A Hybrid Pv And Bess With Transformer Less Configuration For Grid Tied

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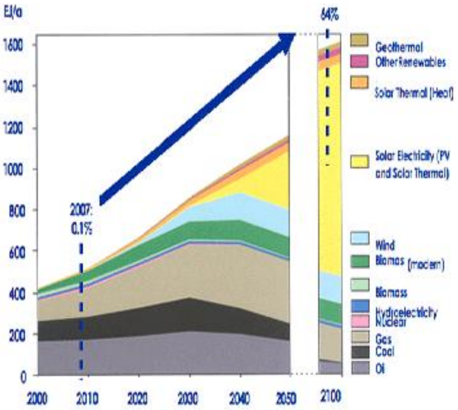
Abstract - Transformer less inverter is widely used in grid-tied photovoltaic (PV) generation systems, due to the benefits of achieving high efficiency and low cost. Various transformerless inverter topologies have been proposed to meet the safety requirement of leakage currents, such as specified in the VDE-4105 standard. In this paper, a family of H6 transformerless inverter topologies with low leakage currents is proposed, and the intrinsic relationship between H5 topology, highly efficient and reliable inverter concept (HERIC) topology, and the proposed H6 topology have been discussed as well. One of the proposed H6 inverter topologies is taken as an example for detail analysis with operation modes and modulation strategy. The power losses and power device costs are compared among the H5, the HERIC, and the proposed H6 topologies. A universal prototype is built for these three topologies mentioned for evaluating their performances in terms of power efficiency and leakage currents characteristics. Experimental results show that the proposed H6 topology and the HERIC achieve similar performance in leakage currents, which is slightly worse than that of the H5 topology, but it features higher efficiency than that of H5 topology.

Index Terms—Common-mode voltage, grid-tied inverter, leakage current, photovoltaic (PV) generation system, transformerless inverter

I. Introduction

With the worsening of the world's energy shortage and environmental pollution problems, protecting the energy and the environment becomes the major problems for human beings. Thus the development and application of clean renewable energy, such as solar, wind, fuel cell, tides and geothermal heat etc., are getting more and more attention. Among them, solar power will be dominant because of its availability and reliability. As predicted by [1], the solar will provide the electricity up to 64% of the total energy by the end of this century as shown in Figure



Photovoltaic (PV) power generation has become one of the main ways to use solar energy. And the renewable energy source based distributed generation (DG) system are normally interfaced to the grid through power electronic converters or inverters [2] as shown in Figure 1.2. Thus developing a photovoltaic grid-connected inverter system is important for the mitigation of energy and environmental issues.

Photovoltaic:

Photovoltaic (PV) is a method of generating electrical power by converting solar radiation into direct current electricity using semiconductors that exhibit the photovoltaic effect. The basic PV cell model is presented in Figure

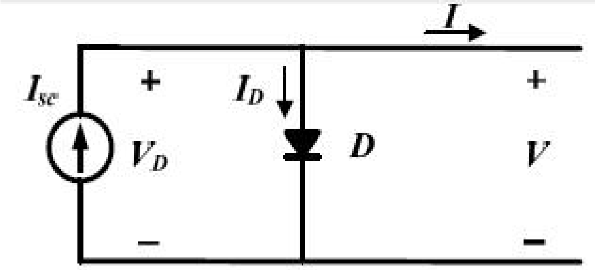


Figure 1. Basic PV cell model

Then the equations (1.1) through (1.3) could be obtained.

$$I_D = I_{sc} - I$$

$$I_D = I_s \cdot \left(e^{\frac{V}{n \cdot V_T}} - 1 \right)$$

$$I_D = I_{sc} - I_s \cdot \left(e^{\frac{V}{n \cdot V_T}} - 1 \right)$$

Solar panels turn energy from the sun’s rays directly into useful energy that can be used in homes and businesses. There are two main types: solar thermal and photovoltaic, or PV. Solar thermal panels use the sun’s energy to heat water that can be used in washing and heating. PV panels use the photovoltaic effect to turn the sun’s energy directly into electricity, which can supplement or replace a building’s usual supply.

A PV panel is made up of a semiconducting material, usually silicon-based, sandwiched between two electrical contacts. To generate as much electricity as possible, PV panels need to spend as much time as possible in direct sunlight (1a). A sloping, south-facing roof is the ideal place to mount a solar panel. A sheet of glass (1b) protects the semiconductor sandwich from hail, grit blown by the wind, and wildlife. The semiconductor is also coated in an antireflective substance (1c), which makes sure that it absorbs the sunlight it needs instead of scattering it uselessly away.

When sunlight strikes the panel and is absorbed, it knocks loose electrons from some of the atoms that make up the semiconductor (1d). The semiconductor is positively charged on one side and negatively charged on the other side, which encourages all these loose electrons to travel in the same direction, creating an electric current . The contacts (1e and 1f) capture this current (1g) in an electrical circuit.

The electricity PV panels (2) generate is direct current (DC). Before it can be used in homes and businesses, it has to be changed into alternating current (AC) electricity using an inverter (3). The inverted current then travels from the inverter to the building’s fuse box (4), and from there to the appliances that need it. PV systems installed in homes and businesses can include a dedicated metering box (5) that measures how much electricity the panels are generating. As an incentive to generate renewable energy, energy suppliers pay the system’s owner a fixed rate for every unit of electricity it generates - plus a bonus for units the owner doesn’t use, because these can help supply the national grid. Installing a PV system is not cheap, but this deal can help the owner to earn back the cost more quickly - and potentially even make a profit one day.

PV array

A PV array consists of a number of PV modules or panels. A PV module is an assembly of a large number of interconnected PV cells.

The inverter in a PV system is employed to transform the DC-voltage generated from a PV module to a three-phase AC voltage. A three-phase inverter has three legs with two switches in each leg. The switching is performed by carrier-based or space-vector- based Pulse-Width Modulation (PWM) [3]. A detailed discussion on different inverter topologies is provided later in this chapter. The inverter is usually interfaced to the utility grid through a transformer. However, transformer-less PV inverter topologies have also been proposed and implemented for single-phase grid-connected PV inverter.

The output quantity of an inverter (voltage in VSI and current in CSI) is pulsed and contains switching harmonics along with a 50 Hz fundamental.

II. LITERATURE SURVEY

Traditional Single Phase Inverter

Conventional two-level inverters, seen in Figure 1.1, are mostly used today to generate an AC voltage from an DC voltage. The two-level inverter can only create two different output voltages for the load, +Vdc2 or –Vdc2 (when the inverter is fed with Vdc). To build up an AC output voltage these two voltages are usually switched with PWM, see Figure 3.2. Though this method is effective it creates harmonic distortions in the output voltage, EMI and high dv/ dt (compared to multilevel inverters) .

This may not always be a problem but for some applications there may be a need for low distortion in the output voltage. The concept of MultiLevel Inverters (MLI) does not depend on just two levels of voltage to create an AC signal. Instead several voltage levels are added to each other to create a smoother stepped waveform, see Figure 1.3, with lower dv/ dt and lower harmonic distortions. With more voltage levels in the inverter the waveform it creates becomes smoother, but with many levels the design becomes more complicated, with more components and a more complicated controller for the inverter is needed. To better understand multilevel inverters the more conventional three-level inverter, shown in Figure 1.4, can be investigated. It is called a three-level inverter since every phase-leg can create the three voltages +Vdc 2 , 0, -Vdc 2 , as can be seen in the _first part of Figure .

A three-level inverter design is similar to that of an conventional two-level inverter but there are twice as many valves in each phase-leg. In between the upper and lower two valves there are diodes, called clamping diodes [1], connected to the a neutral midpoint in between two capacitors, marked n in the _Figure. These capacitor build up the DC-bus, each capacitor is charged with the voltage Vdc 2 .

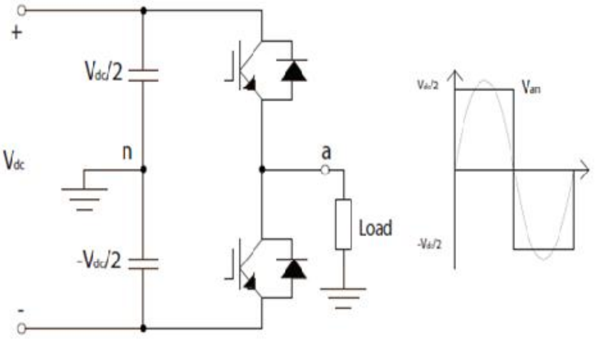


Fig 3.2 Traditional single phase inverter

Together with another phase-leg an output line-to-line voltage with even more levels can be obtained. To create the zero voltage the two switches closest to the midpoint are switched on and the clamping diodes hold the voltage to zero with the neutral point. Now, if more valve pairs, clamping diodes and capacitors are added the inverter can generate even more voltage levels, see Figure 3.3, the result is a multilevel inverter with clamping diode topology.

III. PROPOSED METHOD

The applications of distributed photovoltaic (PV) generation systems in both commercial and residential structures have rapidly increased during recent years. Although the price of PV panel has been declined largely, the overall cost of both the investment and generation of PV grid-tied system are still too high, comparing with other renewable energy sources. Therefore, the grid-tied inverters need to be carefully designed for achieving the purposes of high efficiency, low cost, small size, and low weight, especially in the low-power single-phase systems (less than 5 kW). From the safety point of view, most of the PV grid-tied inverters employ line-frequency transformers to provide galvanic isolation in commercial structures in the past. However, line-frequency transformers are large and heavy, making the whole system bulky and hard to install. Compared with line-frequency isolation, inverters with high-frequency isolation transformers have lower cost, smaller size and weight.

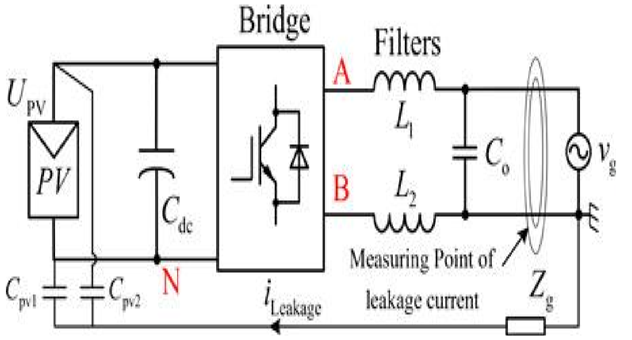


Fig. 1. Leakage current path for transformerless PV inverters

However, the inverters with high-frequency transformers have several power stages, which increase the system complexity and reduce the system efficiency. As a result, the transformerless PV grid-tied inverters, as shown in Fig. 1, are widely installed in the low-power distributed PV generation systems.

Unfortunately, when the transformer is removed, the common mode (CM) leakage currents ($i_{leakage}$) may appear in the system and flow through the parasitic capacitances between the PV panels and the ground. Moreover, the leakage currents lead to serious safety and radiated interference issues. Therefore, they must be limited within a reasonable range [10].

As shown in Fig. 1, the leakage current iLeakage is flowing through the loop consisting of the parasitic capacitances (CPV1 and CPV2), bridge, filters (L1 and L2), utility grid, and ground impedance Zg . The leakage current path is equivalent to an LC resonant circuit in series with the CM voltage, and the CM voltage vCM is defined as

$$v_{CM} = \frac{v_{AN} + v_{BN}}{2} + (v_{AN} - v_{BN})\frac{L_2 - L_1}{2(L_1 + L_2)} \qquad (1)$$

where v_{AN} is the voltage difference between points A and N, v_{BN} is the voltage difference between points B and N. L1 and L2 are the output filter inductors.

In order to eliminate leakage currents, the CM voltage must be kept constant or only varied at low frequency, such as 50 Hz/60 Hz. The conventional solution employs the half-bridge inverter. The filter inductor L2 is zero in the half bridge inverters. Therefore, (1) is simplified as

$$v_{CM} = \frac{v_{AN} + v_{BN}}{2} - \frac{(v_{AN} - v_{BN})}{2} = v_{BN}. \qquad (2)$$

The CM voltage vCM is constant due to the neutral line of the utility grid connecting to the midpoint of the split dc-link capacitors directly. However, a drawback of half-bridge inverters is that, the dc voltage utilization of half-bridge type topologies is half of the full-bridge topologies. As a result, either large numbers of PV panels in series are involved or a boost dc/dc converter with extremely high voltage transfer ratio is required as the first power conditioning stage, which could decrease the system efficiency.

The full-bridge inverters only need half of the input voltage value demanded by the half-bridge topology, and the filter inductors L1 and L2 are usually with the same value. As a result,
(1) is simplified as

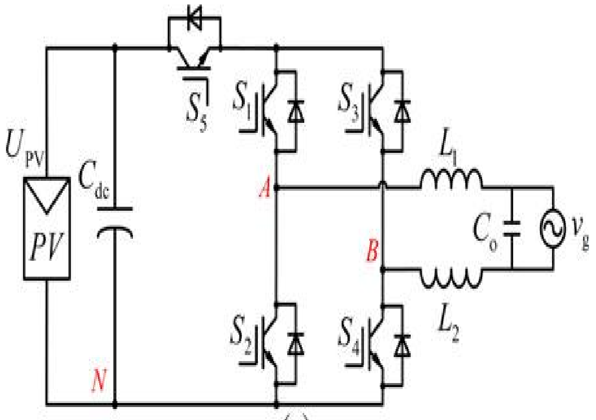
$$v_{CM} = \frac{v_{AN} + v_{BN}}{2}. \qquad (3)$$

Many solutions have been proposed to realize CM voltage constant in the full-bridge transformerless inverters. A traditional method is to apply the full-bridge inverter with the bipolar sinusoidal pulsewidth modulation (SPWM). The CM voltage of this inverter is kept constant during all operating modes. Thus, it features excellent leakage currents characteristic.

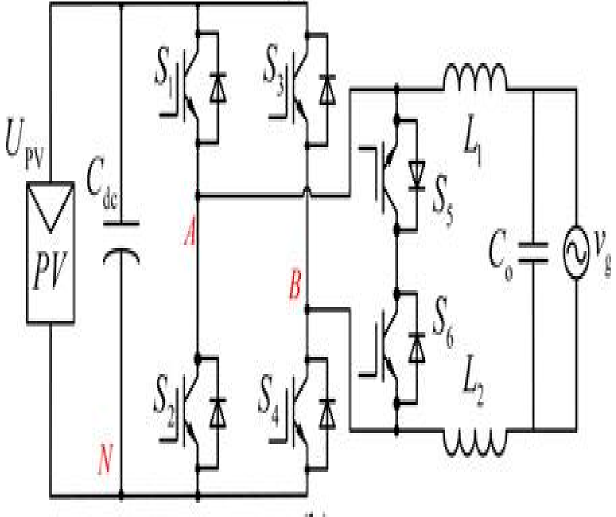
However, the current ripples across the filter inductors and the switching losses are likely to be large. The full-bridge inverters with uniploar SPWM control are attractive due to the excellent differential-mode (DM) characteristics such as smaller inductor current ripple, and higher conversion efficiency. However, the CM voltage of conventional unipolar SPWM fullbridge inverter varies at switching frequency, which leads to high leakage currents. Two solutions could be applied to solve this problem. One solution is to connect the PV negative terminal with the neutral line of the utility grid directly, such as the Karschny inverter derived from buck–boost converter, and the inverters derived from virtual dc-bus concept. The CM voltage is kept constant by these full-bridge topologies with unipolar modulation methods. Another solution is to disconnect the dc and ac sides of the full-bridge inverter in the freewheeling modes. Various topologies have been developed and researched based on this method for keeping the CM voltage constant, such as the H5 topology, the highly efficient and reliable inverter concept

(HERIC) topology, the H6-type topology, and the hybrid-bridge topology, etc., are shown in Fig. 2.

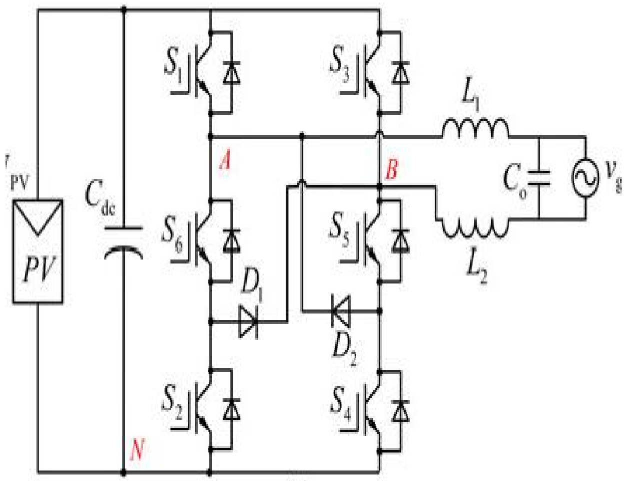
Fig. 2(a) shows the H5 topology. It employs an extra switch on the dc side of inverter. As a result, the PV array is disconnected from the utility grid when the inverter output voltage is at zero voltage level, and the leakage current path is cut off. The HERIC topology shown in Fig. 2(b) employs two extra switches on the ac side of inverter, so the leakage current path is cut off as well. However, its power device cost is higher than that of the H5 topology. Fig. 2(c) and (d) shows the H6-type topology and the hybrid-bridge topology respectively. Comparing with a full-bridge inverter, two extra switches are employed in the dc sides of these two topologies. Furthermore, both the H5 topology and the HERIC topology have been compared in terms of efficiency and leakage currents characteristic. However, these topologies have never been analyzed form the point of view of topological relationships.



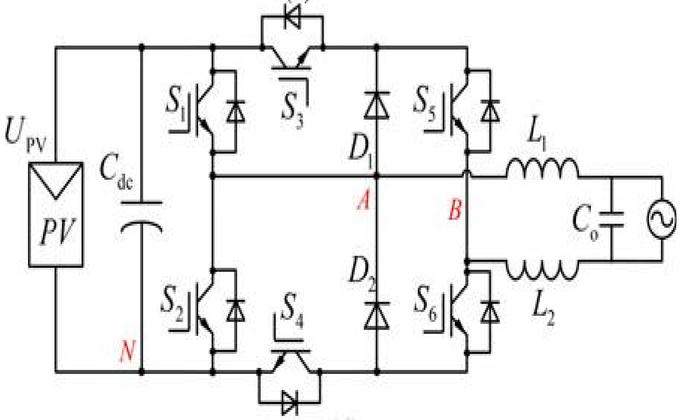
(a)



(b)



(c)



(d)

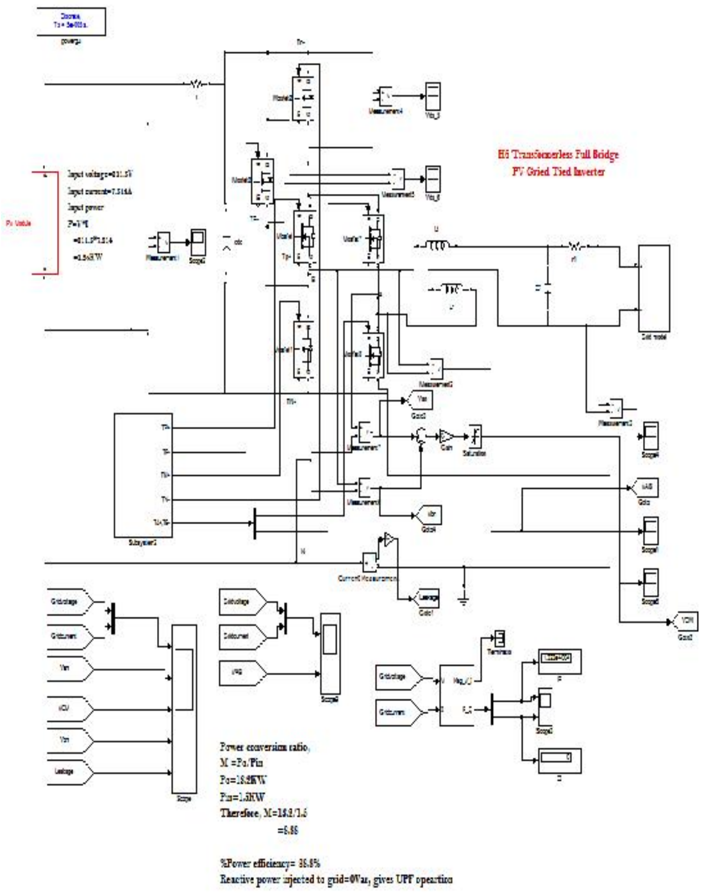
Fig. 2. Four typical topologies of transformerless full-bridge inverters (a) H5. (b) HEIRC. (c) H6-type. (d) Hybrid bridge

In this paper, a family of novel H6 full-bridge topologies is proposed for the transformerless PV grid-tied inverters. An extra switch is inserted to the H5 topology for forming a new current path and for the purpose of reducing conduction loss. Therefore, in the active modes, the inductor current of the proposed H6 topology flows through two switches during one of the half line periods and through three switches during another half-line period. As a result, for comparing with the topologies presented, the proposed H6 topology has achieved the minimum conduction loss, and also has featured with low leakage currents. On the other hand, the topological relationship between H5 topology and HERIC topology is revealed, and the methods for generating HERIC topology from H6-type topology and from hybrid-bridge topology are presented, respectively.

This paper is organized as follows. In Section II, the operation modes and characteristics of the H5 topology and the HERIC topology are presented and compared. The methods of generating HERIC topology from the H6-type topology or from the hybrid-bridge topology are given. A family of H6 topologies is proposed, and the topological relationship between H5 topology and HERIC topology is analyzed. In Section III, one of the proposed H6 topologies is taken as an example for analysis in detail with operational principle and modulation strategy.

The comparisons between H5, HERIC, and the proposed H6 topology are given in terms of power loss and device cost. Experimental results are presented in Section IV, and Section V concludes the paper.

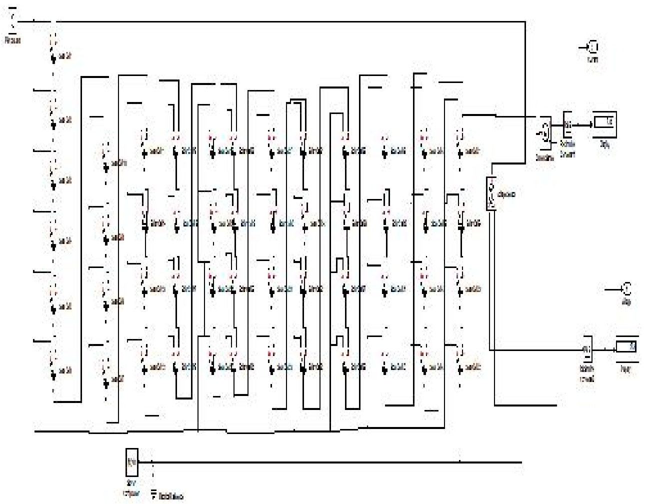
IV.Simulation Results



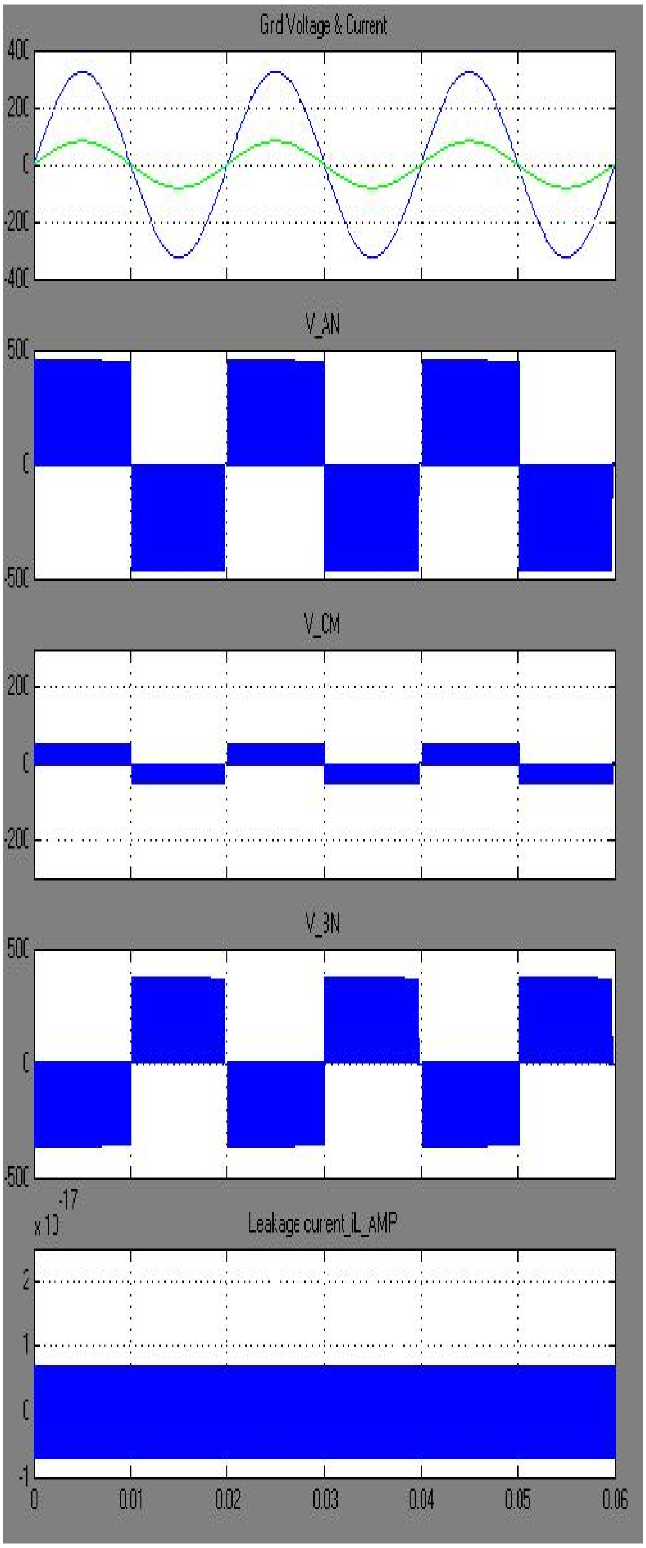
Power conversion ratio,
M =Po/Pin
Po=18.2KW
Pin=1.5KW
Therefore, M=18.2/1.5
=6.88

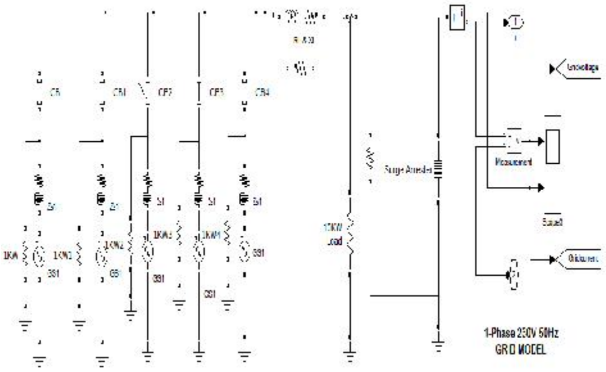
%Power efficiency= 88.8%
Reactive power injected to grid=0Var, gives UPF operation

PV system:

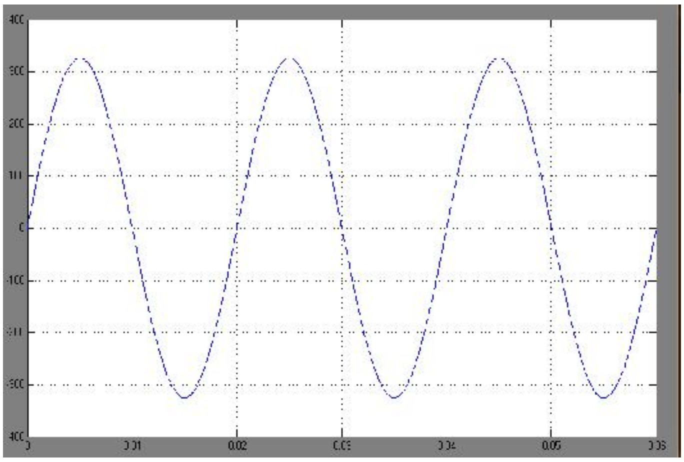


WAVEFORMS





Grid voltages



CONCLUSION

In this paper, from the topological relationship point of view, the intrinsic relationship between H5 topology and HERIC topology is revealed. The HERIC topology can be derived from H5, H6-type, and hybrid-bridge topologies by the idea of reducing conduction loss. Moreover, based on the H5 topology, a new current path is formed by inserting a power device between the terminals of PV array and the midpoint of one of bridge legs. As a result, a family of single-phase transformerless full-bridge H6 inverter topologies with low leakage currents is derived. The proposed H6 topologies have the following advantages and evaluated by experimental results:

1) The conversion efficiency of the novel H6 topology is better than that of the H5 topology, and its thermal stress distribution is better than that of the H5 topology;

2) The leakage current is almost the same as HERIC topology, and meets the safety standard;

3) The excellent DM performance is achieved like the isolated full-bridge inverter with uniploar SPWM. Therefore, the proposed H6 topologies are good solutions for the singlephase transformerless PV grid-tied inverters.

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