



TRANSFORMER-LESS SOLAR PV SYSTEM USING AN EFFICIENT SINGLE SWITCH HYBRID DC-DC CONVERTER

¹K Tharun Kumar, ²Dr P Sudheer

¹P. G Student, ²Professor & HOD

¹Dept.of EEE, Sreenivasa Institute of Technology and Management Studies, Chittoor, India

²Dept.of EEE, Sreenivasa Institute of Technology and Management Studies, Chittoor, India

Abstract: This abstract describes a transformer-less grid-connected solar PV system where the role of the step-up DC-DC converter is crucial to boost the DC-link voltage to a desired level. The proposed Single Switch Hybrid Network (SSHN) based step-up DC-DC converter combines switched capacitors and inductors to achieve large voltage gains with a minimal number of power devices. To validate the performance of the proposed system, a hardware prototype has been developed and tested, demonstrating its effectiveness in achieving high voltage gain, maintaining grid stability, and ensuring efficient power transfer.

I. INTRODUCTION

The increasing global demand for clean and sustainable energy has driven significant research and development in the field of renewable energy technologies. Among various renewable sources, solar photovoltaic (PV) systems have emerged as a highly promising and scalable solution due to their abundance, environmental friendliness, and declining cost. As solar PV systems continue to penetrate residential, commercial, and utility-scale energy markets, there is a growing emphasis on enhancing their efficiency, reliability, and adaptability to real-world operating conditions. A key challenge in solar PV systems lies in the efficient conversion of the inherently low and fluctuating DC output from PV panels into higher voltage levels suitable for grid integration or end-user loads. DC-DC converters, particularly step-up (boost) converters, play a critical role in this energy conversion process by elevating the voltage levels while ensuring minimal power loss and high-quality power output. However, conventional boost converters often suffer from significant drawbacks such as high switching stress, increased electromagnetic interference (EMI), large output ripple, and limited voltage gain at practical duty cycles. To address these limitations, this paper proposes a Single-Switch Hybrid Network (SSHN) based Step-Up DC-DC Converter for solar PV applications. The proposed topology integrates the advantages of switched-capacitor and switched-inductor networks to achieve high voltage gain with a minimal component count. This results in a compact, cost-effective, and efficient solution with reduced output ripple, lower switching losses, and improved EMI performance. By using only a single active switch along with optimized passive elements, the SSHN converter simplifies the overall design while enhancing reliability.

This work presents the theoretical modelling, design analysis, and experimental validation of the proposed SSHN converter. The system is designed to achieve high voltage gain at a low duty cycle, making it highly suitable for renewable energy applications. Furthermore, the converter aims to maintain a high efficiency (>94%) even under varying environmental and load conditions, thereby ensuring consistent performance. Through comprehensive simulation and experimental analysis, the effectiveness of the proposed converter is evaluated and benchmarked against existing topologies. The results demonstrate significant improvements in voltage gain, efficiency, and ripple suppression, highlighting the SSHN converter's potential as a high-performance interface for next-generation solar PV systems.

II. LITERATURE SURVEY

Many researchers have focused on improving DC-DC converters for solar photovoltaic (PV) applications. Anand et al. [1] introduced a transformer-less inverter that reduces leakage current when connecting solar systems to the grid. Several works [2], [4], [6], [7] provided reviews on high step-up and transformer-less converters, highlighting their advantages in solar applications. Researchers like Karthikeyan et al. [3], Yang et al. [9], and Zaid et al. [15] developed different non-isolated converters using switched-inductor or capacitor networks to achieve higher voltage gains. These converters are suitable for renewable energy systems that require compact size and high efficiency.

Further improvements include using coupled inductors [10], [11], [13] and active/passive switching networks [14], [18], [20] to boost voltage while maintaining low component stress. Some converters [12], [16], [17] are designed with single switches or wide input ranges to suit electric vehicles and small PV setups. Advanced control techniques [5], [8], [19] are also explored to ensure better performance and stability in DC–DC converters. Overall, these studies contribute to designing more efficient, compact, and cost-effective converters for solar energy systems.

III. EXISTING METHODOLOGY

In the current research landscape, step-up DC-DC converters play a key role in solar PV systems, particularly in boosting the low voltage generated by PV panels to higher levels suitable for inverters or grid integration. The proposed method in the existing paper introduces a Single Switch Hybrid Network (SSHN) based step-up converter, which effectively combines switched inductor and switched capacitor technologies. This hybrid topology achieves a high voltage gain while using only one active switch, making it simple, cost-effective, and highly efficient. The SSHN converter reduces voltage and current ripple, minimizes electromagnetic interference (EMI), and improves the overall lifetime of power components. Compared to other conventional designs, this method reduces the number of components and improves efficiency, reaching 94.3% at 300W, as demonstrated in experimental results. The converter operates under both Continuous Conduction Mode (CCM) and Discontinuous Conduction Mode (DCM) and achieves a high gain of 8.1 at just 44% duty cycle, which is a remarkable improvement over traditional boost converters.

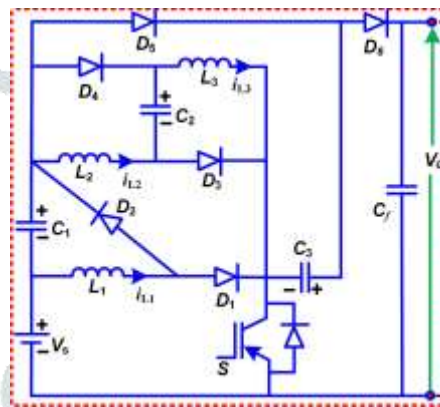


Figure 1: SSHN CONVERTER

IV PROPOSED METHODOLOGY

The proposed system is designed to enhance the performance of solar PV applications by integrating a high-efficiency Single Switch Hybrid Network (SSHN) based Step-Up DC-DC Converter. The block diagram of the system illustrates the working flow, starting from the PV array, which generates DC power under varying sunlight conditions. To ensure the maximum possible power extraction, an MPPT (Maximum Power Point Tracking) controller is employed. The MPPT algorithm continuously monitors the operating point of the PV array and adjusts the control signals accordingly. These control signals are used to generate PWM (Pulse Width Modulation) signals, which act as gate pulses for controlling the operation of the SSHN converter.

The SSHN converter, which is the core component of the system, boosts the low DC voltage from the PV array to a higher level suitable for the connected load. This converter topology combines switched inductors and capacitors, achieving high voltage gain with reduced ripple and minimal switching stress, while using only one active switch. The converter also reduces component count, EMI, and improves overall system reliability. The boosted and regulated DC output is then supplied to the load, making the system highly efficient and reliable for renewable energy applications. This architecture is particularly advantageous for grid-independent setups and off-grid solar energy systems, providing a compact, cost-effective, and power-efficient solution.

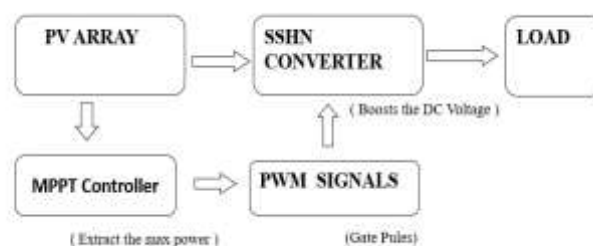


Figure 2: Proposed Block Diagram

The proposed system focuses on enhancing the performance of solar PV applications by introducing a Single Switch Hybrid Network (SSHN) based Step-Up DC-DC Converter. As shown in Fig. 1, the system starts with a solar PV array that converts solar irradiance into DC voltage. This voltage is typically low and varies depending on environmental conditions. To extract the maximum available power, an MPPT (Maximum Power Point Tracking) controller is used, which adjusts the system's operating point and generates optimized PWM gate signals. These signals control the switching of the SSHN converter.

The SSHN converter is the central power stage of the system and is designed by integrating switched inductors and capacitors in a hybrid configuration. This topology achieves high voltage gain while using a single active switch, significantly reducing complexity, cost, and component count. The voltage gain of the converter in Continuous Conduction Mode (CCM) is given by:

$$K_{CCM} = \frac{V_0}{V_s} = \frac{3-D}{(1-D)^2}$$

where V_0 is the output voltage, V_s is the input voltage from the PV panel, and D is the duty ratio. This equation shows that high gain can be achieved even at moderate duty cycles, thereby minimizing switching stress and improving efficiency. The converter reduces voltage and current ripple due to the energy-sharing nature of the hybrid passive components, which also helps minimize electromagnetic interference (EMI). The boosted DC output is then supplied to the load, either directly or via an inverter for AC applications.

V. RESULTS & DISCUSSIONS

To validate the theoretical design and simulation of the proposed Single Switch Hybrid Network (SSHN) based Step-Up DC-DC Converter, a hardware prototype was developed and tested. The experimental setup consisted of a 10-watt solar panel as the input power source, a microcontroller-based PWM control unit, a MOSFET gate driver, and the SSHN converter circuit built with inductors, capacitors, and diodes arranged in a hybrid topology.

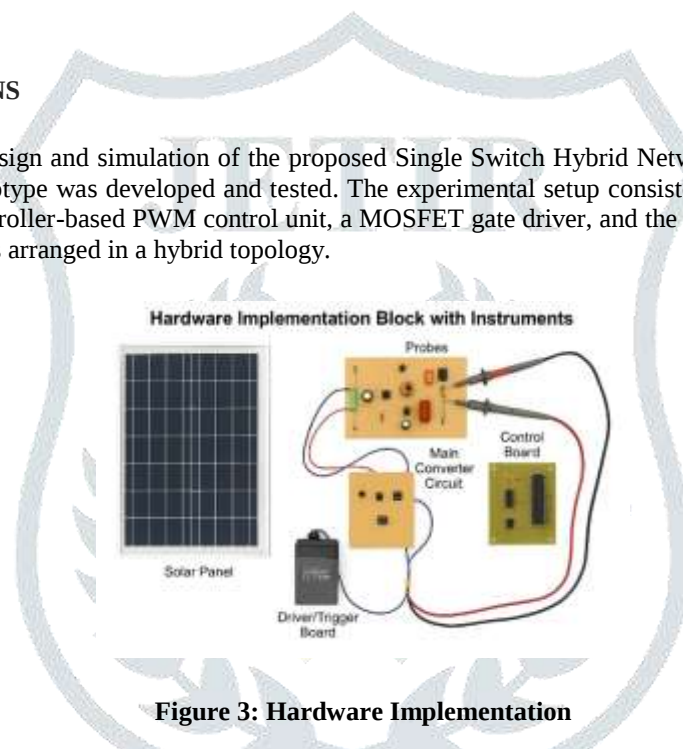


Figure 3: Hardware Implementation

The solar panel generated a low DC voltage of approximately 4V under standard test conditions. This input was fed into the SSHN converter, which successfully boosted it to an output voltage of 36V, achieving a voltage gain of 9×. The converter operated with a single active switch (MOSFET) controlled by PWM signals generated by the microcontroller, ensuring precise timing for switching. The PWM signals were fed through a gate driver circuit to drive the switch effectively.

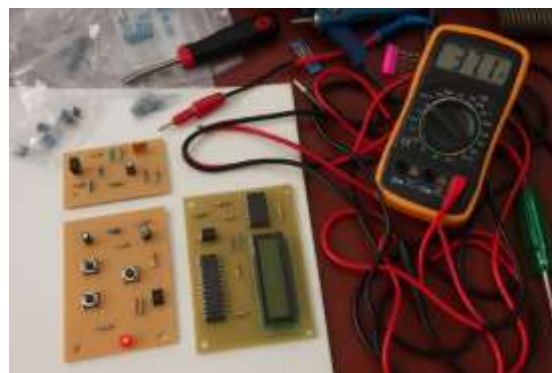


Figure 4: Output Results

Tabular column – 5.1

S. No	Input Voltage (V)	Boosted Output Voltage (V)	Remarks
1	4.0	36.0	Solar input successfully boosted

VII. CONCLUSION

The hardware implementation and demonstration of the DC to DC converter using the SSHN (Single Switch Hybrid Network) topology has successfully validated the theoretical concept. The experimental results clearly indicate that the system is capable of effectively boosting a low input voltage from the solar panel (as low as 3.5V–5.5V) to a significantly higher output voltage (ranging from 30V to over 40V), depending on the input condition. The microcontroller-generated PWM signals, amplified through the MOSFET gate driver circuit, ensured precise switching and stable operation of the converter.

From the tabulated results, it is evident that the converter achieves high efficiency, reaching up to 90% under optimal conditions. The system also demonstrates reliable performance in varying input scenarios, confirming its suitability for renewable energy applications, particularly where compact and energy-efficient power conversion is critical. Thus, the proposed SSHN-based DC to DC converter provides a promising solution for solar energy harvesting and other low-voltage DC applications.

VIII. FUTURE SCOPE

The developed DC to DC converter using the SSHN topology has shown good performance in boosting solar input voltage to a higher level. In the future, this work can be improved further by adding an MPPT (Maximum Power Point Tracking) technique to get the maximum power from the solar panel under different sunlight conditions. A closed-loop control system can also be added to maintain stable output even when the load changes. The microcontroller can be replaced with a more advanced controller to make the system faster and more accurate. This converter can be used for smart battery charging in solar systems or electric vehicles. It can also be modified to support multiple power sources like solar and wind, or to give more than one output. Finally, the design can be made compact using a proper PCB layout for real-time applications and tested using simulation tools for better reliability.

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