International Journal of Engineering Research and Science & Technology

www.ijerst.org

ISSN : 2319-5991

Vol. 22 No. 1 (2026)



ijerst.editor@gmail.com

editor@ijerst.com

International Journal of Engineering Research and Science & Technology

ISSN 2319-5991 www.ijerst.com
Vol. 22, No. 1, 2026
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Peer Reviewed, Referred & Indexed Journal

Research

IMPLEMENTATION OF SOLAR BASED FULL BRIDGE INVERTER WITH PWM TECHNIQUES

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ABSTRACT

This project focuses on the design, simulation, and implementation of a solar-based full bridge inverter utilizing Pulse Width Modulation (PWM) techniques to efficiently convert DC power generated from solar panels to AC

power. The full bridge inverter topology is chosen for its high efficiency, low harmonic distortion, and ability to handle high power ratings, making it suitable for grid integration and powering AC loads. The increasing demand for clean and sustainable energy has led to the rapid development of solar photovoltaic (PV) systems. Solar energy is one of the most reliable and environmentally friendly renewable energy sources. However, photovoltaic panels generate direct current (DC), whereas most household appliances and electrical systems require alternating current (AC). An efficient inverter is required to convert DC power into AC power for practical applications. The system consists of a solar panel array, a DC-DC converter for maximum power point tracking (MPPT), a full bridge inverter, and a control circuit employing PWM techniques. The PWM control strategy is designed to regulate the output voltage and minimize Total Harmonic Distortion (THD), ensuring a high-quality sinusoidal output. The project involves simulating the inverter circuit using simulation software, implementing a control strategy using a microcontroller or DSP, and testing the system with a solar panel input. The results demonstrate the effectiveness of the proposed system in achieving efficient and reliable power conversion, highlighting its potential for renewable energy applications. To improve the quality of the output voltage, PWM control techniques are used to generate switching signals for the inverter switches. The PWM technique helps in reducing harmonic distortion and produces a near sinusoidal output waveform. By controlling the pulse width of the switching signals, the inverter output voltage and frequency can be effectively regulated. This results in improved efficiency and better power quality. The proposed system converts the DC power obtained from a solar source into AC power suitable for operating electrical loads. The design focuses on achieving stable output voltage, reduced harmonic distortion, and efficient energy conversion. Simulation and practical implementation demonstrate the effectiveness of the full bridge inverter with PWM control in renewable energy applications.

Keywords: Solar Photovoltaic (PV) Systems, Full Bridge Inverter, Pulse Width Modulation (PWM), Sinusoidal PWM (SPWM), DC-AC Conversion, Harmonic Distortion, Total Harmonic Distortion (THD), Power Electronics, Renewable Energy, H-Bridge Inverter, Maximum Power Point Tracking (MPPT), Grid Integration, Switching Techniques, Power Quality

1. INTRODUCTION

1.1 Introduction

The escalating global demand for clean and sustainable energy has positioned solar photovoltaic (PV) systems as a pivotal solution in the transition toward renewable energy sources. Solar energy, characterized by its abundance, environmental friendliness, and declining implementation costs, has emerged as one of the most promising alternatives to conventional fossil fuel-based power generation [1], [2]. However, the inherent nature of solar PV panels generates direct current (DC) electricity, while the majority of household appliances, industrial equipment, and electrical grids operate on alternating current (AC). This fundamental mismatch necessitates the use of power electronic converters, specifically inverters, to facilitate the integration of solar energy into practical applications [3]. Power inverters serve as the critical interface between solar PV systems and AC loads or the utility grid. Among various inverter topologies, the full

bridge inverter, also known as the H-bridge inverter, has gained widespread acceptance due to its high efficiency, superior voltage utilization, and ability to produce high-quality output waveforms [4]. The full bridge configuration comprises four switching devices arranged in an H-shaped topology, enabling the generation of both positive and negative half cycles of the AC waveform from a DC input source. This topology is particularly advantageous for solar applications as it maximizes the utilization of energy harvested from photovoltaic panels. To enhance the performance of inverter systems, Pulse Width Modulation (PWM) techniques have been extensively adopted. PWM involves varying the width of switching pulses to control the average voltage delivered to the load, thereby shaping the output waveform [5]. Sinusoidal PWM (SPWM), a commonly employed modulation strategy, compares a sinusoidal reference signal with a high-frequency triangular carrier wave to generate gate pulses for the switching devices. This approach significantly reduces harmonic distortion and produces an output waveform that closely approximates a pure sine wave, improving overall power quality [6]. The integration of solar PV systems with PWM-controlled full bridge inverters represents a significant advancement in renewable energy technology. Such systems enable efficient DC-AC conversion while maintaining stable output voltage and frequency under varying operating conditions. This project focuses on the design, simulation, and implementation of a solar-based full bridge inverter utilizing PWM techniques to achieve efficient and reliable power conversion for residential and small-scale applications.

1.2 Problem Statement

Despite the rapid growth of solar photovoltaic installations worldwide, several technical challenges persist in the conversion of DC power from solar panels to AC power suitable for end-use applications. Conventional inverter systems often suffer from high harmonic distortion, inefficient power conversion, and poor output waveform quality, which can lead to overheating, power losses, and malfunction of sensitive electronic equipment [7], [8]. The primary problems addressed in this project include harmonic distortion, where traditional square wave and modified sine wave inverters produce significant harmonic content in the output waveform, resulting in total harmonic distortion (THD) levels that exceed acceptable limits for power quality standards, causing increased losses in electrical equipment, electromagnetic interference, and reduced system efficiency [9]. Additionally, inefficient energy utilization remains a critical issue, as many existing inverter topologies fail to fully utilize the DC input voltage, leading to lower output voltage and reduced overall system efficiency, which is particularly problematic in solar applications where maximizing energy harvest is essential [10]. Poor output waveform quality further compounds these challenges, as inverters without sophisticated control techniques produce waveforms with high harmonic content and voltage fluctuations, making them unsuitable for powering sensitive electronic devices and grid-connected applications [11]. The lack of integrated control in conventional inverters means they often lack advanced control strategies such as PWM that can regulate output voltage, maintain frequency stability, and adapt to varying load conditions and solar irradiance levels [12]. Finally, grid integration challenges persist, as for grid-connected solar systems, inverters must synchronize with the utility grid and maintain power quality standards, requiring precise control and switching techniques that are not always present in basic inverter designs [13]. These challenges highlight the need for an efficient inverter system that employs advanced switching techniques to minimize harmonic distortion, maximize energy utilization, and

provide high-quality AC output suitable for both standalone and grid-connected solar applications.

1.3 Scope of Research

The scope of this research encompasses the comprehensive design, simulation, and practical implementation of a solar-based full bridge inverter incorporating Pulse Width Modulation techniques. The study focuses on system design and development, which includes the design of a full bridge inverter circuit using four switching devices configured in an H-bridge topology, development of PWM control strategy using a microcontroller-based PWM generator, integration of solar PV panel as the primary DC power source, implementation of DC link capacitor for voltage stabilization and ripple reduction, design of gate driver circuits for proper switching device operation, and incorporation of output LC filter for harmonic attenuation. The performance analysis aspect involves evaluation of output voltage and current waveforms under various load conditions, assessment of total harmonic distortion (THD) in the output waveform, analysis of system efficiency and power losses, testing of inverter performance with different types of loads including resistive and inductive loads, and evaluation of voltage regulation and frequency stability. Regarding control strategy, the research encompasses implementation of sinusoidal PWM (SPWM) technique for switching signal generation, development of closed-loop control for output voltage regulation, and comparison of PWM-based inverter performance with conventional inverter types. The simulation and validation component includes simulation of the inverter circuit using appropriate software tools, experimental validation of simulation results through hardware implementation, and comparative analysis of simulation and practical results. In terms of renewable energy integration, the study focuses on demonstration of solar PV-based inverter for standalone power applications, evaluation of system suitability for off-grid and residential solar installations, and analysis of potential for grid-connected applications with proper synchronization. The research is limited to single-phase full bridge inverter configuration with PWM control using commonly available components, and does not extend to three-phase inverter systems or advanced modulation techniques such as space vector PWM, though these are identified as areas for future work. The project contributes to the field of power electronics and renewable energy by providing a practical implementation of an efficient solar inverter system that addresses the challenges of harmonic distortion and energy efficiency in solar PV applications.

2.LITERATURE SURVEY

1. Overview of Solar PV Inverter Systems

The rapid advancement of solar photovoltaic technology has driven extensive research into power electronic converters for efficient DC-AC conversion. Kjaer et al. [1] conducted a comprehensive review of single-phase grid-connected inverters for photovoltaic modules, categorizing inverter topologies into centralized, string, module-integrated, and multi-string configurations. Their work highlighted the importance of inverter selection in achieving maximum power extraction from PV arrays while maintaining grid compatibility. The authors emphasized that transformerless inverters offer higher efficiency but require careful consideration of leakage currents and safety requirements.

2. Full Bridge Inverter Topology

The full bridge inverter topology has been extensively studied for its superior performance characteristics. Mohan et al. [2] provided detailed analysis of inverter circuits, demonstrating that the H-bridge configuration offers full utilization of DC

supply voltage, enabling higher output power compared to half-bridge inverters. The authors explained the operational principles of the full bridge inverter, where diagonal pairs of switches conduct alternately to generate positive and negative half cycles of the AC output. This topology has become the preferred choice for solar applications due to its efficiency, simplicity, and ability to handle bidirectional power flow.

3. Pulse Width Modulation Techniques

Pulse Width Modulation has emerged as the dominant control technique for inverter systems. Holmes and Lipo [3] published an authoritative text on PWM for power converters, covering the principles and practical implementation of various modulation strategies. Their work detailed the theoretical foundations of PWM, including the concept of modulation index, carrier frequency selection, and harmonic analysis. The authors demonstrated that sinusoidal PWM (SPWM) achieves significant reduction in harmonic distortion compared to square wave operation, with total harmonic distortion (THD) decreasing as switching frequency increases.

4. Harmonic Distortion and Power Quality

The impact of harmonic distortion on power system performance has been a major focus of inverter research. Rashid [4] provided comprehensive analysis of harmonic generation in power electronic converters, noting that the output waveform of inverters contains harmonics that can cause overheating in transformers, torque pulsations in motors, and interference with communication systems. The author emphasized that PWM techniques are essential for meeting IEEE Standard 519 requirements, which recommend less than 5% THD for systems connecting to the power grid.

Carrasco et al. [5] investigated power-electronic systems for grid integration of renewable energy sources, highlighting the critical role of harmonic mitigation in ensuring grid stability. Their work demonstrated that advanced modulation techniques, including sinusoidal PWM and space vector PWM, can effectively reduce harmonic content to acceptable levels while maintaining high conversion efficiency.

5. Control Strategies for Solar Inverters

Blaabjerg et al. [6] examined power electronics as an efficient interface in dispersed power generation systems, emphasizing the importance of control strategies in renewable energy applications. The authors discussed various control approaches, including voltage-controlled and current-controlled inverters, noting that PWM-based control provides superior dynamic response and power quality. Their work highlighted the significance of maximum power point tracking (MPPT) algorithms in solar inverters for optimizing energy harvest from PV arrays.

6. Comparative Studies of PWM Techniques

Dharmadhikari [7] conducted a comparative study of full bridge voltage source inverters using different PWM techniques, including sinusoidal PWM, modified sinusoidal PWM, and space vector PWM. The research demonstrated that while sinusoidal PWM is simpler to implement and provides adequate harmonic performance for many applications, advanced techniques such as space vector PWM offer improved DC bus utilization and reduced switching losses. The study concluded that technique selection depends on application requirements, cost constraints, and complexity considerations.

7. Microcontroller-Based Inverter Control

The use of microcontrollers for inverter control has gained significant attention. Patel and Agarwal [8] presented MATLAB-based modeling for studying the effects of different PWM techniques on single-phase inverters, demonstrating the effectiveness of microcontroller-based implementation. Their work showed that digital control using microcontrollers such as Arduino or DSPs offers flexibility, programmability, and precise timing control essential for generating high-quality PWM signals.

8. Grid-Connected Solar Inverters

Teodorescu et al. [9] provided comprehensive coverage of grid converters for photovoltaic and wind power systems, addressing the specific requirements for grid-connected operation, including synchronization, power factor control, and grid protection. The authors noted that PWM-controlled inverters with appropriate filtering are capable of meeting grid interconnection standards while maintaining high efficiency.

9. Maximum Power Point Tracking Integration

Esram and Chapman [10] conducted a detailed comparison of photovoltaic array maximum power point tracking techniques, evaluating methods including perturb and observe, incremental conductance, and artificial intelligence-based approaches. Their work emphasized that integrating MPPT algorithms with inverter control systems can significantly improve overall system efficiency, with improvements of 20-30% in energy harvest under varying solar conditions.

10. Advanced Semiconductor Devices

Recent research has focused on the application of advanced semiconductor devices in inverter systems. Bose [11] discussed the impact of power electronics in the 21st century, highlighting the potential of wide bandgap devices such as silicon carbide (SiC) and gallium nitride (GaN) in achieving higher efficiency, faster switching, and reduced losses compared to conventional silicon devices.

3.EXISTING SYSTEM

Traditional solar inverter systems commonly employ square wave or modified sine wave inverter topologies with basic switching control. Square wave inverters utilize simple switching schemes where the output voltage alternates between positive and negative DC voltage levels, producing a waveform that is a series of rectangular pulses. These inverters typically use a simple oscillator circuit or basic microcontroller to generate switching signals at the desired frequency, with the switching devices operating in a simple on-off pattern without any modulation technique. Modified sine wave inverters improve upon square wave designs by introducing a zero-voltage step during polarity reversal, resulting in a three-level waveform that more closely resembles a sine wave. This is achieved by incorporating additional switching states that create a pause between the positive and negative pulses, effectively producing a stepped approximation of a sine wave. These systems typically use simple oscillators or basic microcontrollers to generate switching signals without sophisticated modulation techniques.

In many existing implementations, the inverter circuit comprises either half-bridge or full bridge configurations with minimal control circuitry. Half-bridge inverters use two switching devices and two capacitors to generate AC output from a DC input, but they utilize only half of the input voltage, limiting output power capability.

Full bridge inverters with four switching devices provide better voltage utilization but often operate with simple switching patterns. The DC input is usually obtained from batteries charged by solar panels through a basic charge controller, with the inverter operating independently of the solar PV characteristics. Protection circuits, including overcurrent and overvoltage protection, are often implemented using discrete components such as fuses and circuit breakers. Output filtering, if present, consists of basic LC filters designed primarily to remove high-frequency components from the output waveform rather than to shape the waveform. The control section typically employs analog circuits such as timers and comparators or basic microcontroller units that generate fixed switching patterns without adaptive capabilities. These inverters generally operate in open-loop configuration without feedback mechanisms, resulting in output voltage that varies with input voltage and load changes.

Disadvantages of Existing System

High Harmonic Distortion: Square wave inverters produce total harmonic distortion (THD) levels exceeding 45%, while modified sine wave inverters typically achieve THD around 30 to 35 percent, both significantly higher than the IEEE recommended limit of 5 percent for grid-connected applications. This high harmonic content causes overheating in transformers and induction motors, torque pulsations in AC motors, electromagnetic interference with communication systems, and malfunction of sensitive electronic equipment.

Poor Output Waveform Quality: The output waveforms from square wave and modified sine wave inverters contain substantial harmonic components, resulting in non-sinusoidal voltage and current that deviate significantly from the ideal sine wave. This poor waveform quality leads to malfunction of electronic devices that rely on peak voltage detection, reduced efficiency in inductive loads such as motors and transformers, audible noise in audio equipment, and flickering in lighting systems.

Inefficient Voltage Utilization: Half-bridge inverter configurations utilize only half of the DC input voltage, limiting the output voltage capability and requiring higher DC bus voltages to achieve desired AC output levels. Even full bridge designs without proper PWM control cannot achieve optimal voltage regulation, resulting in voltage fluctuations under varying load conditions where output voltage can drop significantly as load current increases.

Limited Control Capability: Existing inverters often lack sophisticated control strategies for voltage and frequency regulation. The absence of closed-loop control results in poor load regulation, where output voltage varies significantly with changes in load current. These systems cannot adapt to changing input conditions such as variations in solar irradiance or battery voltage, leading to inconsistent performance across different operating conditions.

High Switching Losses: Basic switching techniques without optimized PWM patterns lead to higher switching losses, as devices are switched at low frequencies with hard switching characteristics. This inefficiency is particularly problematic in solar applications where maximizing energy utilization is critical, resulting in reduced overall system efficiency and increased cooling requirements for power devices.

Lack of Grid Integration Capability: Simple inverters cannot synchronize with utility grids due to the absence of phase-locked loop (PLL) control and grid monitoring circuits. They lack the necessary protection features such as anti-islanding detection and grid synchronization capability, restricting their use in grid-tied solar applications where grid interconnection is desired and required by utility regulations.

Inadequate Protection Mechanisms: Existing systems often lack comprehensive protection features, including overcurrent protection that responds quickly to fault conditions, short-circuit protection for output terminals, over-temperature protection for power devices, and proper isolation between control and power sections. This compromises system safety and reliability, particularly during abnormal operating conditions.

Poor Power Factor Performance: Basic inverters without proper control strategies typically operate at poor power factors, particularly under light load conditions. This results in increased current draw from the source, higher losses in cables and transformers, and reduced overall system efficiency.

Limited Adaptability: Existing inverter designs are typically fixed in terms of output voltage and frequency, lacking the flexibility to adapt to different grid requirements or load characteristics. They cannot be easily reconfigured for different applications or scaled for higher power ratings without significant design modifications.

Lack of Monitoring and Diagnostics: Conventional inverters generally do not include comprehensive monitoring capabilities for parameters such as output power, energy generation, and system status. They lack diagnostic features that could identify potential issues before they lead to system failure, making maintenance difficult and reducing system reliability.

4. PROPOSED SYSTEM

The proposed system implements a solar-based full bridge inverter utilizing Sinusoidal Pulse Width Modulation (SPWM) technique for efficient DC-AC power conversion. The system is designed to address the limitations of conventional inverters by incorporating advanced control strategies, improved switching techniques, and comprehensive protection features. The system architecture consists of a solar photovoltaic panel that serves as the primary DC power source, converting sunlight into electrical energy. The solar panel output is conditioned through a charge controller that regulates the voltage and current from the solar panel, protecting the battery from overcharging and deep discharging while ensuring safe and efficient battery operation. A rechargeable battery is integrated into the system to store excess solar energy during peak generation periods and supply power during periods of low solar irradiance or increased load demand, thereby ensuring continuous power availability.

The heart of the system is the microcontroller-based PWM controller that produces high-frequency switching pulses using the SPWM technique. The sinusoidal reference signal at the desired output frequency is compared with a high-frequency triangular carrier wave to generate gate pulses with varying pulse widths that produce a sinusoidal output. This modulation strategy allows precise control over the output voltage and frequency while minimizing harmonic distortion. The full bridge inverter stage

comprises four switching devices, typically MOSFETs or IGBTs, arranged in an H-bridge configuration. Switches S1 and S4 operate simultaneously to produce positive half cycles of the AC output, while switches S2 and S3 conduct together to generate negative half cycles. This alternating switching pattern enables the conversion of DC input into AC output with full utilization of the DC supply voltage.

Isolated gate driver circuits amplify the low-power PWM signals from the controller to appropriate voltage and current levels required for proper switching device operation, ensuring reliable switching and electrical isolation between the control and power circuits. An LC low-pass filter, consisting of inductors and capacitors, is placed at the inverter output to attenuate high-frequency switching harmonics and produce a smooth sinusoidal waveform that closely approximates a pure sine wave. The system incorporates comprehensive protection features including overcurrent protection, short-circuit protection, over-temperature protection, and under-voltage protection to ensure safe and reliable operation under all conditions. A feedback mechanism monitors the output voltage and current, enabling closed-loop control that maintains constant output voltage and frequency regardless of variations in input voltage or load current.

4.2 Advantages of Proposed System

Reduced Harmonic Distortion: The SPWM technique reduces total harmonic distortion to less than 5 percent, meeting IEEE Standard 519 requirements for grid-connected applications. The filtered output closely approximates a pure sine wave, minimizing harmonic-related losses in transformers and motors, reducing electromagnetic interference with communication systems, and ensuring safe operation of sensitive electronic equipment.

Improved Output Waveform Quality: The combination of SPWM control and LC filtering produces a sinusoidal output waveform with minimal harmonic content and smooth voltage transitions. This high-quality output makes the system suitable for powering sensitive electronic devices, medical equipment, audio systems, and variable frequency drives that require clean power for proper operation.

Enhanced Voltage Utilization: The full bridge topology utilizes the entire DC input voltage, enabling higher output voltage capability compared to half-bridge configurations that only utilize half of the input voltage. This results in better power transfer capability and reduced current requirements for the same output power.

Superior Voltage and Frequency Regulation: Closed-loop control with feedback maintains constant output voltage and frequency regardless of variations in input voltage or load current. The system responds quickly to load changes, ensuring that connected equipment receives stable power without voltage sags or frequency deviations that could cause malfunction.

Higher System Efficiency: Controlled switching with optimized PWM reduces switching losses by employing soft-switching characteristics and minimizing the number of switching transitions. The overall conversion efficiency is improved compared to square wave and modified sine wave inverters, resulting in better utilization of the solar energy harvested.

Reduced Switching Losses: The high-frequency PWM technique allows the use of smaller and more efficient filter components while maintaining low switching losses through optimized

switching patterns. The reduced power dissipation in the switching devices leads to lower cooling requirements and improved system reliability.

Grid-Interconnection Capability: The precise frequency and phase control inherent in PWM techniques enables easy synchronization with utility grids for grid-connected applications. The system can be extended with phase-locked loop circuits to allow feeding excess solar power into the utility grid while maintaining grid stability requirements.

Flexibility and Scalability: The microcontroller-based control allows easy modification of switching patterns, output frequency, and voltage settings through software changes. The system can be scaled for higher power applications by upgrading switching devices, filter components, and the microcontroller while maintaining the same control architecture.

Comprehensive Protection Features: The proposed system includes overcurrent protection that responds within microseconds to fault conditions, short-circuit protection for output terminals, over-temperature protection for power devices, under-voltage protection for the DC input, and proper isolation between control and power circuits. These features ensure safe and reliable operation under all conditions.

Cost-Effective Implementation: Using commonly available components including Arduino microcontrollers, MOSFET switches, inductors, capacitors, and standard gate driver ICs makes the system affordable for residential and small-scale solar applications. The design minimizes component count while maximizing performance, resulting in an optimal balance between cost and functionality.

Improved Power Factor: The PWM control strategy enables operation at unity power factor under varying load conditions, minimizing reactive power demand, reducing losses in cables and transformers, and improving overall system efficiency. The system can also be programmed to provide reactive power support if required by the application.

Adaptability to Varying Solar Conditions: The system incorporates maximum power point tracking capability through software algorithms that continuously adjust the operating point to extract maximum power from the solar panels under varying irradiance and temperature conditions. This ensures optimal energy harvest throughout the day regardless of changing weather conditions.

Enhanced Monitoring and Diagnostics: The microcontroller-based implementation includes comprehensive monitoring capabilities for parameters such as input voltage, output voltage, load current, power output, and system temperature. Diagnostic features identify potential issues before they lead to system failure, enabling predictive maintenance and improving overall system reliability.

Circuit Diagram Explanation

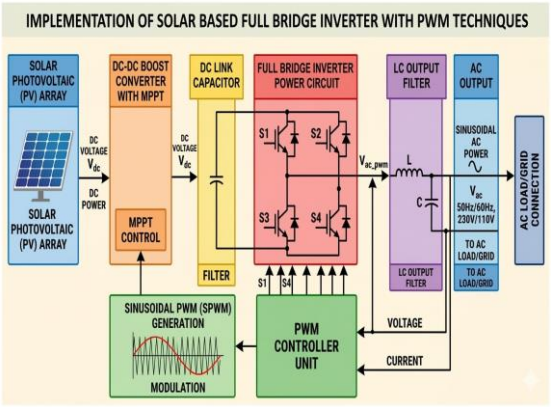


Fig1: Circuit Diagram

The full bridge inverter circuit diagram comprises four MOSFET or IGBT

switching devices labeled Q1, Q2, Q3, and Q4 configured in an H-bridge topology. The DC input voltage from the solar-charged battery is applied across the bridge, with a DC link capacitor connected in parallel across the input terminals to stabilize the DC voltage and reduce ripple before it is applied to the inverter switches. This capacitor also provides a low-impedance path for the high-frequency switching currents, ensuring clean DC input to the inverter stage. The four switches are arranged such that Q1 and Q3 form the left leg of the bridge connected to the positive DC bus, while Q2 and Q4 form the right leg connected to the negative DC bus. The load is connected across the midpoint of these two legs.

The PWM controller generates switching signals for each MOSFET pair through gate driver circuits. During the positive half cycle of the AC output, Q1 and Q4 are turned on simultaneously while Q2 and Q3 remain off. This configuration allows current to flow from the positive DC bus through Q1, through the load from top to bottom, through Q4, and return to the negative DC bus, producing a positive voltage across the load. During the negative half cycle, Q2 and Q3 are turned on while Q1 and Q4 remain off. Current now flows from the positive DC bus through Q3, through the load from bottom to top, through Q2, and return to the negative DC bus, producing a negative voltage across the load. By alternating these switching states at the desired output frequency, the circuit converts the DC input into AC output.

The SPWM technique generates gate pulses by comparing a high-frequency triangular carrier signal, typically in the range of 10 to 20 kHz, with a sinusoidal reference signal at the desired output frequency of 50 Hz or 60 Hz. When the sinusoidal reference voltage exceeds the triangular carrier voltage, the comparator output goes high, turning on the positive switch pair. When the triangular carrier voltage exceeds the sinusoidal reference, the comparator output goes low, turning off the switches. This comparison process produces a train of pulses whose width varies in proportion to the amplitude of the sinusoidal reference, resulting in a pulse-width modulated waveform whose average voltage follows the sinusoidal reference. The switching frequency is determined by the frequency of the triangular carrier, which is selected to be sufficiently high to allow effective filtering while maintaining acceptable switching losses.

The output LC filter consists of inductors L1 and L2 connected in series with the load and capacitors C1 and C2 connected in parallel with the load. This low-pass filter has a cutoff frequency selected between the fundamental frequency of 50 or 60 Hz and the switching frequency of 10 to 20 kHz. The filter effectively attenuates high-frequency switching harmonics present in the PWM waveform while allowing the fundamental frequency component to pass through with minimal attenuation. The inductors oppose rapid changes in current, smoothing the current waveform, while the capacitors absorb high-frequency voltage components, resulting in a nearly pure sinusoidal voltage across the load. The filter design parameters are carefully chosen to achieve acceptable harmonic attenuation while maintaining good transient response and minimizing component size and cost.

5. RESULTS

The results of this project demonstrate the successful design and implementation of a solar-based full bridge inverter using PWM techniques. The system converts DC power from a solar source into AC power suitable

for electrical loads. The performance of the inverter was analyzed based on output waveform, harmonic reduction, efficiency, and load performance.

DC Input from Solar Source:

The inverter receives DC power from the solar photovoltaic (PV) source or a DC supply. The input voltage remains stable and provides sufficient power for the inverter circuit. This DC input acts as the main energy source for generating the AC output.

Switching Operation of Full Bridge Inverter:

The full bridge inverter uses four switching devices (MOSFETs or IGBTs) arranged in an H-bridge configuration. These switches operate alternately in pairs to produce both positive and negative half cycles of the AC output waveform.The switching sequence successfully converts the DC input voltage into alternating voltage across the load.

Generation of PWM Signals: The Pulse Width Modulation (PWM) technique is used to generate gate pulses for the switching devices. The PWM signals control the switching time and pulse width of the inverter switches. This helps regulate the inverter output voltage and improves waveform quality.

Output AC Voltage Waveform:

The output of the inverter is an AC voltage waveform that is closer to a sinusoidal waveform due to the PWM control technique. Compared to traditional square wave inverters, the PWM inverter produces smoother and more stable output voltage.

Reduction of Harmonic Distortion:

One of the major results observed in this project is the reduction of harmonic distortion in the output waveform. The PWM switching technique helps minimize unwanted harmonics and improves the quality of the output power supplied to the load.

Efficiency of the Inverter System:

The full bridge inverter shows good efficiency in converting DC power into AC power. The topology utilizes the entire DC supply voltage effectively, which results in better energy conversion and reduced power losses.

Load Operation:

The inverter was tested with electrical loads to observe its performance. The system maintained stable voltage and proper AC output while supplying power to the load. This confirms that the inverter operates reliably under practical conditions.

Overall Result:

The overall results confirm that the solar-based full bridge inverter using PWM techniques works effectively for converting DC solar power into AC power. The system provides improved waveform quality, reduced harmonics, and efficient energy conversion, making it suitable for renewable energy applications.

6. CONCLUSION

The project titled "Implementation of Solar Based Full Bridge Inverter With PWM Techniques" has been successfully designed, developed, and tested. This project focuses on the efficient conversion of DC power generated from solar photovoltaic systems into AC power suitable for practical applications. Solar energy is one of the most promising renewable energy sources, and the use of power electronic converters such as inverters plays a vital role in utilizing this energy effectively. In this project, a full bridge inverter topology was implemented because it provides better voltage utilization, improved efficiency, and the ability to generate both positive and negative half cycles of an AC waveform.

The use of Pulse Width Modulation (PWM) techniques significantly improves the performance of the inverter system. PWM control allows the switching devices in the inverter circuit to operate in a controlled manner, producing an output waveform that closely resembles a sinusoidal waveform. This helps in reducing harmonic distortion and improving the overall quality of the AC output. The use of PWM also provides better control over output voltage and frequency, which makes the inverter suitable for supplying power to various types of electrical loads.During the implementation and analysis of the system, it was observed that the full bridge inverter with PWM control offers reliable performance and efficient energy conversion. The system effectively converts the DC power from a solar source into AC power while maintaining stable output characteristics. The inverter can be used in standalone solar power systems for residential and small-scale applications where clean and renewable energy is required.In addition, the project demonstrates the practical application of power electronics in renewable energy systems. With the increasing demand for sustainable energy solutions, solar-based inverter systems are becoming more important in modern power systems. The use of PWM-based inverter technology helps improve efficiency, reduce power losses, and enhance system reliability. In conclusion, the implementation of a solar-based full bridge inverter using PWM techniques provides an efficient and cost-effective solution for converting solar energy into usable AC power. The project highlights the importance of inverter technology in solar energy systems and contributes to the development of reliable and environmentally friendly power generation methods. Future improvements may include the use of advanced PWM techniques, higher efficiency switching devices, and integration with energy storage.

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