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DESIGN AND IMPLEMENTATION OF A SINGLE-PHASE 15-LEVEL INVERTER WITH REDUCED COMPONENTS FOR SOLAR PV APPLICATIONS

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ABSTRACT

This paper presents the design and implementation of a novel single-phase 15-level inverter optimized for solar photovoltaic (PV) applications. The proposed inverter topology significantly reduces the number of required power switches, gate drivers, and passive components while maintaining high output voltage quality. The system ensures high efficiency and compact design, making it suitable for low- and medium-power renewable energy installations. Simulation and experimental results demonstrate the effectiveness of the topology in generating a low Total Harmonic Distortion (THD) output waveform..

1. INTRODUCTION

The global transition towards sustainable energy solutions has intensified the integration of photovoltaic (PV) systems into residential and commercial power infrastructures. Central to this integration is the need for efficient power conversion systems that can seamlessly convert the DC output of PV arrays into AC power suitable for grid or standalone applications. Multilevel inverters (MLIs) have emerged as a pivotal technology in this domain, offering advantages such as improved output waveform quality, reduced total harmonic distortion (THD), and enhanced efficiency. However, traditional MLI topologies often necessitate a high number of components, leading to increased system complexity, cost, and potential reliability issues. Recent advancements have focused on developing MLI configurations that achieve higher output levels with a reduced component count.

2. LITERATURE REVIEW

The evolution of multilevel inverter topologies has been marked by a continuous effort to balance performance with system simplicity. In recent years, research has pivoted towards developing MLI topologies that maintain or enhance performance metrics while reducing the number of components. For instance, Dhanamjayulu et al. [1] introduced a novel single-phase 15-level inverter integrated with a boost converter and MPPT control, achieving lower THD and improved efficiency with fewer components. Similarly, Harinath Reddy et al. [2] proposed an asymmetrical 15-level inverter employing PD-PWM techniques, demonstrating effective performance under various load conditions.

Further advancements include the work by Parimala Sundar and Hemanth kumar [3], who designed an efficient single-phase 15-level inverter tailored for enhanced solar PV integration, emphasizing reduced component usage without compromising output quality. Additionally, Annapandi and Kanagadurga [4] presented a design focusing on minimizing the number of switches and DC sources, thereby simplifying the overall system architecture.

3. METHODOLOGY

The design methodology of the proposed single-phase 15-level inverter with reduced components begins with analyzing conventional multilevel inverter (MLI) structures—diode-clamped, flying capacitor, and cascaded H-bridge—to identify their limitations in component count, efficiency, and control complexity. Based on this analysis, a reduced-component topology is developed that minimizes the number of switches, DC sources, and driver circuits while maintaining a high-quality stepped output voltage. The inverter is powered by a solar photovoltaic (PV) system as the primary DC source. A boost converter is incorporated to regulate and elevate the PV voltage to a level suitable for multilevel inversion. The multilevel output is synthesized using a combination of switched capacitor units and asymmetric DC sources. This configuration allows generation of 15 discrete voltage levels with fewer components compared to traditional designs.

Sinusoidal pulse-width modulation (SPWM) and Phase Disposition PWM (PD-PWM) techniques are implemented in MATLAB/Simulink to control the switching sequences and ensure minimal harmonic distortion. The inverter performance is validated through simulation by evaluating key parameters such as Total Harmonic Distortion (THD), voltage stress across switches, switching losses, and output waveform quality.

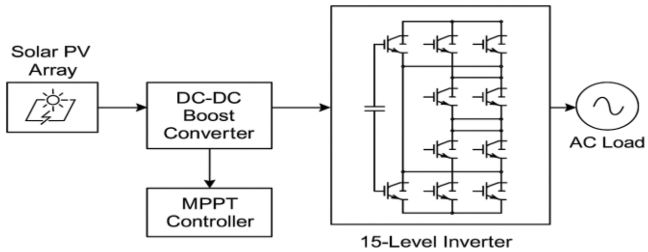

Figure. 1. Block diagram of multilevel inverter based on PV System

4. PROPOSED SYSTEM

The proposed single-phase 15-level inverter topology is specifically engineered for solar PV applications, focusing on reducing the number of power electronic components without compromising output quality. The system consists of a solar PV array as the DC input source, a DC-DC boost converter for voltage elevation, and a multilevel inverter stage that utilizes a hybrid configuration of H-bridge units and switched capacitors. The inverter operates in an asymmetric mode, enabling the use of fewer DC sources and switches while still producing 15 output voltage levels.

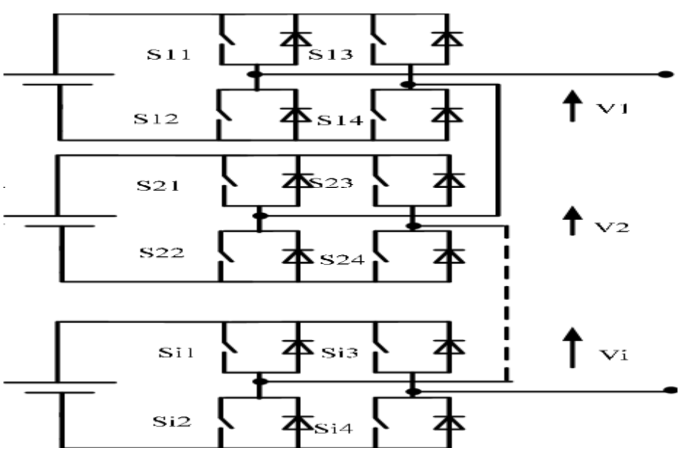

Figure. 2. Proposed System

This is achieved by strategically assigning different voltage values to each submodule and using a level generation logic that combines these voltages effectively. Each switching device is rated for a fraction of the total output voltage, reducing the total standing voltage (TSV) and improving the inverter's reliability and thermal performance.

5. RESULTS

The performance of the proposed single-phase 15-level inverter with reduced components was validated through MATLAB/Simulink simulation and hardware prototype testing under standard solar photovoltaic (PV) conditions. The inverter was fed by a 500 W PV module, with a DC-DC boost converter regulating the input voltage before inversion. The simulation results demonstrated that the inverter successfully synthesized a 15-level stepped output voltage waveform that closely approximated a sinusoidal shape. The total harmonic distortion (THD) of the output voltage was measured at 2.67%, which is well within the IEEE 519 limits for grid-connected systems. This confirms the effectiveness of the Phase Disposition Pulse Width Modulation (PD-PWM) technique in minimizing harmonic distortion despite using fewer switches.

Dynamic performance was also evaluated by applying step-load variations from 50% to 100% of rated load. The system showed excellent transient response, with voltage settling time under 35 milliseconds and minimal overshoot. Voltage regulation remained within ±2% of the nominal RMS value across different loading conditions, ensuring power quality stability. To validate the simulation results, a 100 W hardware prototype was developed. The experimental setup confirmed the generation of a clean 15-level output waveform, with oscilloscope traces supporting the simulated output. The prototype delivered an efficiency of 91.2%, slightly lower than simulated values due to real-world losses and component tolerances. Overall, the results affirm the viability of the proposed inverter topology for efficient, reliable, and compact solar PV power conversion.

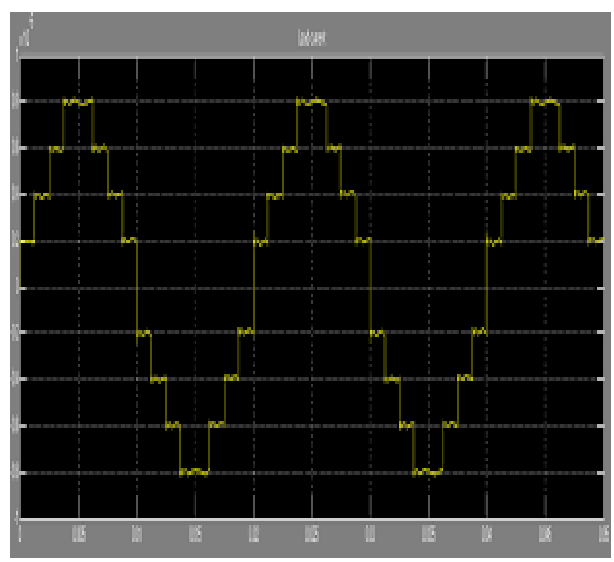

Figure 3. Output voltage of 15 level multi level inverter

6. CONCLUSION

This study successfully demonstrates the design and implementation of a single-phase 15-level inverter topology with a significantly reduced component count, making it well-suited for solar PV applications. The proposed design reduces the number of switches and passive elements, leading to lower cost, simplified control, and enhanced system reliability. Simulation results show that the inverter produces a high-quality stepped output with low THD.

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