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High Efficient Transformerless Single Stage Inverter Topology for Single Phase Grid Connected Photovoltaic System

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Abstract: Rapidly increasing the demand of solar PV energy sector by the benefits of low cost, clean green energy, reliable and energy efficient systems. Maximum solar power obtained by using the concept of Maximum Power Point Tracking (MPPT) which significantly increases the efficiency of the solar photovoltaic system. The Removal of isolation transformer in grid connected Photo Voltaic (PV) inverters is desirable to increase efficiency and reduce the size, weight, and cost of these systems. However, leakage current will be flowing through the stray capacitance between the PV array and ground, causing a safety risk. The proposed inverter has inherent buck-boost capability and also has common ground between the negative terminal of the PV array and the grid neutral. Single stage energy process is achieved in buck and boost operation modes for achieving high efficiency. The smooth mode transition is realized by the proposed unipolar Sinusoidal Pulse-Width-Modulation (SPWM). This topology reduces the output current ripples, number of components, voltage stress across the switches, regulate the output voltage and switching losses. A simulation of the proposed system is modelled and evaluated with desirable results in MATLAB/Simulink.

Keywords: Photovoltaic system, Maximum Power Point Tracking (MPPT), Single-phase Transformerless PV inverter; leakage current elimination, Unipolar Sinusoidal Pulse Width Modulation (USPWM)

I. INTRODUCTION

In recent years, photovoltaic systems reached as a sustainable power solution. By the increasing interest in sustainable energy production through PV, demands attention on different issues like personal safety, grid integration, power quality, stability, reliability and operations under various environmental conditions [1]. Grid tied PV systems are classified into two; with and without transformers. Large number of PV systems is using transformers for security with galvanic isolation. Galvanic isolation not allow the flow of dc current into the power grid, it reduces the leakage current between the PV system and power grid [2]. In DC side high frequency transformers and low frequency transformers are used in the output side of an inverter. Even though, the transformers are large, it increases the system complexity, volume, expense and also it reduces the complete frequency of the power conversion process. Transformerless PV inverters have low cost, high efficiency and high power density. Due to the absence of transformer a leakage current will flow through the PV array and grid due to the parasitic capacitance. Common mode ground current will cause current harmonics, higher losses, safety problems, and electromagnetic interference (EMI) issues. To avoid this problem a common terminal is provided between PV and grid, which ensures zero CMLC. Fig 1 shows the flow of common mode leakage current (icm) through the ground impedance Zg.

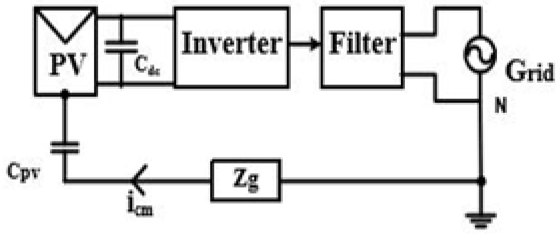

Fig. 1 A transformer-less PV-Grid System

The grid-connected inverters can be classified into multistage and single-stage inverters. Among the multi stage inverters, the two-stage inverters are commonly used in grid-connected PV systems [3]. One stage is dc- dc converters

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and other stage is inverter The dc-dc converter is a non-isolated boost or buck-boost dc-dc converters. They extract maximum power from PV panel, and boost the dc voltage of PV panel. The dc-ac inverter, it converts the dc power of PV panel into ac power. The ac power is then fed into the grid. The two- stage inverters have some drawbacks such as more power processing stages, lower reliability, higher cost, more components, lower efficiency, and larger size. A single- stage inverter can be considered as a better option in terms of lower cost, higher reliability, smaller size and higher efficiency [4]. In single-stage grid-connected inverter topologies, the maximum power extraction from PV panel, boosting the dc voltage of PV panel and inversion of dc power into ac power all are done in a single-stage.

This paper proposes a single stage single phase buck- boost inverter with only four switches, four inductors and two capacitors. It shares a common terminal between the input and output ports, which eliminates CMLC problems and reduce possibilities of consequent panel degradation. It is a combination of two dc-dc buck-boost converter operating sequentially to generate an ac voltage output. Single stage energy process is achieved in buck and boost operation modes for achieving high efficiency. The smooth mode transition is realized by the proposed unipolar sinusoidal pulse-width-modulation (SPWM). This topology reduces the output current ripples, number of components, voltage stress across the switches, regulate the output voltage and switching losses.

II. PROPOSED SYSTEM

Circuit diagram of the inverter in grid connection (GC) shown in Fig. 2. It consists of four MOSFETs, four external diodes, four inductors and two leg capacitors. MOSFET has inherent body diodes and it do not conduct, MOSFET can be used without failure risk caused by reverse recovery of body diode. Each MOSFET is connected in series with an external diode, and they are connected to inductors. Short circuit between the switches is prevented by the inductors. By using MOSFETs in conjunction with external fast recovery diodes, efficiency can be increased. Higher switching frequencies can be used to reduce the volume of passive components.

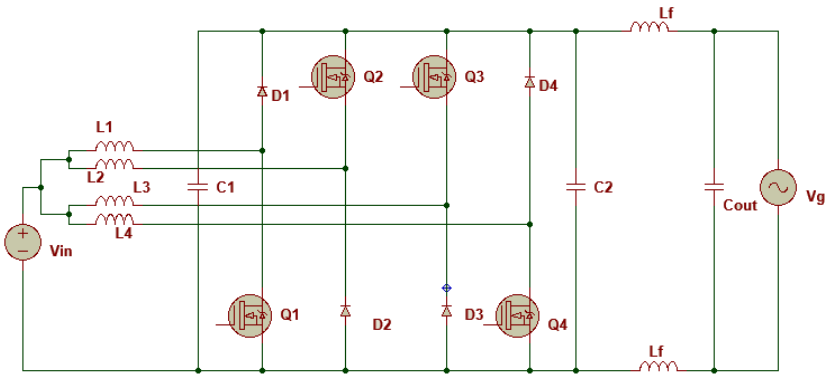
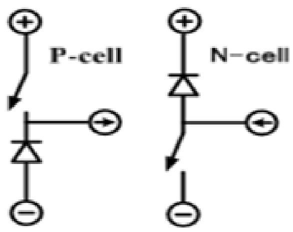


Fig. 2 Circuit diagram of proposed buck boost inverter system

III. HIGH FREQUENCY LEG TECHNIQUE

All power electronics circuits are based on two basic switching cells defined as P-cell and N-cell as shown in Fig. 3. Each cell consists of one switching device and one diode. Cell connected to three terminals: (+) which is connected to the positive of a voltage- source (-) which is connected to the negative of a voltage-source, and a common terminal shown as (→) or (←). The cells can be used directly as the DC converter, and also applied in the technique of inverter and rectifier.



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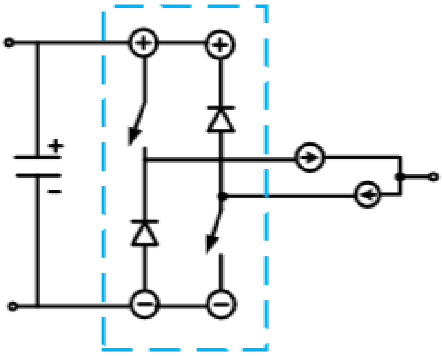
The shoot-through problem in the inverter can be avoided by using P-cell and N-cell. All inverter can be constructed by using basic switching cells. Parallel combination of P-cell and N-cell forms phase leg with bidirectional current flow capacity. The combination of P-cell and N-cell has great advantage over conventional IGBT with antiparallel diode. In conventional system a dead time is required between the switching periods of the two switches to prevent the short circuit of the dc link. In paralleled P-cell and N-cell system an inductor is placed between the common terminals. Because of this no dead time is required. Load current flows through P-cell during the positive half cycle and through the N-cell during negative half cycle.



(b)

Fig. 3 (a) The structure of basic switching cells and (b) The parallel combination of the P-and N-cells form a bidirectional phase leg

In high power level application, instead of IGBT- diode module, MOSFET-diode module based P-cell and N-cell have better performance because IGBT has high switching and conduction loss. IGBT modules also operate in lower switching frequency than MOSFET; so it requires high filtering size. For better performance, integrating multiple bridge legs together and give high frequency switching signals to the switches.

IV. CONTROL OF THE PROPOSED SYSTEM

The unipolar sinusoidal pulse width modulation (SPWM) is used in the proposed system. Fig 4 represent the switching pulse for four switches

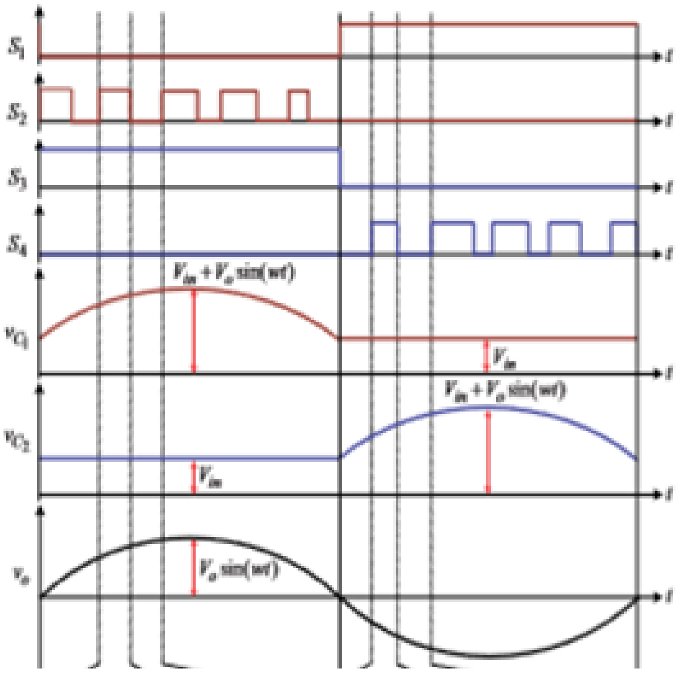


Fig. 4 unipolar SPWM technique

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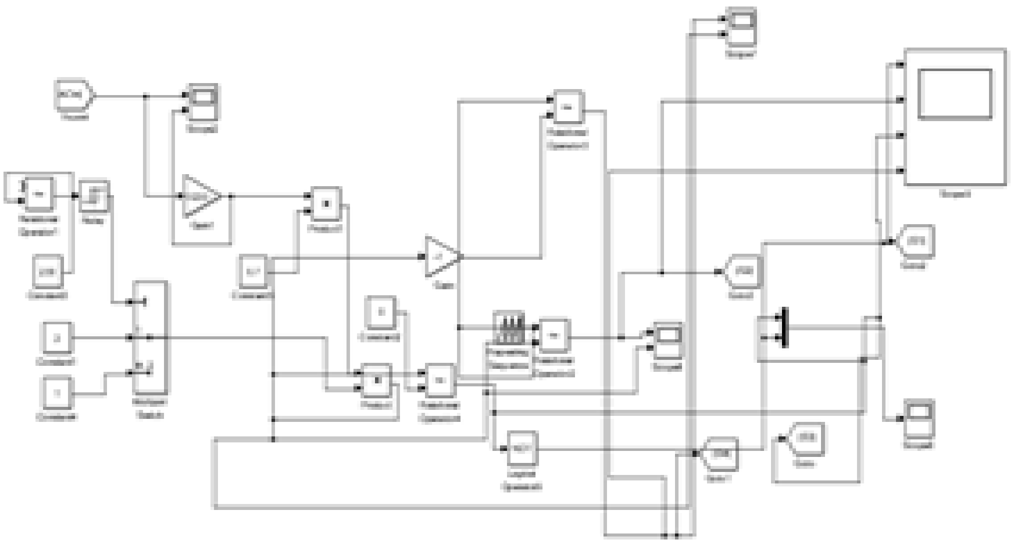


Fig. 5 Implementation of the proposed control strategy Fig 5 shows the implementation of the proposed

unipolar sinusoidal pulse width modulation control scheme. The switch S1 and switch S3 operate at low frequency, and switch S2 and switch S4 operate at high frequency. In each half-cycle of output voltage, only one switch is switched at high frequency. The proposed PWM strategy, eliminates the circulating current and dead-time requirement between the switches. At a time only one switch operates in high frequency. This modulating scheme helps to reduce the output current ripples, number of components, voltage stress across the switches, switching losses and regulate the output voltage.

V. SIMULATION RESULTS

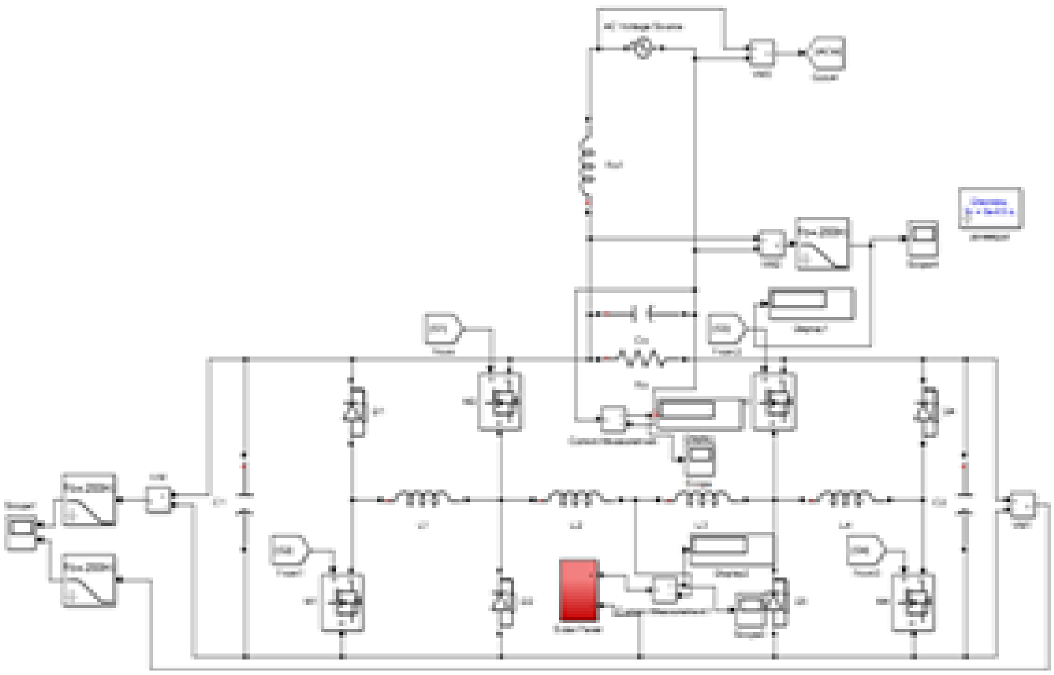


Fig 6. Simulation model of proposed system

The proposed system is simulated and analyzed in MATLAB/Simulink. The simulation of the overall proposed system is shown in Figure 6.

The inverter input voltage is 24V DC, the output is 230V AC. Fig 7 shows the output voltage and current waveform of the converter.

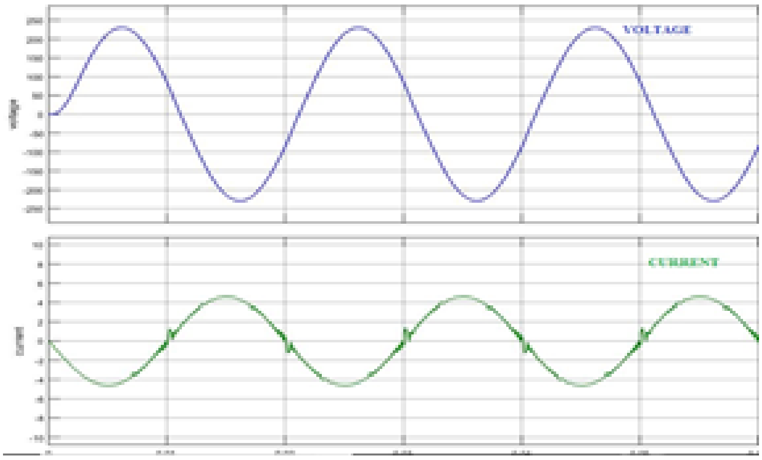


Fig 7 output voltage and current waveform

Since the input source is PV module, in order to obtain maximum power output, perturbance and observe (P&O) algorithm is used. Fig 8 shows the output of 24V solar panel with MPPT.

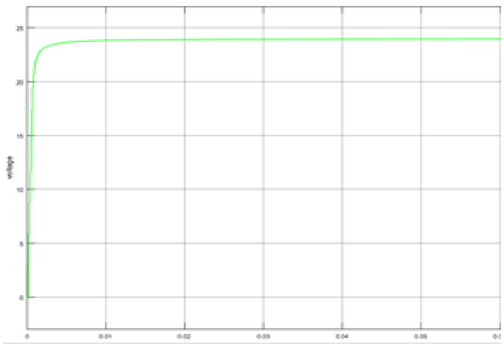
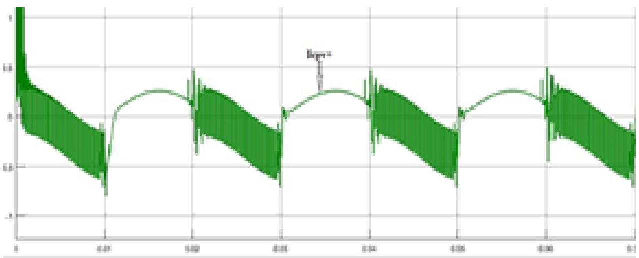


Fig 8 output voltage of 24V solar panel

In grid-connected PV inverters, the main problem is the leakage ground current through the parasitic capacitances. Fig 9 show the leakage current through the parasitic capacitance.


(a)

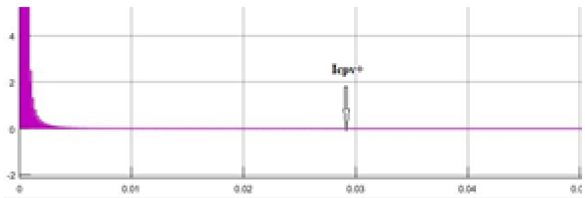


Fig 9 Leakage currents from PV panel to ground through parasitic capacitances for different parasitic capacitances. (a) 10 nF. (b) 1 pF.

The THD of the output voltage waveform of proposed inverter is shown in Figure 10. According to standards the THD level should be below 5%. The THD of the output voltage is about 0.53%. The dc component in the output voltage is

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zero. Fig 11 shows the efficiency comparison of proposed system and the two stage inverter. The efficiency is about 94%.

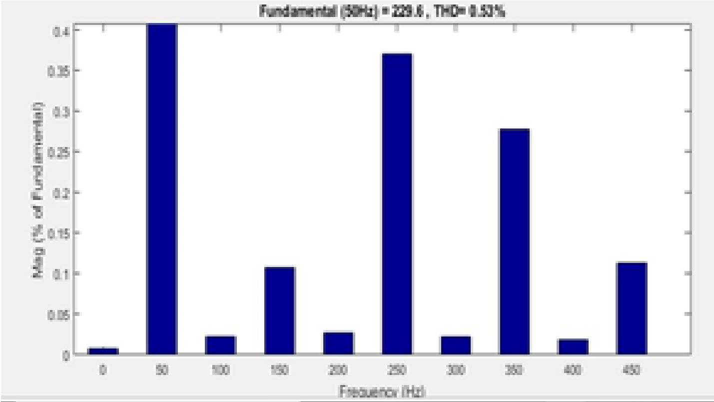

Fig 10 THD of proposed system

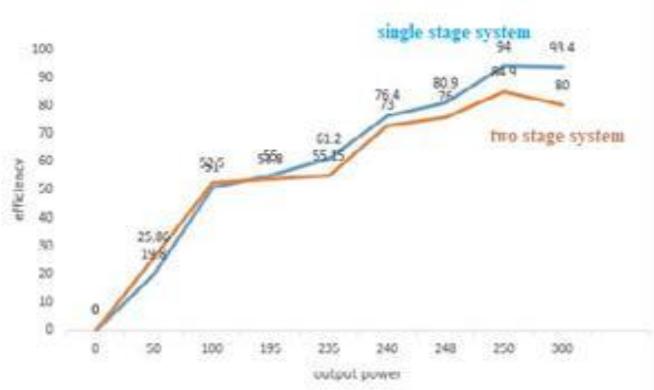

Fig 11 Efficiency comparison

CONCLUSION

This paper introduces a new single stage single phase buck boost inverter for PV systems. The main objective of the system is to get high efficiency and the THD level. It is achieved by less number of components to reduce the complexity of circuit design and analysis. It requires four switches, and only one switch is switched at high frequency under the proposed PWM scheme. As a result, the switching losses can be reduced. The conduction loss in inductor is reduced. The input voltage is 24V dc and the output is 230V ac. Efficiency of the system is 94%. The modified five level inverter with lesser number of components ensures lower THD of the output voltage waveform.

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