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Analysis of the Effectiveness of a Two-Stage Three-Phase Grid-Connected Inverter for Photovoltaic Applications

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ABSTRACT

This paper proposes a two-stage three-phase grid-connected inverter for photovoltaic applications. The proposed inverter topology consists of a DC-DC boost converter and a three-phase grid-connected inverter. The DC-DC boost converter is used to boost the low voltage DC output of the PV array to a high voltage DC level that is suitable for feeding into the grid-connected inverter. The three-phase grid-connected inverter is used to convert the high voltage DC output of the boost converter into a three-phase AC output that is synchronized with the grid voltage. The proposed inverter topology offers several advantages over traditional single-stage inverters. Firstly, the DC-DC boost converter allows for the use of a smaller, more efficient inverter in the second stage, reducing the overall cost of the system. Secondly, the use of a boost converter allows for the maximum power point tracking of the PV array, which can increase the overall efficiency of the system. The proposed inverter topology offers improved control of the grid current, reducing the impact of the PV system on the grid. The proposed topology has been simulated using MATLAB/Simulink and the results show that the system is capable of delivering a high-quality three-phase AC output with low harmonic distortion.

1. Introduction

An integral part of photovoltaic (PV) systems, the grid-connected inverter transforms DC electricity produced by solar panels into AC electricity which may be consumed into the utility grid. The inverter is an essential component in preserving the stability and quality of energy flow between both the PV system

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and the grid. Globally, there is a growing demand for renewable energy sources, and grid-connected PV systems have emerged as a desirable electricity generating possibility. Grid-connected PV system achievement is mainly reliant on the inverter's effectiveness, dependability, and security. Solar PV system customs for producing clean power are rising quickly, and grid-connected PV systems are now a well-liked option for supplying electricity to residences, businesses, and industries. An integral part of a PV system, a grid-connected inverter transforms the DC power from solar panels into grid-compatible AC power. Three-phase grid-connected inverters have drawn a lot of attention recently because of their high efficiency, low price, and capacity to handle a lot of power. Because of the harmful impacts of natural gas, such as climate change, carbon emissions, and other physical hazards, renewable energy sources are now playing an important role in the replacement of conventional fuels.

Yao et al. [1] proposed a novel two-stage three-phase grid-connected photovoltaic inverter with a reduced DC-link voltage. The proposed inverter combines a three-level neutral point clamped (NPC) topology with a buck-boost converter to boost the PV array voltage. The use of a reduced DC-link voltage makes the proposed inverter more efficient and reliable. Xu et al. [2] presented a new control strategy for a two-stage grid-connected photovoltaic inverter that achieves improved performance. The proposed control strategy used combination of maximum power point tracking (MPPT), active power filtering, and reactive power compensation to enhance the overall performance of the inverter. Mondal et al. [3] presented a two-stage three-phase grid-connected inverter with reduced switching losses. The proposed inverter used a resonant gate drive scheme that reduces the switching losses and improves the overall efficiency of the inverter. Krishnan et al. [4] proposed a three-phase grid-connected inverter that improves the power quality of the PV system. The proposed inverter used a high-frequency transformer to reduce the harmonic distortion and improve the power factor of the system. Lu et al. [5] presented a three-phase grid-connected inverter for photovoltaic applications with reduced DC-link capacitance. The proposed inverter used a cascaded H-bridge topology to reduce the DC-link capacitance and improve the overall efficiency of the inverter. Zhao et al. [6] proposed an innovative three-phase grid-connected inverter that improves the dynamic performance of the PV system. The proposed inverter used a proportional-resonant controller to regulate the output voltage and current, which improves the dynamic response of the inverter. Perera et al. [7] presented a simulation of voltage unbalance assessment of solar PV integrated low voltage distribution system in sri lanka using monte carlo. This study showed that voltage unbalance and over voltage problems at load points are key factors in determining the upper limit of solar PV capacity. Zhu et al. [8] proposed a disturbance observer based fuzzy sliding mode control of PV grid connected Inverter, which includes a three-phase DC-DC boost converter and a three-phase DC-AC inverter. The proposed topology enhances the overall efficiency of the system by reducing the switching losses of the inverter, and the boost converter is capable of operating in a wide range of input voltage and current. Sangwongwanich et al. [9] proposed a mitigation of inter harmonics in PV systems with maximum power point tracking to provide reactive power support to the grid. The proposed topology can maintain the grid voltage within the acceptable limits even during the varying power conditions of the photovoltaic array. Mirzakhani et al. [10] proposed a best configuration of an Off-Grid PV-wind-fuel cell system with battery and generator backup. The proposed configuration offers the production of electricity by FCs can be one of the sources of green energy production in a suitable replacement scale for traditional systems based on DGs, especially in rural and remote areas. Azamian et al. [11] proposed an improved low voltage ride-through capability of PV connected to the unbalanced main grid aiming to provide a comprehensive overview of the research done in this area. The author has extensively reviewed the existing literature on the subject, identifying various techniques and methods proposed for improving the low voltage ride-through capability of photovoltaic systems connected to unbalanced grids. Parimalasundar et al. [12] proposed a modular multilevel inverter topology for photovoltaic applications with minimal switches. The proposed topology can reduce the switching losses of the inverter and improve the overall efficiency of the system. Janardhan et al. [13] proposed a transformer less inverter for grid connected photovoltaic system with reduced leakage current. Transformer less inverters (TLIs) have gained significant attention in recent years as a promising alternative to traditional inverters with transformers in grid-connected PV systems. The main advantage of TLIs is their higher efficiency due to the absence of transformer losses. In addition, TLIs are typically smaller and lighter, making them easier to install and maintain. However, one of the main challenges associated with TLIs is the issue of leakage current, which can pose safety risks and cause electromagnetic interference. Jafari et al.

[14] investigated a new topology for multilevel inverters fed by photovoltaic system for linear induction motor. Multilevel inverters (MLIs) have been extensively used in various applications due to their superior performance and efficiency. In recent years, there has been a growing interest in using photovoltaic systems to power MLIs. Linear induction motors (LIMs) are a popular choice for various industrial applications due to their simplicity, reliability, and high efficiency. However, the operation of LIMs requires a high-quality and stable power supply, which can be achieved by using MLIs fed by PV systems. A literature survey reveals that various topologies have been proposed for MLIs fed by PV systems to operate LIMs. The most common topologies include cascaded H-bridge, flying capacitor, and hybrid MLIs. However, these topologies have some limitations, such as complexity, increased cost, and reduced efficiency. Ali Khan et al. [15] investigated photovoltaic inverters due to their ability to convert DC power generated by PV panels into AC power that can be fed into the utility grid. A comprehensive literature survey reveals that various modulation techniques and control strategies have been proposed to improve the performance and efficiency of grid-connected PV inverters. The most commonly used modulation techniques include pulse width modulation (PWM), space vector modulation (SVM), and selective harmonic elimination (SHE), while the most popular control strategies include traditional proportional-integral (PI) control, model predictive control (MPC), and sliding mode control (SMC). These techniques and strategies have been extensively studied and compared based on their performance, cost, and complexity, and several optimal solutions have been proposed to improve the efficiency and power quality of grid-connected PV systems. KS et al. [16] investigated intelligent battery management system controller (IBMSC) can be used to enhance the performance and reliability of the DC-AC converter. A literature survey reveals that pulse width modulation techniques are commonly used in DC-AC converters for solar power systems. However, the conventional PWM techniques have limitations, including harmonic distortion, reduced efficiency, and reduced power quality. To overcome these limitations, an improved PWM (IPWM) technique has been proposed for the IBMSC DC-AC converter using solar power. The proposed IPWM technique offers several advantages, including reduced harmonic distortion, improved power quality, and increased efficiency. The IBMSC controller ensures the safe and efficient operation of the DC-AC converter, improving the reliability of the solar energy system. The proposed converter has been simulated and tested experimentally, demonstrating its effectiveness and feasibility for wide voltage conversion systems in solar energy applications. Sheikhlari et al. [17] proposed a multilevel inverter structure based on the development of full-bridge cells with the minimum number of switches for renewable energy applications. Multilevel inverters have become increasingly popular in renewable energy applications due to their ability to improve power quality, reduce harmonic distortion, and increase efficiency. A literature survey reveals that various MLI structures have been proposed, but they often require a large number of switches, which can increase the complexity and cost of the system. To overcome this limitation, a new MLI structure has been proposed based on the development of full-bridge cells with the minimum number of switches. This structure offers several advantages, including reduced complexity, lower cost, and improved efficiency. The proposed MLI structure has been simulated and tested experimentally, demonstrating its effectiveness and feasibility for renewable energy applications, such as wind and solar power systems. The proposed MLI structure is an attractive solution for applications where reducing the number of switches is a critical factor. Sun et al. [18] presented an advanced frequency support strategy of double-stage grid-connected PV generation. The proposed design methodology considers the size and cost of each component in the inverter, as well as the operating conditions of the PV system. Nkambule et al. [19] investigated comprehensive evaluation of machine learning MPPT Algorithms for a PV system under different weather conditions. MPPT algorithms are essential in PV systems to extract the maximum power from the solar panel under different weather conditions. A literature survey reveals that various MPPT algorithms have been proposed for PV systems, including perturb and observe (P&O), incremental conductance, and hill climbing (HC) algorithms. Zhang et al. [20] proposed a switching control strategy for multiple photovoltaic converters in DC microgrids. A novel switching control strategy has been proposed in recent research, which offers several advantages over existing strategies. The proposed strategy uses a centralized controller to regulate the output power of each PV converter, ensuring equal sharing of the load among converters. The controller adjusts the switching frequency of each converter based on the power output and the load demand, improving the efficiency and stability of the DC microgrid. The proposed strategy also includes a voltage balancing algorithm to maintain the DC bus

voltage within the desired range. The proposed switching control strategy has been simulated and validated experimentally, demonstrating its effectiveness and feasibility for multiple PV converters in DC microgrids. The strategy offers several advantages, including improved power quality, higher efficiency, and reduced component stress. Bu et al. [21] presented a two-layer approach for estimating behind-the-meter PV generation using smart meter data. In the first layer, a Gaussian process regression model is used to estimate the solar irradiance at the site. In the second layer, a machine learning algorithm is used to estimate the PV generation based on the estimated solar irradiance and other relevant features. This approach has been shown to be effective in accurately estimating behind-the-meter PV generation using only smart meter data. Uno et al. [22] proposed a fault tolerant modular differential power processing converter for photovoltaic systems. However, PV systems can experience faults that can impact their efficiency and reliability. A fault tolerant modular differential power processing (DPP) converter has been proposed in the literature as a solution to address this issue. The DPP converter can also enhance the energy harvesting efficiency of the PV system by regulating the voltage and current levels. Samadi et al. [23] investigated boost converter topologies, hybrid boost and new topologies of voltage multiplier in photovoltaic systems. Boost converters are widely used in photovoltaic systems to increase the voltage of the DC output from solar panels. Recently, hybrid boost topologies have been proposed which combine the advantages of two or more boosting converter topologies. In addition to boost converters, voltage multipliers have also been used in photovoltaic systems to increase the voltage level.

Tian et al. [24] proposed a single-phase transformer less common-ground type PV inverter with active power decoupling. A single-phase transformer less common-ground type PV inverter with active power decoupling is a type of inverter used in photovoltaic systems. It is designed to convert DC power generated by PV panels into AC power that can be fed into the grid. Unlike traditional PV inverters that use a transformer to isolate the DC and AC circuits, this type of inverter does not use a transformer, which reduces its cost and size. Instead, it uses active power decoupling to achieve the same level of isolation. Literature surveys of this type of inverter have been conducted to evaluate its performance and effectiveness, including studies on its control strategies, efficiency, and reliability. Mazaheria et al. [25] investigated LCL filters used to attenuate the high-frequency switching harmonics generated by the inverter, which can cause electromagnetic interference (EMI) and voltage distortions in the grid. Various design approaches have been proposed in the literature, including analytical methods based on circuit models, optimization techniques, and simulation-based methods. The choice of LCL filter parameters, such as the inductance and capacitance value, depends on various factors, such as the grid impedance, the inverter switching frequency, and the control strategy. The performance of LCL filters can be evaluated in terms of their attenuation characteristics, stability, and robustness to variations in system parameters. Prasad et al. [26] proposed a solar PV-fed multilevel inverter with series compensator for power quality improvement in grid-connected systems. Ghaffarzadeh et al. [27] investigated performance evaluation in solar system fault classification and fault detection techniques. Nabati et al. [28] discussed non-isolated single switch high step-up DC-DC converters for photovoltaic applications. In a literature survey, it was found that these converters have become increasingly popular due to their high conversion efficiency, compact size, and low cost. Various control strategies, including PWM, MPPT, and voltage regulation have been proposed to optimize their performance. Several researchers have also proposed modifications to the basic topologies to improve their efficiency and reliability. Overall, non-isolated single switch high step-up DC-DC converters are a promising technology for the solar power industry. Ebrahimnaza et al. [29] proposed novel interleaved DC-DC converters with high voltage gain for photovoltaic system applications. these converters offer several advantages, such as high efficiency, low input current ripple, and high voltage gain. Souri et al. [30] investigated three-phase buck-type dynamic capacitor using the model predictive control method for dynamic compensation of the reactive power and load current harmonics. the proposed MPC-based control strategies for three-phase buck-type dynamic capacitors have demonstrated improved performance in terms of reactive power compensation and load current harmonics reduction. Furthermore, some studies have also explored the implementation of intelligent algorithms such as fuzzy logic and neural networks to further improve the performance of the system. Overall, the use of three-phase buck-type dynamic capacitors with MPC-based control strategies is a promising technology for power quality improvement in three-phase power systems.

The design and development of a two-stage three-phase grid-connected inverter for PV applications is an area of active research. While there are many studies available in the literature on grid-connected inverters, there are still some gaps that need to be addressed. For example, most studies focus on single-phase inverters or two-phase inverters, while three-phase inverters are relatively less explored. Additionally, while there are some studies on two-stage inverters, the combination of a two-stage topology with a three-phase grid-connected inverter for PV applications has not been extensively studied. The proposed work aims to address these gaps in the literature by presenting a novel two-stage three-phase grid-connected inverter for PV applications.

To improve the output of photovoltaic, a boost converter links the PV array towards the electrical grid, and a DC to AC inverter converts the voltage drop in DC from photovoltaic arrays integrated further into alternating current supply. Because inverter's input of DC input ought to remain continuous, also a PI control circuit is used to regulate it. For the grid to receive clean current injection, an LC filter has been added. The controller together with all of the elements included in the proposed model are modelled in Matlab/Simulink software. Both stable and transient states are simulated as two distinct examples. The correctness of the concepts and also the efficiency of the management systems have been shown in every simulated data.

The novelty of this work lies in the combination of a two-stage topology with a three-phase grid-connected inverter for PV applications. This topology offers several advantages, including high efficiency, reduced harmonics, and improved power quality. Moreover, the proposed inverter is designed to operate in both grid-connected and standalone modes, providing flexibility in the operation of the PV system. Overall, the proposed work presents a promising solution for the development of efficient and reliable PV systems.

2. PV System and Boost Converter

A PV generator is a device that converts sunlight into electricity using semiconducting materials. There are different models of PV generators, each with its own specifications and features. Figure 1 illustrates the Block diagram of two-stage grid connected PV system photovoltaic generators can be seen as present generators with flexible voltage sources rather than fixed current or voltage sources. In the dark, the solar cell is inoperative.

It produces no current nor voltage. For solar panel cells to work, a p-n semiconductor junction is required. Upon exposure to light, a current is produced DC current. The solar irradiation changes the produced current in a straight line. The PV generator model is a crucial tool for planning and developing solar energy systems, as well as for maximum line voltage. The PV array's maximum power point is controlled to follow the DC to DC conversion. Changing the switch's duty ratio can change a boost converter's output voltage, that determines how long the switch is switched on relative to the duration of the cycle, may be modified. The output voltage increases as the duty cycle increases while lowering as the duty ratio increases. Boost converters are frequently employed in many different situations, such as DC-to-DC voltage conversion, renewable energy systems, battery-operated devices, and electronic power supplies. Since they can step up the voltage to the desired level, they are especially helpful in applications where the input voltage is lower than the intended output voltage. forecasting how well they will function in various scenarios. Figure 2 represents the Equivalent solar cell circuit.

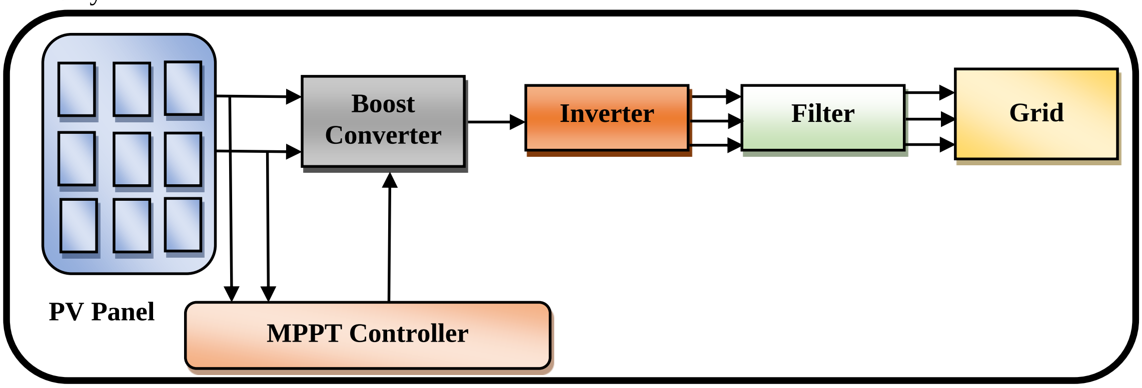

Figure 1. Block diagram of two-stage grid connected PV system

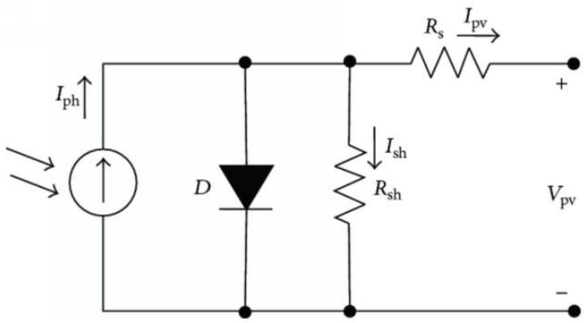

Figure 2. Equivalent solar cell circuit

The following equations (1), (2) and (2) [2] can be used to control the I-V characteristics of the solar cell circuit. The following provides the diode's current:

$$I_D = I_0 [\exp(q(V + IR_s)KT) - 1] \tag{1}$$

$$I = I_L - I_D - I_{sh} \tag{2}$$

$$I = I_L - I_0 [\exp(q(V + IR_s)KT - 1)] - (V + IR_s) / R_{sh}$$
(3)

Two topologies PV systems with one- and two-stages and MPPT, have received the most attention for grid-connected PV applications. Because it provides a greater degree of operational freedom than a one-stage design, PV energy conversion technology with two stages was chosen for this work. Due to the low output voltage of PV cells, low-voltage PV arrays may be employed, which lowers the overall cost. A capacitor is frequently put between both the PV system as well as the boosted circuit to lessen higher - frequency distortions. Batteries and other parts up to the authorized amount. The power point maximum of The DC to DC converter's output is adjusted to drive the Solar panel. By modifying the pulse width of the switch, the output voltage of a boost converter may be changed, which determines how long the switch is on relative to the duration of the full cycle. The output voltage rises with increasing duty cycle while falling with decreasing duty cycle of the converter.

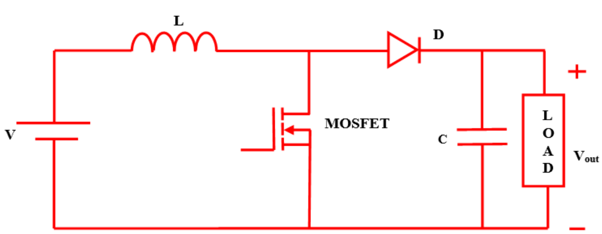

Figure 3. DC - DC Boost converter circuit

Table 1. Parameters of boost converter

Parameters	Values
Duty cycle	89%
Switching Frequency	5000 Hz
Output power	220 Volts
Input voltage	24 Volts
Inductor	3.24 mH
capacitor	7.386 µF
Ripple in capacitor voltage	30%
Ripple in inductor current	5%

The following expressions (4) and (5) [5] are used for designing the boost converter inductor (L) and capacitor (C) values,

$$L = \frac{V_{min} * D}{f_s * I_L} \tag{4}$$

$$C = \frac{I_{max} * D}{f_s * \Delta V_c} \tag{5}$$

Table 1 [9] illustrates design values of boost converter which is connected between PV panel and inverter system. Figure 3 illustrates boost converter circuit which is frequently employed in many different situations, such as DC-to-DC voltage conversion, renewable energy systems, battery-operated devices, and electronic power supplies. Since they can step up the voltage to the desired level, they are especially helpful in applications where the input voltage is lower than the intended output voltage. Boost converters are appropriate for a variety of applications because they may be used to raise the voltage of a DC input signal to any required level. They are helpful in situations where the input voltage may change because they can adjust the output voltage with great precision.

3. Inverter Modelling, Grid-Based Regulate of PV Arrays and MPPT Control

A device known as an inverter or power inverter turns DC sources into AC sources. The electrical equipment and gadgets in homes, workplaces, and automobiles may all be powered by the AC energy generated by an inverter. Typically, inverters function by transforming a low-frequency DC voltage from a battery or other power source into a fast-reacting AC voltage. Then, that AC voltage is changed into a lower-frequency AC voltage that may be used with the majority of electrical equipment and appliances. ranging out of a microcomputer switching electrical supply to big power usage to transmit massive electricity, inverters are employed in a variety of applications. They are therefore excellent choices if the usage of AC power tools or appliances is necessary.

Three distinct wave outputs are produced by power inverters:

- Square Wave
- Modified Square Wave (Modified Sine Wave)
- True Sine Wave.

Three various power output features are corresponding to the three different waveforms. Uneven power distribution produced by square wave inverters makes them useless for supplying the bulk of devices. The original inverter types were square wave inverters, which are no longer produced. Power that seems to be reliable and sufficient is provided by modified sine wave and square wave inverters to operate the majority of devices without issue. Certain medical devices, tools with variable speeds or rechargeable batteries, and other delicate equipment need a sine wave to function properly. In the MATLAB/Simulink system, six IGBT switches may simulate a three-phase inverter.

The DC - AC converter's two primary purposes are to:

- effectively deliver AC signal current at time with AC utility grid; and
- maintain an equilibrium in the Photovoltaic module's overall electricity supply towards the grid.

A photovoltaic system that is linked to the grid produces energy photovoltaic arrays and supplies them to the power grid. Such a system's control entails managing the electricity's flow between the solar panels the electricity grid, its inverter, and the centre of the photovoltaic system that is connected to the grid consists of two components. The primary function of controls the following:

- The MPP tracking regulation is to draw the most electricity possible from the Photo-Voltaic generator.
- The inverter control, whose primary objectives are to: - Adjust that reactive power fed further into grid and control the active power; - Manage the DC supply voltage; - Make absolutely sure the delivered electricity is of a good calibre. Standards for Grid Connected Inverters have to be shown in Table 2 [18].

The management system of a grid-connected PV system ensures that the energy produced by the solar panels is used effectively and that any extra energy is routed back into the power grid. This decreases the need for conventional power sources, increases energy efficiency, and lessens the electrical grid's carbon impact. The inverter in a grid-connected PV system must regulate the voltage and current of the electricity generated by the solar panels to ensure that it is compatible with the electrical grid. This is done using power electronics components such as diodes, capacitors, and inductors. An integral part of the system that guarantees the power produced by the solar panels is used effectively and safely, as well as ensuring the electrical grid is secure and stable is the management of a grid-connected solar power system. A number of parts and systems are used in the intricate process of controlling a grid-connected solar energy system. The command and control system must ensure the system actually safe and effectively functioning, while also safeguarding the electrical grid and enhancing the system's effectiveness.

The amount of insulation and operating temperature have a significant impact on the maximum power that a PV panel can produce. As a result, it is imperative to constantly monitor the maximum power point. A PV system's performance fluctuates practically constantly due to the weather and load fluctuations. To guarantee that the solar arrays produce their maximum power, a dynamic tracking approach is crucial. It employs that disturb and notice (P&O) method. The strategy makes advantage of a basic reporting system with few monitorable parameters. With this technique, the modules voltage is periodically perturbed, and the output power that results is compared to the output power from the perturbing cycle before. The mechanism is slightly disrupted by this technique. When the maximum strength is reached, the fluctuation then flips since the energy only at MPP is zero and then drops within the next moment. Following the occurrence of the technique fluctuates out about maximum power point under steady conditions. The perturbation size must stay very tiny so as to minimise power volatility. The method is sophisticated in that it establishes a reference voltage for the module it is the same as its maximum voltage. The operational position of the device is then changed to that particular voltage level using a PI controller.

4. Simulation Results and Discussion

400 V, 50 Hz network via a boost converter (DC-DC) and inverter (DC-AC) in the system architecture shown in Figure 1. A signal dc to ac inverter consumes the 400 V produced by the boost converter (DC-DC). A boost DC to DC converter's function is to extract energy from a Photovoltaic solar array of cells and provide a Maximum Power Point tracker

that it has received from an MPPT controller to the DC link capacitor. But after DC to AC inverter, a High - pass filter is applied to remove oscillations that can be seen in the output voltage and current. The power converter is responsible for controlling the AC output waveform and regulating the flow of current from the DC supply to the load. It can deliver high-quality AC power, with low total harmonic distortion (THD), even when the load resistance changes. This makes it suitable for applications that require stable AC power, such as computer power supplies, renewable energy systems, and electric vehicles.

Simulation of the Photovoltaic panels like a continuous DC supply the subsystems module of the Simulink libraries device. Voltage, temperature, and irradiance are the three inputs that are needed by the model. Table 2 [18] lists the PV model's parameters. The current is produced by the block's output and its input, which is system feedback.

Table. 2 PV model parameters

Parameters	Range
Module	Sun power SPR315E- WHT-D
Parallel strings	64
Series-connected modules per string	5
Maximum Power	315.072 Watts
Voltage at maximum power point Vmp	54.7 Volts
Current at maximum power point Imp	5.76 Amps
Temperature coefficient	35°C
Irradiation	1000 w/m^2

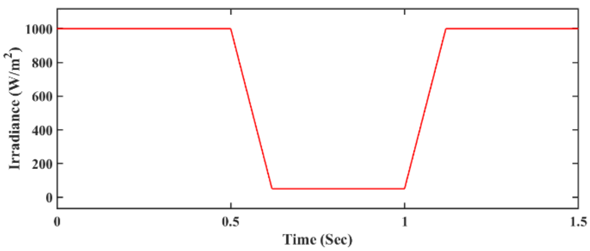

Figure 4. Irradiance of PV system

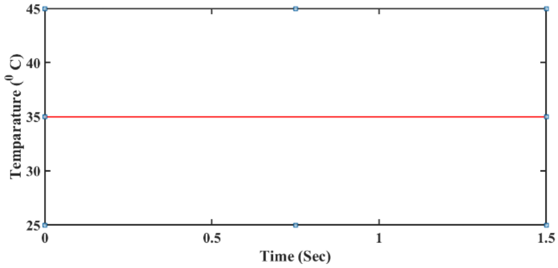

Figure 5. Temperature of PV system

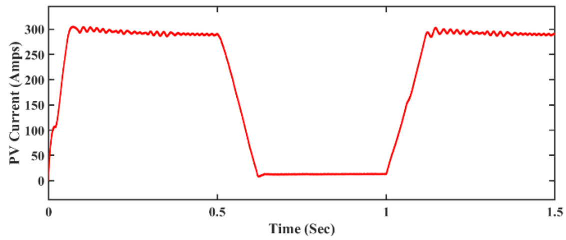

Figure 6. PV current delivered by PV system

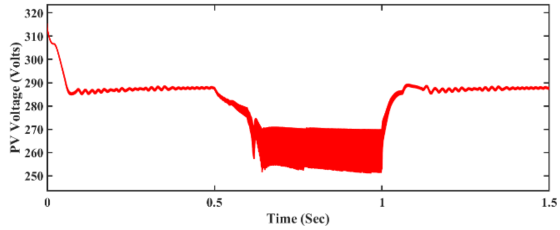

Figure 7. PV voltage delivered by PV system

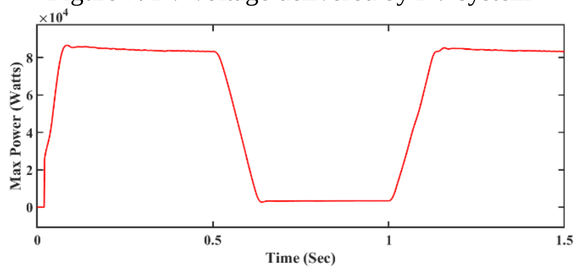

Figure 8. Maximum power delivered by PV system

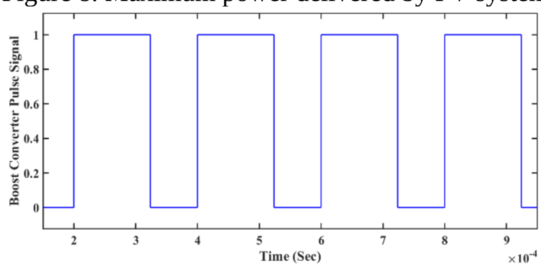

Figure 9. Gating pulse of boost converter

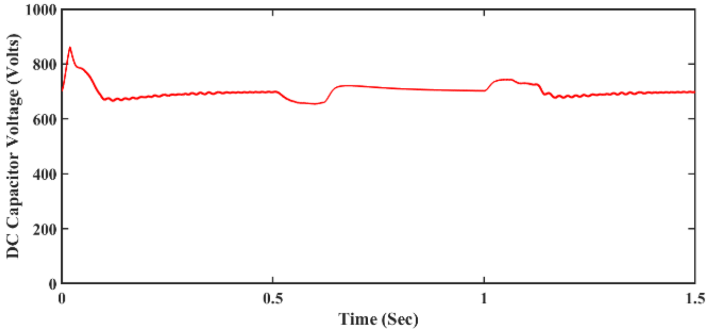

Figure 10. DC capacitor voltage delivered by boost converter

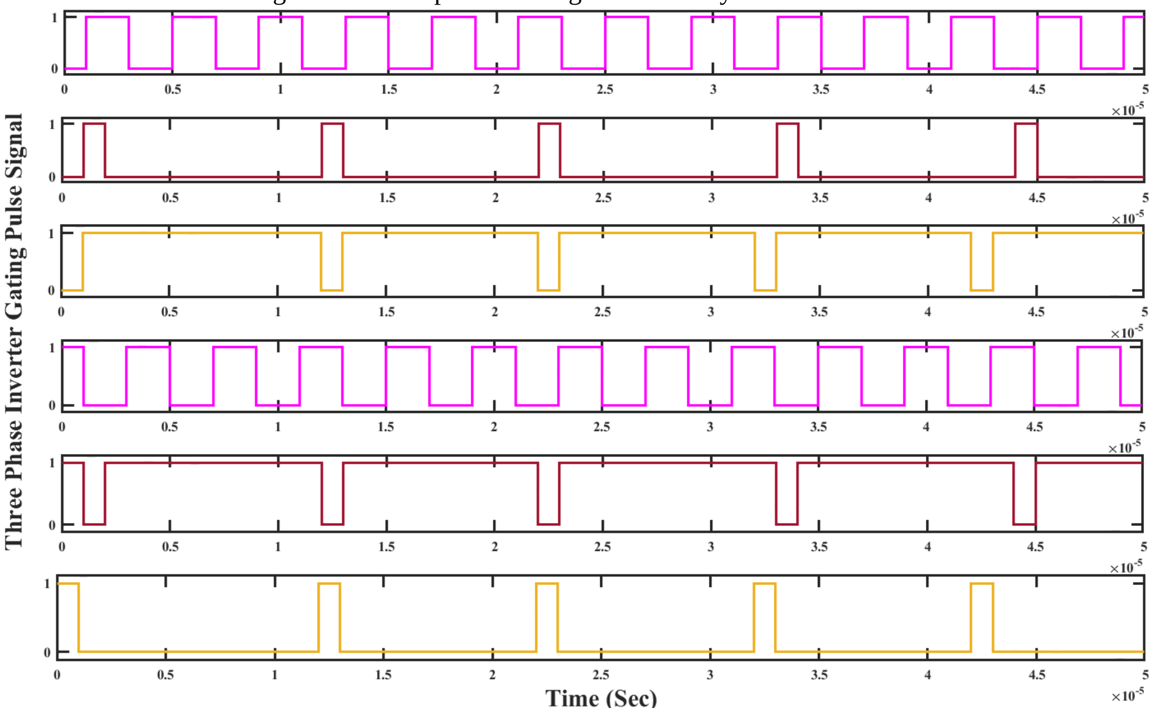

Figure 11. Switching patterns of inverter system

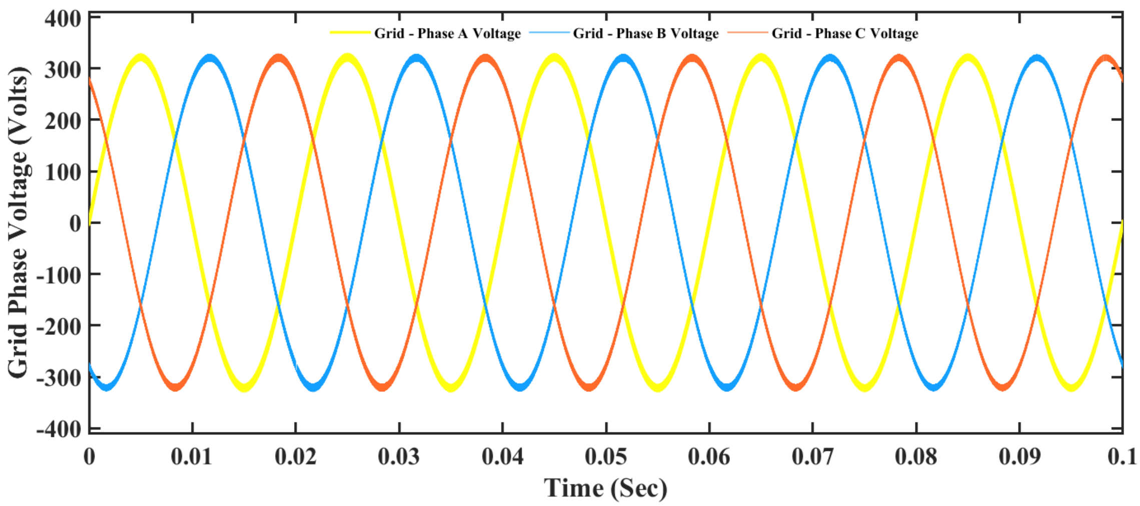

Figure 12. Three phase grid voltage

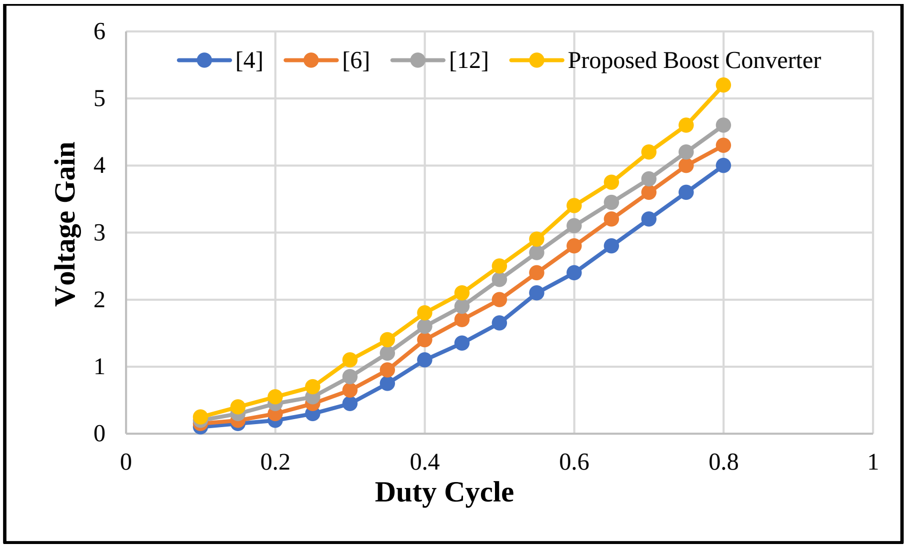

Figure 13. Comparative analysis of voltage gain in boost converter

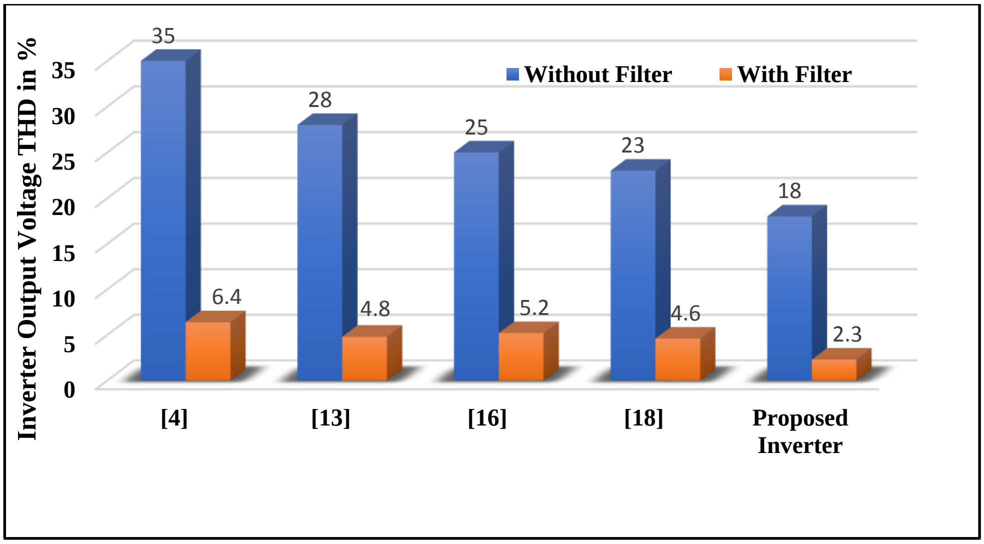

Figure 14. Comparative analysis of THD value of three phase inverter

The amount of solar radiation falling on the surface of the PV panels at any specified time is referred to as the solar insolation of a PV system. Generally, it is expressed in watts per square metre which has the range of under test conditions 1000 (W/m^2). PV system irradiance is shown in Figure 4. A PV system's efficacy and effectiveness may be impacted by temperature. A PV system's performance may suffer as its temperature is raised as it glows brightly in typical circumstances. A PV system's precise temperature might very well vary depending on a number of elements, including the sunlight that it receives, the surrounding temperature, the system's layout, and the components utilised. However, as shown in Figure 5, the temperature of a PV system can generally range from about 35°C. The size and efficiency of the PV panels, the amount of sunlight that hits the panels, and the attributes of the load which the process is boosting (shown in Figure 6) just are a few of the many variables that affect the current that a PV system can supply. The voltage supplied by a PV system is dependent on multiple variables, such as the number and layout of PV modules, the amount of sunlight obtainable, and the temperature of the PV cells. A single PV module can typically generate voltages between 0.5 and 1 volts. The voltages combine to produce a higher voltage when multiple modules are linked together in series. As shown in Figure 7, if four modules produce 0.5 volts each, for instance, integrating those in series would generate an aggregate voltage of 2 volts. A PV system's maximum power output is influenced by a number of variables, including the system's size, the PV modules' efficiency, the amount of sunlight accessible, and the working temperature, as shown in Figure 8. Figure 9 shows the boost converter's duty cycle and it has the gating pulse controls the switching of the MOSFET to regulate the output voltage. The gating pulse is typically generated by a pulse-width modulation circuit, which adjusts the duty cycle of the pulse to control the average voltage applied to the load. The gating pulse is a crucial component of the boost converter, as it determines the efficiency and stability of the circuit. Figure 10 shows that DC - DC converter regulates capacitor voltage. A DC-DC converter regulates the voltage across a capacitor by using a switching device that controls the flow of current through the circuit. The converter works by first storing energy in an inductor or transformer when the input voltage is high, and then releasing that energy into the output capacitor when the voltage drops below a certain threshold. This allows the converter to maintain a constant voltage across the capacitor, despite fluctuations in the input voltage. Figure 11 illustrates the switching pattern of inverter switches with six different patterns. A three-phase inverter is an electronic circuit that converts DC power into AC power with three separate output signals, typically sinusoidal waves that are 120 degrees out of phase. The switching pattern of a three-phase inverter involves the sequential switching of six power transistors or switches to generate the desired AC output voltage waveform. Figure 12 shows the grid voltage of a three-phase system with an integrated inverter and grid system. In a three-phase system with an integrated inverter and grid system, the grid voltage refers to the voltage of the AC power grid to which the system is connected. The grid voltage typically has a fixed frequency and amplitude, which varies depending on the location and characteristics of the grid. The inverter is responsible for converting the DC voltage generated by the system into AC voltage that is synchronized with the grid voltage, and injecting it into the grid. The inverter must also ensure that the injected voltage is of the correct amplitude and phase, and is synchronized with the grid voltage, in order to maintain the stability of the grid. The grid voltage is an important parameter that must be carefully monitored and controlled in order to ensure the safe and reliable operation of the system. Figure 13 illustrates an instance of a duty cycle-based comparative analysis of voltage gain in boost converter topologies. The most effective findings for the proposed boost converter attended a duty cycle of 0.8 and voltage gain values of 5.2. Figure 14 depicts a comparison of three phase inverter THD values, with the validated result of the proposed design value being 2.3

5. Conclusions

In this research, several factors have been considered and adjusted to create a PV network that is a part of the grid and produces the most electricity possible. When used with an accurate PV model, The system's performance employing the maximal power point tracking approach, may be raised. Also necessary is the employment of a controller in between device and the electrical grid for power control as well as for synchronizing with the grid. Simulating is done using MATLAB/Simulink with the MPPT technique and the PV grid attached to it. Both the Photovoltaic system's dynamic and stable state characteristics may be enhanced by the MPPT approach that was simulated in this work. The level of planning the maximum power point tracking successfully, according to simulation results. Additionally, this study demonstrates that the suggested control scheme provides a straightforward method for examining performance of applications utilising utility interfaces. It can generate appropriate the waveforms of unidirectional current and voltage and is easy to implement. The limitations of the two-stage three-phase grid-connected inverter for photovoltaic applications include higher costs due to the need for two inverters, increased complexity, and reduced efficiency. Future work could focus on reducing the cost and complexity while improving efficiency and reliability through advanced control strategies and optimization techniques.

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Nomenclature

C	Boost converter capacitance (F)
D	Duty Cycle
f_s	Boost converter switching frequency (Hz)
I	Solar-cell current (A)

I_{max}	Boost converter maximum current due to capacitance (A)
I_L	Current produced by the light (A) [Short circuit value assuming no series or shunt resistance]
I_0	Current saturable diodes (A)
K	Boltzmann constant (1.38×10-23 J/K)
L	Boost converter inductance (H)
q	Electron charge (1.6×10-19 C)
R_S	Series resistance of solar cells (Ω)
R_{sh}	Shunt resistance in solar cells (Ω)
T	Cell temperature in Kelvin (K)
V	Voltage produced by solar cells (V)
V_{min}	Boost converter minimum input voltage due to inductance (V)
ΔV_c	Change in voltage in boost converter (V)

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