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High-Gain Multiport DC-DC Converter for Renewable Energy

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Dedication

First of all, I would like to thank Allah

for giving me the strength and courage to carry out this modest work.

I would like to dedicate this humble work to:

My loving mother ***Latifa*** *and my dear father* ***Hamid***

My project partner: ***Aymane***

My best friends:
Hamza, Badro, Aymen, Ossama

And to all those who love me and whom I love.

Taallah Mohamed Oussama

Dedication

First of all, I would like to thank Allah

for giving me the strength and courage to carry out this modest work.

I would like to dedicate this humble work to:

My loving mother ***Nabila*** *and my dear father* ***Madani***

My project partner: ***Oussama***

My best friends:
Mohamed, Oussama

And to all those who love me and whom I love.

Benali Aymane Abdelhak

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Abstract

Recent advances in renewable energy systems and smart grids have introduced new challenges in the design of power conversion systems. Due to the intermittent nature of renewable sources and the unpredictability of load demand, it is often necessary to combine multiple energy sources with auxiliary adaptation systems. This approach helps meet load requirements while enhancing system dynamics, steady-state performance, reliability, and availability.

This work aim to explores recent progress in focusing on topologies and control strategies of DC/DC converter using different technique of enhancement in their duty of performance MPPT regulations, also to provide a comprehensive framework to guide high gain converter design and applications.

This study supported comprehensive applying through MATLAB/SIMULINK simulation of system photovoltaic.

Keywords: PV, P&O, IncCond, PSO, Fuzzy logic, MATLAB, DC/DC Converter, Permanent regime, Transient regime.

ملخص

أدخلت التطورات الحديثة في أنظمة الطاقة المتجددة والشبكات الذكية تحديات جديدة في تصميم أنظمة تحويل الطاقة. فنظرًا للطبيعة المتقطعة لمصادر الطاقة المتجددة وعدم القدرة على التنبؤ بالطلب على الأحمال، غالبًا ما يكون من الضروري الجمع بين مصادر الطاقة المتعددة وأنظمة التكيف المساعدة. يساعد هذا النهج على تلبية متطلبات الحمل مع تعزيز ديناميكيات النظام وأداء الحالة المستقرة والموثوقية والتوافر.

يهدف هذا العمل إلى استكشاف التقدم الأخير في التركيز على الطوبولوجيات واستراتيجيات التحكم في محول التيار المستمر/التناوب باستخدام تقنيات مختلفة للتحسين في أنظمة MPPT للأداء، وكذلك لتوفير إطار شامل لتوجيه تصميم المحول عالي الكسب وتطبيقاته.

وقد دعمت هذه الدراسة التطبيق الشامل من خلال محاكاة MATLAB/SIMULINK لمحاكاة النظام الكهروضوئي.

الكلمات المفتاحية: الكهروضوئية، P&O، P&O، IncCond، PSO، المنطق الضبابي، Matlab، محولDC/DC ، النظام الدائم، النظام العابر.

Résumé

Les progrès récents dans les systèmes d'énergie renouvelable et les réseaux intelligents ont introduit de nouveaux défis dans la conception des systèmes de conversion d'énergie. En raison de la nature intermittente des sources renouvelables et de l'imprévisibilité de la demande de charge, il est souvent nécessaire de combiner plusieurs sources d'énergie avec des systèmes d'adaptation auxiliaires. Cette approche permet de répondre aux exigences de charge tout en améliorant la dynamique du système, les performances en régime permanent, la fiabilité et la disponibilité.

Ce travail vise à explorer les progrès récents en se concentrant sur les topologies et les stratégies de contrôle des convertisseurs CC / CC en utilisant différentes techniques d'amélioration dans leur devoir de performance des réglementations MPPT, également pour fournir un cadre complet pour guider la conception et les applications des convertisseurs à gain élevé.

Cette étude a soutenu une application complète via la simulation MATLAB / SIMULINK du système photovoltaïque.

Mots clés : PV, P&O, IncCond, PSO, Logique floue, Matlab, Convertisseur DC/DC, Régime permanent, Régime transitoire.

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General Introduction

Recent advancements in Renewable Energy Sources (RESs), electric/hybrid vehicles, telecommunication, and satellite applications have introduced new challenges in designing DC/DC power conversion systems. For example, despite developments in RES technology, these sources are not inherently reliable for electric energy generation on their own. The primary challenge is their dependence on weather and environmental conditions, leading to variable and uncertain energy output. Consequently, a standalone RES cannot provide the characteristics of an efficient, stable, and reliable energy resource to meet demand (Zhang et al., 2016).

To overcome this, RESs are often combined with Energy Storage Systems (ESSs) to form Hydrogen Refueling Stations (HRSs) (Affam et al., 2021). Earlier works proposed two main structures for power converters. In the typical structure, a conventional SISO (Single-Input, Single-Output) DC/DC converter is used for each input source. The outputs of these individual converters are then coupled by a common DC-link to provide the required load energy, with each SISO DC/DC converter regulated independently. A telecommunication bus is usually employed to exchange data between multiple input sources (Rehman et al., 2015). However, using numerous different power converters and telecommunication equipment in this structure is inefficient, bulky, and increases cost. Furthermore, the need to synchronize separate, individually regulated converters adds to the complexity (Zhang et al., 2016, Affam et al., 2021).

To address these issues, an integrated multi-port system has been suggested (Rehman et al., 2015, Khosrogorji et al., 2016). In integrated multi-port systems, the entire structure functions as a single converter capable of combining energy from various input sources with differing specifications. A central unit controller manages the converter's output power. This type of Multi-Port DC/DC (MPDC) converter is recommended for applications such as hybrid power systems, electric/hybrid vehicles, satellites and telecommunication, and Uninterruptible Power Supplies (UPSs) due to its simpler structure, higher availability and reliability, increased power density, and lower cost (Affam et al., 2021, Bairabathina and Balamurugan, 2020).

The first chapter provides a literary survey as overview of applying DC/DC converter in photovoltaic conversion, reviewing basic concepts, including their topologies and physical arrange, their various classifications, and the principles of adaptation gain. The chapter concludes with a review of the most important their applications.

The second chapter focuses on essential performance and efficiency of PV conversion using duty of DC/DC converter, regulator-improving method by simulation through Simulink/Matlab.

In Chapter 3, we begin the study of build a high gain (high efficiency) of PV system even to expand the study to a good comparison using different MPPT techniques such as P&O, InCond, PSO, and fuzzy logic, all are analyzed and discussed. The comparison was based in the two regime transient and permanent when that to reduce a maximum of transient regime in function of time.

Chapter 1

State of the art

I.1. Introduction:

The rapid expansion of industries, vehicles, and domestic usage has led to a significant increase in energy consumption. However, the depletion of fossil fuels and the resulting environmental pollution, including the rise in global temperatures, pose major challenges. Therefore, there is a pressing need to shift towards renewable energy sources for electricity production [1]. Among all Renewable Energy Sources (RES), Photovoltaic (PV) power generation has gained prominence due to its advantages, such as a longer lifespan, eco-friendliness, mobility, and the portability of its components, as well as its ability to meet peak power demands [2].

Solar power tracking has become a critical issue due to the nonlinear behavior of the current-voltage (I–V) characteristics of PV panels, which operate at a maximum power point (MPP). The power output of PV panels is influenced by atmospheric conditions, specifically solar irradiance and cell temperature, which are not consistent and vary with environmental changes. This necessitates the use of Maximum Power Point Trackers (MPPT) to extract the maximum power from the PV system. MPPT is a vital component that ensures the converter matches the load and delivers maximum power [3]. The primary challenge facing solar PV systems is the irregular availability of solar irradiance. To address this and maintain a constant output voltage, various power electronic DC–DC converters are employed. Since the 1920s, DC–DC converters have been used with solar PV units to replace conventional circuits like rheostats and potential dividers, which were less efficient due to voltage drop [4].

Today, several DC–DC converter topologies are used to regulate the input voltage according to application requirements. DC–DC converters are broadly classified into two types: isolated and non-isolated converters. Isolated DC–DC converters use a high-frequency transformer to create an electrical barrier between the input and output, protecting sensitive loads and offering high noise interference capability. The output of these converters can be configured with positive or negative polarity [5 and 6].

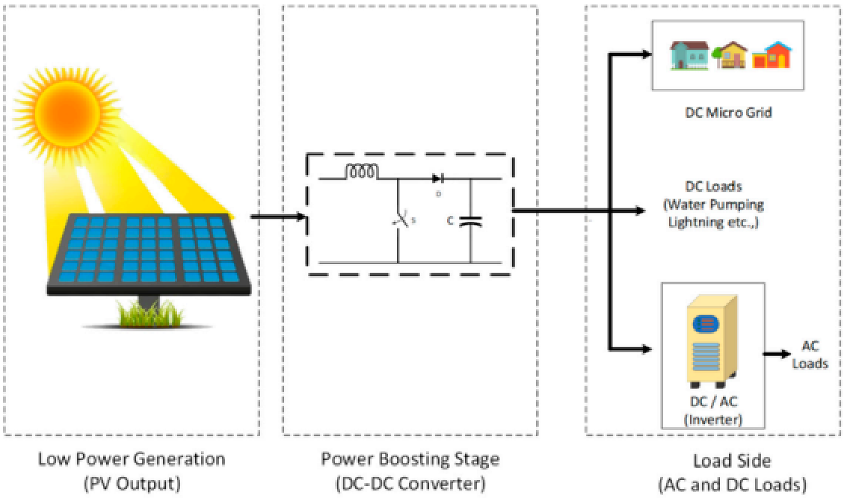

Figure I.1. Solar PV integrated system with DC–DC converters fed to the load [2,6].

I.2. Literature survey:

Samia latreche et al, are proposed a new study about the modern technology to enhance and improving the DC/DC boost converter in the presence of disturbances, a synergistic control (SC) system derived from synergistic theory. The controller exhibits a suitable response with high performances, such as fast transient response, negligible steady-state error, and better performance underload and output voltage fluctuations. (Figure I.2) depicts an experimental setup designed to evaluate and verify the feasibility of the proposed control technique [7].

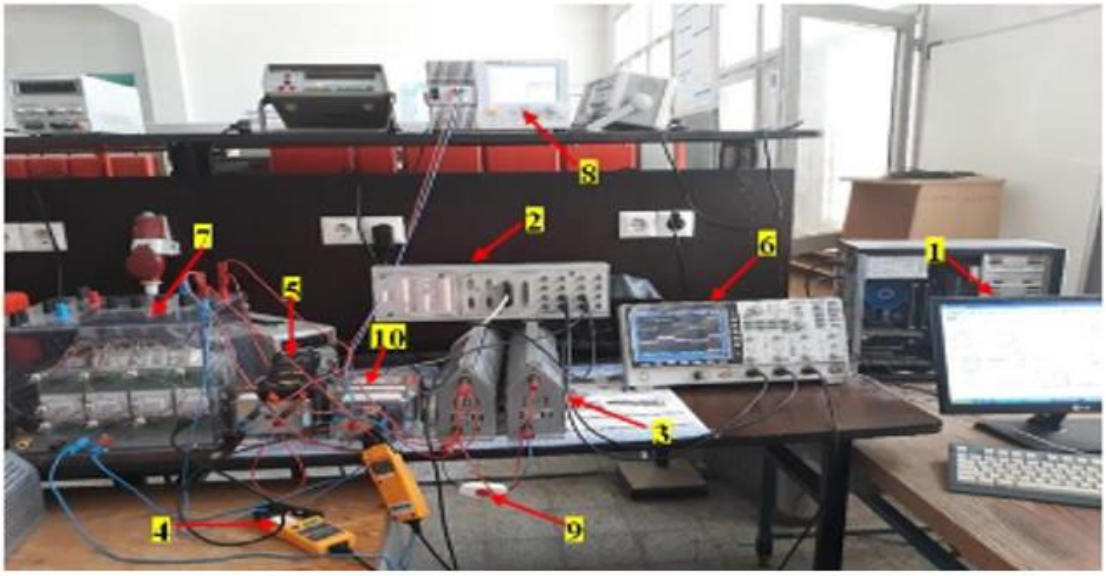

Figure I.2: Hardware prototype built to evaluate the proposed method.

Pasala Gopi proposed a new strategy to converter incorporate an energy storage system (ESS) and a variety of power sources into the micro-grid. This combination offers enhanced system stability, overall efficiency, and optimum energy management. The energy storage system gives the additional energy to the load or takes the surplus energy form the micro-grid. Comprehensive simulations assess the converter’s performance under varying loads, renewable energy source fluctuations, and grid disturbances. Comprehensive simulations are carried out to verify the performance of the suggested ANN control¬ler. The simulation findings demonstrate that the ANN-based control method performs better under various power scenarios when compared to the traditional PI controller [8].

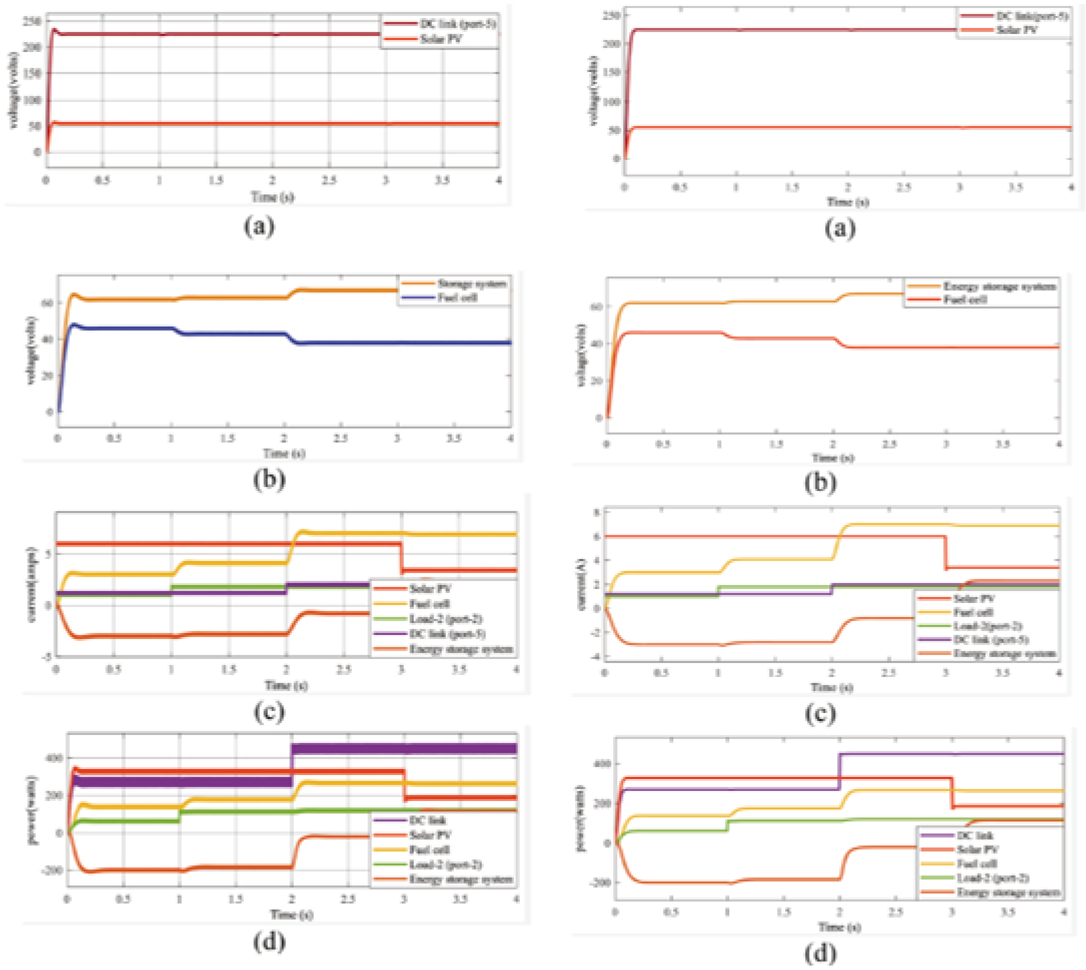

Figure I.3: A multiport DC-DC converter with an intelligent controller for micro grid applications.

The fundamental role of DC/DC converters in adapting the voltage from a photovoltaic generator to optimize power transfer to the load. After describing the various converter topologies, we detailed the principles and challenges of Maximum Power Point Tracking (MPPT), an essential process for maximizing the performance of a PV system.

Performance analysis of converters is crucial when selecting the appropriate one for photovoltaic (PV) system applications. Taghvae et al. [9] examined various DC–DC converters—including buck, boost, buck–boost, Cuk, and SEPIC—and their integration with maximum power point tracking (MPPT) algorithms in PV systems. Their study highlighted the ability of each converter to operate at the maximum power point, with the conclusion that the buck–boost converter is versatile and effective under varying solar irradiance and load conditions for maximizing power extraction. Similarly, Farhat et al. [10] investigated how changes in solar irradiance and cell temperature influence the design and selection of different converter topologies commonly used in PV systems. Their findings indicate that buck–boost and Cuk converters can provide optimal performance under these varying conditions. To reduce output voltage ripple, the filter capacitance should exceed the maximum boundary capacitance value.

Compared to other non-isolated converters, the buck–boost converter demonstrates a reasonable input and output power range, beyond which its efficiency declines as the power ratings increase. In contrast, the Ultra-lift Luo converter exhibits higher efficiency at elevated input and output power levels. Additionally, super-lift, Cuk, and SEPIC converters are primarily used in medium power applications; however, the buck–boost converter is most suitable for low-power utility applications.

For high-power renewable energy systems, the Ultra-lift Luo converter is preferable due to its superior efficiency in industrial applications, as confirmed by experimental results in [10-11]. Like buck–boost and Cuk converters, the Ultra-lift Luo produces an inverted output relative to the input voltage. Its basic circuit design offers improvements over other converters, but the voltage stress on its switch is significant, leading to a higher duty cycle. This increase in duty cycle raises both the cost and the ratings required for the power semiconductor switch [12].

The selection of DC-DC converter topologies for PV-based power supplies must satisfy the requirements outlined in the following sections. A typical configuration of a DC microgrid is illustrated in Figure I.4. These converters can achieve the desired DC voltage level without increasing the stack size. For instance, the DC output from a polymer electrolyte membrane (PEM) fuel cell stack typically ranges in the tens of volts. Consequently, the ripple current induced across the PV system by the switching action of the DC-DC converter should be minimal. It is especially important to prevent rapid surges or drops in current, as well as large high-frequency current ripples, which should be avoided [12].

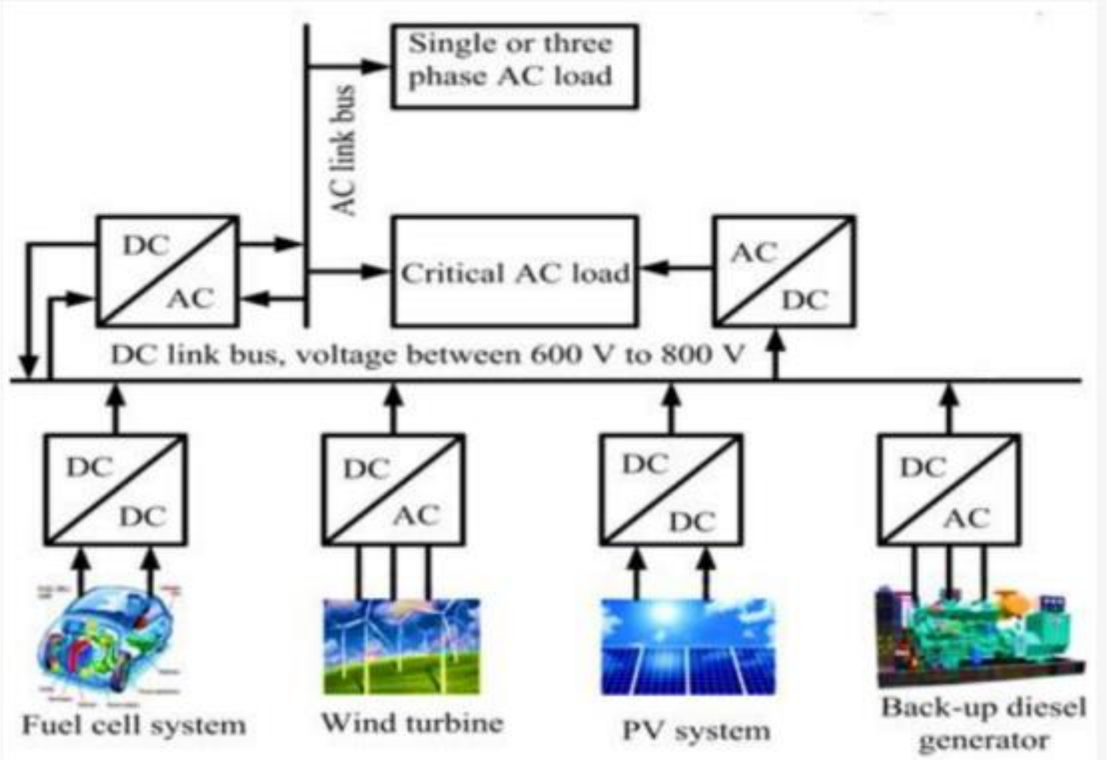

Figure I.4: Layout of DC microgrid.

I.3. Comparative Performance Assessment

Table I.1 illustrates the unique specifications of some emerging experimental DC–DC converter topologies for PV system applications for which the detailed description can be obtained from [12-14 and 15].

Table I.1. Key specifications of the recently advanced DC–DC converter topologies for PV systems.

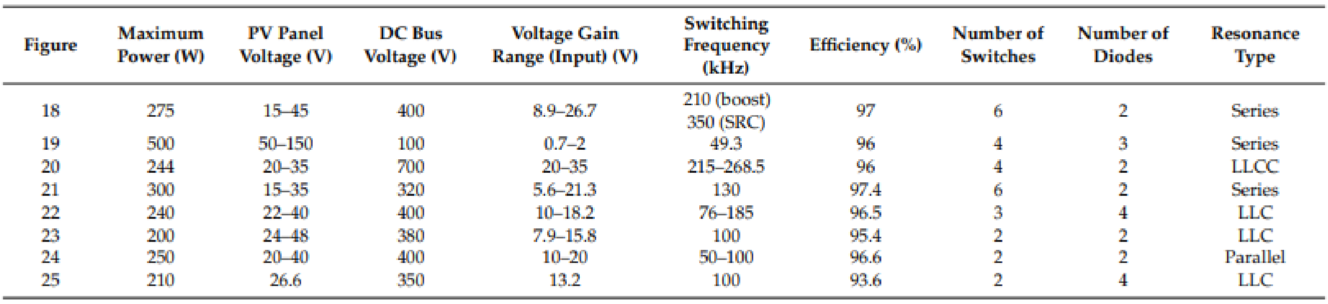

Figure	Maximum Power (W)	PV Panel Voltage (V)	DC Bus Voltage (V)	Voltage Gain Range (Input) (V)	Switching Frequency (kHz)	Efficiency (%)	Number of Switches	Number of Diodes	Resonance Type
18	275	15–45	400	8.9–26.7	210 (boost) 350 (SRC)	97	6	2	Series
19	500	50–150	100	0.7–2	49.3	96	4	3	Series
20	244	20–35	700	20–35	215–268.5	96	4	2	LLCC
21	300	15–35	320	5.6–21.3	130	97.4	6	2	Series
22	240	22–40	400	10–18.2	76–185	96.5	3	4	LLC
23	200	24–48	380	7.9–15.8	100	95.4	2	2	LLC
24	250	20–40	400	10–20	50–100	96.6	2	2	Parallel
25	210	26.6	350	13.2	100	93.6	2	4	LLC

I.4.Various Topologies of High-Voltage-Gain DC–DC Converters

Conventional boost DC–DC converters face challenges when attempting to elevate voltage to grid levels. To address this limitation, numerous studies have explored modifications to the standard boost converter circuit, resulting in a variety of innovative topologies. These new designs can achieve significantly higher voltage levels while ensuring reliability and efficiency.

The modified topologies of the boost DC–DC converter can be categorized into four distinct groups:

Low-Gain Low-Power (LGLP)

Low-Gain High-Power (LGHP)

High-Gain Low-Power (HGLP)

High-Gain High-Power (HGHP)

Among these categories, the High-Gain Low-Power (HGLP) topology is the most commonly utilized in photovoltaic (PV) systems. A general classification of the modified DC–DC boost converter topology is shown in Fig. I.5. In the HGLP converter group, there are many developed topology modifications by researchers, including: (i) three-level boost converters [13–15]; (ii) multilevel switched-capacitor (SC) topology [16, 18].

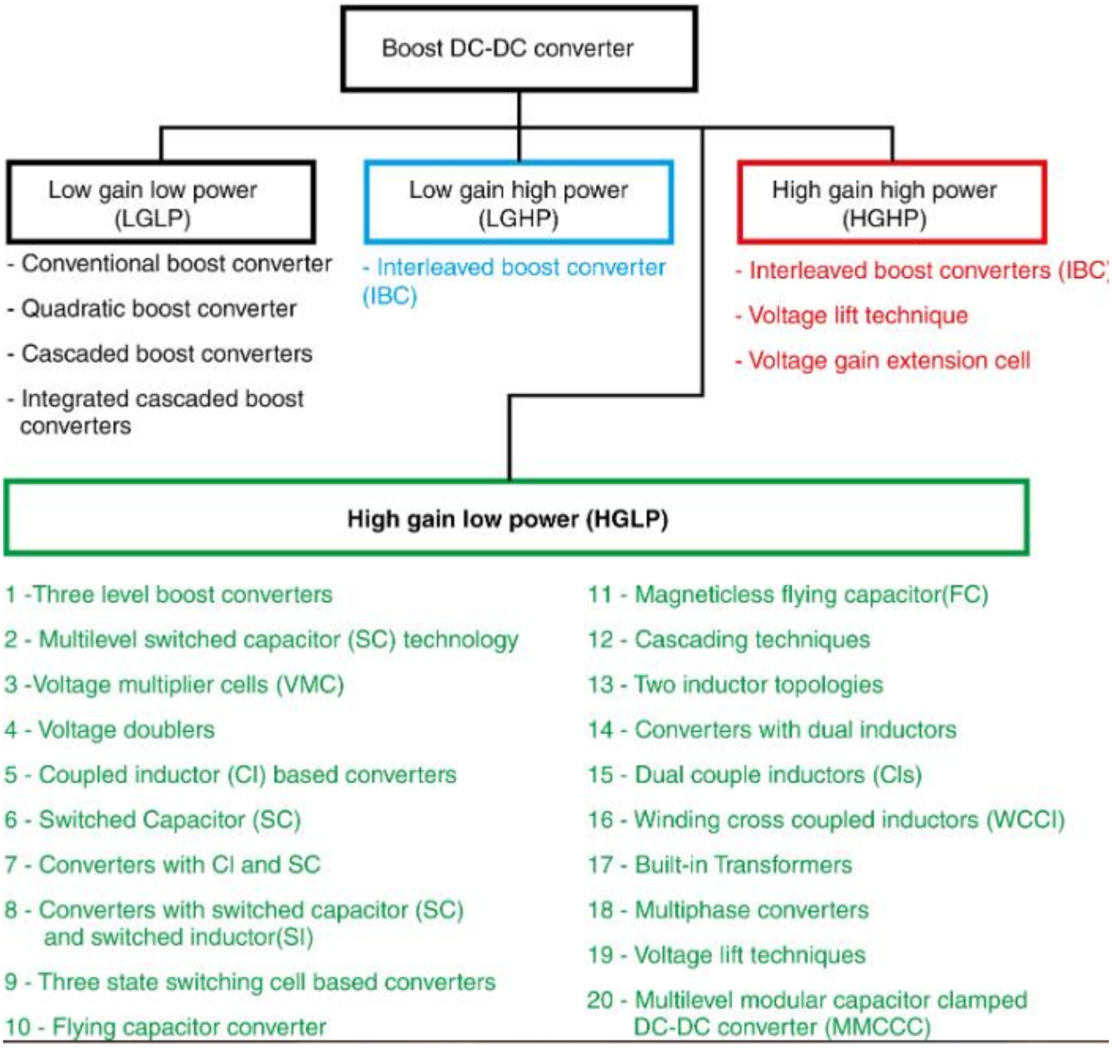

Figure I.5: Layout of DC microgrid Various topologies of the boost DC–DC converter classified based on voltage gain and rated power level.

I.5. Review on MPPT Techniques

This review explores various Maximum Power Point Tracking (MPPT) methods, including Incremental Conductance, Perturb and Observe (PO), Fuzzy Logic Control, and the Hill Climbing method, focusing on duty ratio and PV output power parameters. Results indicate that the Fuzzy Logic Controller outperforms the Hill Climbing, Incremental Conductance, and Perturb and Observe methods in both steady-state and dynamic responses, as demonstrated using PSIM and Simulink software.

To address partially shaded conditions, an MPPT algorithm was developed for photovoltaic systems, enhancing real power support and power quality. When comparing the proposed MPPT algorithm with the conventional Fibonacci search method, the new system exhibited superior tracking speed and power tracking performance. To optimize power generation from the PV system, a power management system integrated with a battery system was also proposed. The Matlab/Simulink environment, along with the MPPT technique and inverter control system, was implemented in a dSPACE controller, resulting in a real-time experimental prototype [19].

The proposed MPPT algorithm [20] was evaluated based on two critical aspects: the PV array characteristic curve under both partial shading and normal conditions, coupled with a modified Fibonacci search method. In grid-connected PV systems, power flow control and power quality improvement were achieved using a single inverter.

The review paper [21] provides an overview of various recent hybrid methods and new MPPT algorithms. Future research in photovoltaic (PV) systems, particularly under partial shading conditions, is expected to be extensive. MPPT methods are categorized into four main groups:

- New Optimization Algorithms

- Hybrid MPPT Algorithms

- Innovative Modeling Methods

- Various Converter Topologies

The PV modeling methodology under partial shading conditions allows for easy identification of power peaks. Different optimization algorithms have been analyzed, including the Shuffled Frog Leaping Algorithm and Particle Swarm Optimization (PSO), as discussed in paper [22]. These algorithms contribute to effectively locating the global maximum power point. The paper also proposes a new control technique featuring a power tracking method and a PWM permutation system, along with AC output voltages from a multilevel DC link converter with five levels, designed for various partial shading conditions.

This system employs buck converter modules linked with two PV systems and a DC-AC H-bridge to supply an AC load. Simulation studies were conducted using the proposed MPPT scheme, demonstrating that maximum power generation can be achieved by each module according to its illumination level. The proposed method yielded significantly higher power output compared to traditional PSO and Perturb and Observe (PO) methods, with improved output voltage waveforms.

Reference [23] introduces an MPPT algorithm utilizing a finely-tuned duty cycle for a DC-DC converter to prevent divergence from the maximum power point. Simulation results and case studies validate the effectiveness of this fast-acting MPPT technique. The paper discusses the proposed algorithm in conjunction with the Incremental Conductance and Perturb and Observe methods, showing superior performance in response to variations in load and solar irradiance. According to simulation results, while conventional MPPT algorithms resulted in fluctuating voltages of around 20 V, the proposed algorithm maintained steady-state current, voltage, and power output.

I.6. Conclusion

Given the various challenges associated with converter topologies for photovoltaic (PV) system applications, both isolated and non-isolated converters are crucial for efficiently interfacing and delivering solar PV energy to the grid. This review provides an in-depth analysis of different topologies and their operational effectiveness in PV applications.

Key findings from the literature highlight a strong interest in maximizing solar energy generation to meet increasing demand. The most effective approach involves using both DC–DC converters and Maximum Power Point Trackers (MPPTs). Among these, buck and boost converters stand out as cost-effective options. However, they face challenges in tracking performance due to varying load conditions, radiation, and temperature.

Other non-isolated topologies, such as buck-boost, SEPIC, and Cuk converters, can achieve optimal efficiencies and are well-suited for MPPT applications, as they are less affected by changes in radiation and temperature. The main drawbacks of Cuk and SEPIC converters include their higher reactive components, which contribute to increased costs despite their efficiency advantages.

Among the non-isolated converters, the buck-boost converter is particularly effective for low-power applications due to its superior performance and reduced power losses. Consequently, it is the most suitable choice for low-power systems, including solar PV installations, permanent magnet (PM) DC motors, and low-power solar-based stepper motors.

chapter 2

Contributions of Photovoltaic Systems to Energy Generation

II.1. Introduction

Directly converting sunlight into electricity without a heat engine, photovoltaic (PV) technology offers robust, simple, and low-maintenance solutions. A key strength of PV devices is their capability to operate as **stand-alone systems**, delivering power from microwatts to megawatts. This adaptability has led to their broad adoption across numerous applications, including power generation, water pumping, remote building electrification, solar home systems, communication infrastructure, satellites, space vehicles, reverse osmosis plants, and large-scale power stations. As a result, the market for photovoltaic technology experiences continuous annual growth.

A typical photovoltaic power generation system consists of **solar cells**, along with their mechanical and electrical connections, mounting structures, and devices for regulating or modifying electrical output. These systems are characterized by their **peak kilowatt (kWp)** rating, which signifies the maximum electrical power they can generate under optimal conditions, such as when the sun is directly overhead on a clear day. In a grid-connected setup, the PV installation is linked to an independent power grid, usually the public electricity network, allowing the generated electricity to be fed directly into it.

This chapter aims to comprehensively compare the influence of solar irradiance, connection methods, and efficiency on PV power generation.

II.2. Photovoltaic generator

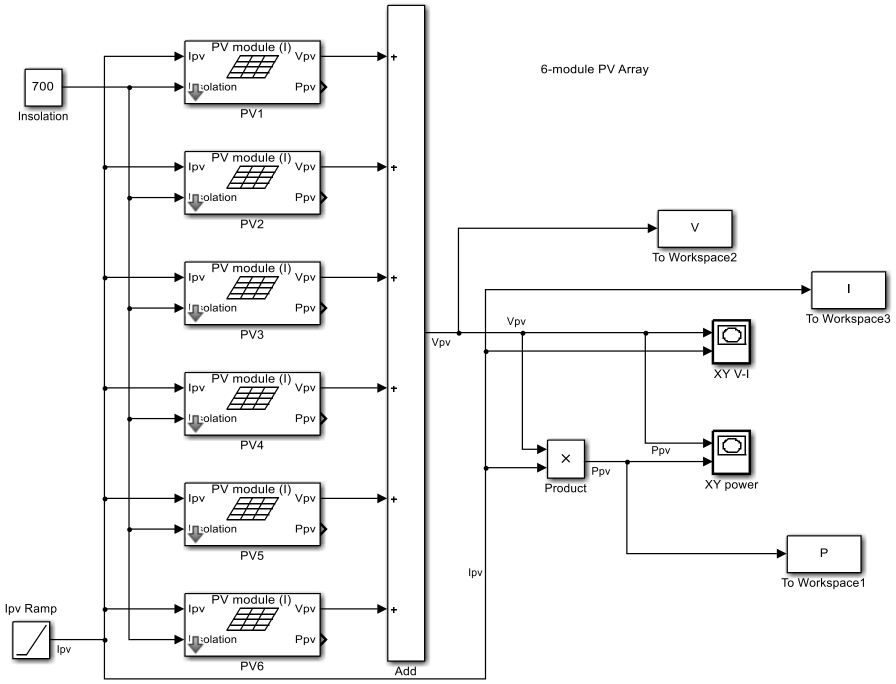

Figure II.1. illustrates the Simulink model of the photovoltaic generator utilized in this study.

The diagram is a **Simulink model** representing a **series connection of six photovoltaic (PV) modules** under uniform irradiance conditions (**700 W/m²**). The model demonstrates how series-connected PV panels behave in terms of output **voltage, current, and power**, and it includes measurement and output blocks to send data to the workspace.

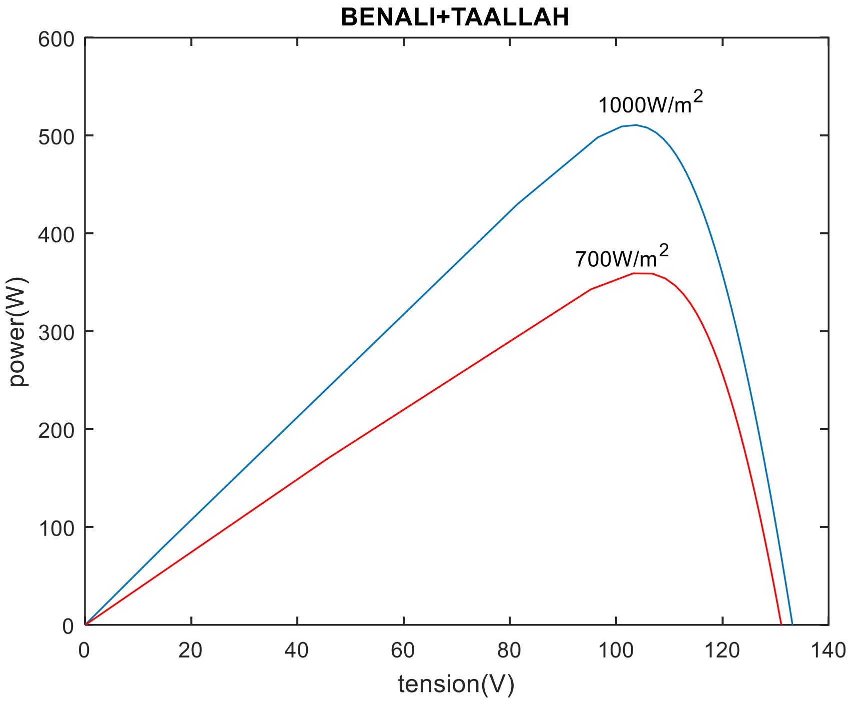

Figure II.2. Impact of Irradiance Solar on PVG power.

✓ Graph description: Impact of Irradiance Solar on PVG power

The graph displays the **power-voltage (P-V) characteristics of a photovoltaic (PV) panel** under two different irradiance levels: **1000 W/m²** (blue curve) and **700 W/m²** (red curve). It shows how the electrical power output (in watts, W) varies with the terminal voltage (in volts, V) of the panel.

- **X-axis (horizontal):** Represents the **voltage (tension)** across the PV panel, measured in **volts (V)**.
- **Y-axis (vertical):** Represents the **output power** from the PV panel, measured in **watts (W)**.
- The **blue curve** corresponds to an irradiance of **1000 W/m²**, representing standard test conditions.
- The **red curve** corresponds to a lower irradiance level of **700 W/m²**.

Key Observations

1. **Power Increases then Decreases:** For both curves, the power initially increases with voltage, reaches a **maximum power point (MPP)**, and then declines. This behavior is typical for PV panels.
2. **Effect of Irradiance:**
    - At higher irradiance (1000 W/m²), the panel produces more power, reaching a peak around 500 W.
    - At lower irradiance (700 W/m²), the peak power output is reduced, reaching around 350 W.
3. **Voltage at MPP:** The voltage at which maximum power occurs is similar for both irradiance levels, suggesting that irradiance primarily affects **current** more than **voltage** in the power equation.

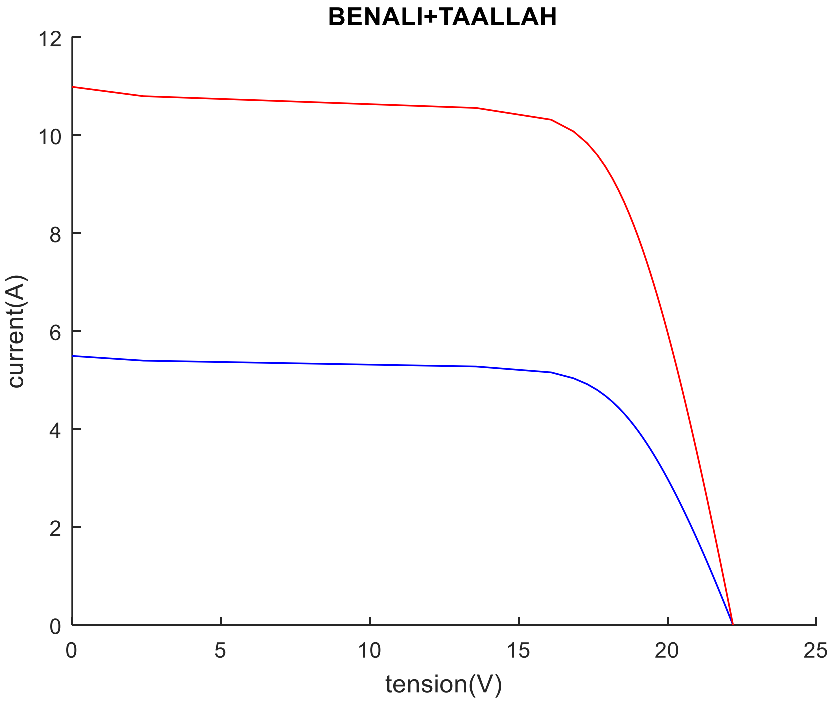

Figure II.3. Impact of parallel connecting of two PV Panel

✓ Graph Description: Impact of Parallel Connection of Two PV Panels

This graph illustrates the **current-voltage (I-V) characteristics** of a photovoltaic (PV) system to demonstrate the effect of **parallel connection** of two PV panels under different irradiance levels.

- **X-axis (horizontal): Voltage (tension)** across the PV system, measured in **volts (V)**.
- **Y-axis (vertical): Current (courant)** output from the system, measured in **amperes (A)**.
- The graph contains **two curves**:
  - The **red curve** shows the I-V characteristic **after connecting two PV panels in parallel**.
  - The **blue curve** shows the I-V characteristic of a **single PV panel**.

✓ Key Observations

1. **Effect of Parallel Connection:**
   - When PV panels are connected in **parallel**, their **voltages remain the same**, but their **currents add up**.
   - This is evident in the graph: both curves reach the same voltage (~22–23 V), but the red curve has almost **double the current** compared to the blue curve.
   - This validates that the red curve represents **two identical PV panels connected in parallel** under similar irradiance.
2. **Current Increase:**
   - The current for the red curve reaches approximately **11–12 A**, whereas the blue curve reaches about **5–6 A**.
   - This matches the expected doubling of current due to the parallel configuration.
3. **Application Implication:**

- Parallel connections are useful when higher **current output** is desired while maintaining the **same system voltage**, which is often the case in low-voltage, high-current DC applications such as battery charging.

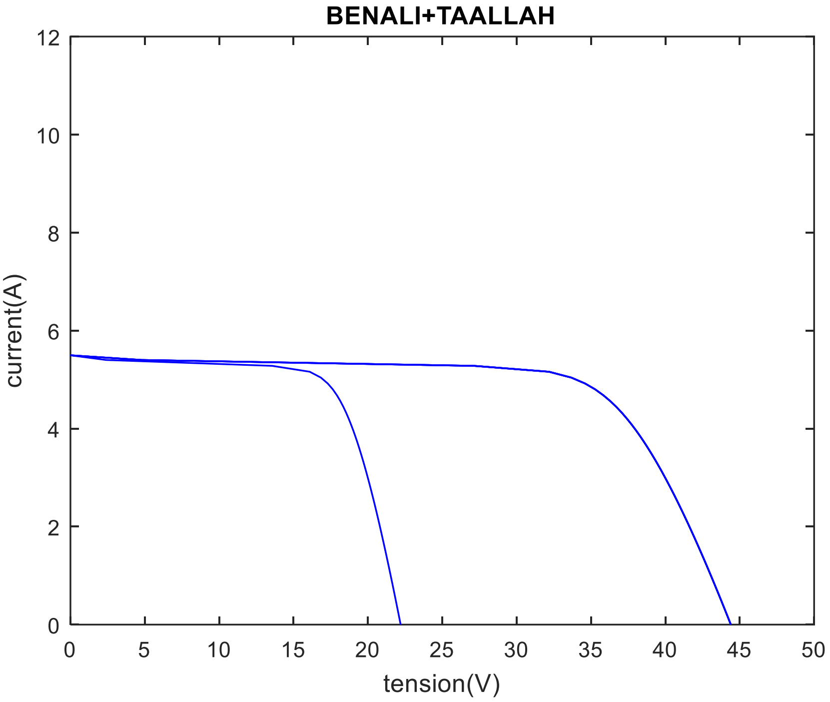

Figure II.4. Impact of parallel connecting of two PV Panel

II.2.1. Analysis

- The **higher current curve** represents the **parallel connection of two identical PV panels**. In a parallel configuration, the **voltage remains the same**, but the **current capacity increases**, roughly doubling compared to a single panel (assuming identical panels).
- The **lower curve** likely corresponds to a **single PV panel**, serving as a reference.
- The drop in current at higher voltages (particularly in the longer curve) reflects the **maximum power point (MPP)** beyond which the PV panel's ability to supply current rapidly declines.
- This graph confirms that **parallel connection increases the total current output** while maintaining the same voltage range, which is beneficial when higher current is needed (e.g., for charging batteries or supplying larger loads).

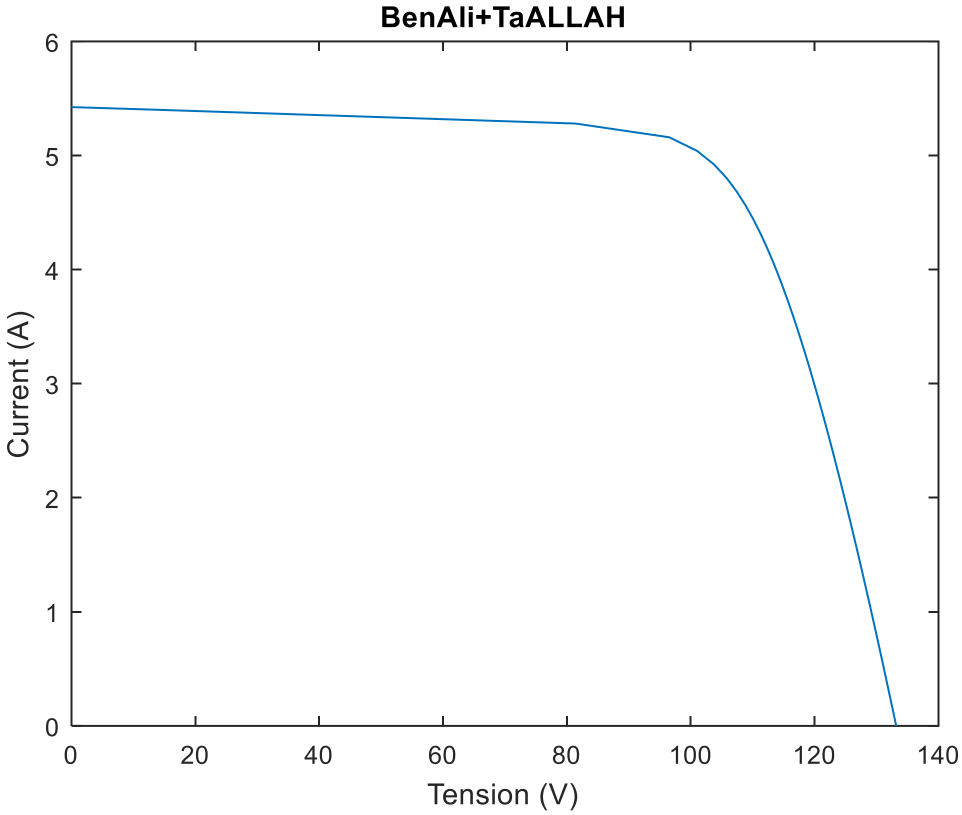

Figure II.5. Current curve of the photovoltaic generator utilized in this study.

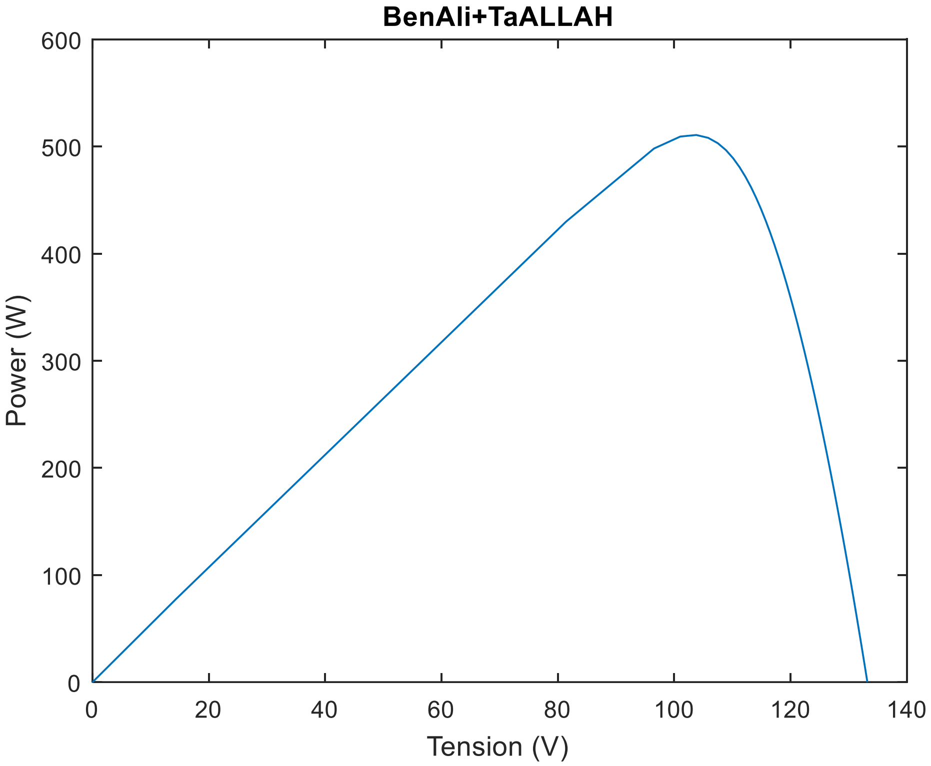

Figure II.6. Power curve of the photovoltaic generator utilized in this study.

II.3. PVG, Inverter DC/DC, Inverter DC/AC

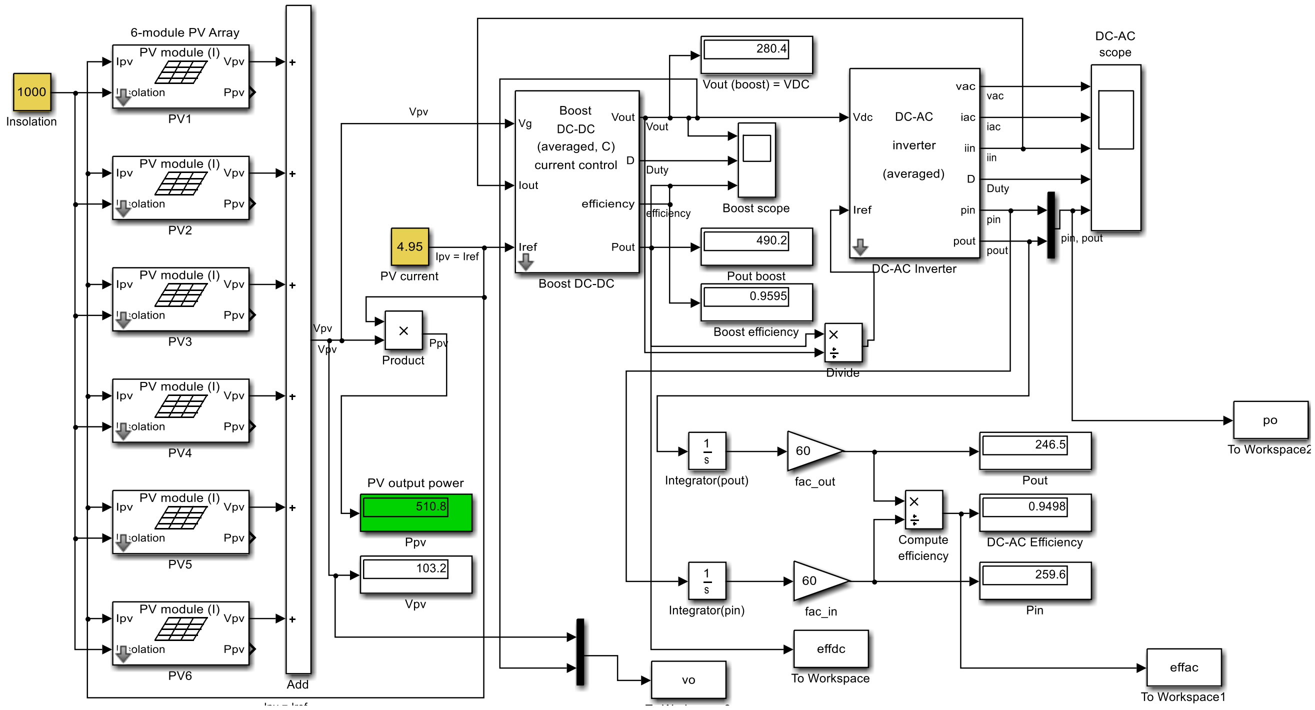

Figure II.7. illustrates the Simulink model of the photovoltaic system utilized in this study.

II.3.1. Boost DC-DC Converter

A **DC-DC Converter** is a power electronic device designed to **boost (increase)** voltage levels from **multiple DC input sources** to provide **multiple higher-voltage DC outputs**. Each input can come from a different power source, such as solar panels, batteries, or fuel cells, and the outputs can be independently controlled to power different loads or charge multiple energy storage units.

This type of converter is especially useful in **renewable energy systems**, **hybrid electric vehicles**, and **distributed energy storage systems**, where flexibility in managing various sources and delivering different output voltages is critical.

II.3.2. DC-AC Converter (Inverter)

A **DC-AC converter**, also known as an **inverter**, is an electronic device that converts **direct current (DC)** into **alternating current (AC)**. The output AC can be of **fixed or variable frequency and voltage**, depending on the application. Inverters are widely used in systems such as **solar power**, **uninterruptible power supplies (UPS)**, **electric vehicles**, and **AC motor drives**, where DC sources (like batteries or solar panels) must be converted to AC to power conventional AC loads.

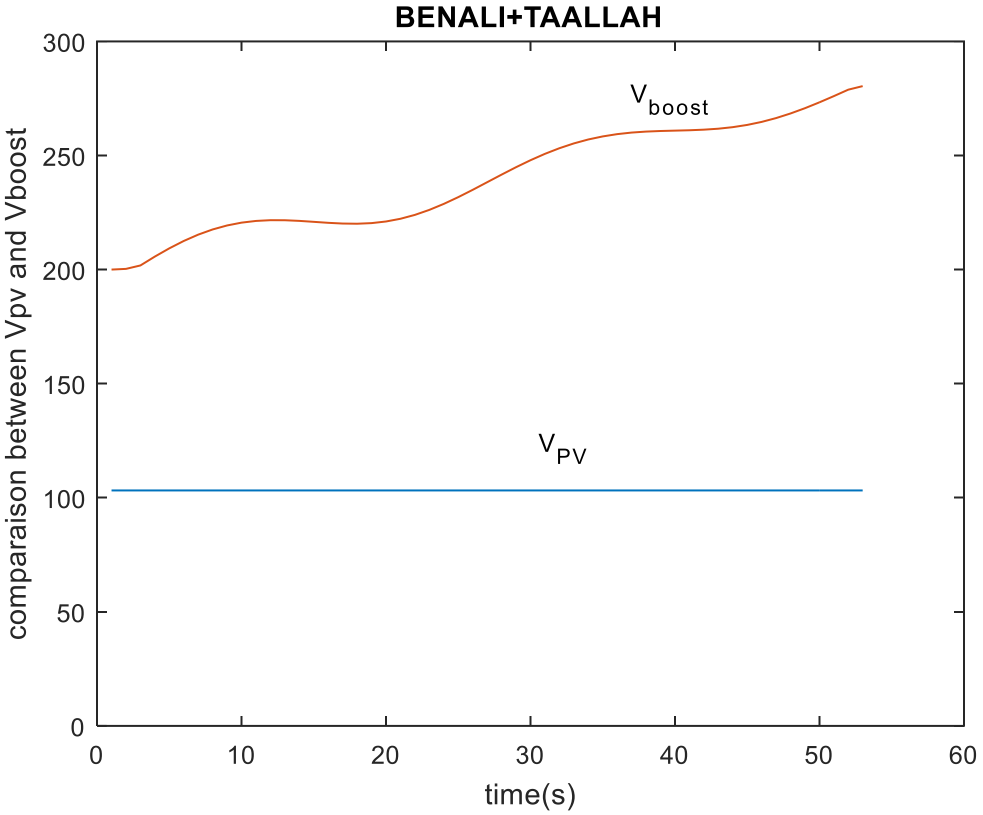

Figure II.8. Voltage curve comparison between V_{PV} and V_{boost}.

✓ Graph Description: Comparison Between VPV and Vboost

The graph presents a **comparison over time** between the **photovoltaic panel voltage VPV** and the **boost converter output voltage Vboost**, observed over a time span of **0 to 60 seconds**.

- **X-axis (Time)**: Time is displayed in seconds (s), ranging from 0 to 60 seconds.
- **Y-axis (Voltage)**: This represents voltage levels in volts (V), labeled as *"comparison between Vpv and Vboost"*.
- **VPV** (blue line): This line remains **constant** over time at approximately **100 V**, indicating that the input from the photovoltaic (PV) panel is stable and does not fluctuate during the observation period.
- **Vboost** (orange/red line): This line starts at around **200 V** and **gradually increases** over time, reaching close to **280 V** by the end of the 60-second interval. This indicates that the boost converter is effectively **increasing the voltage** from the PV panel.

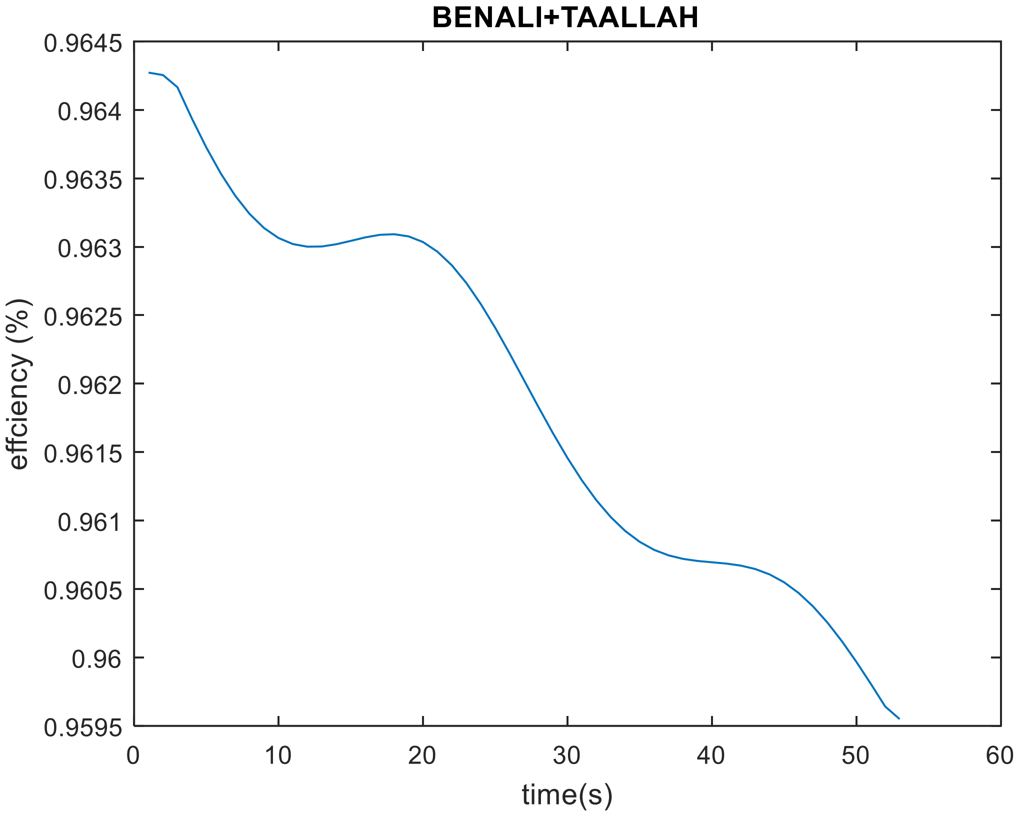

Figure II.9. Efficiency curve DC/DC converter used.

✓ Graph Description: Efficiency curve DC/DC converter used

The graph illustrates the efficiency performance of a boost DC-DC converter over time. The x-axis represents efficiency (%), while the y-axis denotes time (s). The curve exhibits a very lower downward trend, indicating that the efficiency of the boost converter maintain with time progresses. This decline may be caused by factors such as increased internal losses, thermal effects, or degradation of circuit components under prolonged operation. The observed trend highlights the importance of thermal management and reliability considerations in the long-term performance of boost converters.

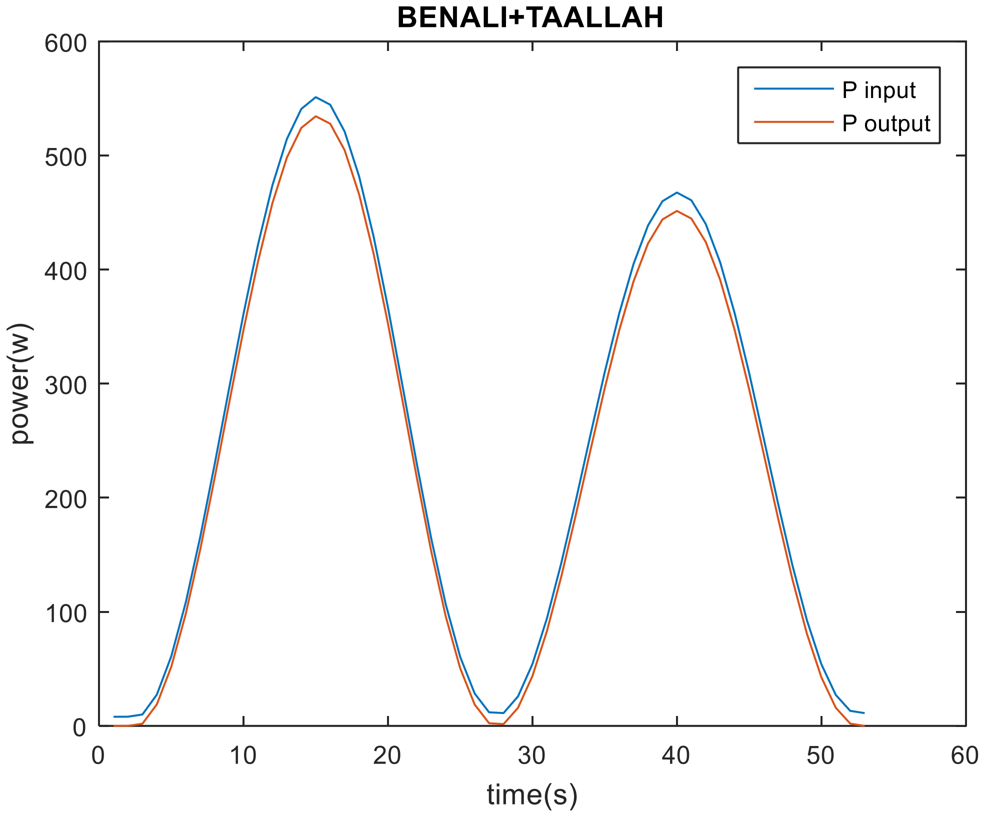

Figure II.10. Output power curve of DC/AC converter used.

✓ Curves output power curve of DC/AC converter used

1. **P input (blue line)**:
   - Represents the input power to the DC-DC inverter.
   - Follows a periodic waveform with two clear peaks around **15s and 40s**, reaching approximately **550–570 W**.
2. **P output (red/orange line)**:
   - Represents the output power from the inverter.
   - Also periodic and follows a similar waveform but slightly **lower in amplitude** than the input.
   - Peaks are around **500–520 W**, indicating **power losses** due to conversion yield efficiencies.

II.3.3. Observations

- The shape of both curves suggests a **sinusoidal or pulsed load behavior**, typical of renewable energy systems (e.g., solar or wind) or pulse-width modulated (PWM) control signals in power electronics.
- The output power closely tracks the input power, demonstrating **good inverter performance** with **minimal delay or distortion**.
- The difference between the two curves is an indication of **conversion losses**, likely due to **switching losses, heat dissipation, or internal resistance** in the inverter

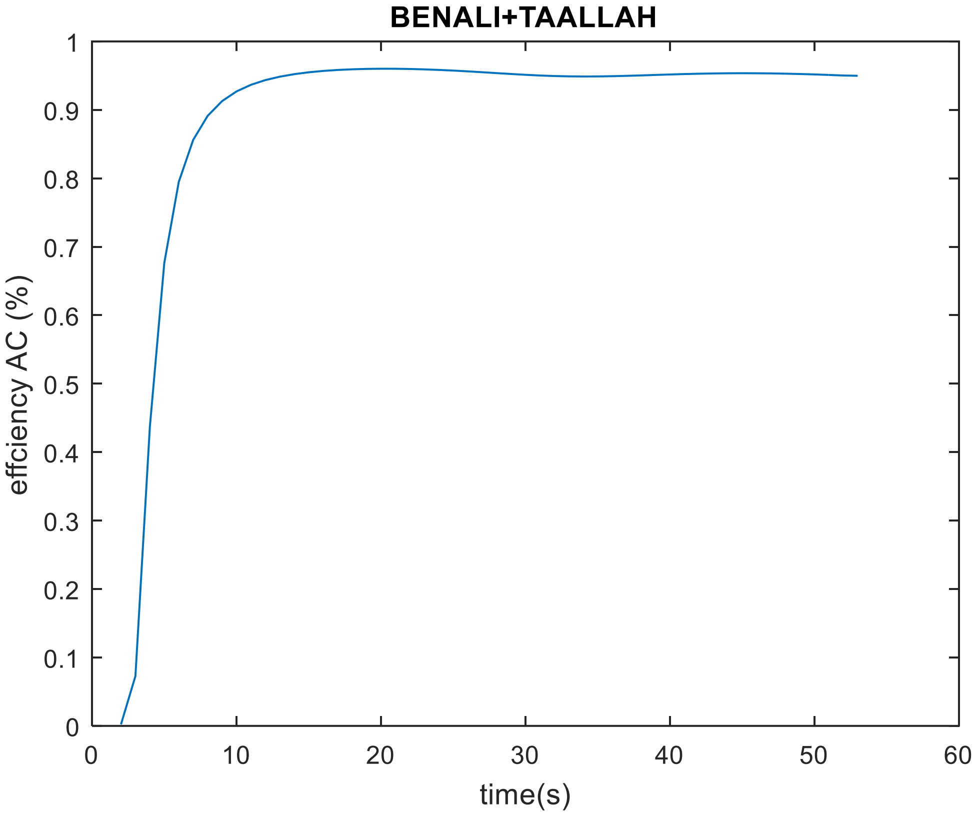

Figure II.11. Efficiency curve DC/DC converter used.

✓ Interpretation

- This graph shows the **transient and steady-state response** of the AC efficiency of a DC-AC inverter.
- The initial increase suggests that the inverter takes a few seconds to reach optimal operation.
- The stable region indicates a **highly efficient conversion process** after the startup phase.

II.4. Conclusion:

This chapter treat the general duty of DC/DC converter and in other hand demonstrates that the DC-AC inverter has a quick and stable response, the both reaching nearly 95% efficiency, which is a strong performance indicator in power electronics applications like solar energy systems or grid interfacing.

chapter 3

Simulation performance comparison of photovoltaic system

III.1. Introduction

A DC-DC Converter (Direct Current to Direct Current Converter) is an electronic circuit or device that alters a direct current (DC) voltage from one level to another. These converters are crucial in various applications, including portable electronic devices, solar energy systems, electric vehicles, and computer power supplies. By adjusting voltage levels, DC-DC converters enhance energy efficiency and ensure compatibility between power sources and device requirements.

A DC-AC Converter, commonly known as an electric inverter, is a device or circuit that converts direct current (DC) into alternating current (AC). It adjusts the output AC voltage and frequency to meet the requirements of devices that operate on AC power. This type of converter is frequently used in uninterruptible power supplies (UPS), solar photovoltaic systems, electric vehicles, and home appliances, allowing DC sources such as batteries or solar panels to effectively power conventional AC equipment.

III.2. Model Simulink of full solar component

The aim of this model is to deliver a comprehensive simulation of a solar energy system using Simulink. It incorporates all key components, from solar panels (photovoltaic modules) to power conversion stages. The model is designed to analyze and optimize system performance by integrating Maximum Power Point Tracking (MPPT) techniques, ensuring that the solar panels operate at peak efficiency under varying environmental conditions such as irradiance and temperature. This simulation facilitates the evaluation of system behavior, energy yield, and the effectiveness of the control strategies employed for energy extraction.

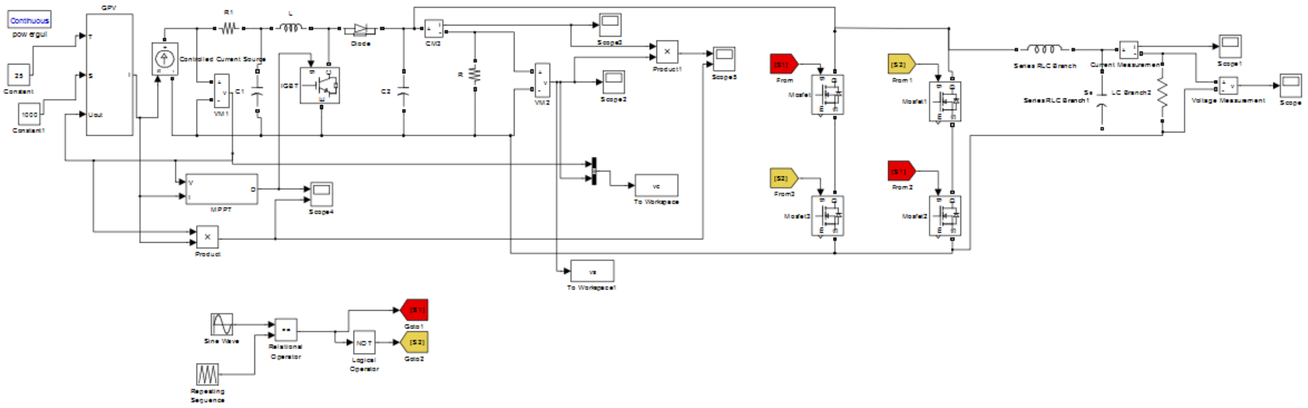

Figure III.1. Simulink model for PVG/DC-DC and DC-AC Converters used in this study.

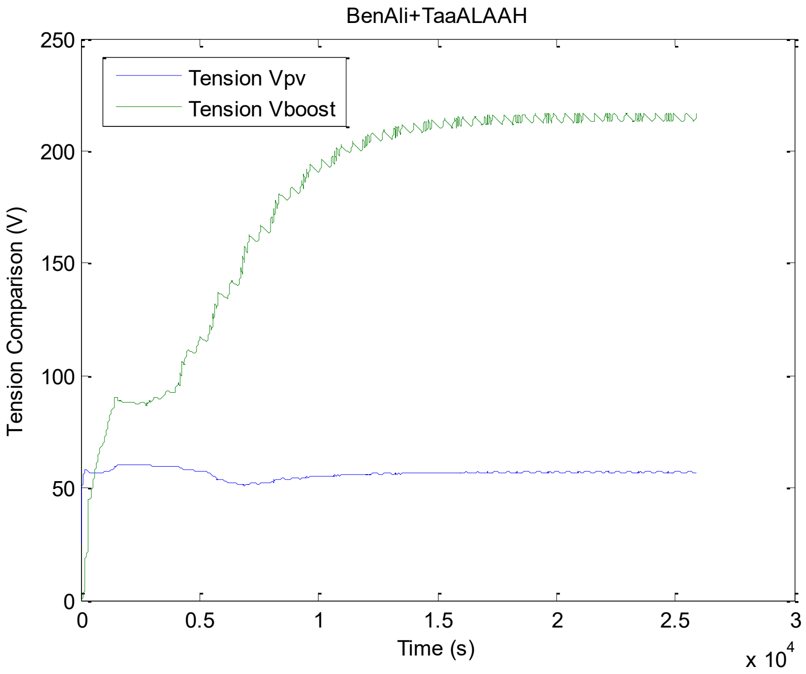

Figure III.2. Comparison between PV and Boost tension.

- ✓ **Analysis**

The boost converter effectively increases the PV voltage, which is crucial in applications requiring a higher and more stable DC voltage, such as supplying inverters or charging batteries.

The rising trend of Vboost suggests that the boost converter may be operating under a Maximum Power Point Tracking (MPPT) algorithm or adapting to changes in load conditions.

The relatively constant value of Vpv indicates stable environmental conditions, such as consistent light intensity and temperature, during the test.

The graph clearly illustrates the role of the DC-DC boost converter in elevating the output voltage of the PV panel. The system reaches a higher and more stable voltage level, which is advantageous for efficient energy conversion and storage in renewable energy systems.

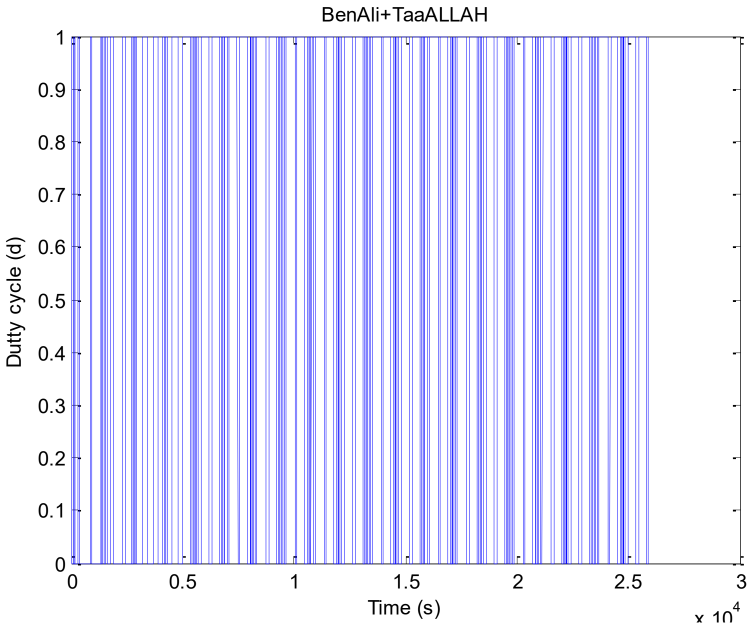

Figure III.3. Duty cycle of regulator MPPT used.

- ✓ **What is the Duty Cycle?**

The duty cycle is the ratio that represents the duration during which a signal is ON compared to its total period in a PWM (Pulse Width Modulation) signal.

Its value ranges from 0 (0%) to 1 (100%) and is used to control power converters such as DC-DC converters to regulate the output voltage.

- ✓ **What is MPPT?**

MPPT (Maximum Power Point Tracking) is an algorithm used in solar energy systems to extract the maximum available power from photovoltaic panels.

It works by continuously adjusting the duty cycle to achieve the optimal combination of voltage and current that results in maximum power output (Power = Voltage × Current).

- ✓ **The Varying Phenomenon**

The rapid changes observed in the graph indicate the following:

a. The duty cycle is not fixed; it changes continuously.

b. These variations reflect the MPPT algorithm's response to dynamic operating conditions such as:

- Changes in solar irradiance.
- Variations in the load connected to the system.

c. Each time the conditions shift, the MPPT updates the duty cycle to keep the system operating at the maximum power point.

Also, The graph demonstrates how the MPPT controller dynamically adjusts the duty cycle over time.

The varying phenomenon represents the value of the duty cycle, which is influenced by environmental and operational conditions such as sunlight intensity and load changes.

Rapid variations may reflect an effective tracking response or, in some cases, excessive oscillation—depending on the specific MPPT algorithm implemented.

III.3. Influence of Capacitor and Inductance on solar component prodution

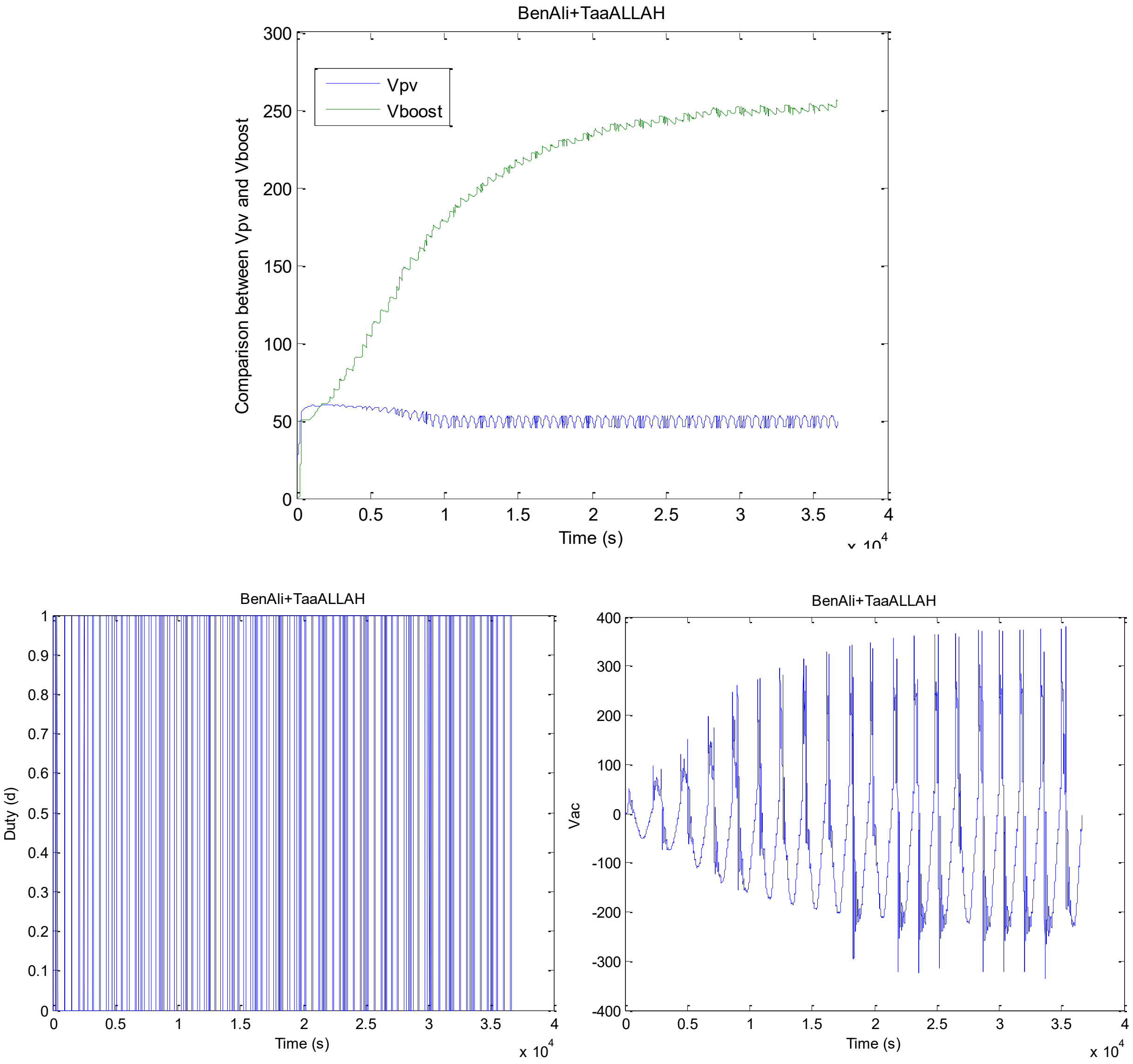

Figure III.4. Comparison between Vpv, Vboost, Duty, and V_{AC} at C1 = C2 = 2e-3 F and L= 2e-3 H.

- ✓ **Analysis of Each Graph Separately:**

A. Top Graph (Vpv and Vboost vs Time):

X-axis: Time (seconds)

Y-axis: Voltage (Volts)

Green curve (Vboost): Converter output voltage starts at ~0V and gradually increases to exceed 200V.

Blue curve (Vpv): Solar panel voltage maintain the valeur nearly between 50V and 60V.

Analysis

The system uses MPPT to extract maximum power from the panel, causing Vpv to rise gradually. Meanwhile, the converter output (Vboost) stays relatively constant because the MPPT regulates the output voltage to keep it within a suitable range.

B. Bottom Left Graph (Duty Cycle vs Time)

X-axis: Time

Y-axis: Duty Cycle value (from 0 to 1)

The dense blue lines represent rapid changes in the Duty Cycle.

- ✓ **Analysis:**

The system uses MPPT to extract maximum power from the panel, causing Vpv to rise gradually. Meanwhile, the converter output (Vboost) stays relatively constant because the MPPT regulates the output voltage to keep it within a suitable range.

Vpv	Starts at ~0V	Gradually increases >50V	Solar panel response with MPPT
Vboost	Starts at ~0V	Gradually increases >200V	Output voltage regulation
Duty	Highly variable	Sharp, fast changes	MPPT control adjustments
Vac	Starts at zero	Sine wave with increasing amplitude	Inverter AC output

The system is working as expected: the MPPT continuously adjusts the Duty Cycle to increase Vpv, from which a relatively stable voltage (Vboost) is extracted and then converted into AC voltage (Vac). The graphs illustrate an effective dynamic interaction between the algorithm and the electrical circuit. The rapid changes in Duty Cycle may need to be improved or smoothed to ensure better efficiency.

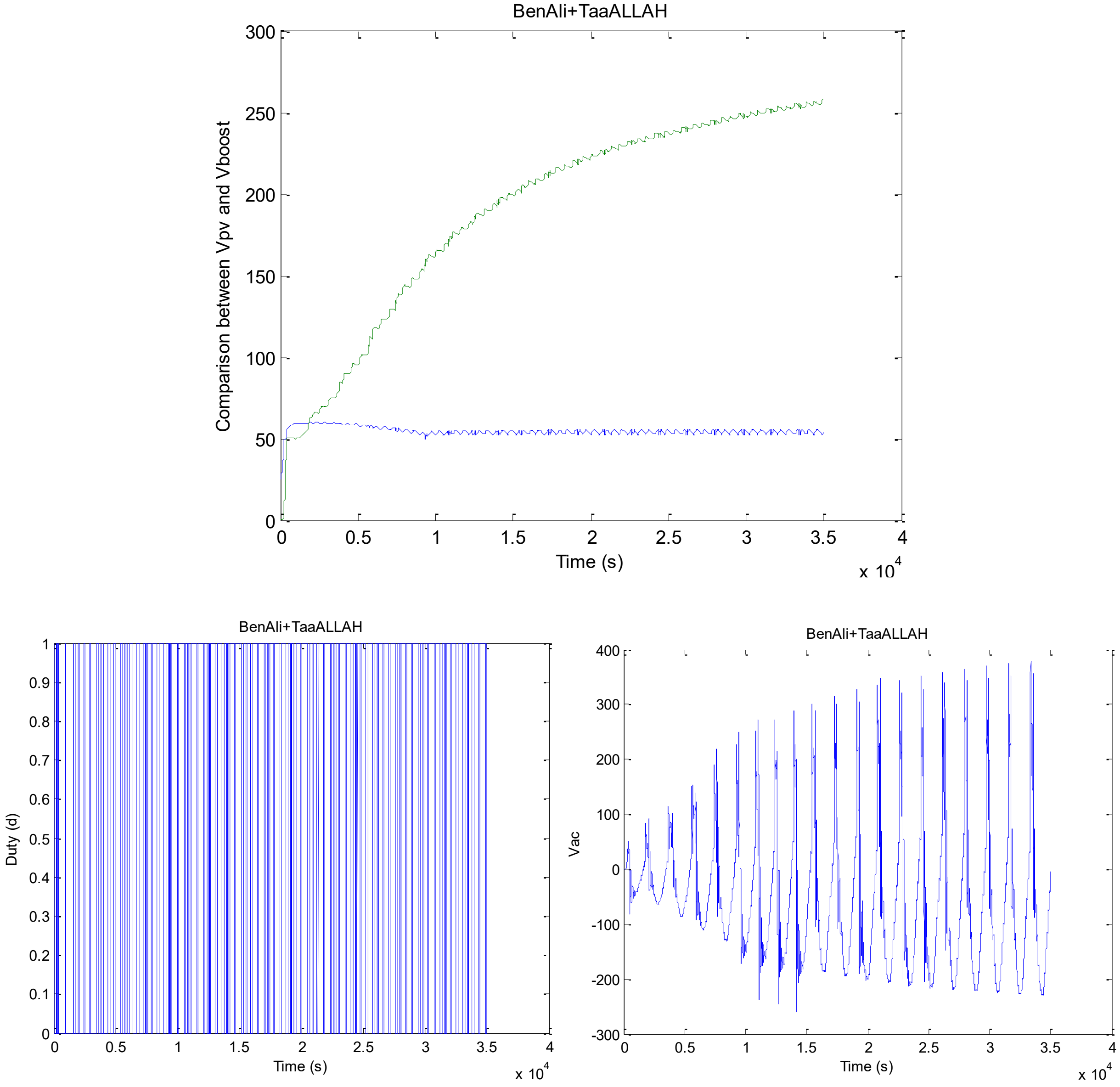

Figure III.5. Comparison between Vpv, Vboost, Duty, and V_{AC} at C1 = C2 = 2e-3 F and L= 3e-3 H.

The photovoltaic system operates efficiently and shows good interaction between its components.

The MPPT algorithm continuously adjusts the duty cycle to extract the maximum possible power from the solar panel.

The Vpv voltage increases gradually, indicating successful tracking of the maximum power point.

The Vboost voltage remains nearly constant, reflecting effective regulation by the boost converter.

The Vac voltage from the inverter appears as a gradually increasing sinusoidal waveform, confirming that the inverter functions correctly and reaches a stable state.

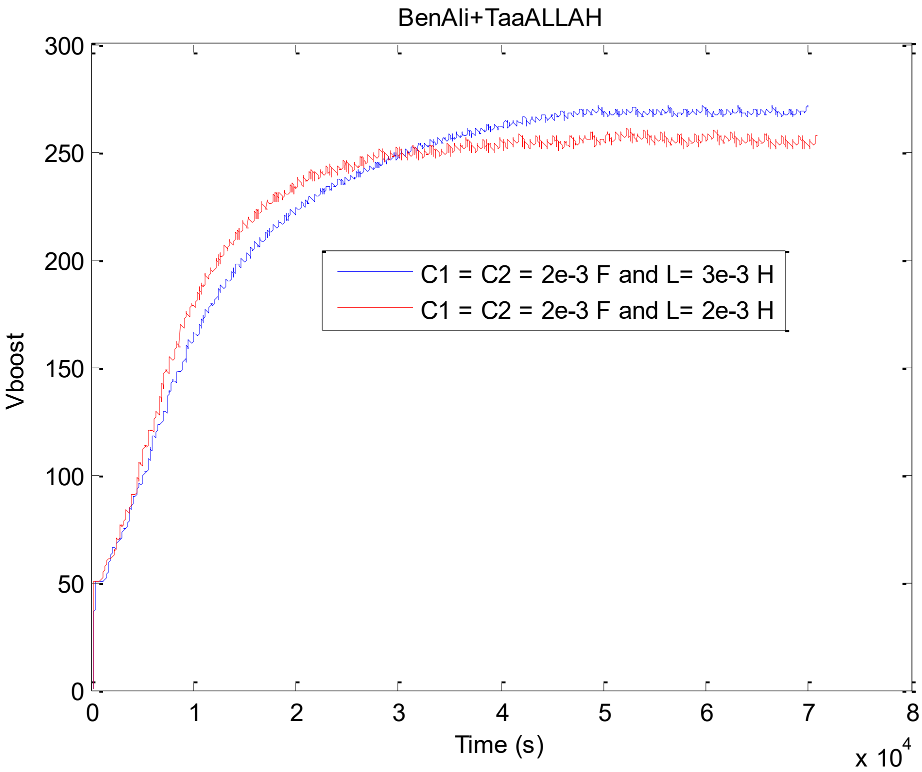

Figure III.6. Simulation results of Vboost at different values on C1, C2, and L.

✓ Graph Analysis

Figure III.6 illustrates the simulation results of the output voltage of a Boost Converter under two different inductance values, while keeping the capacitor values constant.

Experimental Conditions:

- First case (Blue curve)
- Second case (Red curve)

✓ Observations

Both cases exhibit a rising output voltage that eventually stabilizes.

The second case (with lower inductance) reaches a steady state faster than the first case.

The final output voltage in the first case is slightly higher, but it takes longer to settle.

Noticeable voltage ripples are present in both cases, more pronounced in the red curve (lower inductance).

✓ Interpretation

Increasing the inductance results in:

- Slower response time (longer time to reach steady state).
- Slightly higher output voltage.
- Reduced voltage ripples (better voltage quality).

Decreasing inductance leads to:

- Faster system response.
- Slightly lower final output voltage.
- Increased ripples, which may negatively affect voltage quality.

✓ Summary for Report Inclusion

Figure III.6 demonstrates the effect of varying the inductance on the output voltage response of a Boost Converter, with fixed capacitance values. The results show that reducing inductance improves the response time but leads to more pronounced voltage ripples, while increasing inductance enhances voltage stability at the expense of slower response. Therefore, choosing an appropriate inductance value requires a trade-off between response speed and voltage quality.

III.4. MPPT Techniques

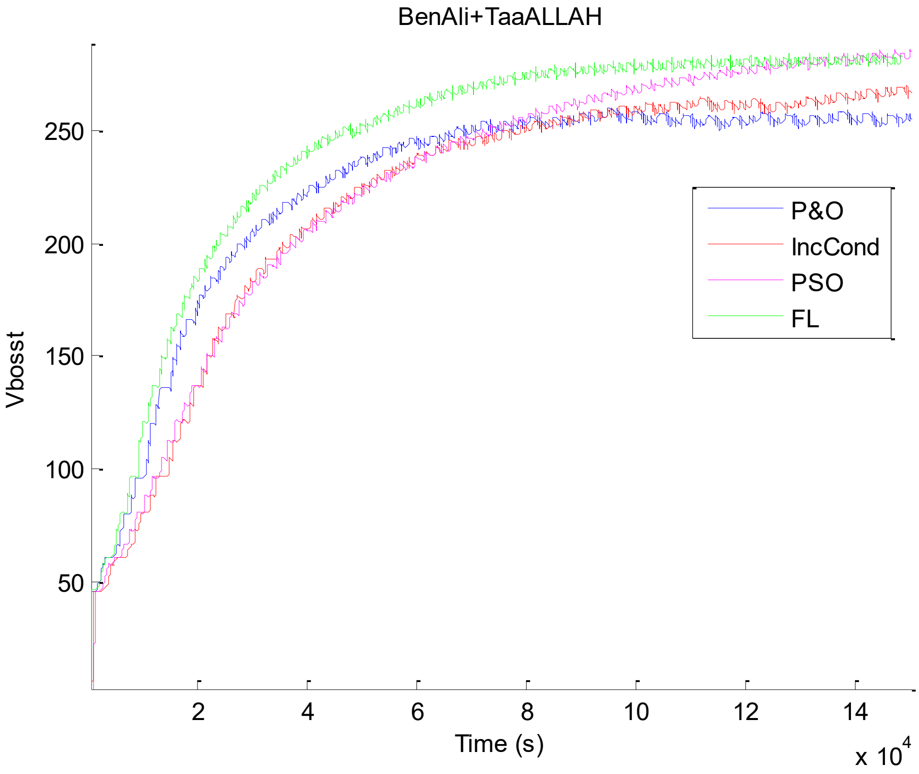

Figure III.7. Comparison between different MPPT techniques.

The Four Techniques Represented in the Graph:

1. **P&O (Perturb and Observe)** - Blue
2. **IncCond (Incremental Conductance) -** Red
3. **PSO (Particle Swarm Optimization)** - Purple
4. **FL (Fuzzy Logic)** – Green

✓ **Analysis and Observations:**

a. Steady State:

All methods reach a final output voltage close to 270 V.

The Fuzzy Logic (FL) technique achieves the highest voltage value and the fastest stabilization.

b. Response Speed:

In terms of speed to reach steady state:

- FL is the fastest
- Followed by PSO and IncCond
- P&O is the slowest

c. Post-Stabilization Ripples:

P&O and IncCond exhibit slight voltage oscillations after reaching steady state.

FL and PSO show more stable behavior, especially FL.

d. Overall Performance:

FL performs best in terms of response speed, stability, and final voltage.

PSO also shows good performance but slightly lower than FL.

P&O is considered the weakest among the four methods.

✓ Summary of the Graph Analysis:

The graph presents a comparison between four MPPT techniques (P&O, IncCond, PSO, FL) for controlling the output voltage of a Boost converter. The results show that the Fuzzy Logic (FL) technique outperformed the others in terms of:

- Response speed
- Steady-state stability
- Achieving the highest output voltage

PSO also demonstrated good performance, while P&O and IncCond were less efficient due to slower response times and noticeable voltage ripples.

III.5. Conclusion

Artificial intelligence-based techniques (FL and PSO) offer more effective control compared to traditional methods, making them the optimal choice for MPPT applications in photovoltaic energy systems. The Fuzzy Logic (FL) technique demonstrates the best performance in controlling the output voltage of a Boost converter, in terms of fast convergence to the Maximum Power Point (MPP), highest final voltage, and minimal ripples the all due to their short time recorded in transient regime. This highlights the effectiveness of artificial intelligence and intelligent control compared to traditional methods like P&O and IncCond.

References

[1] Khare, V.; Nema, S.; Baredar, P. Status of solar wind renewable energy in India. Renew. Sustain. Energy Rev. 2013, 27, 1–10.

[2] Nagayoshi, H. I-V curve simulation by multi-module simulator using I-V magnifier circuit. Sol. Energy Mater. Sol. Cells 2004, 82, 159–167. [CrossRef]

[3] Zeb, K.; Islam, S.U.; Din, W.U.; Khan, I.; Ishfaq, M.; Busarello, T.D.C.; Ahmad, I.; Kim, H.J. Design of Fuzzy-PI and Fuzzy-Sliding Mode Controllers for Single-Phase Two-Stages Grid-Connected Transformerless Photovoltaic Inverter. Electronics 2019, 8, 520. [CrossRef]

[4] Gaikwad, K.; Lokhande, S. Novel maximum power point tracking algorithm (MPPT) for solar tree application. In Proceedings of the 2015 International Conference on Energy Systems and Applications, Pune, India, 30 October–1 November 2015; pp. 189–193.

[5] Available online: https://www.iea-shc.org/Data/Sites/1/publications/task16-photovoltaics_in_buildings-full.pdf

[6] Dong, L.; Fujing, D.; Yanbo, W.; Zhe, C. Improved Control Strategy for T-type Isolated DC/DC Converters. J. Power Electron. 2017, 17, 874–883.

[7] Samia latreche et al, design and real-time implementation of synergetic regulator for a dc-dc boost converter. (2024). REVUE ROUMAINE DES SCIENCES TECHNIQUES, SÉRIE ÉLECTROTECHNIQUE ET ÉNERGÉTIQUE, 69(3), 305-310.

[8] Gopi, P., Rao, S. V., Reddy, G. V., & Reddy, B. V. (2025). A multiport DC-DC converter with an intelligent controller for micro grid applications. In Integrated Technologies in Electrical, Electronics and Biotechnology Engineering (pp. 28-35). CRC Press.

[9] Taghvaee, M.H.; Radzi, M.A.M.; Moosavain, S.M.; Hizam, H.; Hamiruce Marhaban, M. A current and future study on non-isolated DC–DC converters for photovoltaic applications. Renew. Sustain. Energy Rev. 2013, 17, 216–227.

[10] Farahat, M.A.; Metwally, H.M.B.; Abd-Elfatah Mohamed, A. Optimal choice and design of different topologies of DC–DC converter used in PV systems, at different climatic conditions in Egypt. Renew. Energy 2012, 3, 393–402.

[11] Lin, L.F.; Ye, H. Advanced DC/DC Converters; CRC Press: Boca Raton, FL, USA, 2004.

[12] Abid, R.; Masmoudi, F.; Derbel, N. Comparative study of the performances of the DC/DC luo-converter in photovoltaic applications. In Proceedings of the 2017 International Conference on Smart, Monitored and Controlled Cities (SM2C), Sfax, Tunisia, 17–19 February 2017; pp. 117–122

[13] Zhang Y , Sun JT , Wang YF . Hybrid boost three-level DC-DC converter with high voltage gain for photovoltaic generation systems. IEEE Trans Power Electron, 2013, 28:3659–3664.

[14] Rodrigues JP , Mussa SA , Barbi I , et al. Three-level zero-voltage switching pulse-width modulation DC-DC boost converter with active clamping. IET Power Electron, 2010, 3:345–354.

[15] Silveira GC , Tofoli FL , Bezerra LDS , et al. A nonisolated DC--DC boost converter with high voltage gain and balanced output voltage. IEEE Trans Ind Electron, 2014, 61:6739–6746.

[16] Lai CM , Pan CT , Cheng MC . High-efficiency modular high step-up interleaved boost converter for DC-microgrid applications. IEEE Trans Ind Appl, 2012, 48:161–171.

[17] Fardoun AA , Ismail EH . Ultra step-up DC-DC converter with reduced switch stress. IEEE Trans Ind Appl, 2010, 46:2025–2034.

[18] Xiong S , Tan S-C . Cascaded high-voltage-gain bidirectional switched-capacitor DC--DC converters for distributed energy resources applications. IEEE Trans Power Electron, 2016, 32:1220–1231.

[19] Hegazy Rezk and Ali M Eltamaly 2015 A Comprehensive comparison of different mppt techniques for photovoltaic systems Solar Energy 112 1-11

[20] Akshaya K Pati1 and Sahoo1 N C 2016 A new approach in maximum power point tracking for a photovoltaic array power management system using fibonacci search algorithm under partial shading conditions Energy System Springer 7 145-172

[21] Alivarani Mohapatraa, Byamakesh Nayak, Priti Das and Kanungo Barada Mohanty 2017 A review on mppt techniques of pv system under partial shading condition Renewable and Sustainable Energy Reviews Elsevier 80 854–867

[22] Mingxuan Mao, Qichang Duan, Li Zhang, Hao Chen, Bei Hu1 and Pan Duan 2017 Maximum power point tracking cascaded - converter modules using two-stage particle swarm optimization Scientific Reports, Nature 7 1-10

[23] Vijay Muni, Lalitha S V N L, Krishna Suma B and Venkateswaramma B 2018 A new approach to achieve a fast acting mppt technique for solar photovoltaic system under fast varying solar radiation International Journal of Engineering and Technology 7 131-135

General conclusion

General Conclusion

This thesis delves into the design, analysis, and simulation of a novel high-gain multiport DC/DC converter, specifically engineered for renewable energy applications, with a strong emphasis on solar energy systems. As global demand for sustainable and decentralized power solutions continues to soar, this converter offers a robust and highly efficient approach to seamlessly integrate diverse renewable energy sources. The primary goal is to provide a stable DC output, perfectly suited for cutting-edge applications like electric vehicles, smart grids, and standalone power systems.

The work highlights the significant advantages of the singlport architecture. This design enhances flexibility but also facilitates simultaneous power management, it substantially reduces overall system cost and complexity. Through extensive MATLAB-based simulations, the converter's exceptional high-gain performance, efficiency, and reliability were rigorously validated across a range of operating conditions.

Despite the inherent challenges presented by the variability of renewable resources, the proposed converter architecture emerges as a highly promising solution for significantly improving power quality and system resilience. Further optimization by the integration of intelligent control systems to achieve real-time adaptability and even greater efficiency.