

# A Single Phase Quasi H-Bridge Boost Inverter with Common Ground for Grid connected Applications

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**Abstract.** This paper presents a single-phase quasi H-bridge boost inverter with common ground for grid-connected applications. In this topology, the ground of ac grid and input dc voltage source is connected together directly. So, the ground leakage current is significantly limited. Furthermore, by combining a switched-capacitor boost converter with quasi H-bridge inverter, the RMS of output voltage can be greater than input dc voltage source. With the introduced simple PWM strategy, single phase quasi H-bridge boost inverter with common ground is applicable to photovoltaic applications where a low dc voltage source have to be inverted to a desired ac output voltage without transformer. The operating principles and circuit analysis for the single phase quasi H-bridge boost inverter with common ground are described. Simulation results by PSIM software are implemented to validate the performance of the introduced topology.

## 1. Introduction

In the recent, because of energy crisis, using the renewable energy sources is effective remedy. Renewable energy has some merits, i.e. its clean and cheap. But, most renewable energy sources generates a low dc power output. To feed the dc electric energy from the renewable energy sources into ac utility grid, an inverter is used. The inverters can operate in two mode: stand-alone and grid-connected. The voltage source inverters (VSIs) [1]-[5] are popularly applied in high power applications such as distributed power systems, AC motor drives, etc. But, the traditional VSIs are a step down power conversion, where the amplitude of output voltage is not able to be higher than the value of input dc voltage source.

In addition, a grid connected system without transformer produces a ground leakage current. For safe reasons, both the grid and the input dc voltage source should be grounded together. To solve the problems, inverters with common ground were proposed in [6]-[8].

Fig. 1 shows the single phase inverter topology with common ground in [8]. It is comprised of a single capacitor, a single diode, four switches and a single-phase filter. Compared to traditional H-bridge inverter, this topology use one more capacitor and one more diode for sharing a common ground between the utility grid and input dc voltage source.

With the aforementioned merits of the single phase inverter with common ground [8], this paper introduces a single phase quasi H-bridge boost inverter with common ground (qHB2I-CG). It is a combination of a switched-capacitor boost converter [9] with quasi H-bridge inverter [8]. The proposed qHB2I-CG is comprised of an inductor, three capacitors, four diodes and six switches. The operating principles and analysis of single phase quasi H-bridge boost inverter with common ground



for grid-connected applications are introduced. Also, a simple PWM strategy for the introduced topology is demonstrated. Simulation results are illustrated to verify the operating principle of the introduced inverter. The paper is organized as follows: Operating principles and circuit analysis for proposed topology are discussed in section II. The control system algorithm for grid connection is discussed in section III. Simulation results and the conclusion come in section IV and in V section, respectively.

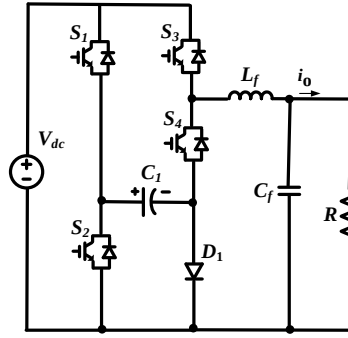


**Figure 1.** Single phase inverter with common-ground [8].

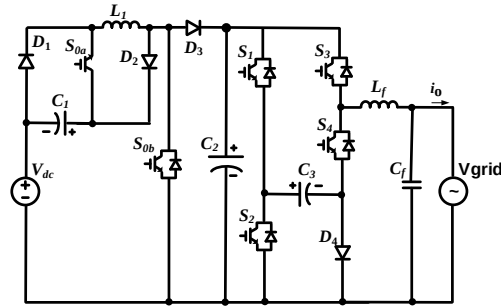


**Figure 2.** Single phase quasi H-bridge boost inverter with common ground for grid connected applications.

## 2. System description

Fig. 2 shows the single phase quasi H-bridge boost inverter with common ground for grid connected applications. It used a inductor ( $L_1$ ), three capacitors ( $C_1$ ,  $C_2$  and  $C_3$ ), four diodes ( $D_1$ ,  $D_2$ ,  $D_3$  and  $D_4$ ), six switches and a single-phase filter.

In the boost state, switches  $S_{0ab}$  and  $S_{0b}$  are turned on simultaneously as shown in Fig. 4(a). Both diodes  $D_1$ ,  $D_2$  and  $D_3$  are blocking. The inductor  $L_1$  is charged. The capacitor  $C_1$  and  $C_2$  are discharged. The time interval in the boost state is  $DT$ , where  $T$  and  $D$  are the switching period and the duty ratio, respectively. We have:

$$\begin{cases} L_1 \frac{di_L}{dt} = V_{dc} + V_{C1} \\ C_1 \frac{dv_{C1}}{dt} = -I_L \\ C_2 \frac{dv_{C2}}{dt} = -i_{PN} \end{cases} \quad (1)$$

For the non-boost state, switches  $S_{0ab}$  and  $S_{0b}$  is turned off simultaneously as shown in Fig. 4(b). Both diodes  $D_1$ ,  $D_2$  and  $D_3$  are conducting. The inductor  $L_1$  is discharged. The capacitor  $C_1$  and  $C_2$  are charged. The time interval in the boost state is  $(1-D)T$ . We get:

$$\begin{cases} L_1 \frac{di_L}{dt} = -V_{C1} \\ C_1 \frac{dv_{C1}}{dt} = I_L - I_{in} \\ C_2 \frac{dv_{C2}}{dt} = I_{in} - i_{PN} \end{cases} \quad (2)$$

Applying the volt-second balance principle to the inductor L1 and the amp-second balance principle to the capacitor C1, C2 in steady state, from (1) to (2), we obtain

$$\begin{cases} V_{C1} = \frac{D}{1-2D} V_{dc} \\ I_L = \frac{1-D}{1-2D} I_{in} \\ I_{in} = \frac{1}{1-D} i_{PN} \end{cases} \quad (3)$$

From (3), we have:

$$I_L = \frac{1}{1-2D} i_{PN} \quad (4)$$

The Bus voltage ( $V_{PN}$ ) that crosses the inverter bridge is expressed as

$$V_{PN} = V_{C2} = V_{dc} + V_{C1} = \frac{1-D}{1-2D} V_{dc} \quad (5)$$

The boost factor of single phase quasi H-bridge boost inverter with common can be expressed as

$$B_s = \frac{V_{PN}}{V_{dc}} = \frac{1-D}{1-2D} \quad (6)$$

A simple PWM Strategy for single phase quasi H-bridge boost inverter with common ground for grid connected applications is introduced in Fig 3. The signal,  $V_{SH}$ , are used to compare with a high frequency carrier waveform,  $v_{tri}$ , to produce the boost control signal for controlling for the switches  $S_{0a}$  and  $S_{0b}$ . Also, a control waveform,  $v_{control}$  is also used to compare to  $V_{tri}$ , to generate control signals for switches of quasi H-bridge as shown in Fig 3.

From (6), it should be noted that the maximum duty ratio of the boost state is less than 0.5. To guarantee a good quality of the output voltage waveform, the amplitude of  $v_{control}$  is not set higher than 1. Note that the constant voltages  $V_{SH}$  is determined as  $(1-D)$ .

The peak ac output voltage is determined as

$$v_{ac} = M \cdot V_{PN} = \frac{M \cdot (1-D)V_{dc}}{1-2D} \quad (7)$$

The dc-ac inversion voltage gain is expressed as

$$G = M \cdot \frac{1-D}{1-2D} = \frac{v_{ac}}{V_{dc}} \quad (8)$$

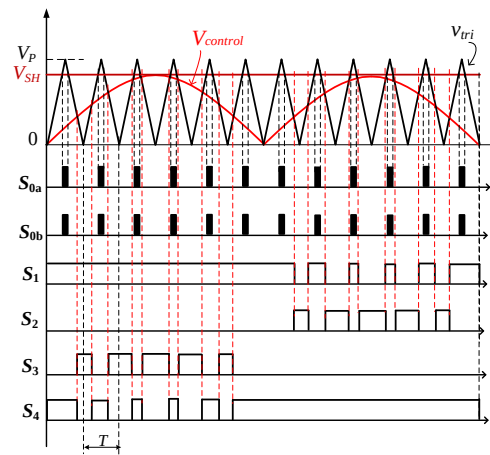


Figure 3. PWM Strategy for single phase quasi H-bridge boost inverter with common ground for grid connected applications.

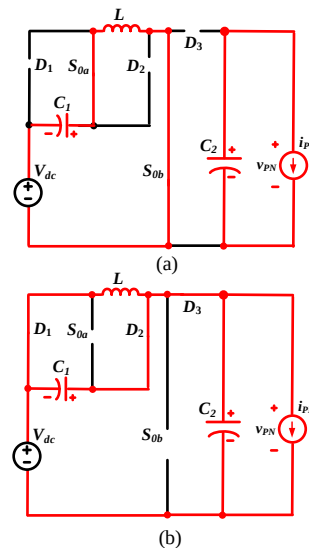


Figure 4. Operating states of single phase quasi H-bridge boost inverter with common ground. (a) boost state and (b) non-boost state.

### 3. Control system algorithm for grid connection

To deliver energy from dc voltage source to the ac grid, a inverter is used. Moreover, the output voltage of inverter and ac grid bear a close resemblance in terms of the phase and frequency. So, a grid synchronization technique is demanded to get the phase angle of the utility grid voltage. The synchronization strategies must behave significantly to varies of the utility grid. A lot of synchronization techniques have been introduced to get the phase angle of the grid such as zero detection [10], phase locked loop (PLL) [11]-[14]. A PLL is a closed loop control where an internal oscillator is controlled by using a feedback loop to maintain the time and phase of an external periodical signal. Fig. 5 shows structure of PLL controller. A simple current control for single phase quasi H-bridge boost inverter with common ground for grid connection is introduced in Fig. 6.

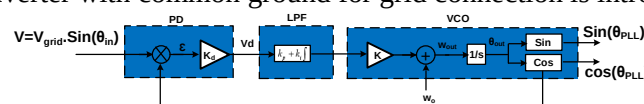


Figure 5. Block diagram of the PLL.

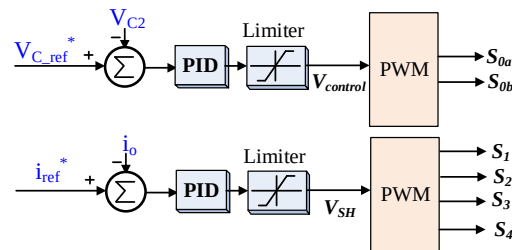


Figure 6. Overall control configuration of the grid connected system.

**Table 1.** Parameters of the proposed inverter

| Parameter             | Value          |
|-----------------------|----------------|
| DC input voltage      | 60V            |
| ac output voltage     | 110 Vrms /50Hz |
| Grid voltage          | 110 Vrms /50Hz |
| Inductors ( $L_1$ )   | 2 mH           |
| Capacitors $C_1, C_2$ | 2200 $\mu$ F   |
| Capacitors $C_3$      | 1000 $\mu$ F   |
| Inductor ( $L_f$ )    | 3 mH           |
| Capacitor ( $C_f$ )   | 10 $\mu$ F     |
| Switching frequency   | 20KHz          |

#### 4. Simulation results

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To confirm the operating principle of single phase quasi H-bridge boost inverter with common ground, the simulation results with PSIM simulation software is used. Table I lists the simulation parameters for single phase quasi H-bridge boost inverter with common ground.

The input dc voltage source is set to 60 V in the proposed system in order to test properties of single Fig. 7, Fig. 8 and Fig.9 show the simulation waveforms of the single phase quasi H-bridge boost inverter with common ground when  $V_{dc} = 60$  V.

As shown in Figure 5, the simulation result of PLL illustrates that the PLL can successfully extract, without errors, the phase angle of the grid voltages, which allows for synchronization with the grid.

We can see that the output voltage of the proposed inverter is 110Vrms with 3-level as shown in Fig. 8. The average inductor current is 10.3

Fig. 9 illustrates the simulation waveform of current and voltage of the grid. From Fig. 9, the current inject to the grid ( $i_o$ ) is sinusoidal. The single phase quasi H-bridge boost inverter with common ground is tied with the grid at 110 Vrms. The inverter injects a real power of 390 W to the grid as shown in Fig 9.

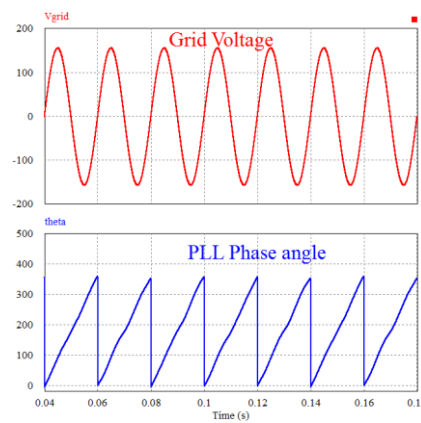


Figure 7. Simulation results of Grid Synchronization.

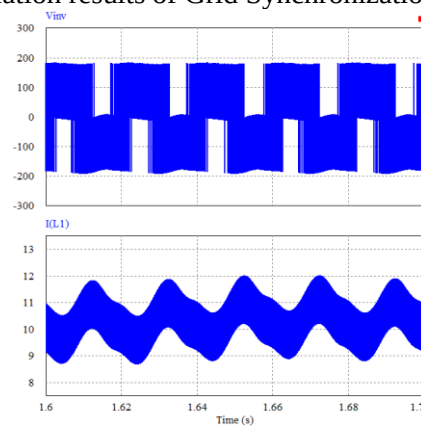


Figure 8. Simulation results for single phase quasi H-bridge boost inverter with common ground. From top to bottom: 3-level output voltage, inductor current.

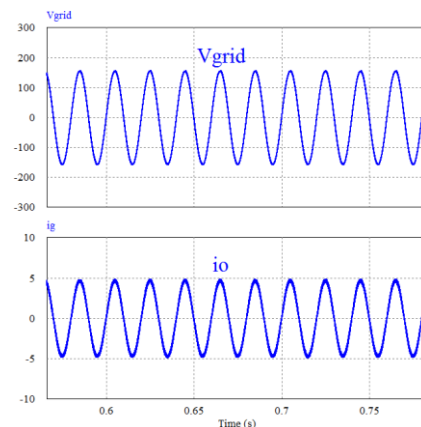


Figure 9. Simulation results for single phase quasi H-bridge boost inverter with common ground. From top to bottom: voltage and current of the grid.

## 5. Conclusion

This paper presents the operating principles and analysis of the single-phase quasi H-bridge boost inverter with common ground. With sharing the same ground with grid, the ground leakage current is significantly limited. Furthermore, by combining a switched-capacitor boost converter with quasi H-bridge inverter, the RMS of output voltage can be greater than input dc voltage source. Therefore, the

single-phase quasi H-bridge boost inverter with common ground is applicable to photovoltaic applications where a low dc voltage source must be inverted to a desired ac output voltage without transformer. Also, the single-phase quasi H-bridge boost inverter with common ground is in line with connecting directly to grid without using transformer. The system is tested for grid connection with the introduced PWM technique and PLL technique. Simulation results for the single phase quasi H-bridge boost inverter with common ground are presented.

## 6. References

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