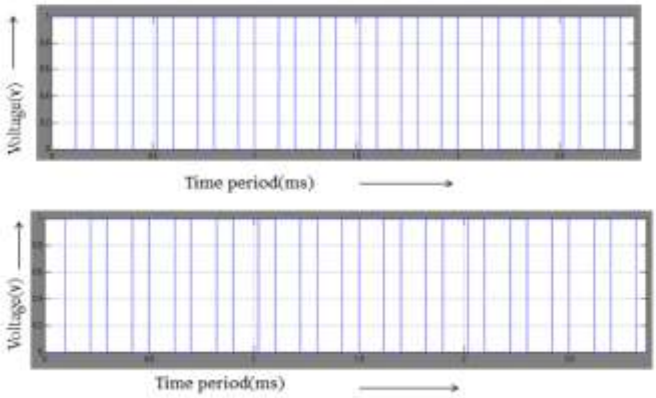

Fig-8 Gate pulses for the switches

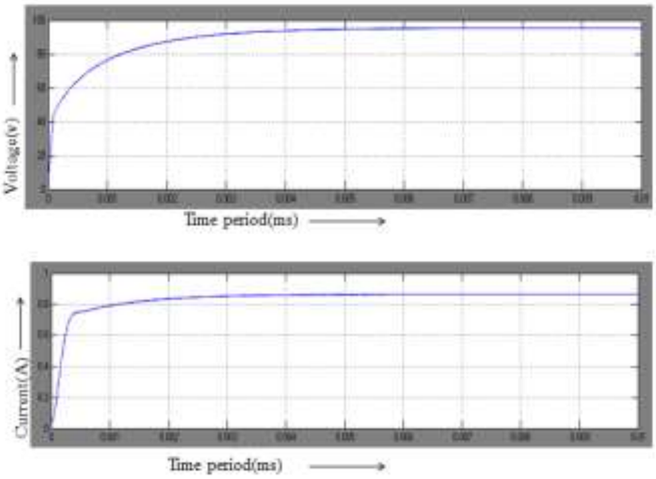

Fig-9 DC output voltage and current

C. Simulation Of High Step-Up Dc-Dc Converter With PV Panel: The Simulink diagram of interleaved flyback converter with PV panel as source is shown in Fig-10. The voltage and current measurement blocks are connected to measure the output voltage and output current. DC input voltage and current are shown in the Fig-11. The output current and output voltage is shown in the Fig-12.

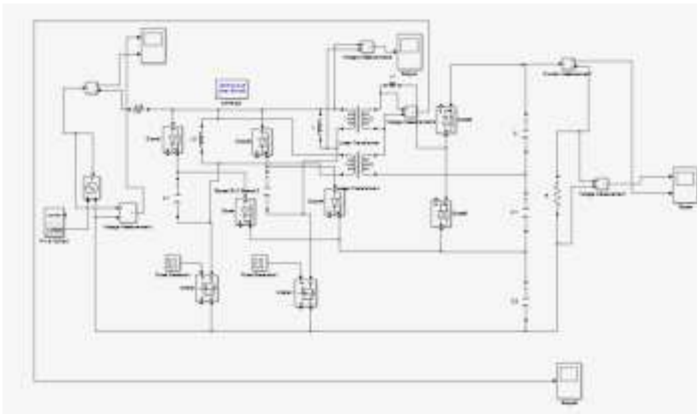

Fig-10 interleaved flyback converter with solar input source.

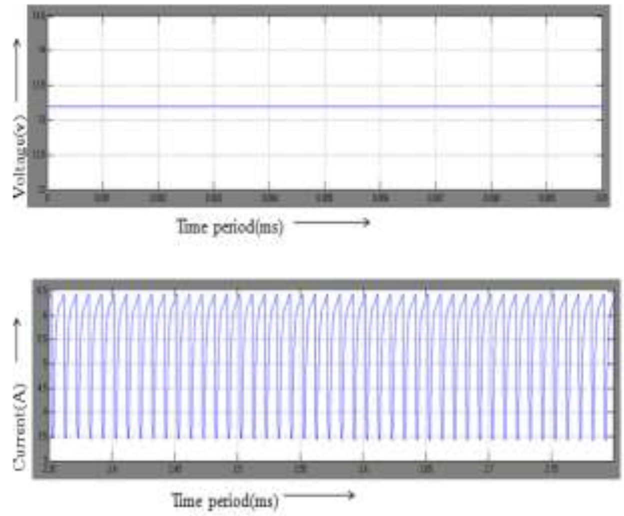

Fig-11 Input Voltage and Input current for the converter

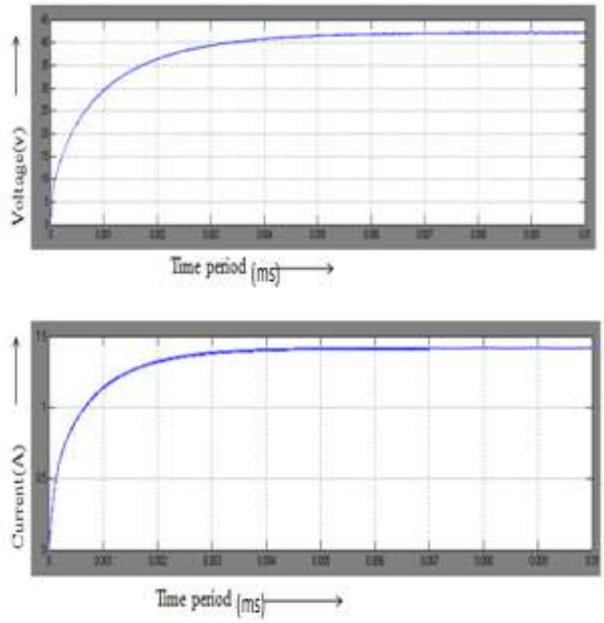

Fig-12 DC output voltage and current

D. Simulation of High Step-Up Dc-Dc With MPPT Technique: The Simulink diagram of interleaved flyback converter with MPPT control technique is shown in Fig-13. The voltage and current measurement blocks are connected to measure the output voltage and output current. DC input voltage and current are shown in the Fig-14. Voltage across the primary winding and secondary winding of the transformer is shown in Fig-15. The output current and output voltage is shown in the Fig-16.

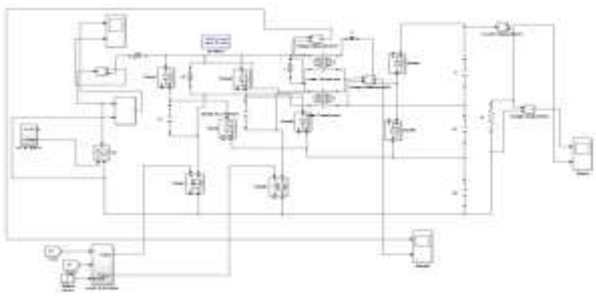

Fig-13 Interleaved flyback converter with MPPT control

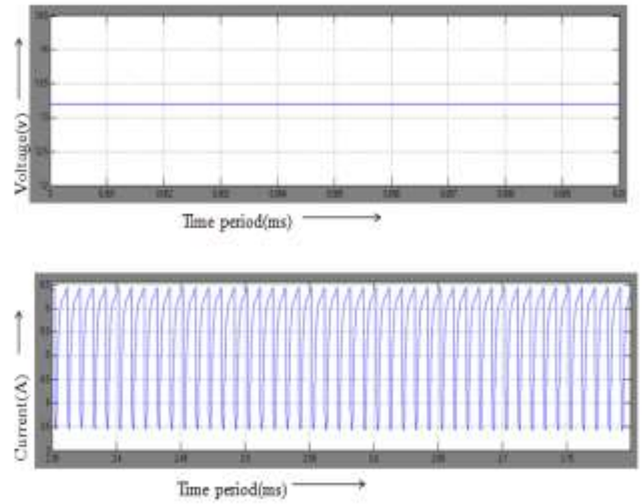

Fig-14 DC input voltage and current

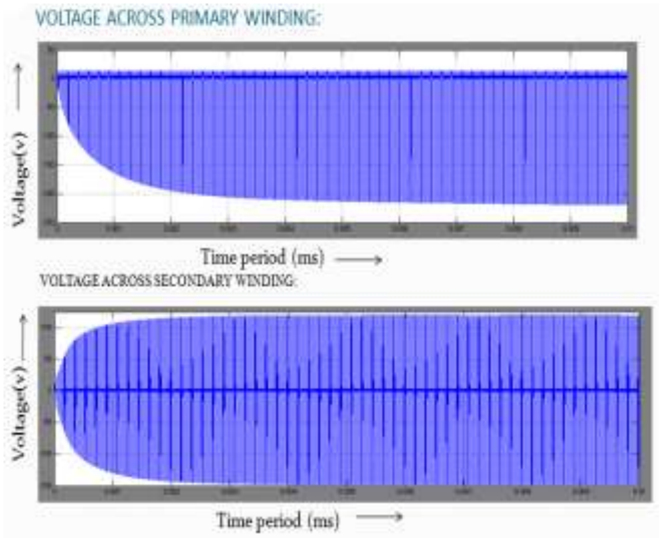

Fig-15 voltage across primary winding and secondary winding

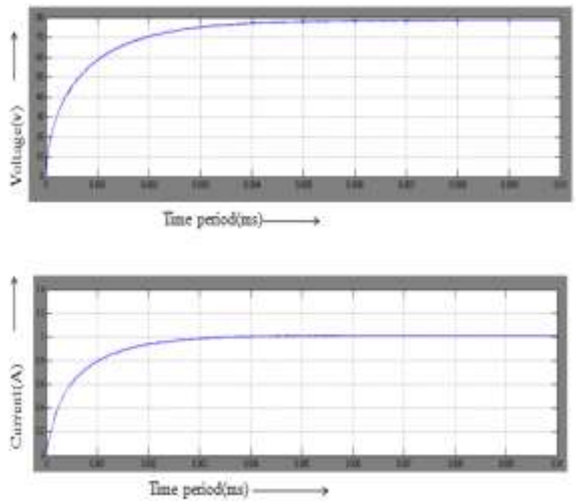

Fig-16 DC output voltage and output current

V. COMPARISONS

The below table shows the comparison of voltage gain and efficiency of the interleaved flyback converter with and without passive absorption circuit. The below table shows clearly that the interleaved flyback converter with passive absorption circuit have high voltage gain and high efficiency.

High step-up dc-dc converter	**Input voltage**	**Output voltage**	**Input power**	**Output power**	**Voltage Gain**	**Efficiency**
Without passive circuit	12v	70v	90w	70w	5.8	77.7%
With passive circuit	12v	96v	90w	80w	8	88.8%
With PV panel as source	13.2v	42v	84.48 w	60w	3.18	71%
With MPPT control	13.2v	78v	84.48 w	78w	5.9	92%

VI. DESIGN SELECTION FOR SIMULATION

Selection of right converter for specific application is an important task for the users. The following are the few criteria to be considered in the selection of appropriate topology of the converter for a particular application.

Vin=12V

L_1, L_2 = (1-D)2DR/2F

C_{01}, C_{02}, C_{03}= (DV_0) VrRF

C_1,C_2=V_0T_S/4R

F_s= 50Khz

V_0/V_s = D/n(1-D)

n- transformer turns ratio.

VII. EXPERIMENTAL RESULTS

In order to verify the effectiveness of the theoretical analysis, a 500-W prototype is built and tested with the specifications shown in Table. In fact, the coupled inductor in the proposed converter can deliver the energy to the load both on the turn-on stage and turn-off stage, and the leakage energy also can be delivered to the load.

PARAMETERS OF THE PROTOTYPE

D1/D2/Do1/Do2	BYW99W200
S1/S2	59N30
Np:Ns	1:2
C1/C2	100µf
Co1/Co2/Co3	400µf
Switching Frequency	50KHz
Input voltage	10V/12V

Fig-17 the 500W interleaved flyback converter prototype

VII. CONCLUSION

A high step-up dc–dc converter has been presented in this paper. The coupled-inductor and passive absorption circuits are integrated in the proposed converter to achieve high step up voltage gain. The energy stored in the leakage inductor of the coupled inductor can be recycled. The improved Flyback-Forward converter with passive absorption circuit has been proposed. By the proposed passive absorption circuit, the number of switch devices can be reduced, the output voltage can be lifted dramatically. The high step-up voltage gain and high efficiency can be achieved. Because the passive absorption circuit can transfer the leakage energy to the load, the improved Flyback-Forward converter has little influence on the leakage inductance of coupled inductor.

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