

# The High Efficiency Renewable PV Inverter Topology

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## Abstract

The recent trend in photovoltaic inverter is to use topologies with the absence of transformers to acquire higher efficiency. This gives very low ground leakage current. After the elimination of transformer in a grid/Load connected Photovoltaic (PV) system, a galvanic connection exists between the grid/Load and the PV array. The different inverter topology that generates no varying common-mode voltage is proposed to avoid leakage currents, this proposes a new topology with six switches and two diodes that generates no varying common-mode voltage and exhibits high efficiency.

**Keywords:** Ground Leakage Current, H-Bridge, Photovoltaic Inverter, Transformer Less Topology

## 1. Introduction

The transformer less system for Photovoltaic (PV) inverter a new emerging part in the field of power electronics. The PV inverter converts the output of PV cell to an alternating current than can be used by the utility. As the demand for the PV system is increased, our focus on the photovoltaic inverter.

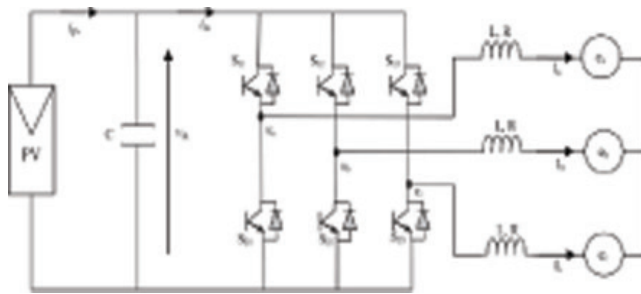
The proposed H6-ZVR topology, consist of diode rectifier, and a new ac H-bridge bypass circuit thus the ground leakage problem is reduced<sup>1</sup>. The efficiency of the transformer less system is not reduced due to losses but offers safety. A high efficiency is obtained using low-input voltage and common mode voltage is not generated in the system, Similar to bipolar PWM full bridge<sup>2</sup>. In PV systems a new conversion topology is used to get assured behaviors and reduced electromagnetic interference<sup>3</sup>. Due to this new conversion topology common mode voltage is generated which improves the behavior of the system and reduces electromagnetic interference<sup>4</sup>. Comparisons of the transformer less topologies are analyzed and the results were found in favour<sup>5</sup>. The new topology used is

H-bridge (consists of six diodes) in this the ac bypass circuit consisting of a diode rectifier and a switch is attached to the midpoint<sup>6</sup>. The step down converters are used to modulate a half wave of the output current. Higher efficiency and reliability is achieved because of the straight forward design, reduced number of semiconductor and its simple operation<sup>7</sup>. Due to the use of Sinusoidal Pulse Width Modulation (SPWM) high frequency common-mode voltages are developed this has been avoided in the unipolar SPWM full-bridge inverter<sup>8</sup>.

## 2. General Transformer Less Photovoltaic Inverter

To reduce ground leakage currents and to improve the efficiency of the system various topologies are present. The various benefits in transformer less systems are namely improved efficiency, smaller size and reduced weight. The various topologies used in this system are discussed below. The general photovoltaic inverter without transformer is shown in the Figure 1.

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**Figure 1.** Schematic diagram of transformer less inverter.

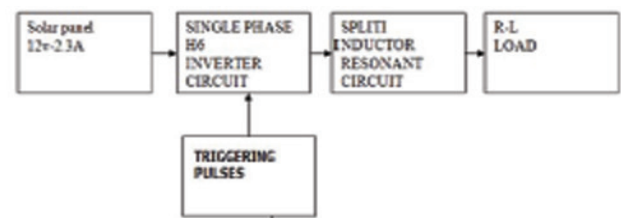
### 3. Proposed Transformer Less PV System

To avoid the problems in the circuit a new transformer less PV system is proposed. The system efficiency is increased and ground leakages current are also reduced. This is shown in Figure 2.

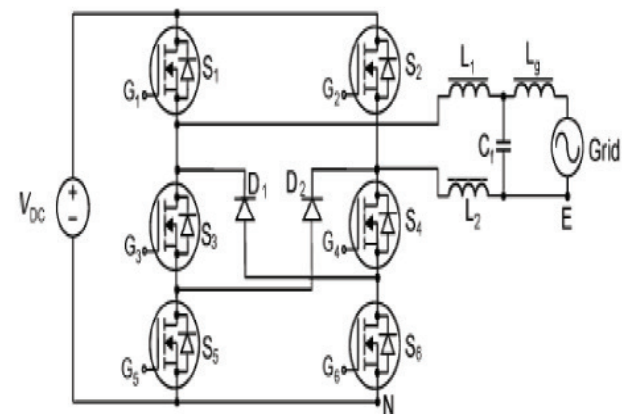
The first block in this system is the solar panel, this supplies input to the system then is the single phase H6 inverter circuit, which is a type of arrangement where the six MOSFET switches are connected in the shape of H arrangement. This inverter is used to convert the available dc into the ac current ready to be used by the utility. Then comes the split inductor circuit, this plays a main part in the system of increasing the voltage level of the system. The system input is twenty four Volts and the output of the system is 200 Volts. The LC circuit is of series type, where the voltage level is boosted. The RL load can be a motor. The triggering pulses are given to the MOSFET switches at equal intervals of time, such that the positive and negative cycles conduct.

This circuit is well suited for non isolated ac-module applications because of the following advantages,

- High efficiency over a wide load range by using MOSFETs for all active switches since their intrinsic body diodes are naturally inactive.
- Low ground leakage current because the voltage applied to the parasitic ground-loop capacitance contains only low-frequency components.
- Smaller output inductance as compared to that of the common full-bridge inverter with bipolar PWM switching.
- Low-output ac current distortion because there is no need to have dead time for the proposed circuit since the three active switches in the same phase-leg never all turn ON during the same PWM cycle.



**Figure 2.** Schematic block diagram of the proposed method.



**Figure 3.** Schematic circuit diagram of the proposed method.

In this system the efficiency is increased than all other systems developed using transformer less topology. As we know that if the efficiency is increased the losses are decreased. This is the main concept of the system. The existing system at present uses diodes, which has more conducting losses and reduced efficiency. The proposed system uses MOSFET switches instead of diodes thus the conduction losses are reduced and efficiency is increased.

The ground leakage current is also reduced, because the time taken to cross the zero voltage state is also reduced. There is no dead time introduced in the circuit hence the leakage current is reduced. The circuit diagram is shown in Figure 3.

The existing system uses PWM signals for generation of output also use separate algorithms, but in the proposed system there are no such problems. The transformer less (no transformer) topology is used here. By this the weight and the size of the system is reduced. The core losses are also reduced. The complication of the circuit is also reduced by using less power switches.

The system consists of four main parts which are discussed below. These are the i) solar panel, ii) full bridge inverter, iii) LC circuit and iv) load.

### 3.1 Solar Panel

The solar panel used here is of the capacity of 12 Volts and 2.3 Amps this is of smaller capacity, but can be increased according to the load needed. There are various types of solar panel used based on the applications needed. This is shown in Figure 1.

### 3.2 Full Bridge Inverter

The full-bridge inverter is one of the single stage dc-ac conversion topology that is used often in PV inverters. In the Transformer less Photo Voltaic inverters the electronic switches can be switched in either the bipolar or the unipolar mode. In the bipolar mode, the diagonally opposite switches of present in the inverter bridge in the two legs are switched as pairs. In the unipolar mode, switches are not switched simultaneously but are controlled separately. The output voltage swing is half of that in the bipolar mode than that of unipolar mode. Thus here full conversion of the dc voltage takes place. In our proposed method there are two zero voltage states namely positive zero voltage state and negative zero voltage state. During this state less amount of current is leaked into the ground, hence the efficiency of the system is increased.

### 3.3 LC Circuit

The type of circuit used here is series LC; here the voltage level is boosted. In our system the voltage level is boosted from 24 Volts to 100 Volts. The resonance effect is as a result of inductive and capacitive reactance's that are equal in magnitude. The resonant frequency is called as the frequency at which this equality holds for a particular circuit. The resonant frequency of the LC circuit is

$$\omega_0 = \frac{1}{\sqrt{LC}}$$

The unit of angular frequency is radians per second. The equivalent frequency is

$$f_0 = \frac{\omega_0}{2\pi} = \frac{1}{2\pi\sqrt{LC}}$$

The LC circuits are often used as filters; the L/C ratio is one of the factors that determine their "Q" and so selectivity.

### 3.4 Freewheeling Circuit

There is also a freewheeling circuit present in this system.

The purpose of this circuit is to free wheel the current even during the off condition of the switches. Thus there is always conduction inside the system.

### 3.5 MOSFET Switches

Power MOSFET used in the circuit is a specific type of Metal Oxide Semiconductor Field-Effect Transistor that is designed to handle different power levels. The main advantage is high commutation speed and good efficiency at low voltages.

## 4. Analysis of Different Topologies

### 4.1 HB with Unipolar Switching

Most single-phase HB inverters use unipolar switching to improve the injected current quality of the inverter, the output voltage is modulated to have three levels with twice the switching frequency. This modulation decreases the losses in the inverter and reduces the stress on the output filter.

### 4.2 HERIC (Highly Efficient and Reliable Inverter Concept)

HERIC topology combines the advantages of the three-level output voltage of the unipolar modulation and bipolar modulation. Thus the efficiency of the inverter is increased, without compromising the common-mode behaviour of the whole system. A bidirectional switch is used to realise the zero-voltage state. This bidirectional switch is made up of two Insulated-Gate Bipolar Transistors (IGBTs) and two diodes.

### 4.3 HB-ZVR (Zero-Voltage State Rectifier)

In HB-ZVR, the zero-voltage state can be attained using a bidirectional switch made of one IGBT and one Diode Bridge. The bidirectional switch is used as an auxiliary component. To fix the potential of the PV array during the zero-voltage vector when inverter switches are open the bidirectional switch is clamped to the midpoint of the dc-link capacitors. An additional diode is used to protect from short-circuiting the lower dc-link capacitor.

## 5. Different Modes of Operation of the System

### 5.1 Mode-1

During the grid positive half cycle, the switches S1, S4 and S6 are ON and the other switches and diodes are OFF, the inductor current is charging as shown in Figure 4.

### 5.2 Mode-2

In the freewheeling interval during the positive grid half cycle shown in Figure 5. The switches S1 and S6 are simultaneously turned OFF and S4 and D1 are ON. Under this condition the S1 and S6 share the dc-link voltage when they are simultaneously turned OFF.

### 5.3 Mode-3

During the grid Negative half cycle, the switches S2, S3 and S5 are ON and the other switches and diodes are OFF, the inductor current is charging as shown in Figure 6.

### 5.4 Mode-4

In the freewheeling interval during the negative grid half cycle shown in Figure 7. The S2 and S5 simultaneously

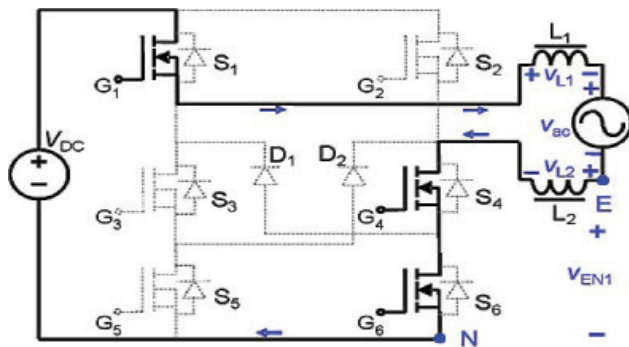


Figure 4. Mode 1 operation.

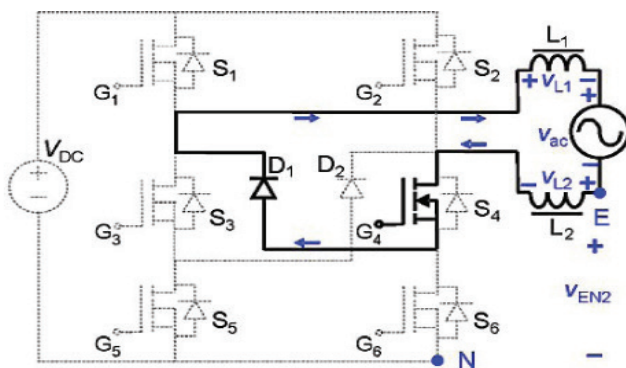


Figure 5. Mode 2 operation.

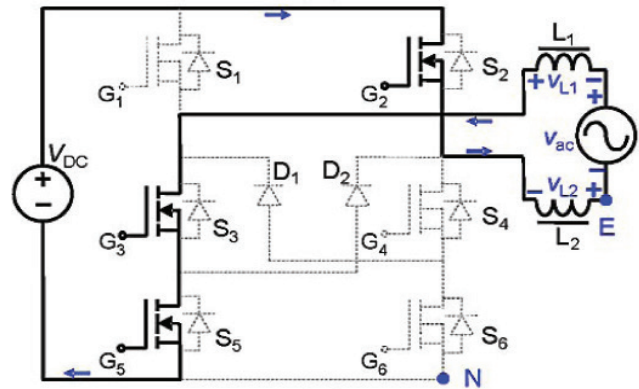


Figure 6. Mode 3 operation.

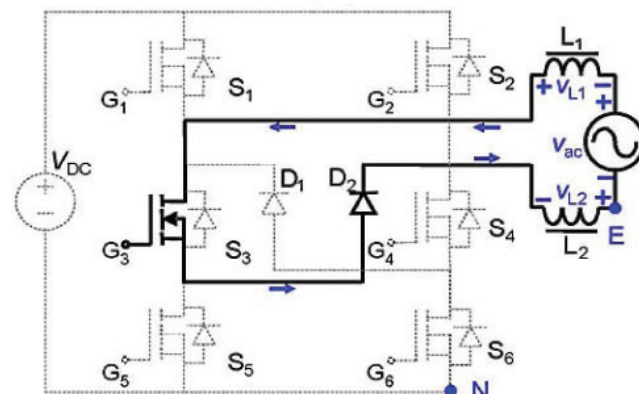


Figure 7. Mode 4 operation.

turn OFF and S3 and D2 are ON. Under this condition that S2 and S5 share the dc-link voltage when they are simultaneously turned off.

All these modes are simulated and the results are also verified using Matlab simulation.

## 6. Simulation Results

### 6.1 Input Voltage

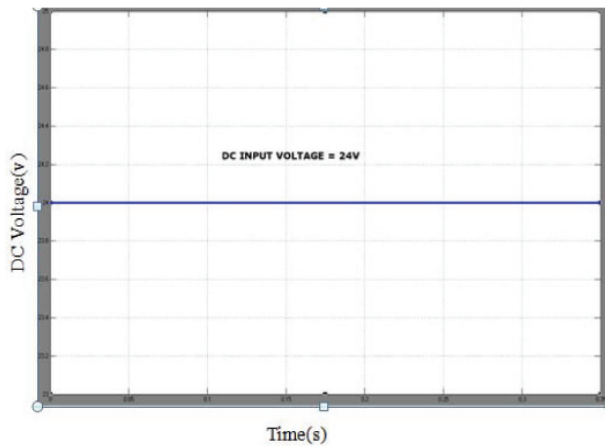
The input voltage given to the system is 24 V. This is from the solar pane as a shown in Figure 8.

The different triggering pulses given to the switches are given below. There are six switches used in our proposed system, and their switching sequences are demonstrated below in Figure 9. At first during the positive cycle three switches conduct they are S1, S4 and S6, hence they are first triggered.

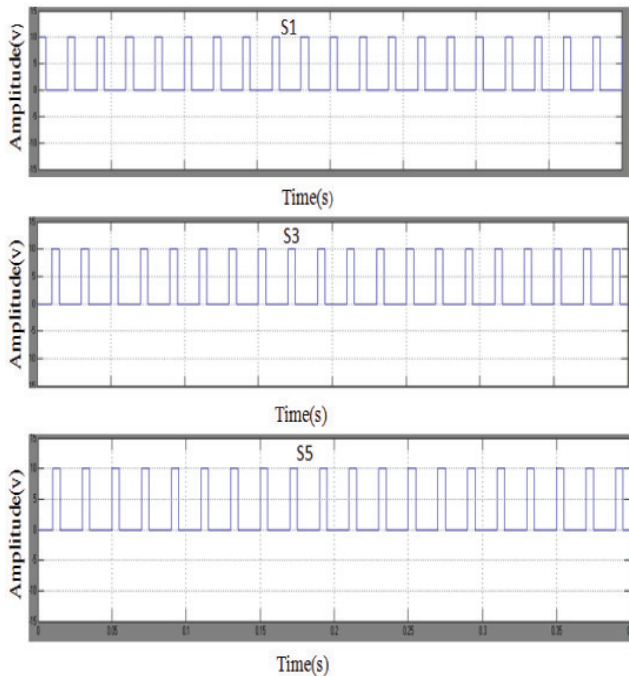
### 6.2 Triggering Pulses

The switches are triggered as such, for switches S1, S3, S5 in Figure 10:





**Figure 8.** DC input voltage.



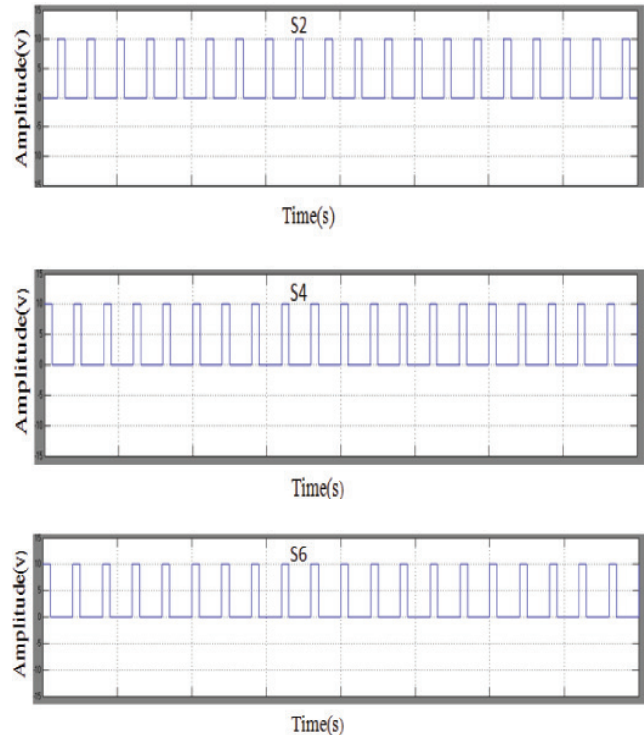
**Figure 9.** Triggering Pulses for S1, S3 and S5.

- Amplitude : 10 volts.
- Time Period : 0.02 seconds.
- Pulse width : 25 %.
- Phase delay : 0

For switches S2, S3, S5:

- Amplitude : 10 volts.
- Time Period : 0.02 seconds.
- Pulse width : 25 %.
- Phase delay : 0.01seconds.

In the negative cycle switches S2, S3 and S5 conduct, and their triggering pulses are mentioned above.



**Figure 10.** Triggering Pulses for S2, S4 and S6.

The simulation parameters are,

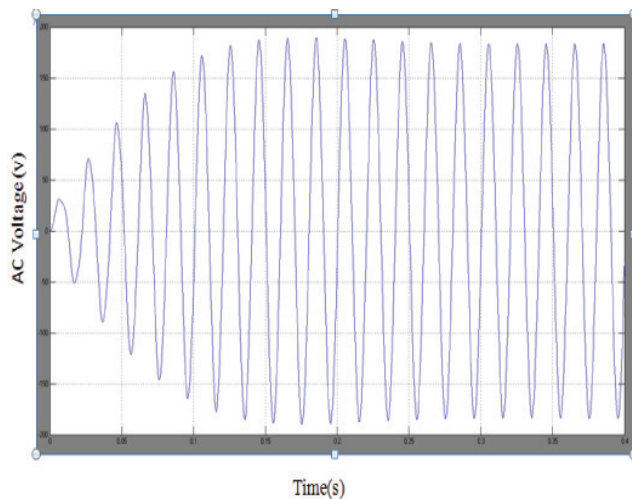
- Input voltage : 24 volts.
- Split inductor L1 : 120 e-3 Henry.
- Split inductor L2 : 90 e-3 Henry.
- Split inductor L1 : 200 e-3 Henry.
- Resonant capacitor C : 42 e-6 farad.
- Output voltage : 200 volts

### 6.3 Output Voltage

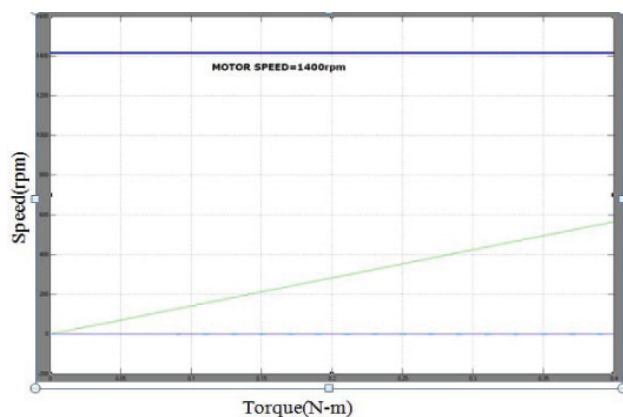
If we want we can get the output as given below or it can be used as input to an ac motor. The motor speed and torque as are also given below in Figure 11 and 12.

## 7. Conclusion

Transformer less inverters offers a better efficiency, compared to those inverters that have a galvanic isolation. On the other hand, in case the transformer is omitted, the generated common-mode behaviour of the inverter topology greatly influences the ground leakage current through the parasitic capacitance of the PV. This paper proposes a new transformer less, single-phase PV inverter with six switches and two diodes. The proposed H6 topology generates constant common-mode voltage, exhibits a



**Figure 11.** AC output voltage.



**Figure 12.** Motor Speed and torque Waveform.

high efficiency. Hence the prototype model of a proposed transformer less heric is implemented in hardware and the results are analysed. The future scope is, due to the reduced availability of power all nations are in search of sources which are renewable and does not affect the environment and this projected will serve for better renewable energy use.

## 8. References

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