

# Development of New Three-Level Current-Source Inverter for Grid Connected Photovoltaic System

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**Abstract** This paper discusses a single-phase three-level current source inverter (CSI) driven by a single gate-drive power supply in both chopper and inverter, and its feasibility on grid connected photovoltaic system application. Using this new topology, the complexity of the chopper and inverter circuitry is dramatically reduced by using single gate-drive power supply for all power switches. The circuit works properly at a unity power factor operation when the quasi-sinusoidal current is injected into the grid. The simulation results provide firm evidences about the practical feasibility of the proposed system.

**Keywords** : current-source inverter (CSI), grid connected photovoltaic system

## 1. INTRODUCTION

Solid state inverters allow to put photovoltaic (PV) systems into the power grid with interconnecting circuit [1]. However, not many PV systems have so far been placed into the grid due to the relatively high cost of power converters. Therefore, cost reduction per inverter watt is important to make such PV systems more attractive [2]. Focus has, therefore, been placed on new, cheap, and innovative inverter solutions.

Multilevel CSI has been proposed in [3], but this converter needs two large balance inductors to achieve intermediary three-level current and the balanced current sharing among the switches. Reference [4] reported the multilevel CSI driven by single gate power supply in an inverter side only.

This paper proposes a new three-level current-source inverter and its feasibility on a grid connected PV system application. This new topology implements common emitter topology of all switches in the chopper and the inverter sides. Therefore, it makes possible to drive all switches using only a single gate-drive power supply. The effectiveness of this topology has been studied through simulations using PSIM software.

## 2. CIRCUIT CONFIGURATION

### 2.1. CHOPPER CIRCUIT

The main goal of a grid connected PV energy converter is to process the PV power and inject a sinusoidal current into the utility grid. Such a low distorted current is obtained using three-level current-source inverter. The current source, in the input of the dc-to-dc converter, is composed with the PV arrays connected to input inductors ( $L_{in}$ ) as shown in Fig.1. As the optimum current of the PV is determined by a short circuit current of the PV, where photovoltaics are modeled with simple DC voltage sources connected in series with their internal resistance. Power decoupling capacitors  $C$  are inserted between the PV arrays and the input inductors to reduce the voltage ripple in the PV arrays. Two diodes are placed between the input inductors and the capacitors in order to keep the current to flow only in one direction when inverter is connected with the grid.

Current control mode is applied to control the output current of each chopper. Making the output current follow the reference current  $I^*$  is the objective of this current controller. The switching gate signals of switch  $Q1$  (dc-to-dc switch) is generated by

comparing the error signal of the average value of the detected currents  $I_1$  and  $I_2$  flowing through both input inductors and a triangular carrier wave after passing through a PI regulator as shown in Fig.2. This signal is used to control the duty cycle of the chopper according to the optimal current produced by PV.

For analysis purpose of the buck chopper circuitry, we can consider this circuit comprises two buck choppers with common switch ( $Q1$ ). The chopper behaves as a current source. When the switch is closed for a period  $DT$ , the input inductor current rises and energy is stored in the input inductor. If the switch is opened during time  $(1-D)T$ , the stored energy is transferred into the inverter, where  $D$  is the duty cycle of chopper.

The input inductor produces current  $I_L$ , a part of it will flow through diode ( $I_d$ ) during the switch *on* and the other part ( $I_o$ ) will flow into the inverter during the switch *off*. The input inductor current ( $I_L$ ), gating signal ( $V_{gate}$ ) and output current ( $I_o$ ) flowing into the inverter are shown in Fig. 3.

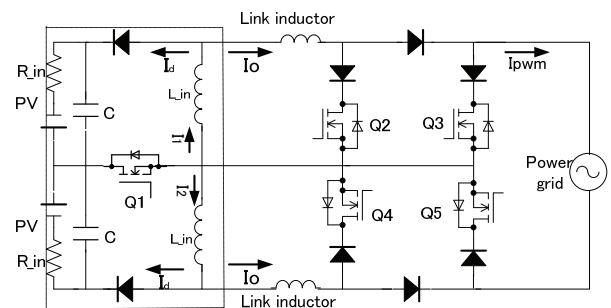


Fig. 1. Buck chopper connected to inverter with link inductors.

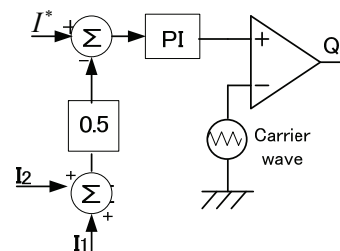


Fig. 2. Gating signal generation of chopper switch.

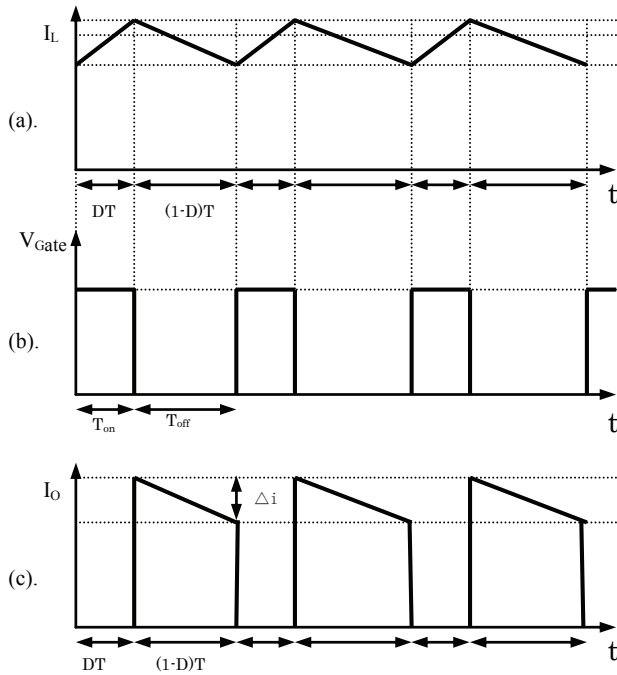


Fig. 3. (a). Input inductor current during switch *on* ( $DT$ ) and switch *off* ( $(1-D)T$ ), (b). Gating signal of switch (c). Output current flowing into inverter.

## 2.2. INVERTER CIRCUIT

The inverter circuit comprises of four switches and six diodes as shown in Fig.1. Sinusoidal PWM is used to produce a three-level current with a grid frequency. Switching frequency is chosen to achieve low switching losses and small harmonic amplitude of odd harmonic component of the output current at the same time.

The gating signals of the inverter are produced by using a sinusoidal reference wave modulated with two triangular carrier waves with the same frequency but with opposite offset. This strategy is able to perform the sinusoidal PWM of the inverter. Output current is  $I_o$  when switches Q2 Q3 are *off* and Q4 Q5 are *on*. When Q3 Q5 are *off* and Q2 Q4 are *on*, no current will flow into the grid and the reverse current  $-I_o$  will flow when Q4 Q5 are *off* and Q2 Q3 are *on*.

## 3. SIMULATION RESULT

This section describes the simulation results of the proposed topology when connected to the power grid of 100 V 50 Hz. It should be noted that even the input inductor was chosen as  $L_{in}=100$  mH to get enough current as determined by the reference current signal, the circuit also works for smaller input inductor. The decoupling capacitor used in this simulation is 100  $\mu$ F, hence it makes possible to use film capacitors whose lifetime is much longer than electrolytic capacitors.

The inverter injects a three-level current directly into the grid which is modeled as an ideal sinusoidal power source. A 10  $\mu$ H inductor is used to connect the chopper and the inverter sides. The switching frequency has been chosen to be 10 kHz for the dc-to-dc converter and 30 kHz for the inverter. Phase relationship between output current and the grid voltage is shown in Fig.4. Fig.5 shows the fourier transform (FFT) of the output current.

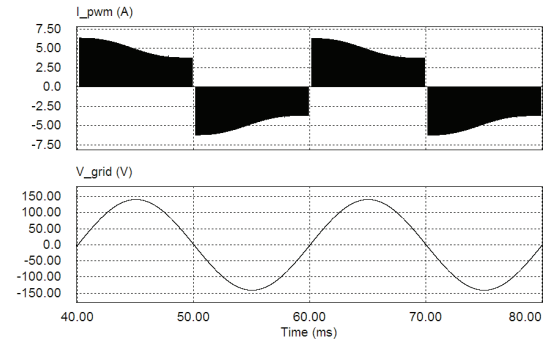


Fig. 4. Output current and grid voltage waveform.

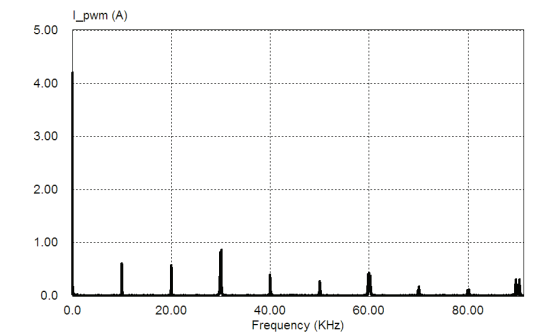


Fig. 5. Harmonic spectrum of the output current.

The simulation results show that the output current of the inverter is in phase with the grid voltage. Thereby, the high power factor operation is achieved. From FFT analysis result, it shows that harmonics appear as sidebands around multiples of the chopper switching frequency. Hence, it can be easily eliminated using simple low pass filter or operating with a higher switching frequency.

These results provide evidences about the practical feasibility of the proposed system.

## 4. CONCLUSION

In this paper, a three-level current-source inverter with a chopper driven by a single gate-drive power supply has been studied as a grid connected photovoltaic energy converter. The results have shown that the proposed strategy works properly and is quite effective to simplify the PV system with a grid connection.

## References

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