



Optimized High-Gain DC-DC Converter for PV Applications

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A B S T R A C T

Photovoltaic (PV) systems frequently encounter low and fluctuating output voltages, which can significantly impede efficient energy utilization and necessitate more advanced power conversion solutions. Addressing this challenge, the study aims to develop a high-gain DC-DC converter topology that offers stable voltage regulation, making it suitable for PV applications. The proposed solution targets the essential need for substantial voltage boosting while maintaining reliable performance even under varying solar irradiance conditions. The core of the design is based on a Quadratic Boost Converter (QBC) integrated with Voltage Multiplier Cells (VMC), collectively referred to as QBC-VMC. This innovative configuration enhances the voltage gain capability compared to traditional converters. To ensure precise control of the output voltage, a Proportional-Integral (PI) controller is implemented. The system undergoes thorough analysis, including detailed modeling, simulation, and the design of its control structure, to optimize performance. The results demonstrate that the proposed converter can achieve a voltage gain of up to 12 times the input voltage. The PI controller effectively maintains a stable output voltage at approximately 600 V with a tolerable variation of $\pm 0.7\%$. Additionally, the system exhibits an energy conversion efficiency approaching 81%, even under fluctuating irradiance conditions. This indicates a strong dynamic response and steady-state performance, essential for reliable PV operation. By integrating QBC-VMC with PI control, the proposed approach significantly enhances voltage stability and energy conversion efficiency. Overall, this system provides a promising solution for high-performance PV power systems, capable of delivering reliable power output under varying environmental conditions.

INTRODUCTION

Global warming and environmental degradation caused by the excessive use of conventional energy sources—particularly fossil fuels—have emerged as critical national and global concerns. In response, Renewable Energy (RE) technologies are increasingly being promoted as sustainable alternatives to fossil-based energy systems. Among the various RE options, solar energy, particularly through photovoltaic (PV) systems, has become one of the most widely developed and deployed technologies due to its availability, scalability, and environmental benefits.

Despite their growing adoption, PV systems face several inherent limitations. The electrical power generated by a PV panel is highly dependent on environmental conditions, primarily the intensity of solar irradiance and ambient temperature, both of which fluctuate throughout the day and across seasons [1]. Under low irradiance conditions, the power output of PV panels drops significantly, preventing the system from operating at optimal efficiency. Moreover, a single PV module typically produces a relatively low DC voltage, in the range of 24–48 V, which is insufficient for applications that require higher voltage levels—such as grid-tied inverters or industrial DC loads that commonly operate at 600 VDC.

One conventional solution to achieve the required voltage level is to connect multiple PV panels in series. However, this method introduces challenges such as mismatch losses due to panel variability, increased complexity in system configuration, and reduced overall reliability. Therefore, an efficient high-gain power conversion system is needed to step up the low DC voltage from PV panels to a usable high-voltage level while maintaining system stability and performance under variable environmental conditions.

Generally, RE sources require a single converter to serve as a power transfer connector to the DC Bus network. However, conventional single converters cannot significantly increase the voltage to meet the demands of a DC bus network. These converters are suitable for low-power conversion applications but are less effective for energy conversion from RE sources with relatively low output voltages [1], [2]. Due to this limitation, previous research has focused on developing high-step-up DC-DC converters. A DC-DC converter consists of several components: inductors, capacitors, diodes, and switches. These components are interconnected to facilitate energy exchange between the inductor and the capacitor. In the first stage of the process, energy is stored in the inductor and subsequently transferred to the capacitor, resulting in an increased output voltage.

A DC microgrid energy system requires a DC-DC converter to regulate the DC voltage at a certain voltage level, as shown in Figure 1. High-gain DC-DC converters are becoming very popular today as an alternative to replace conventional DC-DC boost converters because of their ability to increase the voltage level quite high. In addition, conventional boost converters have several disadvantages, including a significant voltage drop, electromagnetic interference (EMI), input current ripple, and low efficiency. Conventional boost converters must operate at higher duty ratios when integrated into a microgrid, resulting in increased current and voltage stresses on the converter [3]. As the duty ratio increases, the equivalent series resistance (ESR) of the capacitors and inductors also increases significantly, resulting in substantial losses in voltage gain and overall converter efficiency.

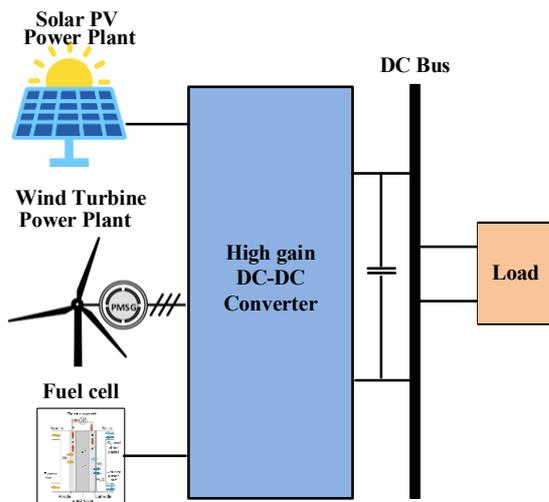


Figure 1. Scheme of high gain DC-DC Converter for Renewable Energy Source

Various isolated and non-isolated DC-DC boost converter designs have been utilized to achieve higher voltage gains than conventional boost converters, making them suitable for various applications, including renewable energy systems. Non-isolated converters [4], [5], [6], [7], [8] and isolated converters [9], [10], [11], [12], [13] are used based on specific implementation requirements and safety considerations.

A non-isolated converter does not provide galvanic isolation between the input and output sides, meaning that variations in the input sources directly affect the converter's output. On the other hand, an isolated converter has separate grounding between the input and output, allowing it to operate with different input sources while maintaining a stable output. Isolated converters are preferred for safety-critical applications, such as protecting users and preventing short-circuit currents in the load. Meanwhile, non-isolated converters, which do not require isolation transformers, offer higher efficiency. If user safety is not a primary concern, non-isolated converters are well-suited for renewable energy systems.

Given the challenges associated with using conventional boost converters in renewable energy sources, this study proposes a new high-gain converter topology that can increase the DC voltage level to meet the requirements of a DC bus network. The proposed converter is specifically designed for systems that use renewable energy sources, which typically generate low voltages.

Several studies on high-gain converters have been conducted, including research on quadratic boost converters [14], [15][3], [15], [16], [17], [18], [19], interleaved boost converters[20], [21], [22], [23] and cascade converters[24], [25], [26]. However, most of these studies still experience conversion losses due to the use of power electronic components, resulting in suboptimal efficiency. In addition, many converters were tested using a constant DC voltage source. In an interleaved topology, the voltage gain remains constant, similar to a conventional boost converter. This type of converter is commonly used to minimize current ripple. A cascade converter, which combines two or more boost converters, provides a straightforward approach to achieving a higher voltage conversion ratio compared to conventional boost power circuits.

Research proposes [27] a high-power DC-DC step-up converter without isolation or inductor coupling for renewable energy system applications. The converter can increase the output voltage from a low-power source while offering several advantages, including high power capability, continuous input current, low voltage stress on the switch, the use of only two switches and a single PWM signal, a simple design, and ease of control. Research [28] discusses the design of a DC-DC boost converter capable of adjusting the fuel cell source voltage over a wide input range to match the vehicle's DC bus requirements. Research[29] presents the design and simulation of a high-performance non-isolated DC-DC converter integrated with a Maximum Power Point Tracker (MPPT) algorithm for a solar panel-based DC microgrid system

Based on the reviewed literature [1]–[30], there remains a limited number of studies focusing on the implementation of high-gain DC-DC converters integrated with voltage multiplier techniques, particularly in the context of renewable energy sources, such as photovoltaic (PV) systems. To address this gap, this paper proposes a high-gain DC-DC converter topology that combines a Quadratic Boost Converter (QBC) with Voltage Multiplier Cells (VMC). The proposed converter is designed for PV system applications operating under variable environmental conditions. Structurally, the converter features a single-switch configuration similar to conventional boost and quadratic topologies, but with enhanced voltage step-up capability. The power circuit comprises one transistor, three inductors, four capacitors, and four diodes, enabling the system to achieve significantly higher output voltage levels compared to traditional boost converters. To ensure stable operation, particularly in maintaining the DC-Bus voltage under fluctuating irradiance, a Proportional-Integral (PI) control strategy is implemented. The PI controller plays a crucial role in regulating the output voltage and maintaining system stability, ensuring that the DC bus voltage remains relatively constant despite dynamic changes in input power.

The major contributions of this proposed system include the integration of a Quadratic Boost DC-DC Converter (QBC) and Voltage Multiplier Cells (VMC) to enhance the performance of photovoltaic (PV) systems under varying conditions. A PI Controller is employed to regulate the converter's output voltage, maintaining a high voltage output that remains relatively constant at 600 volts. This setup achieves a voltage gain of up to 12 times that of conventional converters.

METHOD

Figure 2 illustrates the circuit diagram of the proposed system configuration. The system for the PV system consists of PV with a lower voltage, a Quadratic Boost Converter, Integrated Voltage Multiplier Cells, and a PI control system. The integrated QBC scheme with VMC consists of three inductors, four capacitors, four diodes, and a single switch element. As shown in Figure 2, V_{in} represents the input source, derived from a renewable energy source, specifically a Photovoltaic (PV) system, while V_o denotes the output voltage corresponding to the voltage level of the DC bus network.

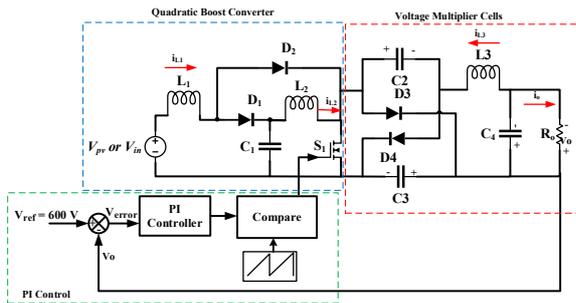


Figure 2. Quadratic Boost Converter Integrated Voltage Multiplier Cells with PV System

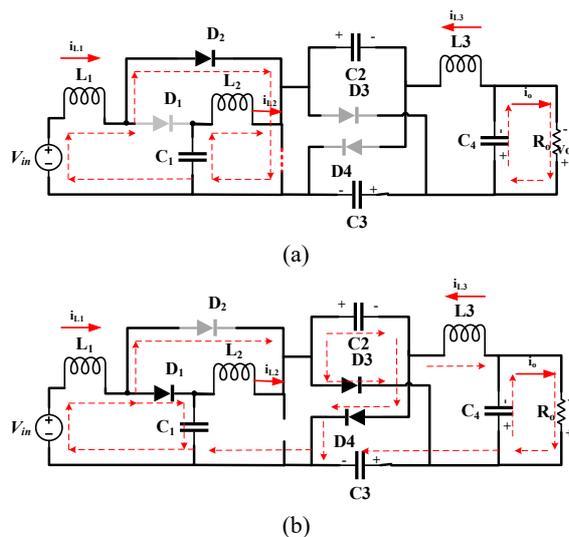


Figure 3. State of Quadratic Boost Converter Integrated Voltage Multiplier Cells (a) ON, (b) OFF

The analysis of the proposed Quadratic Boost Converter (QBC) integrated with Voltage Multiplier Cells (VMC) is carried out under the assumption that all semiconductor components operate under ideal conditions, neglecting switching losses, parasitic resistances, and leakage inductances. The power converter is analyzed in Continuous Conduction Mode (CCM), where the inductor current and capacitor voltage are assumed to remain relatively constant with minimal ripple, ensuring stable and predictable operating behavior. These include the assumptions of ideal switching devices, negligible parasitic resistances in the passive components, and an ideal DC source. The circuit topology, as depicted in Figure 3, operates in two primary switching states: the ON-state, during which the main switch is closed, and the OFF-state, during which the switch is open. These

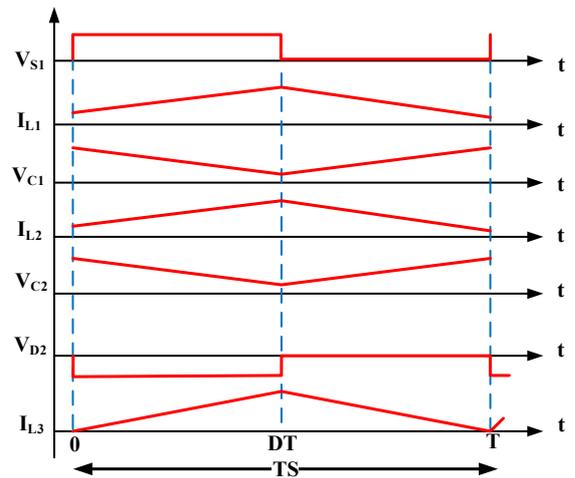


Figure 4. Operation Mode

two states govern the energy transfer and voltage boosting mechanisms within the converter. The corresponding voltage and current waveforms for the integrated QBC-VMC configuration are shown in Figure 4. These waveforms serve as the basis for analyzing the dynamic behavior of the circuit during each switching interval. By examining the switching waveforms and operating conditions in each state, the output voltage expression of the converter topology can be systematically derived. This analysis provides a foundation for further control design and performance optimization of the high-gain converter in photovoltaic (PV) applications.

State 1: At time $0 < t < DT$, the switching element is in the 'closed' condition, referred to as the ON state. During this state, inductors L_1 , L_2 , and L_3 store energy from the input voltage source. All diodes are in the open condition, making this a reverse bias state. Capacitor C_1 supplies stored energy to inductor L_2 , while capacitors C_2 and C_3 discharge, transferring their stored energy to the output inductance L_3 . As a result, all inductor currents increase linearly during the ON switching state. However, as shown in the waveform in Figure 3(a), the inductor current decreases linearly between $t=0$ and $t=T$. Equation (1) represents the inductor current in State 1.

$$\left\{ \begin{aligned} \frac{diL_1}{dt} &= \frac{V_{in}}{L_1} \\ \frac{diL_2}{dt} &= \frac{V_{C1}}{L_2} \\ \frac{diL_3}{dt} &= \frac{2V_{C2}-V_o}{L_2} \end{aligned} \right. \quad (1)$$

State 2: At time $DT < t < T$, the switching element is in the 'open' condition, referred to as the OFF state. In this state, inductor L_1 transfers its stored energy to capacitor C_1 , while inductor L_2 delivers its energy to capacitors C_2 and C_3 , as well as the load resistance R . Similarly, inductor L_3 supplies its stored energy to the load resistance. As a result, all inductor currents decrease linearly during the OFF state. As shown in the waveforms in Figure 3(b), the inductor current decreases linearly between $t=DT$ and $t=T$. Equation (2) represents the inductor current in State 2

$$\left\{ \begin{aligned} \frac{diL_1}{dt} &= \frac{V_{in} - V_{C1}}{L_{11}} \\ \frac{diL_2}{dt} &= \frac{V_{C1} - V_{C2}}{L_{12}} \\ \frac{diL_3}{dt} &= \frac{V_{C2} - V_o}{L_2} \end{aligned} \right. \quad (2)$$

Equations (1) and (2) describe the change in inductor current over time. V_{in} and V_o represent the input and output voltage values of the quadratic boost converter, respectively, while V_{C1} and V_{C2} denote the capacitor voltages within the converter, D is Duty Cycle, T is period and T_s is Time sampling. To determine V_o , the change in inductor current must be zero to ensure steady-state operation over one complete period. By utilizing Equations (1) and (2), we can derive an Equation to calculate the output voltage.

$$L_1 \rightarrow V_{in}DT_s + (V_{in} - V_{C1})(1 - D)T_s = 0 \quad (3)$$

$$L_1 = \frac{V_{in} D}{\Delta I_{L1} f}$$

$$L_2 \rightarrow V_{C1}DT_s + (V_{C1} - V_{C2})(1 - D)T_s = 0 \quad (4)$$

$$L_2 = \frac{V_{in} D}{(1 - D) \Delta I_{L2} f}$$

$$L_3 \rightarrow (2V_{C1} - V_o)DT_s + (V_{C2} - V_o)(1 - D)T_s = 0 \quad (5)$$

$$L_3 = \frac{V_o D (1 - D)}{\Delta I_{L3} f}$$

Using Equations (3) to (5), the output voltage of the converter is derived and expressed in Equation (6)

$$V_o = V_{in} \frac{(1 + D)}{(1 - D)^2} \quad (6)$$

Similarly, the voltage across each capacitor can be calculated using Equations (7) and (8).

$$V_{C1} = \frac{V_{in}}{(1 - D)} \quad (7)$$

$$V_{C2} = V_{C1}(1 - D) = \frac{V_o}{(1 - D)} \quad (8)$$

The voltage stress of the switching element is given Equation (9)

$$V_{S-stress} = V_{C2} \quad (9)$$

The voltage stress of the diodes ($D1$, $D2$ and $D3$) are defined on Equation (10) - (12)

$$V_{D1-stress} = \frac{(1-D)V_o}{(1+D)} \quad (10)$$

$$V_{D2-stress} = \frac{DV_o}{(1+D)} \quad (11)$$

$$V_{D3-stress} = V_{C2} \quad (12)$$

Control

To ensure stable and regulated output voltage in the proposed Quadratic Boost Converter (QBC) integrated with a Voltage Multiplier Circuit (VMC), a Proportional-Integral (PI) control strategy is employed. The PI controller is designed to minimize steady-state error and enhance the dynamic response of the system. The controller parameters were obtained using a systematic tuning approach based on trial-and-error method, and the detailed tuning steps, including the selected proportional and integral gains, have now been added in the controller design subsection. These revisions allow other researchers to replicate the proposed control strategy more accurately. As illustrated in Figure 5, the controller continuously monitors the output voltage

and compares it to a predefined reference voltage (V_{ref}), which in this study is set to 600 V. The control law utilizes proportional (K_p) and integral (K_i) gains to generate a control signal that adjusts the converter's switching behavior accordingly. In the implemented design, the proportional and integral gains are set to $K_p = 1$ and $K_i = 75$, respectively. The Proportional and integral gains were selected on the Bode plot of the open-loop transfer function to achieve a phase margin of approximately 18.9° and a gain margin of approximately 12.8 dB. These values provide a good compromise between fast transient response and steady-state accuracy, while maintaining robust stability under input voltage and load variations.

The controller operates by computing the error signal, defined as the difference between the measured output voltage and the reference voltage. When the output voltage deviates below the target level, the PI controller increases the duty cycle of the switching signal, thereby supplying additional power to raise the output voltage. Conversely, when the voltage exceeds the reference, the controller reduces the duty cycle to stabilize the system. This closed-loop control approach effectively maintains the output voltage at the desired level despite fluctuations in input power or load conditions, ensuring reliable operation of the converter in photovoltaic (PV) applications.

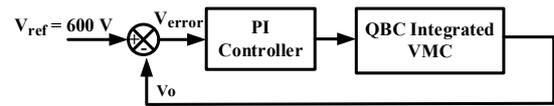


Figure 5. PI controller for Quadratic Boost Converter integrated with Voltage Multiplier Cells

RESULTS AND DISCUSSION

The primary objective of this technical analysis is twofold: (1) to evaluate the performance and effectiveness of the Quadratic Boost Converter (QBC) integrated with Voltage Multiplier Cells (VMC) in maintaining a stable DC bus voltage under varying solar irradiance conditions, and (2) to verify the capability of the Proportional-Integral (PI) controller in regulating the converter's output voltage in real time. To assess these objectives, the proposed converter configuration is tested using a simulated input voltage of 54 V DC, representing the output of a photovoltaic (PV) array, and is connected to a resistive load of 500 W. The system is designed to produce a regulated output voltage of 600 V DC, suitable for high-voltage applications such as grid-tied inverters or industrial DC buses.

The modeling, simulation, and analysis of the converter are carried out using MATLAB/Simulink, which allows for detailed examination of both the steady-state and dynamic behavior of the system. The simulation environment also facilitates the implementation and tuning of the PI controller. The electrical parameters and component specifications used in the power circuit design are summarized in Table 1, serving as the basis for validating system performance under various operating conditions.

Table 1. The parameter values of QBC integrated with VMC

Components	Part name	Values
V_{iPV}	PV Source	54 V – 9.25 A – 500 W
(f_{sw})	Switching Frequency	100 kHz
$D_{1,2,3,4,5}$	Diode	600 V – 15 A – 1.7 V
S_1	Switch	
$L_{1,2,3}$	Inductor	680 μ H, 1500 μ H,
$C_{1,2,3} C_4, C_5, C_o$	Capacitor	4.5 μ F, 130 μ F, 70 μ F,

The first test was performed by varying the converter input voltage using a constant DC source in the range of 8–57 V. This test was conducted to validate the converter performance prior to the application of the photovoltaic (PV) system as the input source. The experimental results show that the proposed QBC-VMC system is capable of achieving a voltage gain of up to 12, where an input voltage of 54 V successfully produces an output voltage of 600 V. Changes in the input voltage are regulated by the PI controller through duty cycle modulation to ensure that the output voltage remains at the specified reference value. The corresponding results are presented in Table 2 and Figure 6.

Table 2. The efficiency system of QBC-VMC

D	Vin (V)	Vo (V)	Efficiency (%)
45	57.72	299.8	97
55	55.6	425.58	85
62	53.79	604.1	81
65	26.61	544.97	73
70	16.55	312.61	57
75	8.415	235.62	29

As presented in Table 2, the highest recorded efficiency reaches 97%; however, this occurs at an output voltage of only 299.8 V, corresponding to a duty cycle of 45%. While this condition yields optimal efficiency, it does not meet the required voltage level for the intended application. To achieve an output voltage approaching the target of 600 V, the converter must operate within a higher duty cycle range, specifically between 55% and 65%. Within this range, the output voltage varies from approximately 425 V to 600 V, which is more suitable for high-voltage DC applications such as grid integration or industrial loads.

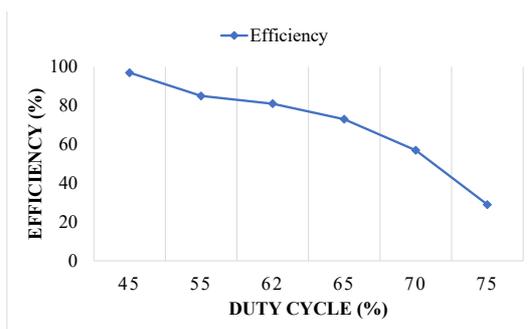


Figure 6. Efficiency system QBC-VMC

To ensure voltage stability under varying operating conditions, the PI controller is configured with a reference voltage of 600 V. The controller dynamically adjusts the converter’s duty cycle within the 55%–65% window to maintain the desired output voltage. This closed-loop control strategy allows the system to balance between maintaining high voltage gain and ensuring efficient power conversion. Although efficiency may slightly decrease at higher duty cycles compared to the peak value at 45%, the trade-off is justified by the need to meet the required voltage specification for practical deployment in photovoltaic (PV) systems

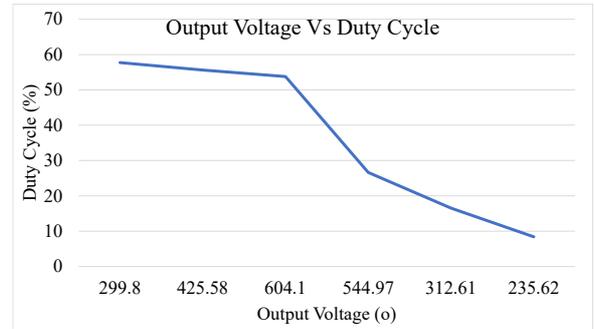


Figure 7. The duty cycle value relative to variations in the output voltage of the QBC-VMC

The relationship between the duty cycle and the resulting output voltage is depicted in Figure 7. The analysis shows that an output voltage of 600 V is achieved when the duty cycle reaches 62%, demonstrating that the converter operates most effectively within this range. The experimental results demonstrate that the proposed converter operates effectively over a wide range of operating conditions. At the optimal operating point, the system achieves a maximum energy conversion efficiency of approximately 81%. Despite this relatively high efficiency, several power losses are still observed. These losses are mainly attributed to voltage stress during the high-frequency switching process and the intrinsic conduction and switching losses of the diode. As the switching frequency increases, the switching losses become more dominant, leading to a slight reduction in the overall efficiency.

However, it is important to note that the proposed converter topology imposes considerable voltage stress on several semiconductor components, particularly on the capacitors and diodes within the Voltage Multiplier Cells (VMC). These components are exposed to elevated voltage levels during the switching transitions, which contributes to conduction and switching losses. Consequently, although the converter successfully boosts the voltage to the desired level, the overall efficiency is inherently limited and cannot approach 100%. These losses are a natural outcome of the energy transfer and voltage multiplication process, especially under high step-up conditions. Despite this limitation, the system maintains a reasonably high efficiency while delivering the target output voltage, validating its suitability for integration in PV-based energy systems.

The performance of the Proportional-Integral (PI) control system implemented in the Quadratic Boost Converter integrated with Voltage Multiplier Cells (QBC-VMC) was evaluated by monitoring the stability of the output voltage under varying operating conditions. As illustrated in Figure 8, the PI controller

successfully maintains a relatively constant output voltage of approximately 600 V with transient time 0.15s, even when subjected to fluctuations in solar irradiance. During the simulation, the irradiance levels were varied to 500 W/m², 1000 W/m², and 800 W/m² to represent realistic environmental changes in a photovoltaic (PV) system. The results demonstrate that the control system is capable of dynamically compensating for the impact of irradiance variation, ensuring consistent voltage regulation.

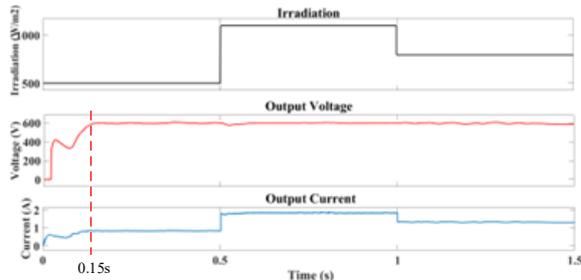


Figure 8. The fluctuations of solar irradiance to the output voltage of the QBC-VMC

Furthermore, as presented in Table 3, the PI controller also exhibits robust performance under load variation scenarios. Although a minor transient oscillation is observed immediately following abrupt changes in load power, the system quickly restores voltage stability. The average steady-state error in the DC-Bus voltage is maintained at approximately 0.7%, indicating high accuracy and effective regulation. These findings confirm that the PI control strategy is well-suited for maintaining voltage stability in high-gain DC-DC converter systems, particularly under variable conditions typical of PV applications.

Table 3. The Output Voltage with Variance of Irradiance

Irradiance (W/m ²)	V _{dc} -Output	% V _{dc} -output
500	605	0.8%
1000	603	0.5%
800	595	0.8%

Comparison ff The Studied Converter And Existing Converter

A comparative study is carried out between the proposed topology and several voltage multiplier cell (VMC)-based high step-up converters. The evaluation focuses on both the performance metrics and structural characteristics to validate the effectiveness and feasibility of the proposed converter. The comparison parameters include voltage gain, component count, efficiency, and output power. The specifications of the reported converters and the proposed topology are summarized in Table 4. Unlike the converters presented in previous studies that operate with a constant input voltage, the proposed topology is powered by a renewable energy source (RES) that provides a variable input voltage. Furthermore, this work emphasizes a high step-up converter that evaluates not only the voltage gain as the primary metric but also the overall power-handling capability.

Based on the obtained results, the proposed converter exhibits a higher output voltage gain compared to the other reported converters. Although the converters presented in [20] and [24] are capable of achieving voltage step-up ratios of up to 13, they are

primarily intended for lower power applications than the proposed design. In contrast, the converter introduced in [25] achieves an output power of 3000 W with an efficiency of 96%. In addition, the proposed converter employs a PI controller-based control strategy to maintain a near-constant output voltage and ensure system stability, while accounting for the inherent voltage variations of the PV system caused by changes in solar irradiance. In the design of the proposed converter, the number of components is kept within a practical and acceptable limit. In general, achieving a high voltage conversion ratio requires the inclusion of additional components due to the inherent complexity of high step-up converter topologies. However, excessive component usage should be avoided to prevent increased cost and converter size. Although the proposed converter provides a higher voltage gain, its component count remains comparable to those reported in [15], [18], [20]-[23], and [25], the proposed topology employs approximately 12 components while still preserving structural efficiency.

The key findings of the research are summarized below: The QBC-VMC for PV systems integrated with PI control has been evaluated using MATLAB simulation. The simulation results under irradiance variation demonstrate that the PI control can maintain the output voltage relatively constant. Additionally, the QBC-VMC converter is capable of transforming the lower voltage from the PV source into a higher voltage suitable for the DC bus, operating within an input voltage range of 54 V and delivering an output voltage of 600 V with a gain of 12 times. The percentage tolerance of the reference voltage relative to the overall system output voltage is 0.7%.

CONCLUSIONS

This paper has investigated the implementation of PI control system for Quadratic Boost Converter- Voltage Multiplier Cells (QBC-VMC) for PV system. Modelling, control structure and detailed analysis was explained. This converter used to convert lower voltage of PV to be high output voltage. This converter can boost the voltage level from 54 to 600 volts. PI Controller used to regulate the output voltage high variation condition of irradiance. The test results demonstrate that the control system effectively maintains a stable output voltage, even in the presence of changes in conditions of irradiance. The voltage tolerance between the DC bus reference and the output voltage is within 0.7%. The efficiency of this converter is 81%.

The investigation of integration between artificial intelligence control system with QBC-VMC and experiment validation can be considered a potential direction for further research.

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L_1, L_2, L_3	Inductors (Henry)
QBC	Quadratic Boost Converter
$MPPT$	Maximum Power Point Tracker
PV	Photovoltaic
PI	Proportional-Integral
$QBC-VMC$	Quadratic Boost Converter- Voltage Multiplier Cell
RES	Renewable Energy Source
RE	Renewable Energy
S_i	Switch
$V-DC$	Direct Current Voltage
V_{iPV}	Photovoltaic Input Voltage
V_{err}	Error Voltage
V_{ref}	Reference Voltage
V_o	Output Voltage

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NOMENCLATURE

C_1, C_2, C_o	Capacitor (Farad)
D_1, D_2, D_3, D_4	Diode
D	Duty Cycle
f_{sw}	Switching Frequency



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