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ENHANCING THE EFFICIENCY OF A PHOTOVOLTAIC (PV) SYSTEM THROUGH THE UTILIZATION OF A COUPLED- INDUCTOR SINGLE-STAGE BOOST INVERTER (CLSSBI) AND NSPWM TECHNIQUE

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ABSTRACT

The transformer less photovoltaic (PV) power system has been attracting more and more attention for its lower cost, smaller volume, as well as higher efficiency, compared to the ones with transformer. One of the technical challenges is the safety issue of the leakage current caused by the common mode voltages, conducting in the loop with parasitic capacitors between the solar panel and the ground. A coupled inductor single-stage boost inverter (CL-SSBI) is proposed in, which introduced an impedance network, including coupled inductor in the front-end of the inverter bridge. the method to reduce the leakage current of the transformer less grid-connected PV system based on CLSSBI.A diode is added in the front of the topology to block the leakage current loop when in the active vectors and open-zero vectors. In addition, the near-state PWM (NSPWM) technique is used with one-leg shoot-through zero vectors to reduce the leakage current caused in the transient states of changing from and to open-zero vectors.
Keywords: Coupled Inductor, NSPWM, Photovoltaic (PV) system, Leakage current

I. Introduction

The converter steps up the bus voltage by storing and transferring energy within the special impedance network using shoot-through zero vectors. It is also possible to optimize the boost gain by adjusting the connected inductor's turns ratio inside the impedance network. As a result, the ac output voltage may be adjusted throughout a large range and increased. The drawback of inverters of this sort is that larger boost gain would be necessary, which would need more power loss and lesser efficiency. The equivalent switching frequency as seen from the impedance network can be six times the switching frequency of the inverter bridge, which will significantly reduce the power density and cost of the inverter. Shoot-through zero vectors are vectors that are evenly distributed among the three phase legs during a switching period. This letter outlines a CLSSBI-based technique for reducing the leakage current of a transformer-free grid- connected PV system. To stop the leakage current loop when in the active vectors and open zero vectors, a diode is placed to the front of the topology. Additionally, the leakage current induced in the transient stages of switching from and to open-zero vectors is reduced by using the near-state PWM (NSPWM) approach with one-leg shoot-through zero vectors. Additionally, because NSPWM's modulation index remains in the high modulation region, the leakage current may be efficiently controlled without reducing the maximum magnitude of the output reference voltage.

II. Existing System:

Higher power loss and lower efficiency would be unavoidable if higher boost gain is required, which is the disadvantage of inverters of this type. As shoot-through zero vectors evenly distributed among the three phase legs during a switching period, because conventional system switching frequency is low these converters may be used to regulate the voltage and current at the load, to control the power flow in grid connected systems and mainly to track the maximum power point (MPP) of the device.

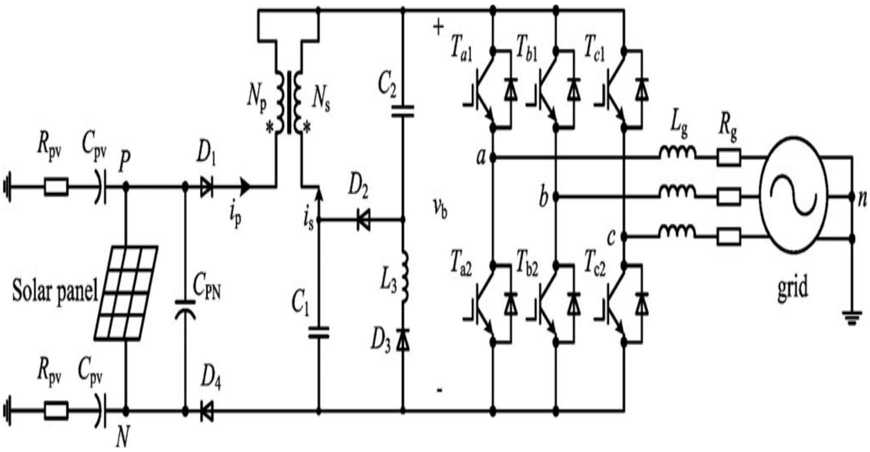

Fig.1 Transformer less grid-connected PV system based on CL-SSBI.

DC to AC converters, commonly referred to as inverters, are categorized into voltage source inverters (VSIs) and current source inverters (CSIs), depending on the type of power source and the circuit topology. Single-phase VSIs are typically used for low-power applications, while three-phase VSIs are employed in medium to high power applications. These inverters are designed to provide a three-phase voltage source with control over amplitude, phase, and frequency of the voltages. Three-phase DC/AC voltage source inverters are extensively utilized in various applications such as motor drives, active filters, unified power flow controllers in power systems, and uninterruptible power supplies. They enable the generation of controllable frequency and AC voltage magnitudes through various pulse width modulation (PWM) strategies. A coupled inductance single-stage boost inverter (CL-SSBI) has been proposed, introducing an impedance network that includes a coupled inductance at the front end of the inverter bridge.

III. Problem Statement:

The downside of these inverters is that they require a higher boost gain, which results in increased power loss and reduced efficiency. In a typical system, the switching frequency is relatively low, so shoot-through zero vectors are often evenly distributed across the three-phase legs during each switching period. To minimize leakage current during transitions between open-zero vectors, the proposed system employs the Near State Pulse Width Modulation (NSPWM) technique with one-leg shoot-through zero vectors. This approach helps reduce both the magnitude of common-mode voltages and the leakage current caused by other transitions.

IV. Objectives:

The "Modified Coupled Inductor Single Stage Boost Inverter Based Grid-Connected Photovoltaic (PV) System" is proposed with the following objectives:

1. Reduce the magnitude of reference common mode voltages and the leakage current induced by these voltages in grid-connected photovoltaic (PV) systems.
2. Enhance the boost gain to regulate a diverse range of output voltages, thereby minimizing power loss and improving overall system efficiency.

V. Methodology

V.I) SINUSOIDAL PWM IN SINGLE-PHASE VOLTAGE SOURCE INVERTERS

As in the single phase voltage source inverters PWM technique can be used in three-phase inverters, in which three sine waves phase shifted by 120° with the frequency of the desired output voltage is compared with a very high frequency carrier triangle, the two signals are mixed in a comparator whose output is high when the sine wave is greater than the triangle and the comparator output is low when the sine wave or typically called the modulation signal is smaller than the triangle. This phenomenon is shown in Figure V.I. As is explained the output voltage from the inverter is not smooth but is a discrete waveform and so it is more likely than the output wave consists of harmonics, which are not usually desirable since they deteriorate the performance of the load, to which these voltages are applied.

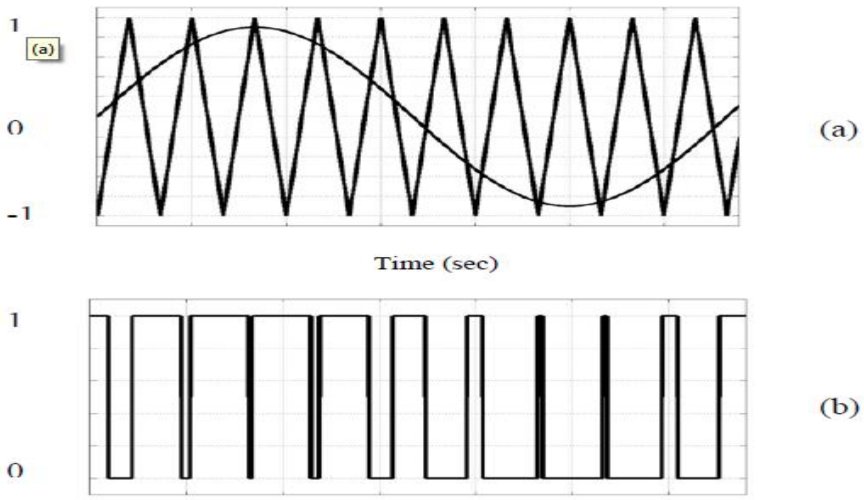

Fig V.I PWM illustration by the sine-triangle comparison method (a) sine-triangle comparison (b) switching pulses

V.II) NEAR STATE PULSE WIDTH MODULATION (NSPWM) IN SINGLE PHASE VOLTAGE SOURCE INVERTER

The near-state pulse width modulation (NSPWM) method, which reduces the common-mode voltage/current, is proposed for three-phase pulse width modulation (PWM) inverter drives. The method is described, its optimal voltage vectors are found, and the sequence that these vectors are applied is determined. Its voltage linearity and DC bus and AC output PWM current ripple characteristics are studied. Its output line-to-line voltage pattern is carefully studied with regard to switching transients that may cause over voltages at the motor terminals, particularly for long-cable applications. The PWM switching frequency has to be much higher than what would affect the load (the device that uses the power), which is to say that the resultant waveform perceived by the load must be as smooth as possible. Typically switching has to be done several times a minute in an electric stove, 120 Hz in a lamp dimmer, from few kilohertz (kHz) to tens of kHz for a motor drive and well into the tens or hundreds of kHz in audio amplifiers and computer power supplies.

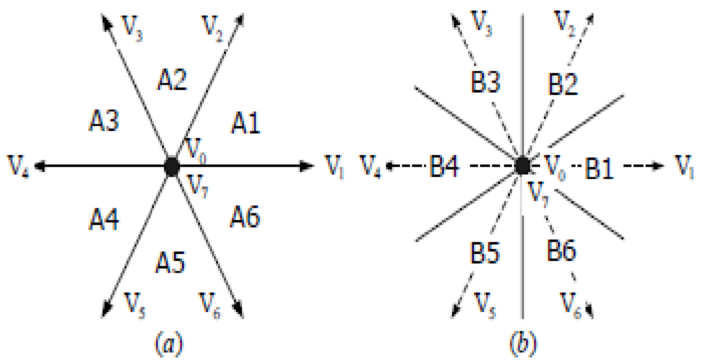

Fig V.II Voltage space vectors and 60◦sector definitions

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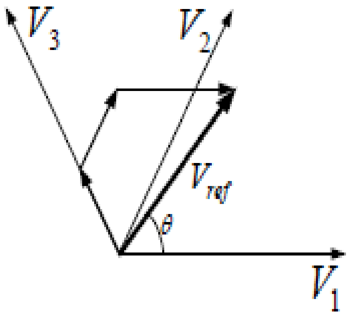
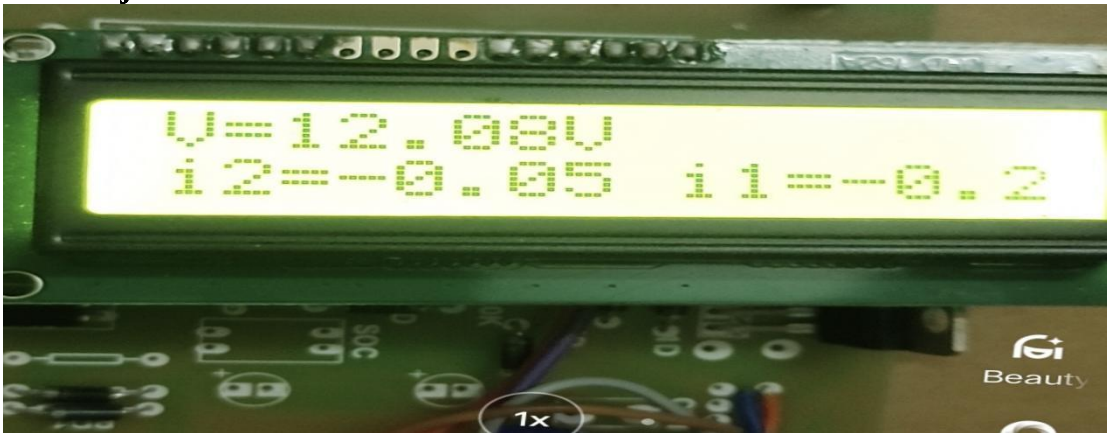


Fig V.III Illustration of the NSPWM space vectors for B2.

The Near State PWM (NSPWM) method optimizes by selecting a group of three adjacent voltage vectors to closely match output and reference volt-seconds. These vectors are chosen such that the closest vector to the reference and its two neighboring vectors (to the left and right) are employed. This selection rotates every 60 degrees across the voltage vector space, as illustrated in Figure V.II.To implement NSPWM, the voltage vector space is segmented into six regions. For instance, in region B2 (spanning from 30 degrees to 90 degrees, as depicted in Figure V.III, the utilized voltage vectors are V1, V2, and V3. Extensive research has examined NSPWM's effectiveness, comparing its performance against traditional PWM methods.

VI. Project Hardware Results:



At No Load condition Leakage current with NSPWM (I2) is Low
(I2) is Less than leakage current with PWM (I1) technique (50-60 mAmp)

At with Load condition Leakage current with NSPWM (I2) with Load is Low
(I2) is Lesser than Leakage current with PWM (I1) (370 mAmp)

VII. Conclusion:

A transformer less grid-connected PV system utilizes a coupled inductor single-stage boost three-phase inverter. In this setup, diode D4 is introduced alongside D1 at the topology's forefront to prevent leakage current loops during active and open-zero vectors. Transient states, where shoot-through zero vectors are engaged or disengaged, also contribute to reduced leakage current thanks to the NSPWM technique. This method selectively uses one-leg shoot-through zero vectors while excluding open-zero vectors. Furthermore, common mode voltages are minimized, consequently reducing leakage currents during various transitions. A comparison between CL-SSBI with NSPWM shows significant reductions in both amplitude and RMS values of leakage currents, often falling well below permissible thresholds. These results affirm effective mitigation of leakage currents and highlight improved boost gain capabilities for regulating a wide range of output voltages. Importantly, these advancements are achieved without increasing overall power loss, thereby enhancing system efficiency.

VIII. Future scope:

In future developments, ensuring the safety of transformer less PV systems remains a key challenge due to leakage currents caused by common mode voltages (CMV) and parasitic capacitors between solar panels and ground. Current strategies focus on maintaining constant CMV to reduce leakage, but modulation methods like OPWM and EPWM, which use only odd or even active vectors for output synthesis, can increase harmonic distortion in waveforms. Future research aims to refine modulation techniques to balance CMV reduction with minimizing harmonic distortion, improving system safety and efficiency for widespread grid-connected PV deployment.

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