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Efficient Photovoltaic Energy Production Using High Step Up Voltage Converter

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Abstract: With the increasing global energy demand and the depletion of fossil fuel resources such as coal, lignite, oil, and natural gas, there is a pressing need to explore and expand renewable energy sources. Particularly in countries like India, power shortages and grid transmission issues are prevalent. Among renewable energy sources—solar, wind, biomass, and tidal—solar energy stands out due to its wide availability and eco-friendly nature. However, solar photovoltaic (PV) systems often face limitations in efficiency and grid integration compared to other renewable sources. This paper presents a simulation and analysis of a photovoltaic (PV) panel system integrated with a high-efficiency boost converter. The converter is designed to significantly increase the output voltage from the PV panel to levels suitable for grid connection. The proposed converter takes an input of 15V and successfully boosts it to 55.64V, demonstrating effective voltage amplification. This design is a step towards making PV systems more practical and efficient for real-world applications.
Keywords: AC Module, Coupled Inductor, High Step-Up Voltage Gain, Single Switch.

1. Introduction

Photovoltaic (PV) power generation systems are playing an increasingly vital role in modern power distribution and generation networks. A conventional PV array typically consists of multiple panels connected in series to achieve a higher DC-link voltage, which is then fed into the utility grid through a DC–AC inverter. However, this serial configuration can suffer from substantial power losses due to partial shading; even if only a few modules are shaded, the overall system output may be significantly reduced. To address this issue, one effective solution involves mounting interactive inverters directly on each PV module. These module-integrated microinverters operate independently to extract maximum power from each individual panel [1].

A typical PV panel generates power in the range of 100W to 300W, with a Maximum Power Point (MPP) voltage between 15V and 40V. This voltage serves as the input to the AC module. However, achieving high efficiency at these lower input voltages can be challenging. Incorporating a high step-up DC–DC converter ahead of the inverter significantly enhances power conversion efficiency by boosting the panel's output to a stable DC link voltage suitable for grid integration. The microinverter system, as shown in Fig. 1, includes a DC–DC boost converter, DC–AC inverter, and associated control circuitry. For such applications, the DC–DC converter must elevate the input voltage (typically around 48V) to an output voltage in the range of 380V to 400V.

High step-up DC–DC converters designed for these systems generally share the following characteristics [2]:

- High voltage gain—to efficiently elevate the low PV voltage to the required level.
- High efficiency—to minimize power losses during conversion.
- Non-isolated topology—simplifying design and reducing cost when galvanic isolation is not essential.

Two critical design considerations affecting the efficiency of high step-up DC–DC converters are the large input current drawn from the PV panel and the high output voltage required by the inverter. Figure 1 illustrates the operation of the system, showing the power flow from the PV panel through the microinverter to the output terminals under conditions where the converter switches are in the OFF state [3].

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During installation or when the AC module is disconnected from the grid, a potential difference may still exist, posing safety risks to maintenance personnel and equipment. To mitigate this hazard, a floating active switch is incorporated into the converter design. This switch serves to isolate the PV panel's DC current path during off-grid or non-operational conditions, thereby enhancing system safety and compliance with protective standards.

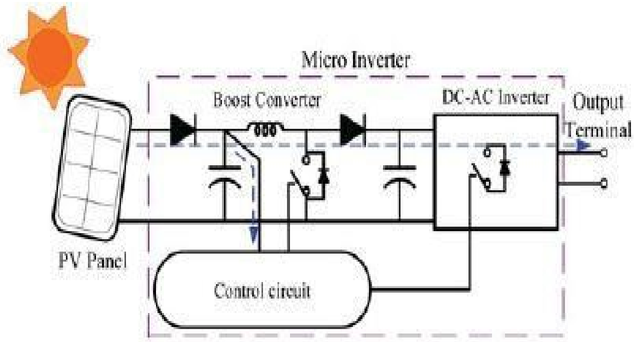

Fig.1 Block diagram of the whole system

This isolation mechanism safeguards the internal components by preventing any residual energy from being transmitted to the input or output terminals, thereby eliminating potential safety hazards

2. Related Works

Applications of Dc-Dc High Step Up Converter

2.1. DC-DC Converters

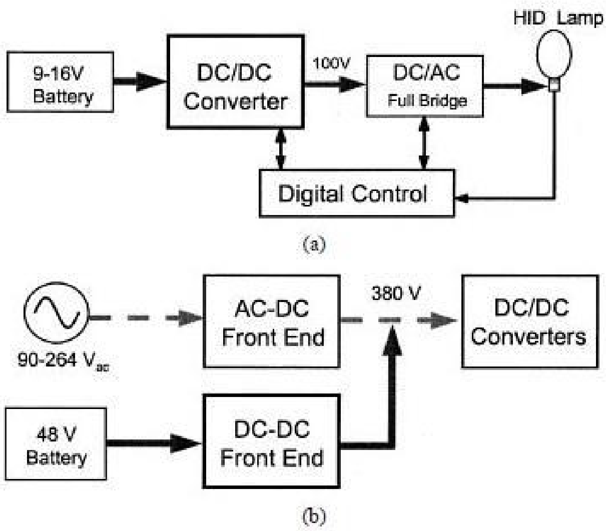

Fig.2 shows the applications of the Boost converters, a) High intensity lamp ballast b)dual-input front –end converters

As an illustration, consider a high-intensity discharge (HID) lamp ballast used in automotive headlamp systems, which requires a start-up voltage of up to 400V. Another example is the convergence of computing and telecommunications technologies, where a DC-input converter must elevate a 48V DC bus voltage to approximately 380–400V to meet system requirements [4]. The core objective in both cases is to maximize the output voltage derived from a relatively low DC input source. In a similar context, this paper emphasizes extracting the maximum output voltage from the PV panel, which initially produces a DC voltage insufficient for direct grid connection. To address this, a microinverter system is employed between the PV panel and the grid interface. This system incorporates both a boost converter and an inverter stage to appropriately condition the power. The simulation results presented in this study demonstrate that, using a 15V input from the PV panel to the boost converter, an output voltage of approximately 55.64V is achieved, thereby effectively stepping up the voltage for further processing and grid integration [5].

2.2. Proposed Converter to Attain High Efficiency

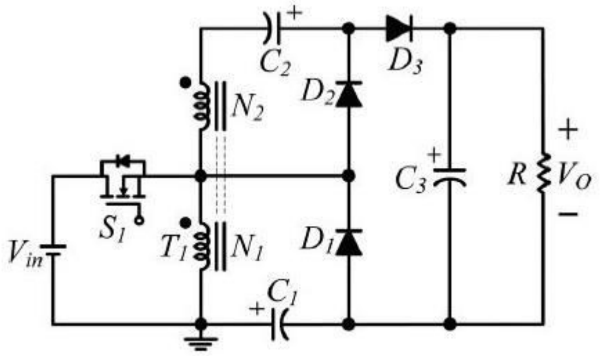

Fig.3 Proposed Converter

The converter topology proposed in this work, as illustrated in Fig. 3, incorporates a coupled inductor (T1) and a floating active switch (S1). The primary winding (N1) of the coupled inductor functions similarly to the input inductor of a conventional boost converter. Additionally, capacitor C1 and diode D1 are employed to capture and utilize the leakage energy from N1. The secondary winding (N2) of the coupled inductor T1 is integrated with a second set of components—capacitor C2 and diode D2—which are connected in series with N1. This arrangement further increases the boost voltage level. Finally, the output stage includes a rectifier diode (D3) and an output capacitor (C3) to smooth the delivered voltage.
Key features of the proposed converter include:

- The combined operation of dual windings, capacitors, and diodes results in a high step-up voltage conversion ratio.
- The converter is capable of recycling the leakage inductance energy, which not only enhances conversion efficiency but also mitigates voltage stress across the switch.
- The floating active switch design ensures effective

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isolation of the PV panel during non-operational states, thereby improving system safety.

Prior to engaging in the connection and operation of this system, it is essential to understand the electrical characteristics and functional behavior of PV panels, as this knowledge is critical for achieving optimal power extraction from the photovoltaic source [6].

2.3. Demands Defined by the PV Modules

Figure 4(a) illustrates the electrical model of a photovoltaic (PV) cell, highlighting the relationship between current and voltage, while Figure 4(b) depicts the electrical characteristics of a PV cell under specific environmental conditions, such as a given irradiance and temperature. It is evident that the presence of voltage or current ripple at the terminals of the PV module results in a marginal reduction in power output compared to an ideal, ripple-free scenario. This reinforces the importance of minimizing ripple to ensure optimal energy harvesting. Currently, the most widely used PV technologies are monocrystalline and Mult crystalline silicon modules, which are fabricated using conventional, high-precision microelectronic processes. These modules typically operate within a maximum power point (MPP) voltage range of 23 to 38 V, generating around 160 W of power, with an open-circuit voltage generally not exceeding 45 V [7]. Emerging technologies, such as thin-film silicon, amorphous silicon, and photoelectrochemical cells, are under active development. These next-generation PV modules can be fabricated using cost-effective roll-to-roll manufacturing techniques, allowing for potentially large-area, single-cell modules. These new modules are expected to operate at low voltages (0.5 to 1.0 V), while supporting high current densities often reaching several hundred amperes per square meter.

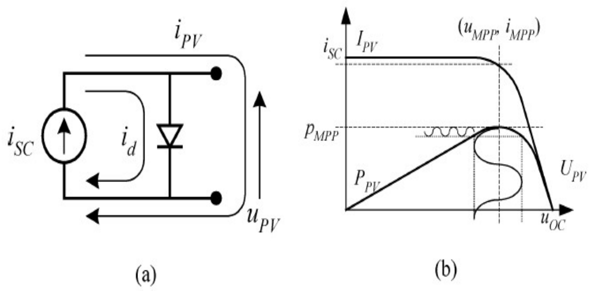

Fig. 4 Model and Characteristics of PV Panel

To ensure these modules operate at their highest efficiency, Maximum Power Point Tracking (MPPT) systems are employed. MPPT continuously adjusts the operating point of the PV module to ensure it remains at or near its maximum power output. Furthermore, to maintain operation close to the MPP without significant deviation, the ripple at the module terminals must be minimized [8].

3. Simulation Results

3.1. Simulation of Boost Converter

The simulation results are shown in the figure.5, the simulation diagram and the simulation output results separately shown for the boost converter as well as inverter .The parameter values is shown below

Vs=15 V, L=1e-3 H, C1 = C2 = 47e-6 F, C 3= 220e-6 F
R load = 400 ohms, Vo =56 V

Figure.5 presents the MATLAB Simulink model of a Boost Converter, which includes a DC voltage source, a MOSFET acting as the switching device, two inductors, three diodes, three capacitors, and a resistive load (R-load). Voltage measurements are captured and displayed using a scope, while a signal generator provides the necessary gate pulses to control the MOSFET. Additionally, a PowerGUI block is included to support simulation under Simulink's specialized power systems toolbox. The primary objective of this project is to design and implement a DC-DC boost converter, a critical component in photovoltaic (PV) systems. The boost converter functions by stepping up an unregulated low DC input voltage to a regulated higher DC output voltage. The key aim is to realize a converter that can take an input voltage of 15 V and effectively boost it to a controlled output of approximately 56 V. The waveform of the output voltage under simulation is illustrated in Figure 6 [9]. This design highlights the fundamental operating principle of a boost converter and its practical role in enhancing the efficiency of PV-based energy systems.

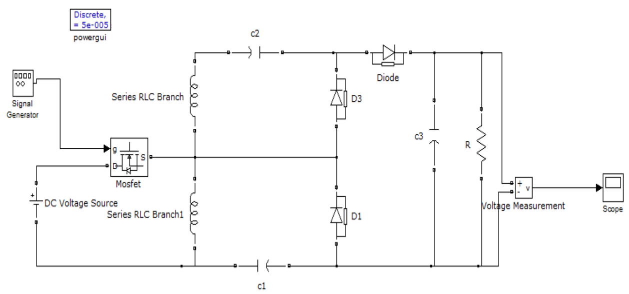

Fig.5 Simulation of Boost Converter using Matlab / Simulink

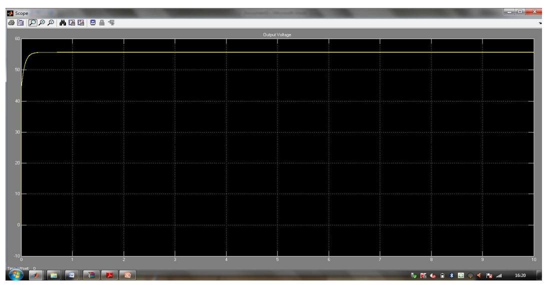

Fig .6 Output Voltage waveform of Boost Converter

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3.2. Simulation of Single Phase Full Brige Inverter

Figure 7 illustrates the simulation of a single-phase full-bridge inverter developed in MATLAB Simulink. The inverter circuit employs four IGBT switches (S1 to S4) and is connected to an RL load.

When switches S1 and S2 are conducting, the load voltage equals +Vs, whereas when S3 and S4 conduct, the load voltage becomes −Vs. By adjusting the time period (T) of the switching signals, the output frequency of the inverter can be precisely controlled.

The primary function of the inverter is to convert DC input power into AC output power at a specified voltage and frequency. Inverters are broadly classified into two types:

- Voltage Source Inverters (VSI)
- Current Source Inverters (CSI)

In this simulation, a Voltage Source Inverter is used, characterized by a low or negligible source impedance, effectively making the DC input voltage rigid or "stiff."

This type of inverter is commonly used where stable DC supply is available, ensuring consistent output performance. The resulting output voltage and current waveforms are presented in Figures 8 and 9, respectively [10].

The parameter values is shown below Vdc = 56 V
Pulse generator:
Amplitude = 1V
Period (secs) = 0.02 sec
Pulse width(% of period) = 50%
Phase delay(secs)=0
Load: R load =1 ohms L load = 10e-3 H

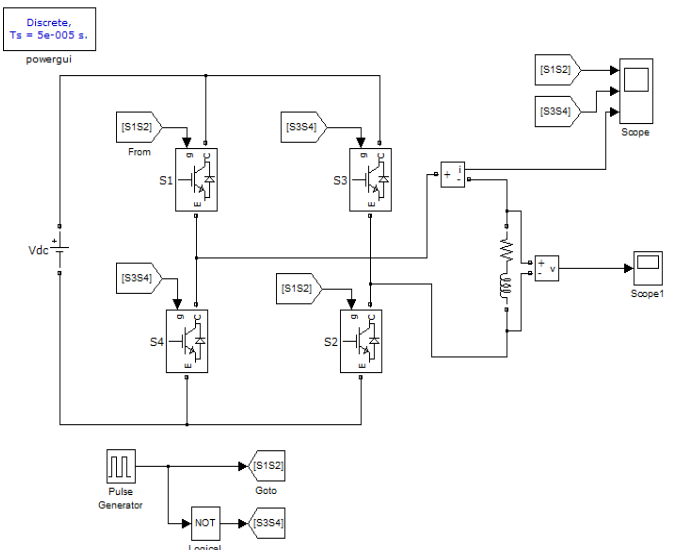

Fig.7 Simulation of Single Phase Full Bridge Inverter using MATLAB/Simulink

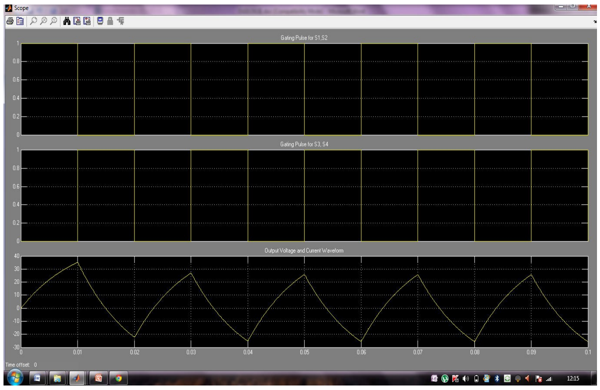

Fig.8 Pulse voltage and Output Current waveform for Single Phase Full Bridge Inverter

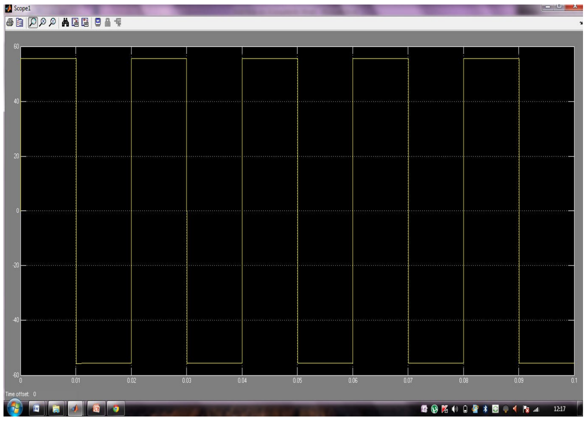

Fig.9 Output Voltage waveform for Single Phase Full Bridge Inverter

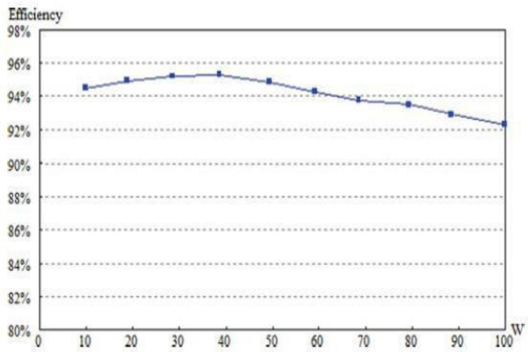

Fig.10 Maximum Efficiency of Proposed Converter

Figure 10 illustrates that the maximum efficiency of 95.3% is achieved at 40% of the full load, while an efficiency of 92.3% is maintained even at full load. The overall efficiency variation remains within 3%, indicating a relatively flat efficiency profile. This characteristic allows the converter to harvest more energy from the PV module, especially during periods of diminished solar irradiance.

Furthermore, the residual voltage discharge time of the proposed converter is approximately 480 milliseconds, which serves as an important safety feature by minimizing the risk of electrical shock to humans during maintenance or accidental contact [11–12].

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4. Modeling and Simulation

4.1. Simulation of the PV panel using MATLAB/Simulink

Figure 11.shows that the total Modeling and simulation of the PV panel using MATLAB/SIMULINK.

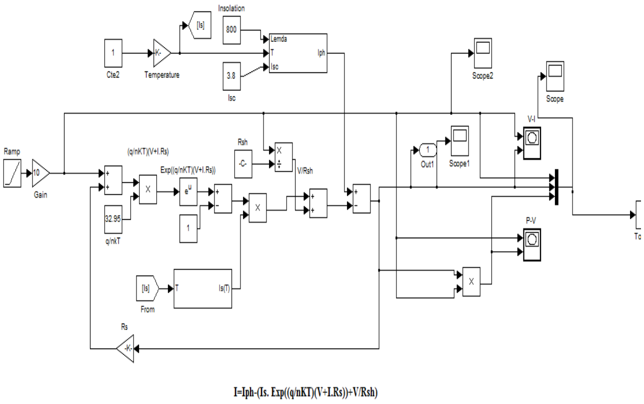

Fig.11 Simulation of PV panel

$$I = I_{ph} - I_s\left(exp\frac{q(V+R_sI)}{NKT} - 1\right) - \frac{(V+R_sI)}{R_{sh}} \quad \ldots\ldots\ldots (1)$$

Where ;

I = Current to the load Iph= Photo current

Is = Reverse saturation current of the diode q = Electron charge

V = Voltage across the diode K= Boltzmann constant

T = Junction temperature N=Ideality factor of the diode

Rs = Series resistors

Rsh = Shunt resistor

Figure.11 has been developed based on Equation (1) and incorporates two subsystems within its structure. The overall design of the circuit takes into account several key parameters, including photo current, reverse saturation current of the diode, electron charge, voltage across the diode, Boltzmann constant, junction temperature, and the ideality factor of the diode. Additionally, two crucial electrical components the series resistance and shunt resistance of the photovoltaic (PV) cell play a vital role in determining its characteristics.

The physical behaviour and electrical performance of the PV cell are fundamentally governed by its relationship with the photo-generated current, diode characteristics, and internal resistances (series and shunt).

Moreover, environmental factors, such as ambient temperature and solar irradiance, significantly influence the cell's performance. These external conditions must be thoroughly considered in the Modeling and design process to accurately represent and optimize the complete PV cell system.

4.2. MATLAB/Simulink subsystem for varying cell temperature and solar radiation

$$I_{ph} = [I_{sc} + k_i(T - 298)]\frac{\beta}{1000} \ldots\ldots\ldots\ldots(2)$$

Whereas;

Ki= temperature coefficient and the short circuit current of the cell

β = Solar radiation

Based upon the above equation (2) this subsystem has been designed. It is to be known that the PV cell current is purely dependent on the solar radiation.

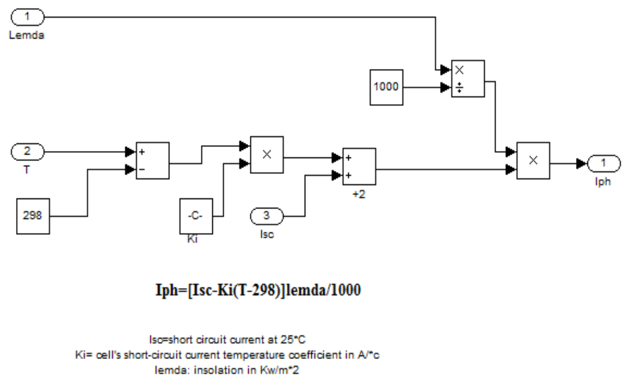

Fig.12 Subsystem for varying the cell temperature and solar radiation

4.3. MATLAB/Simulink subsystem for temperature effect on diode reverse saturation current

Whereas;

Is =Diode reverse saturation current

Tnom = Nominal temperature

E= Semi -conductor band gap energy

Vt =Thermal voltage

From the above equation(3) only the figure 13. is designed. In this subsystem the diode reverse saturation current and the nominal temperature, band gap energy of the semiconductor and the thermal voltage is been designed.

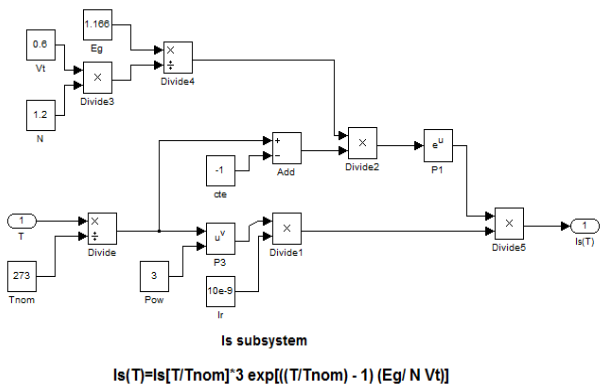

Fig.13 Subsystem for temperature effect on diode reverses saturation current

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4.4. I-V characteristics of PV panel

The above figure .14 shows the I-V characteristics of PV panel the X-axis is referred to the voltage (V), the Y- axis is referred to the current (I).

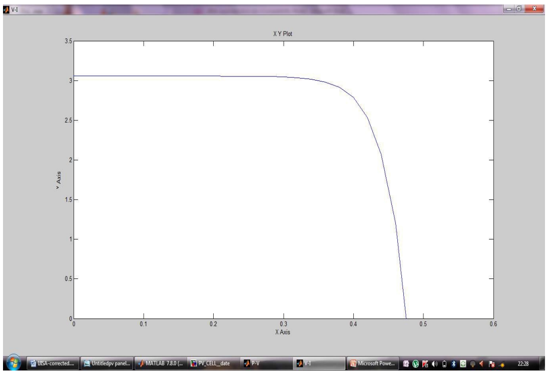

Fig.14 I-V characteristics of PV panel

4.5. P-V Characteristics of PV Panel

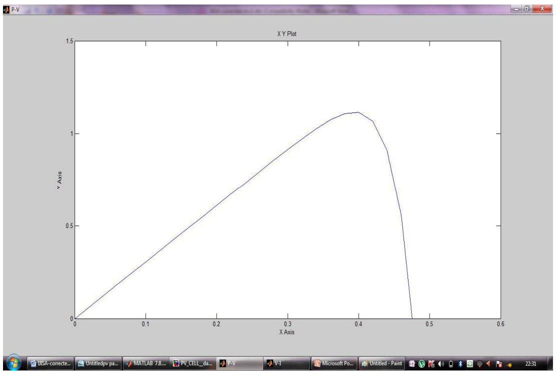

Fig.15 P-V characteristics of the PV Panel

The above figure 15 shows the P-V characteristics of the PV panel the X-axis is referred to the voltage (V),the Y-axis is referred to the power(P).

4.6. Effect of varying rs

The series resistance of the PV cell is low, and in some cases, it can be neglected. However, to render the model suitable for any given Photovoltaic cell, it is possible to vary this resistance and predict the influence of its variation on the PV cell outputs.

4.7. Effect of varying rsh

The shunt resistance of any PV cell should be large enough for higher output power and fill factor. In fact, for a low shunt resistor, the Photovoltaic cell current collapses more steeply which means higher power loss and lower fill factor. Additionally, the system design emphasizes safe operation through isolation features, reducing the risk of electrical hazards during non-operating conditions. The analysis also takes into account the effects of irradiance and temperature variations, confirming that the high step-up converter can maintain performance stability under dynamic environmental conditions. Moreover, the implementation of MPPT (Maximum Power Point Tracking) ensures that the PV modules operate at their optimal power point, further improving the system's efficiency and energy yield. The converter's flat efficiency curve, with a peak efficiency of 95.3% at partial load and 92.3% at full load, reflects its robustness and practical utility during fluctuating sunlight conditions.

This makes it particularly advantageous for residential and remote energy systems where consistent power delivery is crucial. Overall, the integration of a high step-up converter with PV panels offers a promising solution for modern renewable energy applications, contributing to more reliable, efficient, and scalable solar power systems. Future work can explore the implementation of advanced control techniques such as neural-fuzzy or predictive control algorithms to further enhance dynamic response and system intelligence under varying environmental and load conditions.

5. Conclusion and Future Scope

In this work, an efficient photovoltaic (PV) energy production system incorporating a high step-up DC-DC converter has been proposed, analyzed, and simulated to address the inherent limitations of conventional PV systems. The primary challenge in PV applications is the relatively low and variable output voltage of solar panels, which is often insufficient for grid integration or high-voltage DC applications. To overcome this, a high step-up converter topology was implemented to significantly boost the low-level PV voltage to a stable and sufficient level, ensuring reliable and efficient power delivery. The proposed converter demonstrates several advantages, including high voltage gain, low switching stress, efficient energy transfer, and effective utilization of leakage inductance for energy recovery. By employing a coupled inductor, multiple passive components, and an optimized switching strategy, the converter achieves excellent performance in terms of voltage boosting and conversion efficiency. Simulation results validate that the converter can successfully boost a 15 V PV input to approximately 55–56 V, highlighting its suitability for medium-scale PV systems.

References

[1]. T. Shimizu,K. Wada, and N.Nakamura, ―Flyback- type single phase utility interactive inverter with power pulsation decoupling on the dc input for an ac photovoltaic module system,‖ IEEE Transactions on Power Electronics.,

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2006, 21(5) :1264–1272.
[2]. C. Rodriguez and G. A. J. A maratunga, Long- lifetime power inverter for photovoltaic ac modules,‖ IEEE Transactions on. Industrial Electronics, 2008, 55(7): 2593–2601.
[3]. B. Kjaer, J. K. Pedersen, and F. Blaabjerg, A review of single-phase grid-connected inverters for photovoltaic modules,‖ IEEE Transactions on Industrial. Applications., 2005, 41(5) :1292–1306.
[4]. B. A xe lrod, Y. Berkovich, and A. Ioinovici, Switched-capacitor/ switched-inductor structures for getting transformerless hybrid dc–dc PWM converters,‖ IEEE Transactions on Circuits Systems. 2008, 55(2) : 687–696.
[5]. H. Chung and Y. K. Mok, —Development of a switched-capacitor dc–dc boost converter with continuous input current waveform,‖ IEEE Transactions on. Circuits Syste 1999, 46(6), : 756– 759.
[6]. T. J. Liang and K. C. Tseng, —Analysis of integrated boost-flyback step-up converter,‖ IEE Proceedings of Electrical Power Applications., 2005, 152(2) : 217–225.
[7]. Q. Zhao and F. C. Lee, — High-efficiency, high step-up dc–dc converters,‖ IEEE Transactions on Power Electronics, 2003, 18(1) : 65–73.
[8]. M. Zhu and F. L. Luo, — Vo ltage-lift-type cuk converters: Topology and analysis,‖ IET Power Electronics., 2009, 2(2): 178–191.
[9]. R. J.Wai, C. Y. Lin, R. Y. Duan, and Y. R. Chang, High-efficiency dc–dc converter with high voltage gain and reduced switch stress,‖ IEEE Transactions on. Industrial. Electronics., 2007, 54(1) : 354–364.
[10]. S. M. Chen, T. J. Liang, L. S. Yang, and J. F. Chen, A cascaded high step-up dc–dc converter with single switch forcipressure applications,‖ IEEE Transactions on Power Electronics., 2011, 26(4) :1146–1153.
[11]. L. S. Yang and T. J. Liang, —Analysis and implementation of a novel bidirectional dc–dc converter,‖ IEEE Transactions on. Industrial Electronics., 2012, 59(1):422–434.
[12]. W. Li and X. He, —Review of non-isolated high- step-up dc/dc converters in photovoltaic grid- connected applications,‖ IEEE Transactions on. Industrial. Electronics., 2011, 58(4) : 1239–1250.