Advanced International Journal of Multidisciplinary Research
E-ISSN: 2584-0487
editor@aijmr.com
Volume 4, Issue 2, March-April 2026
CrossRef DOI: 10.62127/aijmr.2026.v04i02.1269

Two Stage Single Phase Grid Connected Solar PV System with Simplified Power Regulation

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Abstract
This paper describes a two-stage, single-phase grid-connected solar photovoltaic (PV) system with a simplified power regulation strategy designed to achieve efficient energy conversion and reliable grid integration. The first step is to use a DC–DC converter to get the most power out of the PV array using Maximum Power Point Tracking (MPPT). This keeps the DC-link voltage stable even when the temperature and solar irradiation change. This makes sure that the solar energy that is available is used in the best way possible, even when the weather changes. A single-phase inverter changes the regulated DC power into synchronized AC power that can be fed into the utility grid in the second stage. The suggested system uses a simpler control strategy that keeps the system running smoothly while making it easier to do calculations. It also makes sure that the total harmonic distortion (THD) is low and that the power factor is one, which improves the quality of the power. The design of the system also puts less stress on the power electronic parts, which makes them last longer and makes the whole system more reliable. The efficient power regulation method cuts down on losses and makes conversion more efficient. The proposed system is a cost-effective, reliable, and efficient solution for modern grid-connected PV applications. It helps move forward the development of clean and sustainable energy technologies.

Keywords: Solar Photovoltaic (PV) System, Grid-Connected Inverter, DC–DC Converter Maximum Power Point Tracking (MPPT), DC-Link Voltage Regulation, Single-Phase Inverter, Power Regulation Strategy, Total Harmonic Distortion (THD), Unity Power Factor Renewable Energy Systems, Energy Conversion Efficiency.

I.INTRODUCTION

The rapid rise in global energy demand and growing worries about the environment have led to the widespread use of renewable energy sources, especially solar photovoltaic (PV) systems. Solar energy is plentiful, clean, and long-lasting, which makes it a great way to cut down on fossil fuel use and carbon emissions. However, the performance and efficiency of PV systems are significantly affected by environmental conditions such as solar irradiation, temperature fluctuations, and partial shading. These things can cause power losses, lower efficiency, and unstable energy generation. So, it is very important to create efficient ways to control and get power from solar energy so that it can be used to its fullest potential. For grid-connected PV systems to work well, they need to be able to convert power and sync with the utility grid. In this process, power electronic converters are very important because they control voltage levels, manage power flow, and keep the system stable. In a two-stage conversion process, a DC–DC converter uses Maximum Power Point Tracking (MPPT) to get the most energy possible from the PV array while keeping the DC-link voltage stable. The second stage has a single-phase inverter that changes the DC power into AC power that is in sync with the grid. This makes sure that energy is transferred quickly and that the grid standards are met.In spite of these developments, challenges like high control

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complexity, harmonic distortion, and component stresses still remain. For these challenges to be addressed, new power regulation techniques with low computational complexities and high performance are being developed. These techniques can ensure high efficiency, high reliability, and low losses. Considering this scenario, the proposed two-stage single-phase grid-connected PV system can be considered one of the best solutions for the current renewable energy sector. For optimal performance, sophisticated power electronic interfaces are required in grid-connected PV systems. In most cases, a two-stage power conversion scheme is utilized. In the first stage, a DC-DC converter in combination with MPPT techniques is used. The MPPT techniques ensure that the maximum power available from the PV panel is extracted, while the DC-link voltage is maintained constant. This stage is vital in coping with varying environmental conditions. In the second stage, a single-phase inverter is used to transfer the constant DC power in a sinusoidal AC format in synchronism with the utility grid. Synchronization of the power transfer is essential for smooth power transfer, power quality, and grid code compliance. However, despite the efficiency of conventional methods, issues such as increased complexity of controls, switching power loss, harmonic distortion, and power electronic devices remain a great concern. This has led to the need to look for alternative solutions to overcome these challenges, with simple power regulation techniques being considered to reduce complexity, thereby improving efficiency and reducing cost. This has led to an improvement in system performance, reducing complexity and ensuring durability.

II.LITERATURE SURVEY:

[1] Chandel et al. (2015) provided a broad review of SPWPS technology, system components, field performance, and challenges for irrigation & community water supplies. They emphasized the need for efficient design and control strategies to improve reliability. (Chandel, Naik & Chandel 2015)Muhsen, Khatib & Sopian (2017) focused on SPWPS design methods and control strategies, comparing different power conversion topologies and MPPT techniques while highlighting practical field performance variations under real climatic conditions. (Muhsen, Khatib & Sopian 2017).[2] Gopal et al. (2013) presented one of the early comprehensive reviews on renewable energy water pumping systems, discussing DC and AC motor-driven configurations. The authors highlighted the importance of proper system sizing and efficient motor–pump matching to improve overall system performance.Periasamy, Jain, and Singh (2015) reviewed the development of PV water pumping systems, emphasizing advancements in power electronic converters and motor drive technologies. They compared DC motors with AC motors and concluded that AC motor-driven systems offer better durability and lower maintenance. [3] Sontake and Kalamkar (2016) presented a detailed review of solar PV water pumping systems, including energy analysis, economic considerations, and system design approaches. Their study showed that the performance of PV pumping systems largely depends on converter topology and motor efficiency.Muhsen, Khatib, and Sopian (2017) examined design methodologies and control strategies used in PV water pumping systems. They stressed the importance of intelligent MPPT algorithms and optimized control schemes to improve system adaptability under fluctuating environmental conditions.[4] Chandel, Naik, and Chandel (2015), who reviewed solar PV water pumping technologies and emphasized accurate modeling of PV arrays under varying irradiation and temperature conditions. Sontake and Kalamkar (2016) analyzed energy performance and system configurations of solar PV pumping systems, concluding that system efficiency strongly depends on converter topology and control strategies.[5] Muhsen, Khatib, and Sopian (2017) analyzed design methodologies and control strategies in photovoltaic systems. They highlighted that accurate modeling of environmental factors improves prediction of system performance.Rawat, Kaushik, and Lamba (2016) investigated energy efficiency and lifecycle cost management in PV systems, recommending optimization techniques for enhanced economic viability.[6]

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Rawat, Kaushik, and Lamba (2016) discussed the role of solar PV in reducing carbon emissions and improving lifecycle energy efficiency. Their study showed that large-scale solar installations contribute substantially to emission mitigation.Skoplaki and Palyvos (2009) emphasized that although PV systems are environmentally friendly, performance efficiency must be optimized to maximize environmental benefits.[7] Voyant et al. (2017) reviewed artificial intelligence techniques such as Artificial Neural Networks (ANN), Support Vector Machines (SVM), and hybrid models for solar radiation forecasting.Muhsen, Khatib, and Sopian (2017) emphasized the role of advanced predictive control strategies in improving PV system reliability and energy management.[8] Singh, Chandra, and Al-Haddad (2015) discussed power quality improvement techniques using advanced converter-based compensators.The Canadian PV-STATCOM study extends this concept by utilizing existing PV inverter infrastructure, thereby reducing additional investment costs for separate compensation equipment.[9] Singh, Chandra, and Al-Haddad (2015) analyzed power quality improvement techniques using converter-based compensators and emphasized advanced control strategies for reactive power controllers, Sauter, and Hung (2010) reviewed future trends in smart grid control and noted that renewable energy inverters must evolve into active grid-support devices.[10] Skoplaki and Palyvos (2009) analyzed the impact of temperature on PV module efficiency and emphasized accurate performance modeling.Dubey, Sarvaiya, and Seshadri (2013) reviewed temperature-dependent efficiency characteristics of PV modules and suggested improved cooling and material design strategies.

EXISTING SYSTEM

A grid-connected two-stage transformer-less inverter is used to convert DC power from solar PV panels into AC power for injection into the utility grid without the need for a bulky isolation transformer. The system consists of two main stages: a DC-DC boost converter, which steps up the PV output voltage and implements Maximum Power Point Tracking (MPPT) to extract maximum energy, and a DC-AC inverter, which converts the boosted DC voltage into grid-synchronized AC power with low harmonic distortion. The transformer-less design reduces system size, weight, and cost while improving overall efficiency.

DISADVANTAGES:

- Lack of galvanic isolation
- Leakage current issues
- Emi and noise problems
- Grounding and protection challenges
- Grid compliance requirements
- Limited voltage boost range
- Thermal stress on power devices

PROPOSED SYSTEM

The proposed system is a two-stage single-phase grid-connected solar PV system with a simplified power regulation strategy to ensure efficient and stable power delivery to the utility grid. In the first stage, a DC–DC boost converter is connected to the solar PV array to extract maximum power using a Maximum Power Point Tracking (MPPT) algorithm and to regulate the PV output voltage to a stable DC-link level. This stage compensates for variations in solar irradiance and temperature, ensuring consistent power availability. In the second stage, a single-phase DC–AC inverter converts the regulated DC power into synchronized AC power and injects it into the grid with unity power factor. The simplified power regulation is achieved by controlling the DC-link voltage and using a basic PI-based current control

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method, which reduces control complexity while maintaining stable grid synchronization and good power quality. The overall system offers improved efficiency, reduced computational burden, reliable grid interaction, and effective utilization of solar energy.

ADVANTAGES:

- Simple control structure
- Reduced system complexity
- Improved power quality
- Stable grid synchronization
- Efficient energy transfer

III.SYSTEM MODULE

HARDWARE REQUIREMENTS

- Dspic30f2010 Micro Controller
- TLP350 MOSFET driver
- IRF840 MOSFET
- Capacitor
- Diode
- Resistance
- PV solar panel
- Multi tap transformer

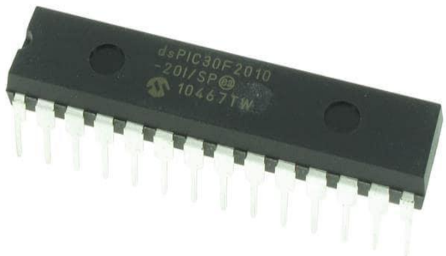

Fig1: Dspic30f2010 Micro Controller

The dsPIC30F2010 Microcontroller is a high-performance 16-bit Digital Signal Controller developed by Microchip Technology, designed to combine the features of a microcontroller with the computational power of a Digital Signal Processor (DSP). It belongs to the dsPIC30F family and is widely used in embedded systems requiring real-time signal processing such as motor control, power electronics, and industrial automation. The device operates with a modified Harvard architecture and supports both DSP and MCU instructions, making it suitable for applications that demand fast mathematical computations. It typically operates up to 30 MIPS (Million Instructions Per Second) and features 24 KB of Flash program memory, 1 KB of RAM, and 1 KB of EEPROM for data storage.

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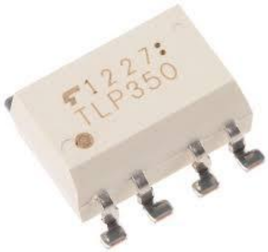

Fig2: TLP350 MOSFET driver

The TLP350 is a high-speed optically isolated gate driver primarily used for driving power MOSFETs and IGBTs in switching applications. It is manufactured by Toshiba and provides electrical isolation between the low-voltage control circuit and the high-voltage power stage. The device contains an infrared LED on the input side and a photodetector with a totem-pole output stage on the output side, enabling it to directly drive the gate of a MOSFET or IGBT. It typically operates with a supply voltage of around 15V to 30V on the output side and offers fast switching performance with high peak output current capability, making it suitable for high-frequency

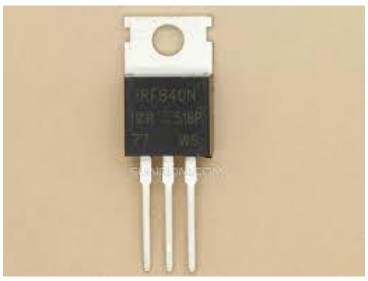

Fig3: IRF840 MOSFET

The IRF840 is an N-channel enhancement-mode power MOSFET widely used in high-voltage switching applications. It is designed to handle a maximum drain-to-source voltage of about 500V and can conduct continuous drain currents up to approximately 8A under proper heat sinking conditions. The device is commonly available in a TO-220 package, which allows efficient heat dissipation. The IRF840 operates with fast switching characteristics, low gate charge, and high input impedance, making it suitable for high-frequency switching circuits. It requires a positive gate-to-source voltage (typically around 10V) to turn fully ON and allows efficient control with minimal gate current.

Fig4: Capacitor

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capacitor is a passive electronic component that stores electrical energy in the form of an electric field between two conductive plates separated by an insulating material called a dielectric. When a voltage is applied across its terminals, electric charge accumulates on the plates, creating a potential difference and storing energy. The ability of a capacitor to store charge is called capacitance, which is measured in farads (F). The capacitance value depends on the surface area of the plates, the distance between them, and the type of dielectric material used. Capacitors are widely used in electronic circuits for filtering, energy storage, coupling and decoupling signals, timing applications, and power factor correction.
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Fig5: Diode

A diode is a two-terminal semiconductor device that allows current to flow in only one direction and blocks it in the opposite direction. It is made from a PN junction formed by joining P-type and N-type semiconductor materials. When the diode is forward biased (positive voltage applied to the P-side and negative to the N-side), it conducts current easily. When it is reverse biased, it offers very high resistance and prevents current flow except for a small leakage current. The main function of a diode is rectification, which means converting alternating current (AC) into direct current (DC).

Fig:6 Resistance

Resistance is the property of a material that opposes the flow of electric current. It determines how much a material resists the movement of electrons when a voltage is applied across it. The unit of resistance is the ohm (Ω), and it is represented by the symbol R. According to Ohm's Law, resistance is defined by the relation , where V is the voltage and I is the current. The resistance of a conductor depends on its length, cross-sectional area, material, and temperature. It is directly proportional to the length and resistivity of the material, and inversely proportional to the cross-sectional area.

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Fig:7 PV solar panel

A PV (Photovoltaic) solar panel is a device that converts sunlight directly into electrical energy using the photovoltaic effect. It is made up of multiple solar cells, usually fabricated from semiconductor materials such as silicon. When sunlight falls on the surface of the solar cells, photons transfer their energy to electrons in the semiconductor material, causing them to move and generate direct current (DC) electricity. The output voltage and current of a solar panel depend on the intensity of sunlight, temperature, and panel specifications.


Fig:8 Multi tap transformer

A multi-tap transformer is a type of transformer that has multiple tapping points provided on its primary or secondary winding to obtain different voltage levels from a single transformer. These tap connections allow the user to select various output voltages without changing the transformer itself. The taps are usually brought out to terminals, and by selecting different tap points, the number of effective turns in the winding changes, which in turn changes the output voltage according to the transformer turns ratio principle.

IV.RESULTS

The proposed two-stage single-phase grid-connected solar PV system demonstrates effective performance in terms of energy conversion, power quality, and system stability. The DC–DC converter successfully tracks the maximum power point under varying irradiation and temperature conditions, ensuring optimal utilization of solar energy. It also maintains a stable DC-link voltage, which is essential for efficient operation of the inverter stage.

The single-phase inverter produces a well-synchronized AC output with the utility grid, maintaining a near unity power factor. The simplified power regulation strategy reduces control complexity while ensuring stable and reliable system performance. Additionally, the system achieves low total harmonic distortion (THD), indicating improved power quality and compliance with grid standards.
The overall system shows enhanced efficiency due to reduced switching losses and minimized stress on power electronic components. This contributes to improved reliability and longer system lifespan.

Furthermore, the proposed approach enables smooth power flow from the PV system to the grid without significant fluctuations.
These results confirm that the proposed system provides an efficient, stable, and cost-effective solution for grid-connected solar PV applications, making it suitable for modern renewable energy integration.

V.CONCLUSION

The two-stage single-phase grid-connected solar PV system with simplified power regulation provides an efficient and reliable solution for integrating solar energy into the utility grid. By using a DC–DC converter for maximum power point tracking (MPPT) and a single-phase inverter for grid interfacing, the system ensures effective energy conversion and stable operation.
The simplified power regulation strategy reduces control complexity by minimizing the number of control loops while maintaining accurate power injection and unity power factor. This approach improves dynamic performance, reduces computational burden, and enhances overall system stability.
Overall, the proposed system achieves efficient maximum power extraction, stable DC-link regulation, low harmonic distortion, and reliable grid synchronization. Due to its simple control structure and improved performance, it is well suited for residential and small-scale grid-connected solar PV applications.

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