High Voltage Gain Interleaved DC Boost Converter Application for Photovoltaic Generation System

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Abstract

This paper presents a novel high voltage gain interleaved DC boost converter. This converter is non-isolated boost converter, which can level up DC voltage from 24 Vdc input voltage to 130 Vdc output voltage. This is adequate suitable in order to develop and apply with any dc output renewable energy source, such as PV generation system and etc. The converter in this paper has power rating at 350W. The proposed converter has totally four modules of DC boost converter, which are connected in parallel. At the same purpose, these switching devices are controlled by 90 degree shifting to each other, due to an interleaving technique. This will leads to a smoother output dc current. Nevertheless, the High gain DC boost converter in this project was done by MATLAB / SIMULINK based Digital Signal Processing Board (here is TMS320F2812) implementation. The laboratory experiment shows that the converter works very well, and its result is in a good satisfaction.

Keywords: non-isolated boost converter; 4 phase Interleave technique**;** DSP implementation

1. Introduction

In general, Photo Voltaic cell (or Solar cell) can transform the energy form any light sources into an electrical dc power source. When the electromagnetic wave in light source impacts the semiconductor junction in the PV cells, energy will be transformed by causing a movement of electrons in PV's semiconductor junction. By connecting the external of the load side, the current will flows into an electrical circuit. However, there are some limitations on the PV's power rating. Due to the output voltage of such PV cell and PV panel is not high enough to provide to a customer in general, thus, the PV's output voltage has to be boosted up higher enough for providing any electrical appliances, it is depending on its applications.[3]

- 42 V (Power Net) a new standard voltage for automobile systems,
- 48 V; 120 V; or 400 V to 480 V for stand-alone or parallel grid connections,
- 270 V or 350 V for the standard on the all-electric aircraft,
- 350 V (transit bus systems) to 750V (tramway and locomotive systems).

Or converted into AC by using DC-AC converter (Inverter) for AC loads. Therefore, DC boost converter is needed to boost up a dc voltage. Normally, a traditional non-isolated DC boost converter has a significant disadvantage due to its low voltage. Thus, a high gain DC converter has to be proposed. However, such DC converter must have a good reliability in long time operation. In which, it also should be a small size in order to ease of installation, maintenance, power lossless and toughness [1-7]. The proposed system are shown in Figure 1.

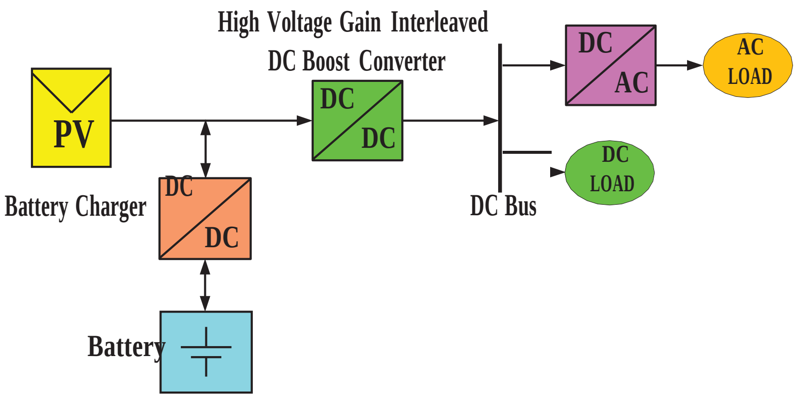

Fig. 1. The proposed system

2. DC Boost Converter Topologies

Typical boost converter

High voltage gain DC converter that proposed in this paper is considered from a traditional non-isolated DC boost converter as shown in Figure 2. However, the difference between DC Converter in Figure 2 and 3 is the location of diode, but its operations of both circuits are the same. Thus, voltage gain of the circuit is given in (1). [8]

$$G_B = \frac{U_O}{U_S} = \frac{1}{(1-D)} \qquad (1)$$

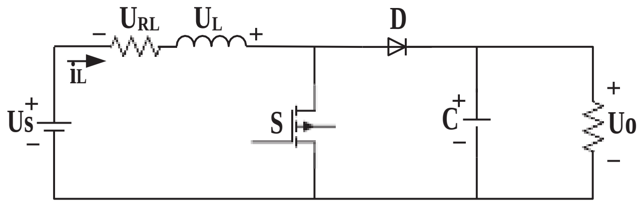

Fig. 2. Boost converter with inductor and diode in positive side

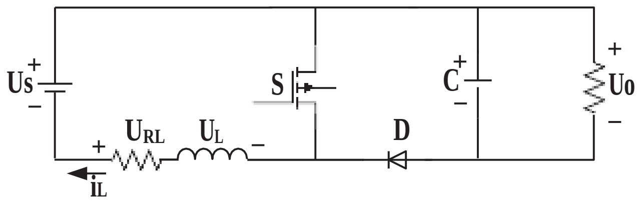

Fig. 3. Boost converter with inductor and diode in negative side

Double Dual Boost Converter

The topology of this converter is shown in Figure 4. The configuration is composed of two conventional boosts with input coupled inversely. Switches commands of each boost are delayed of a half switching period each. [2]

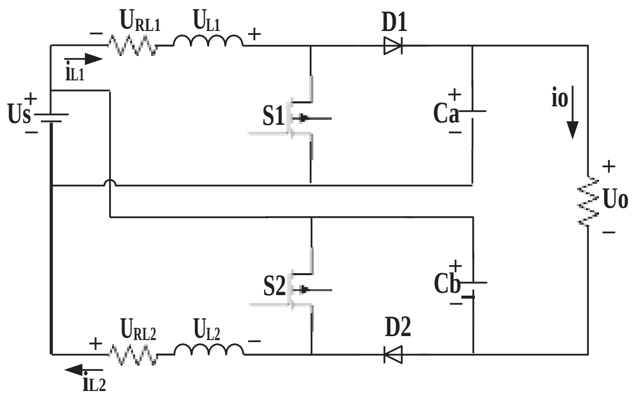

Fig. 4. Double dual boost converter

The relation of voltage gain and duty-cycle of this topology is given in (2).

$$G_{DDB} = \frac{U_O}{U_S} = \frac{(1+D)}{(1-D)} \quad (2)$$

From (1) and (2), it is clear that G_{DDB} is greater than G_B $(D + 1)$ times. Moreover, structures like boost, the higher the duty-cycle, the lower the efficiency. This is an advantage of double dual boost compared with a classical boost in the case of the same power, same input and output voltage.

Interleaved boost converter

In this section, the connection of converters based on the basic boost topology. For example, connecting two boost converters in parallel at the input derives the well-known interleaved boost sourced by a single DC voltage source as shown in Figure 5 and the interleaved boost version is shown in Figure 6. However, if one wishes to use a single source to power two boost converters but not of the same type.[1]

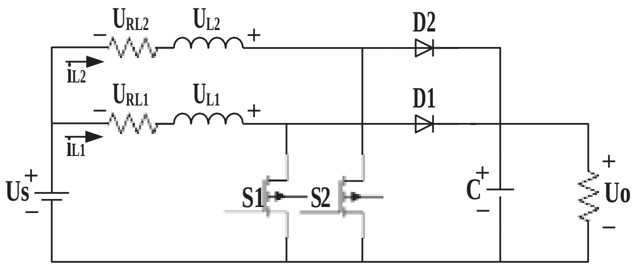

Fig. 5. Two phases interleaved Boost converter
(inductor and diode in positive side)

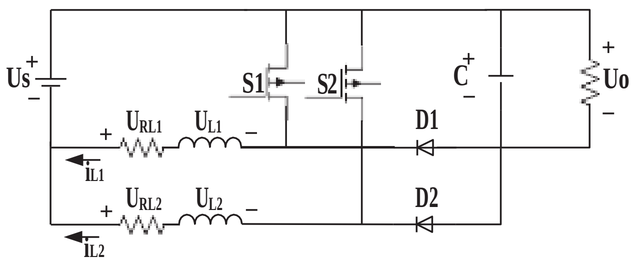

Fig. 6. Two phases interleaved Boost converter
(inductor and diode in negative side)

There are two configurations of interleaving DC boost converter circuit in this project as shown in Figure 5 and 6, respectively. An advantage of the interleaved technique is to reduce the converter size (especially inductor), reduce a ripple current and also increasing the converter's efficiency.

3. High Voltage Gain Interleaved DC Boost Converter

High voltage gain DC boost converter that proposed in this paper is a combination of two 2 phase interleaved boost converter from Figure 5 and 6 together as shown in Figure 7. Such circuit is called as 4 phase interleaved DC boost converter. The four switching devices (here is Power MOSFET IRF3415) are controlled in 90° phase delay to each others simultaneously (interleave technique method), in order to smooth output ripple current, raising power rating and efficiency as described above. [1-3]

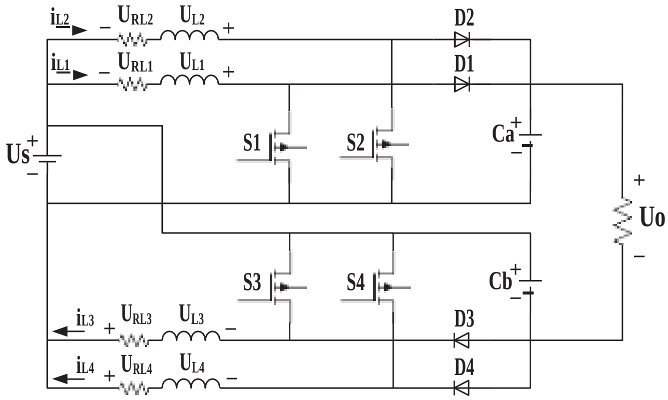

Fig. 7. High voltage gain Interleaved DC boost converter

Voltage gain of the circuit can be determined by applying KVL in two separated circuits as follows is (3) and (4).

$$-U_O + U_{Ca} + U_{Cb} - U_S = 0 \tag{3}$$

$$U_O = U_{Ca} + U_{Cb} - U_S \tag{4}$$

when U_S is DC input voltage

U_O is DC output voltage

U_{Ca} is Capacitor voltage across C_a

U_{Cb} is Capacitor voltage across C_b

Thus, voltage gain of the circuit is given in (5).

$$\frac{U_O}{U_S} = \frac{(1+D)}{(1-D)} \tag{5}$$

This means that the voltage can be raised over than a traditional non-isolated boost converter depend on the value of the duty cycle.

Inductance Design

Since the interleaving concept can reduces input current ripple also with inductance sizing, but the converters must be operated in continuous conduction mode (CCM). With a maximum current ripple (ΔI_L), it allowed to use for determining an appropriate value of And the current through the inducto inductance as follows is (6).

$$L = \frac{D.U_S}{4.\Delta I_L . f_S} \tag{6}$$

Capacitance Design

The output voltage ripple of the circuit depends the size of capacitor. However, there are two capacitors that connected in series, which effect to output voltage ripple (ΔU_{bus}). The value of each capacitor depends on output current (I_{out}), duty cycle (D) and depends inversely with ΔU_{bus} , switching frequency (f_S) as follows is (7).

$$C_{bus} = \frac{I_{out}.D}{2.\Delta U_{bus}.f_S} \qquad (7)$$

Table 1. Component specification

Devices	Value
Inductances (L_1,L_2 ,L_3,L_4)	840—H , EE42core
Capacitances (C_a,C_b)	470—F,450V
Power switches (S_1,S_2,S_3,S_4)	IRF3415
Diodes (D_1,D_2 ,D_3,D_4)	RURG3020
Input voltage	24 Vdc
Output voltage	130 Vdc
Maximum power output	350 W
Switching frequency; f_S	25 kHz

4. Experimental Results

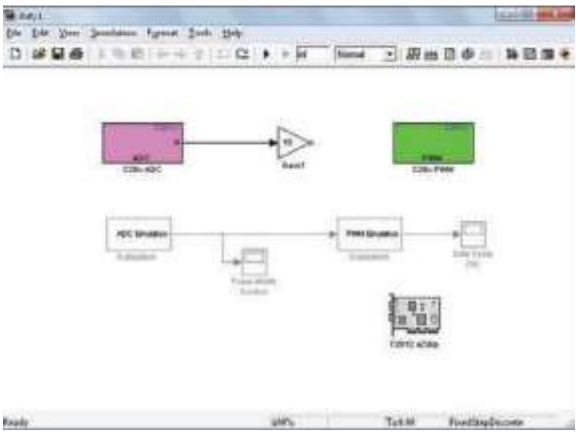

Fig. 8. TMS320F2812 control model

The proposed DC boost converter is built in a laboratory scale using TMS320F2812 DSP board. The DSP board is set for generating a suitable control signals for all four switching devices in the circuit. However, in order to controlling the essential data and some important control parameters, MATLAB/Simulink is used as a basis platform for managing the control model and such control data through TMS320F2812 DSP board are shown in Figure 8 and 9

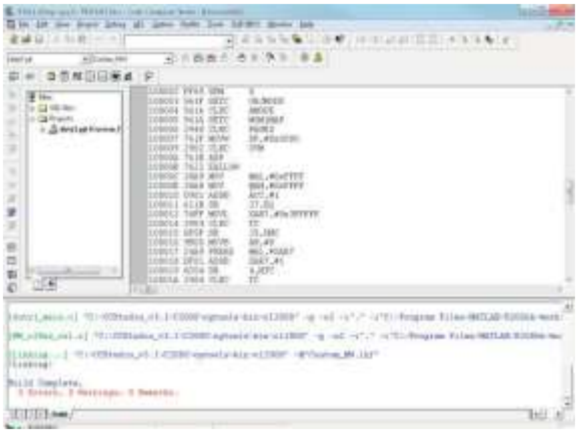

Fig. 9 TMS320F2812 command windows

The gate driving signals of switching devices generated from TMS320F2812 are shown in Figure 10. A phase angle of each gate driving signals is 0, 90, 180 and 270 degree.

The experimential results shown that the steady state interleaved averaged inductor currents i_{L1}, i_{L2} i_L and i_{L4} were 3.4A, 3.8A, 3.4A and 3.2A respectively. The inductor current waveforms are shown in Figure 11.

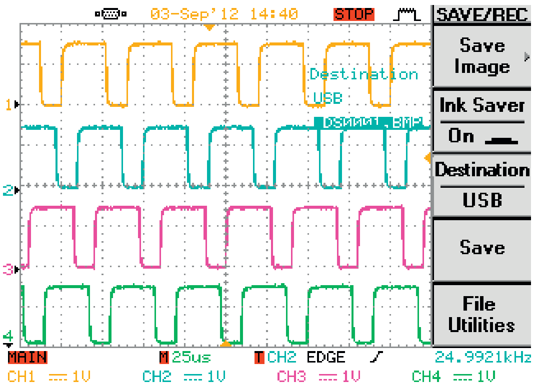

Fig. 10 Gate driving signals generated from TMS320F2812

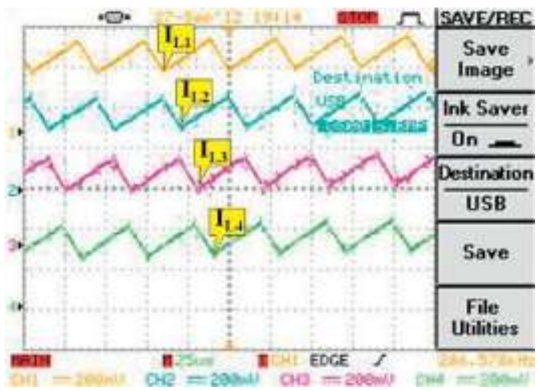

Fig. 11 The steady state inductor currents of proposed converter

The voltage of output capacitors U_C and U_{Cb} are the same as 78V. The capacitor voltage waveforms ar shown in Figure 12.

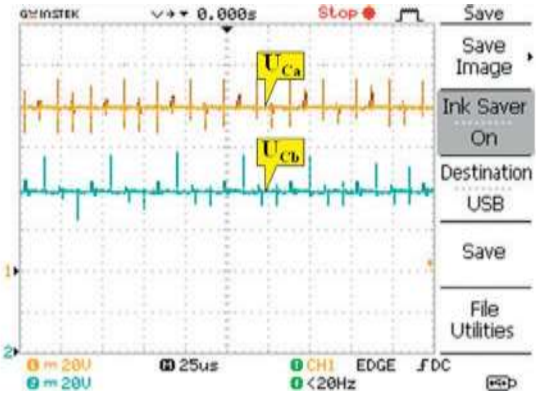

Fig. 12 The voltage waveforms of output capacitors

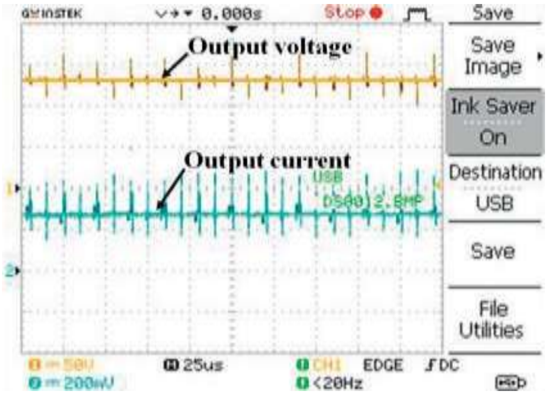

Fig. 13 The steady state inductor currents of proposed converter

The aximum output power of proposed converter is 350W This output power is calculated by multiply output voltage 130Vdc and output current 2.8A. The output voltage waveform and output current waveform are shown in Figure 13

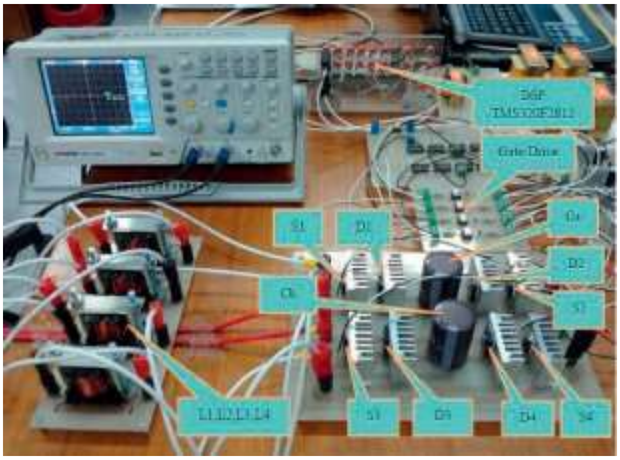

Fig. 14 The proposed prototype converter system

5. Conclusion

This paper present DC Boost Converter for applying to the photovoltaic generation system by using interleaves technique. This converter is non isolated boost converter, which can level up DC voltage from 24Vdc input voltage to 130Vdc output voltage at power rating of 350W Four phase of each witching control signal are differenceat 90 degree. However, inductor currents in each phase in the experimental results are not exactly the same because of the inductors' parasitic. High voltage gain interleaved DC boost converter in this paper could be applied to any renewable energy systems and some related applications.

Further research is to analyze in balancing the inductor currents and feedback control scheme in order to stabilize the converter output voltage.

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