

NON-ISOLATED HIGH STEP-UP DC-DC CONVERTER BASED ON BOOST CONVERTER ELEMENTS

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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 an addition switched, an inductor, a capacitor, and a diode. Non-isolated high step-up converter overcomes the drawback of the conventional boost converter. In this converter, a high step-up conversion ratio and distributed voltage stress can be achieved and reduce reverse recovery on diodes. Based on a conventional quadratics boost converter, the derived converter satisfies all there feature. The operational principle and characteristics of the proposed converter are presented and verified experimentally with a 1.6 kW of power, 290 V input voltage, and 350 V output voltage prototype converter.

Keywords: Non-isolated; High step-up; Flyback converter; Voltage stress; Boost converter.

1. INTRODUCTION

In recent years, researchers in the field of renewable energy system [1], [2] using low voltage energy sources such as fuel cells, solar cell. This is because of the high voltage gain and high efficiency. Lots of efforts have been made to develop high step-up DC-DC converters with high efficiency [3]. The basic boost converter used to obtain a 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. That is, a high voltage diode causes a severe recovery problem requiring and additional current snubber and high voltage switch increase conduction loss [4]. To achieve high step-up gain and low voltage stress on devices, varies types of the step-up converter have been developed based on the classical boost converter. Which utilize as cascaded structure [5], a Quadratic boost [6] or a multiplier cell in series of converter [7]. But these additional requirements are more complex due to the multiple switches and complex circuits result in high cost and reduce reliability. In order to overcome these problems, this paper proposes a

high-efficiency DC-DC converter for low-dc renewable sources. The proposed nonisolated high step-up DC-DC converter is obtained from stacking basic boost converter elements with some modifications as is presented in Fig. 1. is very suitable for an application that requires high power density level and high efficiency. It is also intended to be used at higher switching frequency than traditional topologies since the reduced switch voltage stress allows the use of faster semiconductor devices. High step-up DC-DC converters will be simulated and experimental by PSIM with the help of a laboratory prototype.

2. TOPOLOGY OF NONISOLATED HIGH STEP-UP DC-DC CONVERTER

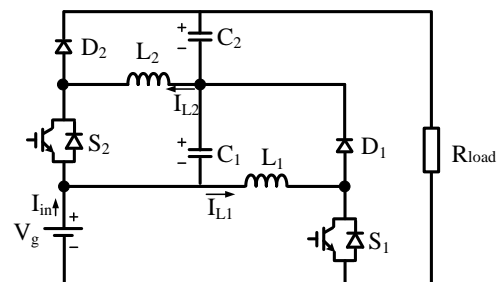


Fig. 1. Nonisolated high step-up DC-DC converter.

The high step-up DC-DC converters in continuous conduction operating mode (CCM) are considered. The equivalent circuit of the high step-up DC-DC converter topology is shown in Fig. 1. Assuming that all semiconductors ideal and the inductor large enough being treated as current sources,

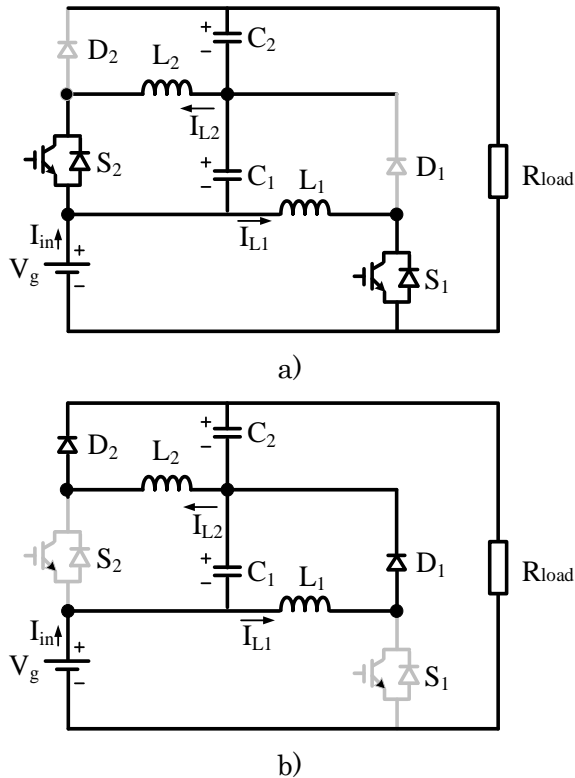


Fig. 2. Operation modes for a continuous conduction mode of proposed nonisolated high step-up stacked DC-DC converter: a) Mode 1 and b) Mode 2.

A. Mode 1 ($t_0 - t_1$) Fig 2.a.

At time $t = t_0$, all the switches (S_1 and S_2) are turned ON, the energy from the input power source and the capacitors charged previously (C_1) are stored in the inductors L_1 and L_2 . The load is supplied by capacitor C_2 according to Fig. 3.

B. Mode 2 ($t_1 - t_2$) Fig 2.b.

At time $t = t_1$, all the switches (S_1 and S_2) are turned OFF. During this time, the diodes (D_1 and D_2) become forward biased so that they conducted. The stored energy of the

the stacked capacitors are long enough so that the voltage in these capacitors are considered as constant during the entire switching cycle. The main waveforms are presented in Fig. 2. The two operation modes are briefly described as follows:

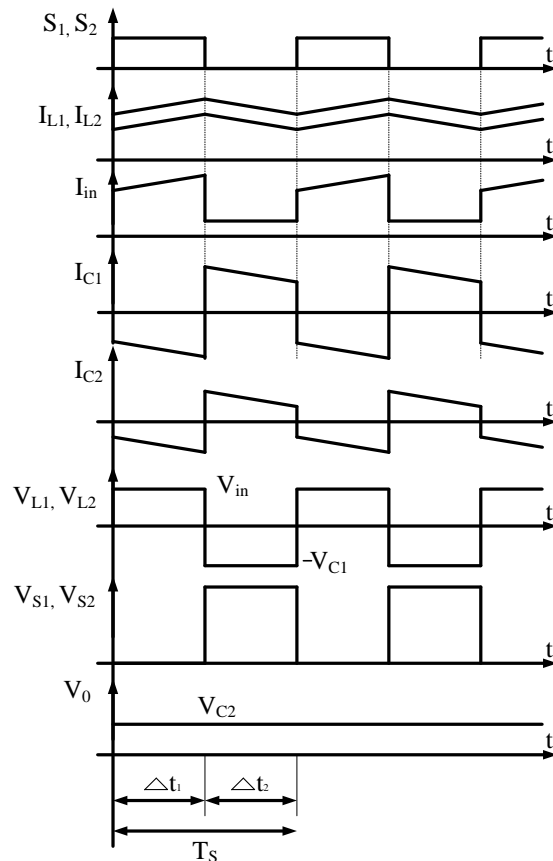


Fig. 3. Main waveforms of the proposed converter for CCM operation.

inductors in Mode 1 is released to the output load and to load the capacitors C_1 and C_2 for the next switching cycle.

3. STEADY-STATE ANALYSIS FOR NONISOLATED HIGH STEP-UP DC-DC CONVERTER

To analyze the steady-state characteristics of the high step-up DC-DC converter in CCM, the winding resistance and transient characteristic as of the MOSFET are neglected, assuming ideal power devices and all capacitors are extremely large, a constant output voltage is

ensured. The total static gain as a function of the duty cycle is defined [8].

$$\frac{V_0}{V_g} = 1 + \frac{D}{1-D} + \frac{D^2}{(1-D)^2} \quad (1)$$

The high step-up DC-DC converter static analysis will be performed to provide the fundamental equations that can be used as a basis in design procedure elaboration. Thus, all components in the power stage can be correctly chosen in order to meet all the design specification.

In order to yield high power density level and high efficiency, the inductances L_1 , L_2 and are given by (2) and (3)

$$L_1 = \frac{V_g D}{\Delta I_{L1} f_s} \quad (2)$$

$$L_2 = \frac{V_g D^2}{\Delta I_{L2} f_s (1-D)} \quad (3)$$

And the switch voltage stress in S_1 and S_2 are given by (4) and (5).

$$V_{S1} = \frac{V_g}{(1-D)} \quad (4)$$

$$V_{S2} = \frac{D V_g}{(1-D)^2} \quad (5)$$

A comparison of boost ratios between the two configurations (conventional and the proposed converters) is shown in Figure 4.

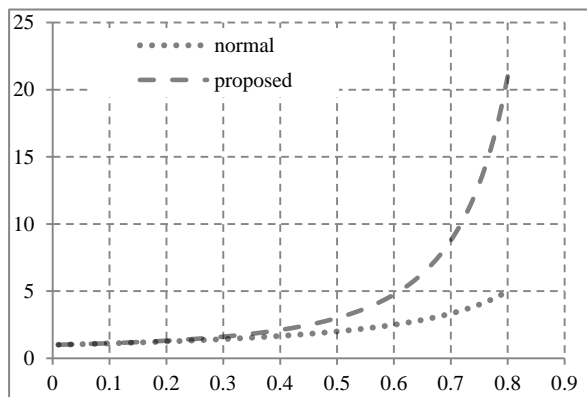


Fig. 4. Compare the boost ratio between the conventional and the proposed converters

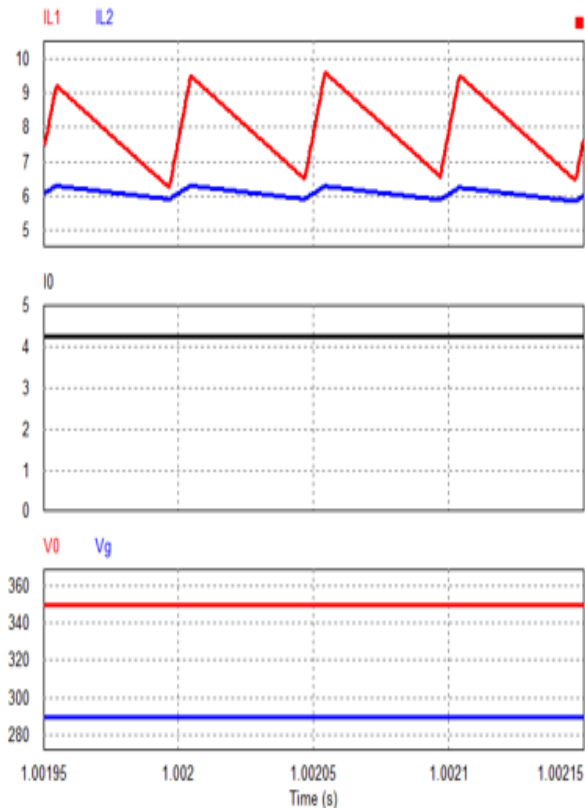
In Fig. 4 shows the result of the proposed configuration has a boost ratio (with the same duty-cycle D) which is higher than that of the conventional configuration. This is especially evident with a D ratio greater than 0.5. For the same boost requirement of 5 times, the conventional configuration requires a duty-cycle $D = 0.8$. The proposed configuration only requires a duty-cycle $D = 0.6$ equivalent to a reduction of 25%.

4. SIMULATION AND EXPERIMENTAL RESULTS.

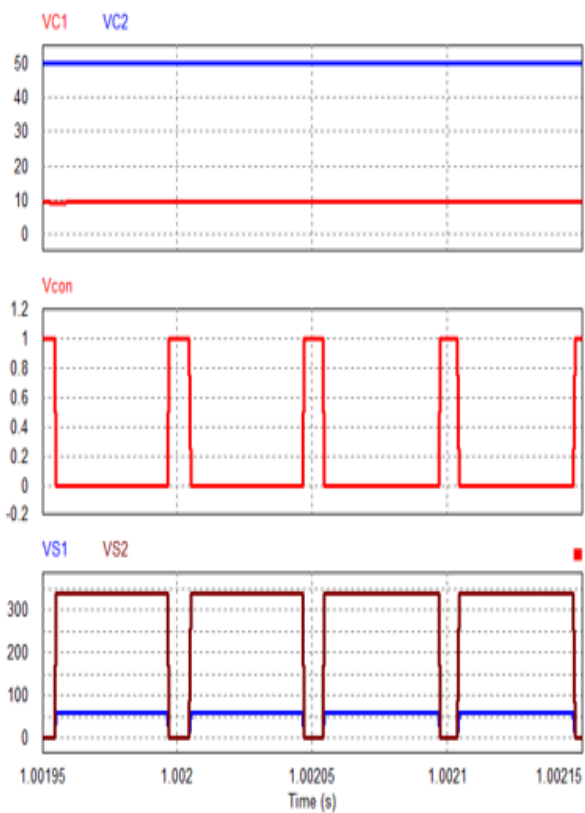
Table 1. Parameters Used in Simulation and Experiment

Parameter/Component	Attributes	
Input voltage	V_{dc}	290 V
Desired output voltage	V_0	350 V
Carrier frequency	f_s	20 kHz
Inductor	L_1	0.7mH
	L_2	1mH
Capacitors	C_1	4700 μ F/400 V
	C_2	2200 μ F/400 V
RL load	R_{load}	22 Ω

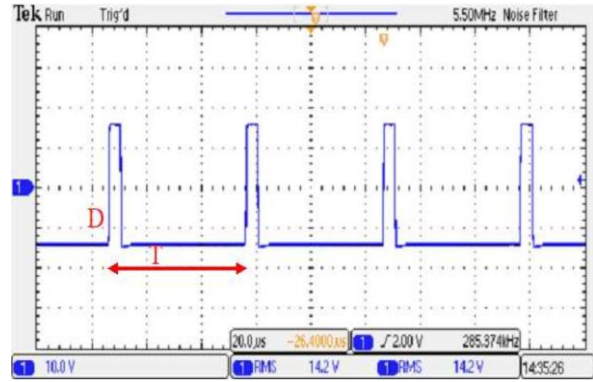
In order to validate the operation principles of the high step-up DC-DC converter, the boost conventional converter, the converter with two stacked DC-DC converter was simulated to investigate their device stress. In Fig. 5 simulation results for the proposed converter are showed. The presented values were obtained by simulating all converters with an input voltage of 290 V, output voltage equal to 350V and output power equal 1600 W. The switching frequencies for the two-stacked converter are 20 kHz. Table I shows the major circuit parameters of the nonisolated high step-up DC-DC converter.



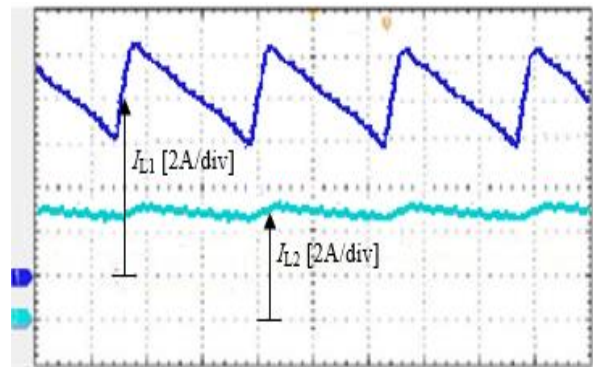
a)



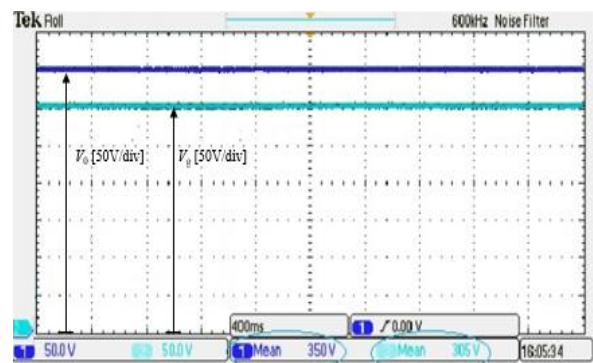
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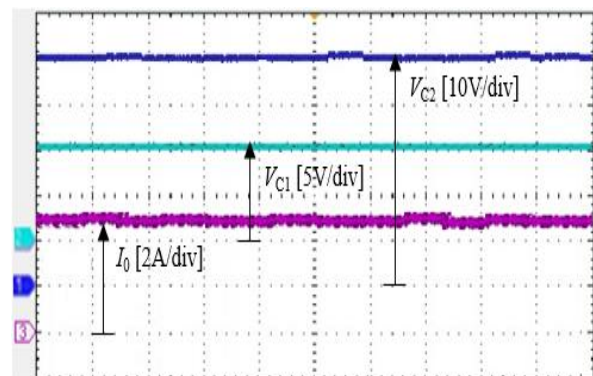
a)



b)



c)



d)

Fig. 5. The results of the nonisolated high step-up DC-DC converter

Fig. 6. The experimental of nonisolated high step-up DC-DC converter.

Table 2. Values of stresses in the components of DC high step-up converter compare with conventional converter value

Stresses	Propose topology		Conventional topology
	2SC	1SC	
V_{S1}	341 V	350 V	350 V
V_{S2}	60.2 V	-	-
D%	15%	17%	17%
L_1	0,725 mH	1,64 mH	1,64 mH
L_2	1,5 mH	-	-

Table 2 shows values of stresses in the proposed converter and conventional converter. Due to the fact, the nonisolated high step-up DC-DC converter used low duty cycle, so the low gain voltage. However, when the nonisolated high step-up DC-DC converter is used high gain voltage this topology has stress in component of DC high step-up converter very low suitable in high power systems. The proposed topology compares with tradition topology have the duty cycle D, inductor L and the capacitor and switch stress voltage in propose topology are lower than tradition topology. As a result, the proposed topology used in the high power which will be great gain so suitable for renewable systems.

Fig. 6a is gating control signal of S_1 , S_2 . The output voltage and the input voltage are being presented by Fig. 6b. Note that the output voltage is about 350 V. Since the converter is operating in CCM. The output current and the input current are being presented by Fig. 6c. The output current I_0 and two capacitors voltage V_{C1} and V_{C2} are shown in Fig 6d. Compares the values of the voltages from the simulation and experimental results of the nonisolated high step-up DC-DC converter. The simulated values are close to the measured values. The output voltage is stabilized by the PID control system. The nonisolated high step-up

DC-DC converter is checked and the technology transferred to the place of order.

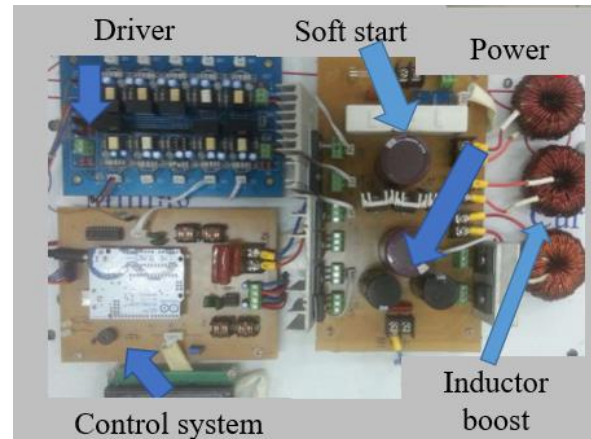


Fig. 7. A laboratory a prototype of the nonisolated high step-up DC-DC converter.

The nonisolated high step-up DC-DC converter has been implemented to validate its principle of operation for 290 V input voltage and 350 V voltage. The maximum output power is 1600 W and the chosen switching frequency is 20 kHz. The duty cycle for this gain of the converter is yielded equal to 0.15. A picture of the prototype is shown in Fig. 7. All FGL40N150D IGBTs in the prototype are controlled by TLP250 amplifiers, two diodes power diodes are DSEI60-12A.

5. CONCLUSIONS

An alternative structure to obtain high step-up gain for nonisolated application is introduced in this paper. Based on stacked basic boost converters and distribute voltage stress in devices. The main advantage of the proposed topology, when compared with a conventional boost converter, is that the voltages across the switches lower than the output voltage. The presented converter can be interesting for application where a high voltage ratio and high output power are necessary, what can be a case of clean energy source application, but only when transformer isolation not required.

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