Developed Non-isolated High Step-up Converter with Low Voltage Stress

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Abstract - ***Many of these conventional DC–DC converters have the disadvantages of operating at high duty-cycle, high switch voltage stress and high diode peak current. The conventional boost high step-up converter can provide very high voltage gain without operating at high duty-cycle by employing a coupled inductor, a switched capacitor and an additional diode. Non-isolated high step up converter overcomes this drawback. This converter reduces voltage stress on switch and diode by using additional one capacitor and rearranging components in conventional single switch high step-up converter. At the same time, the switch voltage stress is reduced greatly, which is helpful to reduce the conduction losses by using low power rated components and efficiency will increase. Single switch is used in the non-isolated high step up converter, thus reduce the entire cost of the converter. This non-isolated high step-up converter is used in many applications such as renewable energy system using low voltage energy sources such as fuel cells, solar panels, photo voltaic cell. This converter has low voltage stress and high efficiency with low rated power components. The reverse-recovery energy of the output diode and the leakage inductance energy are recycled. The converter has high efficiency under entire load conditions due to the low conduction loss. The simulation of the circuit with 24 V input, 250V/125W output is done using PSIM.***

Key Words: *Non-isolated,High step up,Flyback converter,Voltage stress,Boost converter.*

1. INTRODUCTION

In present scenario, research and development in the field of renewable energy system [1],[2] using low voltage energy sources such as fuel cells, solar panels, photo voltaic cell. This is because of the high efficiency and high voltage gain. For these applications it needs voltage gain around ten or above. The basic boost converter used to obtain high voltage, but this cannot provide high gain with extremely high duty cycle. This is due to the switching losses and diode losses in the converter. To overcome this drawback introduces a transformer in converter thus form flyback converter, forward converter, push-pull converter, half bridge converter and full bridge converter. These converters have high gain by adjusting the turn's ratio of the transformer [3]-[11]. Among them, the flyback converter is used because of the simple structure and low cost. The basic flyback converter has single switch, diode and a transformer. The flyback converter is widely used in low power application such as portable computers, storage devices and mobile/battery charges [1]. Due to the presence leakage inductance of the transformer the primary switch and secondary diode experiences high voltage stress. Because of this drawback the flyback converter cannot use in high power applications [3].

To overcome these problems non-isolated high step-up converter is derived. Non-isolated high step-up dc-dc converters are widely used in the front end stage of the renewable energy applications and the dc back up energy system such as fuel cell, solar arrays, uninterrupted power supply and high-intensity discharge (HID) lamps for automobile head lamps [3].

High output voltage can also be generated by manipulating the charge transference of capacitor or inductor. Charge pumps, switched-capacitor converters and Luo converter with voltage-lift technique are typical examples [12]-[14]. Alternatively,switched-capacitor/switched-inductor structure,voltage doubler/multiplier cells inserted in the basic dc-dc converter circuit to further boost up the output voltage [15], [16]. Some of these converters involve the use of multiple switches and magnetic components with relatively complex circuits, which leads high cost and lower reliability.

The flyback converter suffers from several limitations that lower its efficiency and degrade its performance in high step-up applications. The leakage inductance generates huge turn-off voltage spike in the power switch, which results in high-voltage stress on the components and requires voltage snubber to clamp the switch voltage. The leakage inductance also induces ringing across the switch thus reduce the power efficiency and induce EMI effects [17]. But it used in practical applications due to the simplicity and low cost. Some research efforts have been spent on further improvements of the flyback topology. Active clamping and soft-switching functions have been added to the flyback converter to reduce the voltage stress across the switch and diodes [18]-[21]. Further research take place to reduce the conduction losses by using synchronous rectification [22],[23]. Then aimed to increase the efficiency and increase its application by connecting one or more flyback converter serially /parallel [24]-[26] or combined with other converter topology [1]-[27]. But these additional requirements are more complex due to the multiple switches and complex circuits results high cost and reduce reliability.

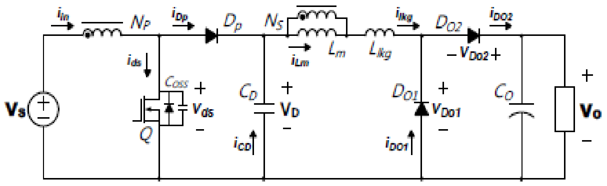
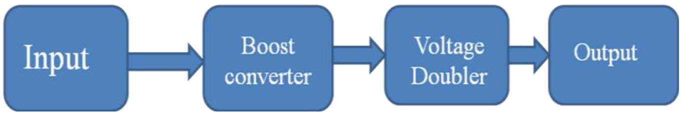


Fig -1: Non-isolated single switch high step-up converter with clamping diode.

To overcome these problems a one non-isolated single-switch high step-up converter is derived using a clamping diode and voltage doubler structure based on the conventional flyback converter. Fig -1 shows the non-isolated single switch high step-up converter with clamping diode [3]. Voltage stress across power components like switch and diode can be reduced by the use of clamping diode and voltage doubler structure. Further reduction in voltage stress by adding additional capacitor and rearrange the power components. Thus form the non-isolated high step-up converter topology. The new converter has single switch so stress is comparatively reduce. It consists of one switch, boost capacitor, doubler capacitor, and clamping diode.

2. NON-ISOLATED HIGH STEP-UP CONVERTER TOPOLOGY

In Fig.2 shows the basic block diagram of the non-isolated high step-up converter. The 24V input supply is boosted by using basic flyback converter and then this output is boosted by using doubler circuit.The new non-isolated high step-up converter has been shown in Fig. 3. The non-isolated high step-up converter is derived from the conventional flyback converter. And additional clamping diode, capacitor, and voltage doubler structure are added to the conventional flyback converter. To reduce the voltage stress on the diode, the voltage doubler rectifier is added to the converter circuit. Thus the voltage stresses on the diodes is clamped to the output voltage V_o. The doubler capacitor C_B, as shown in Fig. 4, acts as clamping voltage source for the switch and voltage doubler



Fig–2: Basic block diagram of non-isolated high step-up converter

capacitor, simultaneously. Also it act as boost output capacitor and it is not dependent on the boost converter gain, but the voltage across C_B is dependent on the input voltage. The output voltage across the C_B is clamp the switch and clamp the output diode. The voltage stress on the primary switch can be limited to V_D by using the clamping diode D_P. Through the five modes of operation the non-isolated high step-up converter operation takes place.

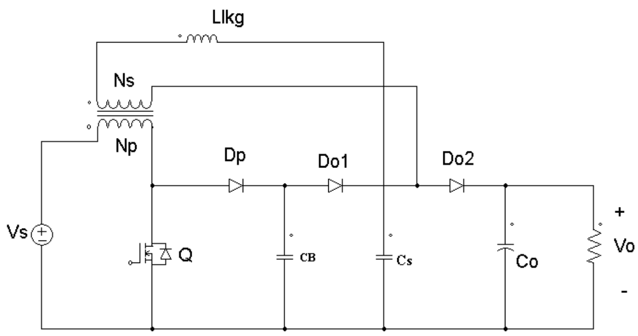


Fig-3: Non-isolated high step-up converter

3. MODES OF OPERATION

In mode 1 switch Q is turned ON. The leakage current decreases to zero value. The next mode begins when leakage current equals to zero. The diode Do1 is turned ON and leakage current flowing through it. When the diode Do2 is turned OFF. The mode 3 begins when the switch Q is turned OFF. The clamping diode is turned ON. Next mode 4 begins when leakage current reaches zero. The diode Do2 is turned ON and the leakage current flowing through it. In this mode diode Do1 is turned OFF. The last mode begins when leakage current reaches the magnetizing current, which flow through the diode Do2. This mode ends when the switch is turned ON.

4. DESIGN

The capacitor voltage V_{CS} can be obtained by applying volt second balance,

$$V_{cs} = (1-D)V_o + DV_B \tag{8}$$

Magnetizing current can be obtained by applying current second balance,

$$I_{Lm} = \frac{D^2 T_s (nV_s + V_B - V_{cs})}{2L_{lkg}(1-D)} \qquad (9)$$

Voltage conversion ratio M,

$$\frac{V_o}{V_s} = \frac{D^2(n+1)}{Q + D^2(1-D)} \qquad (10)$$

Where Q is the damping factor,

$$Q = \frac{2L_{lkg}}{R_o T_s} \qquad (11)$$

Value of capacitor C_B,

$$C_B = \frac{DV_B}{R_o \Delta V_o f_s} \qquad (12)$$

5. SIMULATION RESULTS

The simulation of the non-isolated high step-up converter has been carried out. An input voltage of 24V and switching frequency of 80 kHz is chosen and an output of 250V/0.5A is obtained. The duty ratio of the switches is equal to 0.4. The turn's ratio of the transformer is 8/45 and the corresponding parameters are listed in Table -1.
In order to achieve good voltage regulation closed loop control methods are introduced. In pulse width modulation (PWM) control, the duty ratio is linearly modulated in a direction that reduces the error. Then the input voltage is perturbed, that must be sensed as an output voltage change and error produced in the output voltage is used to reduce the duty ratio to give the output voltage to the reference value. The simulation takes place in PSIM software. The output voltage, current across the power components and voltage across the power components are obtained.

The ON time of the switch is DTs and OFF time of the switch is (1-D)T_S. In Fig. 4 shows the input voltage and output voltage of the new converter. 24 V supply voltage is stepped up to 250 V/0.5A.
It is clear from Fig-5 that the input current is discontinuous. It can be noted that the output ripple current is highly reduced. Fig-6 shows the leakage inductor current.

Table -1: Parameter list

Components	
Switching frequency(f_s)	80kHz
Leakage inductance(L_{lkg})	28.15µH
Magnetizing inductance(L_m)	1.31mH
Transformer turns($N_P : N_S$)	8:45
Capacitors(C_B, C_S)	2.2µF
Output capacitor(C_O)	82µF

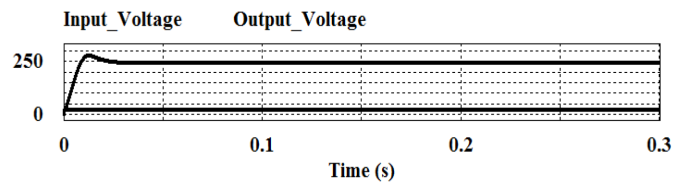


Fig-4: Input and output voltages.

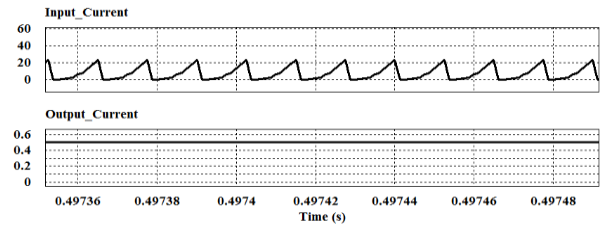


Fig-5: Waveform of input current and output current

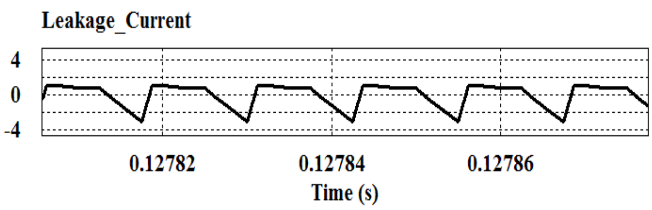


Fig-6: Waveform of leakage current

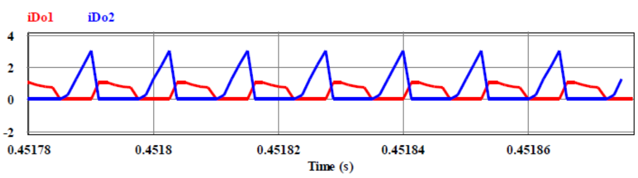


Fig-7: Waveform of current through diodes Do1 and Do2

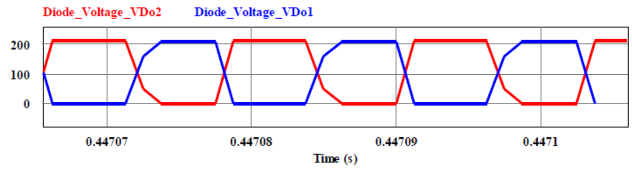


Fig-8: Waveform of voltage across diodes Do1 and Do2

Fig-7 and Fig-8 shows the current through the diodes Do1 and Do2 and voltage across the diodes Do1 and Do2 respectively. The voltage stress of the doubler capacitor and the switches are approximately 40 V, i.e., approximately twice of the input voltage. The voltage stress across the diodes is decreased with compared to Non-isolated single switch high step-up converter.

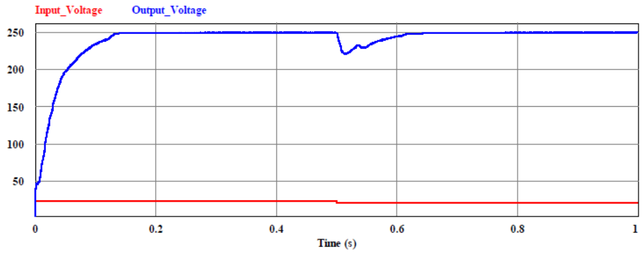


Fig-9: Line regulation of the converter at Step down from 24V to 21V

In Fig-9 shows The line regulation at step down from 24V to 21V. Table-2 shows the load regulation at different load conditions.

Table-2: Load regulation at different loads

Resistance R(Ω)	**Output current** I_0
500Ω	0.5A
700Ω	0.35A
1000Ω	0.25A
5000Ω	0.05A
10000000Ω	0.0025mA

6. CONCLUSIONS

Non-isolated high step-up converter is presented. The non-isolated high step-up converter has single switch, and the converter is derived from the conventional flyback converter. This converter has low voltage stress and high efficiency with low rated power components. The converter has high efficiency under entire load conditions due to the low conduction loss. The gate pulses are generated using PWM control scheme. The validity is tested by using the PSIM software and obtained the required output. With this non-isolated high step-up converter, short circuit protection can be implemented.

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