The Basic Harmonic And Power Factor Concepts In The Pv Power System Styles.

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Article History:

Received: 12-03-2025

Revised: 06-05-2025

Accepted: 13-05-2025

Abstract

Eventually, most power grids will rely heavily on sustainable power sources. Scientists are devoting a great deal of on photovoltaics (PV) systems, namely how to make them more efficient so that they comply with grid rules and how to make them more intelligent so that they can be controlled more effectively. Both the most popular and recently developed topologies for PV systems, based on multilayer converters, are covered in this study. Additionally, the Model Predictive Control (MPC) approach to converter control is detailed, with a focus on its salient characteristics as they pertain to PV applications. Traditional inverters are known to have a detrimental effect on output quality due to the fact that the use of a transformer substantially increases Total Harmonic Distortion (THD). By combining buck and boost converters instead of a transformer, we may create an inverter without a transformer, which significantly lowers the total harmonic distortion (THD) and increases efficiency, thereby overcoming this constraint. Selecting an appropriate DC-DC converter as an intermediate step is critical for maximizing performance, efficiency, and reliability in photovoltaic (PV) systems, which rely on transformation of solar radiation into usable electrical energy in an efficient manner. This research provides an in-depth evaluation of several solar PV DC-DC converter topologies. For example, there are buck-boost, Cuk, Zeta, SEPIC, and flyback filter topologies.

We look into the working principles, benefits, drawbacks, and compatibility with various PV system configurations of each converter. In addition to discussing the difficulties caused by changing climatic circumstances, the article delves into how these voltage regulation, current ripple mitigation, system stability, and the efficiency of power conversion are all impacted by converters. Solar photovoltaic (PV) system optimization for increased efficiency and improved grid integration may be greatly aided by the insights provided by this study, which compares and contrasts various converter topologies.

The research shows that choosing the right DC-DC converter is critical for enhancing the overall reliability and efficiency of renewable energy systems, which contributes to the advancement of sustainable power generation. A PV system that uses a maximum power point tracker (MPPT) developed from the modified perturbation and observation (P&O) algorithm is part of the work structure. Another component is a single switch buck-boost dc-dc converter, which stores excess energy in batteries. A three-phase inverter, which searches for the best switching angles for harmonic control using sinusoidal modification of pulse width (PWM), interconnected by three-phase (Φ) induction motor load is also part of the system.

KEYWORDS

Total harmonic distortion (THD), point of common coupling (PCC), nonlinear loads, single-phase systems, and photovoltaics (PV) systems

INTRODUCTION

Worldwide, Concern for sustainability and the need to reduce human impact on the environment have driven a significant transition toward renewable energy sources. When weighed against one another, renewable energy sources exhibit varying degrees of reliability, efficiency, cost, and maintenance needs. Photovoltaic (PV) systems are a crucial technology in this shift to renewable energy sources since they can directly transform sunlight into electricity using semiconductor materials.

Modern power networks are increasingly incorporating photovoltaic (PV) systems due to their scalability, which allows for installations ranging from tiny residential to huge utility-scale. Stable and efficient power generation is challenging to achieve due to the intermittency and fluctuation of solar energy. In addition, power electronics solutions are required to control, condition, or boost the voltage output from PV panels since it is often inadequate for practical applications.

In recent years, dc-dc sustainable energy converters that use emerged as the best option for power production of all kinds due to their abundant availability, cheap operating costs, lack of pollution, and reduced maintenance needs. Additionally, compared to other energy sources, solar PV sources have garnered a lot of attention. In The MPPT algorithm is crucial for improving the SPV system's efficiency. Despite the abundance of other maximum power point tracking (MPPT) algorithms, the point-and-operate (P&O) method which is the simplest, always gets the job done. regardless of environmental factors, age, etc.

In a nutshell, this approach finds the MPP at steady state by comparing the SPV voltage (Vpv) and current (Ipv), then changing the values of these variables after introducing a delay. This usually leads to reduced system responsiveness and fluctuations. In order to fix the problem, this study suggests a tweaked P&O algorithm that changes the reference step size and hysteresis band-width. A technique called auto-tuning perturbation steps and a hysteresis band are used. In this case, the duty cycle of the dc-dc converter is adjusted using MPPT controllers in order to control the suggested converter.

The energy demand curves have been steadily rising because to the ever-increasing use of electronic devices and the ever-increasing scientific and technological achievements. It is equally critical to decrease the use of traditional fuels, particularly petroleum fuels. In light of all the positive environmental concerns, the researchers have decided to create a new way to generate electricity that is clean, renewable, and less harmful to the environment. The study forecast indicates that the demand for electrical energy is growing at a much faster pace than the maximum potential generating capacity on a global scale.

A huge chasm opens up as a result of this. Incremental usage has the potential to deplete the fuel (coal) needed at the producing plant. The main problems with thermal plants are the pollution they generate by releasing carbon emissions into the air and the fuel transportation process. A solution to these problems is power generation and distribution that makes use of renewable resources. It is possible to replenish renewable energy sources during a human lifetime. Solar energy, wind energy, tidal power, and heat from geothermal sources are all instances of such sources.

One of the most exciting emerging forms of renewable energy is photovoltaic (PV) cells energy sources since they can directly transform solar energy into electrical energy with no middleman, and they are widely accessible across the world.

LITERATURE AND REVIEW

T R, Premila & L., Maheshwari. (2023) The study recommends a renewable energy source single-switch buck-boost converter driven by photovoltaic (PV) panels in order to reduce the costs of implementation, voltage and current stresses on capacitors and diodes, and switching power losses. The work structure includes solar panels, a three-phase inverter with sinusoidal pulse width modulation (PWM), an induction motor load, a battery backup system, and a maximum power point tracking (MPPT) system that is based on modified P and O algorithms. Reducing the inverter's line-to-line voltage reduces total harmonic distortion (THD). The proposed circuit's performance is investigated by doing a steady-state examination of the dc-dc converter architecture in MATLAB/SIMULINK. A three-phase full-bridge inverter that runs on 440V, 15A AC is supplied by the proposed converter, which converts a 520V, 35A PV array into an output of 363V, 45.5A DC. An ideal power source for high-quality output is the solar-powered single-switch buck-boost with maximum power point tracking (MPPT), thanks to its low losses and great efficiency.

Chakraborty, Sajib & Annie, Saila & Razzak, Md. (2014). The output of a conventional inverter is thought to be unfavorably impacted by the addition of a transformer, as the Total Harmonic Distortion (THD) is substantially increased. Total Harmonic Distortion (THD) is thought to have a negative effect on the inverter's output. Making an inverter that doesn't need a transformer and instead makes use of buck and boost converters is one way around this restriction. Consequently, THD will fall precipitously and efficiency will surge. Using a buck and boost converter with just one stage, this article explains how to build a solar inverter. Two types of single-stage switch-mode converters—one for buck conversion and one for boost—are being considered for usage. If you have a 24V PV array, a boost converter can turn it into 312V DC, but a buck converter can take 312V AC grid and turn it into 7.07V pulsed DC. A single-phase full-bridge inverter is powered by the constructed buck and boost converters. Using the PSIM tool, the circuit may be virtually constructed. The simulation findings demonstrate that a transformer-less inverter design may be achieved by substituting the constructed buck and boost converters for the transformers in traditional inverter circuits. This architecture can be low-THD, highly efficient, and affordable.

Hosseini, Seyed Hossein & Farakhor, Amir & Haghighian, Saeideh. (2013). Based on the Newton-Raphson process, this study presents a new approach to maximum power point tracking (MPPT) for PV power systems. This approach greatly improves the efficiency of PV power plants by making them more sensitive to changes in their environment. Engineers use the variable-step Newton-Raphson approach, which is a derivative of the improved perturb and observe (IP&O) program, to manage the current flowing out of a boost converter. The MPPT tracker uses a boost DC/DC converter to maintain the system's peak efficiency. A two-level three-phase inverter supplies power to the load. The suggested setup is described using MATLAB/Simulink program and simulation results are provided.

Bhargav, Kelam & Antony, A. (2016). One sustainable energy source that is plentiful in nature is solar power. Since this renewable energy source may be used all day long, it is essential that the panel captures as much energy as possible. It is essential to maximize energy extraction by MPPT algorithm is used. A multilayer inverter takes many levels of direct current (dc) voltages as inputs and produces an output voltage of the user's choosing. Using a basic frequency-switching system, the output voltage may be used to create a sinusoidal waveform from an increasing number of dc voltage sources. Reduced switching losses, improved output quality, and a negligible output voltage are all benefits of using a multilayer inverter. In this research, we show a solar power system with a maximum power point tracking controller. A dc/dc converter and a one-of-a-kind nine-level inverter make up the system.

Mohammed Sulthan, Sheik & Devaraj, D. & Ahamed, Imthias. (2017). This study proposes optimizing a fuzzy Maximum Power Point Tracking (MPPT) controller using Learning Automata (LA) technique. LA determines the ideal energy consumption of a DC-DC converter circuit under different settings. Learning data is used to develop the fuzzy MPPT controller. Using MATLAB software in a standard PV test environment, the model is constructed and tested. We examine the standard Perturb and Observe (P&O) MPPT, a PV system that use the variable step size Fuzzy MPPT, and the fuzzy MPPT in comparison. Evaluate the performance of the P&O MPPT and the LA Fuzzy MPPT in a photovoltaic system by set up experiments and do testing. The results demonstrate how fast and accurate the suggested LA-based Fuzzy MPPT method is for tracking.

PV POWER SYSTEM STYLES

Due to the wide range of situational needs and the fast advancement of technology, there are several solar power system topologies. As a result of their increasing complexity and usefulness, PV topologies are now a hotspot for study, especially in the realm of high-power applications.

A. General Topologies

The multilevel topologies are based on the four main types of PV topologies. Here are the four types of topologies: Three types of AC modules are: 1) centralized, 2) string, and 4) multistring.

1. Centralized Topology

One may see the centralized structure in Figure 1. A PV A single inverter links the string to the grid. To avoid using a boost converter, these strings are made by connecting many panels in series to provide a higher DC voltage. An increase in available power is achieved by placing many strings in parallel with a shared DC bus. To stop the passage of electricity in the other direction, diodes must be used in the strings.

The simplicity of the centralized topology makes it a desirable alternative. Nevertheless, this topology is now outdated due to a number of major disadvantages:

- The efficiency of the topology is reduced due to diode conduction losses.
- Power loss and poor output due to a single MPPT system controlling all PV panels
- Power loss occurs due to partial shadowing and module mismatches

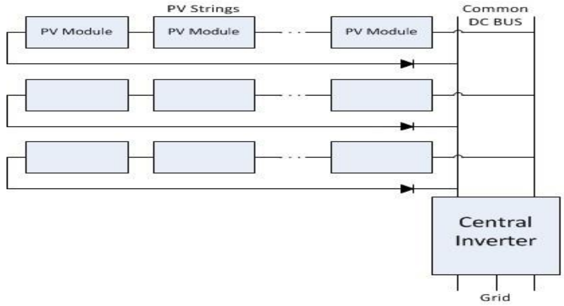

Figure 1. Centralized Topology

- There is a limit on how many panels and strings can be connected to the centralized inverter, thus adding more won't be possible.
- High-voltage DC wires link the strings.

2. String Topology

Figure 1.6 displays the topology of the strings. Similar to the centralized inverter scenario, but without the diode, the strings are formed in the same manner. Here, the grid (a common AC bus) is interfaced with individual inverters (usually single phase) on each string. If the DC voltage output is inadequate from the number of panels, a boost converter may be included into the string.

3. AC Modules

Figure 1.7 displays the structure of the AC module. A separate inverter connects each photovoltaic module to a shared AC bus, which is usually the grid. Small power applications, such as those in the home, are the ideal use case for AC modules.

BASIC HARMONIC AND POWER FACTOR CONCEPT

- **Concept of Harmonics**

As their frequencies are integral multiples of the fundamental frequency, sinusoidal components of a periodic wave are called harmonics. Fifty hertz is the basic frequency. Therefore, many more frequencies than 100 Hz, 150 Hz, 200 Hz, and 250 Hz are harmonic frequencies.

Two common methods for determining these frequencies are the number of harmonics and the main frequency's multiple. An example of a harmonic is the third harmonic, which has a frequency of 150 Hz (50x3=150). Each cycle of the fundamental waveform is accompanied by three complete harmonic waveform cycles in this case. To differentiate between "odd harmonics" and "even harmonics," we might say that the former are multiples that cannot be divided by the fundamental frequency and the latter are divisible by it.

- **What Harmonics Can Do**

Unwanted harmonics disrupt the voltage waveform. By using By dividing the total squared harmonics produced by a single load by the nominal 50 Hz waveform value, one may determine the relationship between the fundamental and distorted waveforms.

When applied to this problem, the First Fourier Transform (FFT) theorem provides useful mathematical guidance. A nonlinear voltage or current waveform's total harmonic distortion (THD) may be found using this computation approach. Electronic devices produce several harmonic frequencies. Computers can produce third, ninth, and fifteenth harmonics, for instance. "Triplen harmonics" describe them. They generate more problems than just distorted voltage waveforms, which is why they are a worry to architects and engineers. The wiring, transformers, and end-user equipment are all susceptible to overheating and subsequent failure.

In addition to overheating use equipment like motors, harmonics may overload wires and transformers The neutral conductors of three-phase, four-wire systems may get too hot. may be caused by triplen harmonics in particular. Odd order harmonics increase to the fundamental frequency in a neutral conductor, whereas even order harmonics cancel out. Even with a balanced load, the neutral current could be 1.73 times the mean phase current. One layer of protection for the neutral conductor is eroded by the increased heat produced by this higher loading.

- **Importance of Correcting the Power Factor**

Every AC-DC converter features a full-bridge rectifier with a big filter capacitor at the input stage. Due to its massive and abrupt peak current pulses, the input current to the rectifier circuit exhibits substantial harmonic distortion. The input current is significantly distorted by diode rectifiers because of their short conducting time. When the capacitor voltage is higher than the mains voltage, which occurs at this point, we say that the condition has occurred. Full capacitor charging draws a large amount of current from the line due to the brief intervals when the voltage across the capacitor is higher than the voltage across the instantaneous mains.

A typical single-phase diode rectifier filter's current and voltage waveforms are shown by the circuit design and the simulated line. Illustrations 2 and 3, correspondingly. This form of rectification typically has a power factor of around 0.6 and an input current harmonic distortion ranging from 55% to 65%. The harmonics produced by a current wave and its form are both affected by the line impedance.

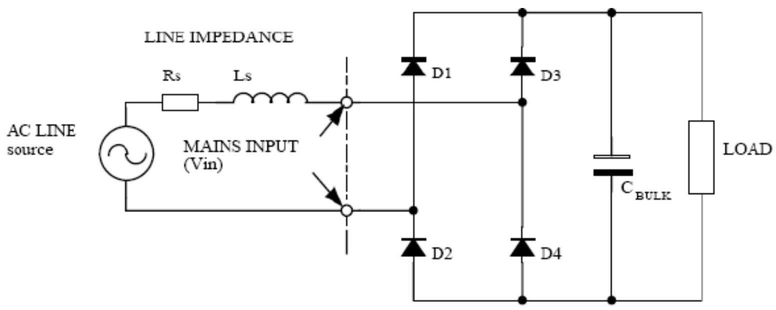

Figure 2: Integrated Circuit for a Capacitor-Filtered Single-Phase Diode Rectifier

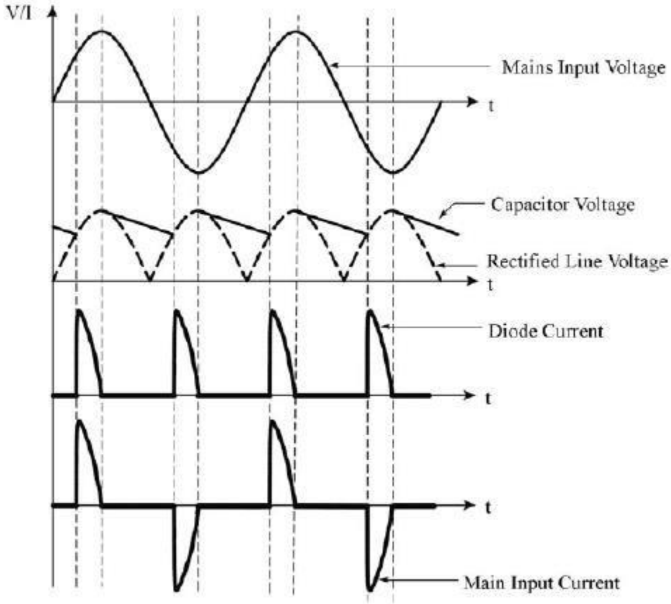

Figure 3: Standard Voltage and Current Waveforms

Therefore, traditional Unfortunately, alternating current (AC) rectification is an inefficient process that alters the mains current waveform. The circuit configuration shown in Figure 1.24 is typical of AC-DC converters that operate on mains power. The interference from these harmonics sent into the power line is more pronounced at higher power levels (200 to 500 watts and beyond). Distribution transformers, electrical utility line cabling, and installations must include these peak currents. values, which means that energy utility companies will have to pay more for their power. In conclusion, the following are the primary drawbacks of traditional AC rectification:

First, it induces electromagnetic interference (EMI) and harmonics; second, its power factor is low; third, it results in significant losses; fourth, it necessitates over-dimensioning of parts and components; and fifth, it lowers the line's maximum power capacity.

Remedial Action for Passive Power Factor

Anxieties about power line disruptions brought on diode rectifier and phase-controlled circuits have proliferated persisted well into the late 1970s. Some of the first works discussed passive power factor adjustment methods. For applications with low power PFC, passive approaches continue to be appealing. Passive PFC approaches have the potential to produce power factors as high as 0.98, according to reports. What follows is a brief overview of the passive PFC circuits.

An Inductive Filter

A typical rectifier circuit with an inductive filter, as shown in Figure 1.26, places an inductor between the rectifier's output and the capacitor. Adding an inductor increases the current pulse's conduction angle and decreases its peak and rms values. The input current is pulsing and discontinuous at low inductance levels. Having said that, the PF for such a system cannot go over 0.9, regardless of the inductance value.

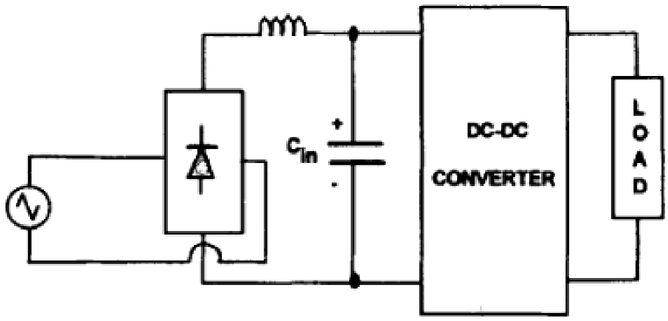

Figure 4: The Inductive Filter in a Traditional Rectifier Circuit

Figure 5 shows the addition of a first-stage LC filter; line inductance is not depicted. This improves harmonic performance by attenuating higher-order harmonics of the line frequency by a factor of 80 dB. A reported PF of 0.86 is achievable with even a tiny inductance value, which is a significant improvement over the non-capacitance scenario.

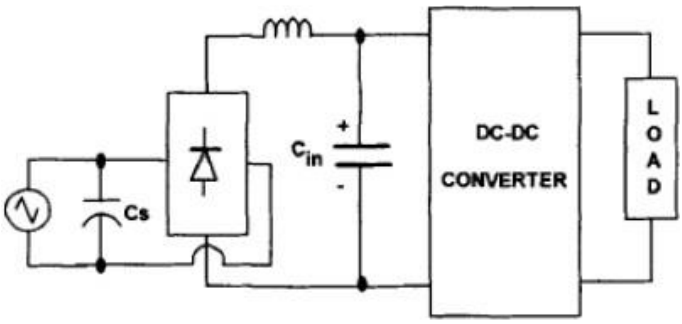

Figure 5: An LC Filter-Input Rectifier Circuit

Input Filter with Resonance

Power factor correction using the input series filter configuration yields excellent results, with power factors reaching 0.94 (as shown in Figure 6). In addition, the harmonic performance is commendable. Applications with a high supply frequency often use this circuit configuration. big rms currents in the two filter capacitors and the need of big element sizes are drawbacks of this configuration.

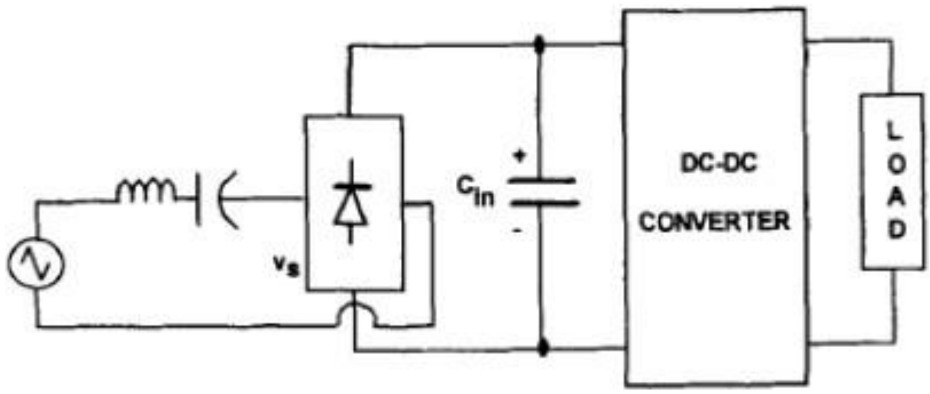

Figure 6: An Input Filter and Rectifier Circuit with a Series Resonant Design

Figure 7 shows that PF is further enhanced by using a parallel resonant input filter. This configuration gets the extremely near to 0.95 in terms of power factor. By far the most noticeable harmonic component, the third one,is subjected to a filter that is set to provide an extremely high impedance. To prevent oscillations in the circuit, a high-value parallel resistor is used.

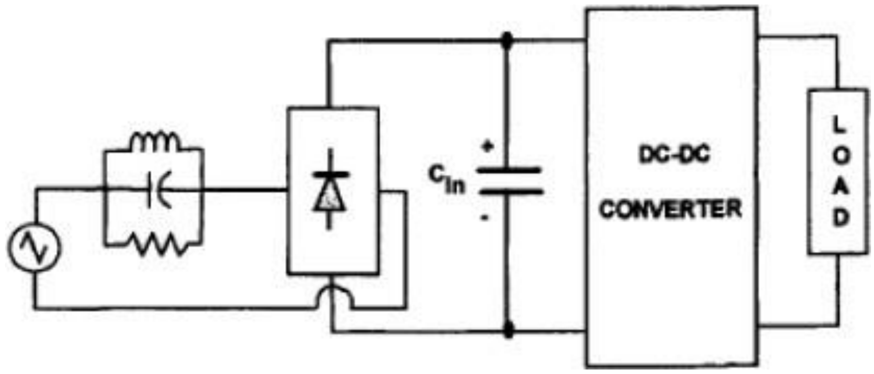

Figure 7: Circuit for Rectifier Using a Parallel Resonant Input Filter

CONCLUSION

The many PV power system topologies have been discussed. Benefits of multilayer converter topologies for PV power systems include improved harmonic performance to meet grid requirements, higher power and voltage capabilities, and more. Intelligent control systems for multilevel converters also allow the introduction of MPPT methods, which further enhance efficiency and remove unneeded converters. Future studies on PV power systems, especially those focusing on large-scale installations, are likely to concentrate on systems that use multilayer converters. Following previous attempts to reduce distortion, enhance efficiency, and stabilize capacitor voltages, fault tolerant control and fault detection have lately taken center stage in control research. The simplicity and usefulness of MPC have led to its use into power converter control systems. More research into the potential use of MPC to PV power systems should provide improved performance when compared to more traditional methods of managing converters, as mentioned before. Upon completion of this report, more research will be carried out to go deeper into this subject.
The inverter's efficiency and low cost are both enhanced by this design. The 0.02% total Compared to the IEEE 519 standard; the circuit's harmonic distortion (THD) is much reduced. In addition to being efficient, lightweight, and cheap, the proposed transformer-less inverter reduces total harmonic distortion (THD). The harmonic distortion (THD) of the circuit is much lower than that of the IEEE 519 standard. In addition to being efficient, lightweight, and cheap, the proposed transformer-less inverter reduces total harmonic distortion (THD).
Based on the buck and boost converter design specifications, the specified duty cycle for the boost converter is 85%, which is rather high for standard MOSFET switching. Buck converters are notoriously difficult to activate MOSFETs due to their 2% duty cycle. Even though they are helpful for obtaining suitable duty cycles, we will examine dual-stage buck and boost converters elsewhere.
In order for PV systems to transform solar energy into electricity, the topologies of the DC/DC converters used must be optimally selected. There are advantages and disadvantages to every kind of converter, including buck, boost, buck-boost, Cuk, Zeta, SEPIC, and flyback converters.
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boost converter is 85%, which is rather high for standard MOSFET switching. Buck converters are notoriously difficult to activate MOSFETs due to their 2% duty cycle. Even though they are helpful for obtaining suitable duty cycles, we will examine dual-stage buck and boost converters elsewhere. In order for PV systems to transform solar energy into electricity, the topologies of the DC/DC converters used must be optimally selected. There are advantages and disadvantages to every kind of converter, including buck, boost, buck-boost, Cuk, Zeta, SEPIC, and flyback converters. crucial to choose the optimal topology taking into account particular application needs and environmental factors. These converters provide dependable power conversion in photovoltaic systems by controlling voltage, current ripple, efficiency, and operational stability, among other critical performance metrics. Thanks to advancements in converter technology, novel control strategies, and soft-switching procedures, modern PV systems are more efficient and last longer than ever before. These converters play an essential role in renewable energy applications that aim to increase the scalability and stability of solar power generation. This, in turn, facilitates the overall shift towards renewable energy. Selecting the best DC/DC converter design guarantees efficient and effective solar energy harvesting, which in turn maximizes the performance of PV systems.

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