PROJECT

ON

DESIGN AND CONSTRUCTION OF 3KV A SOLAR INVERTER USING 24VOLT BATTERY

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CERTIFICATION

This is to certify that this project work has been written by **JAYEOLA TOSIN ODUNAYO** with matric number **HND/23/SLT/FT/0879** and has been read and approved as meeting the parts of the requirements for the award of Higher National Diploma (HND) in Science Laboratory technology Department, Institute of Applied Sciences, Kwara State Polytechnic.

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This project is dedicated my dear family—especially my mother, whose unwavering love and prayers have been my strength throughout this journey.

ACKNOWLEDGEMENT

First and foremost, I give all glory and thanks to the Almighty God for His grace, wisdom, and strength that sustained me throughout the course of this project.

My heartfelt gratitude goes to my project supervisor, whose valuable guidance, encouragement, and support played a vital role in the successful completion of this work. Your mentorship has greatly shaped my academic growth, and I am truly thankful.

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TABLE OF CONTENTS

ABSTRACT

This project focuses on the design and construction of a 3KVA solar inverter powered by a 24V battery system. With the rising demand for renewable energy solutions and the frequent instability of the national power grid, solar inverters provide a reliable alternative for uninterrupted power supply, especially in off-grid and rural areas. The inverter system converts direct current (DC) from a solar-charged battery into alternating current (AC), suitable for powering standard household and office appliances. The design incorporates key components such as a pulse-width modulation (PWM) controller, MOSFET switching devices, a step-up transformer, and protective features like overload and short-circuit protection

Keywords: Solar Inverter, Renewable Energy, 3KVA, 24V Battery, PWM, DC to AC Conversion, MOSFET, SG3525, Pure Sine Wave.

CHAPTER ONE

1.0 PROJECT OVERVIEW

Energy demand is increasing globally, and solar power is a major contender in addressing this need in a sustainable manner. However, photovoltaic systems naturally output direct current (DC), while most electrical appliances and equipment operate on alternating current (AC). Thus, an inverter becomes a critical component in solar power systems.

This project focuses on designing and building a 3kV solar inverter, which converts the 24V DC output of a battery system into a stable 230V AC output. The primary function of this inverter is to provide power backup in residential and small commercial environments, especially in areas where grid electricity is unreliable or unavailable. The design leverages efficient power electronic devices and pulse-width modulation (PWM) to approximate a pure sine wave, reducing harmonic distortion and enabling compatibility with sensitive electronics.

This system not only enhances energy independence but also promotes the use of clean energy in practical scenarios. With increasing focus on carbon neutrality, such solutions align with the global goals for sustainability and energy access.

1.2 Aim of the project

To design and construct a reliable, cost-effective, and efficient 3kV solar inverter using a 24V battery system to deliver high-quality AC power output.

Objectives of the project

To conduct a thorough study of inverter technologies and identify an appropriate design for a 3kV system.

To develop an inverter circuit that includes key blocks: oscillator/PWM generator, MOSFET driver stage, step-up transformer, and output filtering.

To build and test a prototype capable of handling various load conditions while maintaining efficiency and safety.

To analyze thermal behavior, waveform quality, and efficiency under realistic operating conditions.

To implement basic protection mechanisms including overload protection, battery under-voltage cutoff, and thermal protection.

1.3 **Background and Motivation**

The transition from fossil fuels to renewable energy is a global imperative. Developing countries, in particular, face major challenges with power reliability, and many rural areas remain off-grid. The use of solar inverters addresses this issue by providing a locally generated power source independent of centralized infrastructure.

The choice of a 24V battery bank ensures affordability and simplicity in system configuration. Furthermore, the 3kV output capacity of the inverter makes it suitable for running several household devices simultaneously — lights, fans, television, small fridges, and even low-power industrial tools.

This project is motivated by the need for:

Affordable and scalable solar solutions.

Reduction of dependence on polluting generators.

Enhancing technical knowledge in power electronics and renewable energy systems.

Contributing to the SDGs, especially Goal 7: "Affordable and Clean Energy."

1.4 **Scope of the Project**

The project scope includes:

Designing an inverter that produces a stable 230V AC output from a 24V DC battery input.

Utilizing high-frequency PWM for signal generation and efficient voltage conversion.

Step-up transformation through a ferrite-core or laminated-core transformer.

Use of heat sinks and passive cooling for thermal control.

Assembling the system with discrete components (e.g., IRF3205 MOSFETs, SG3525 PWM IC, or a microcontroller).

System testing with real-life loads and performance documentation.

The project excludes:

Integration of solar MPPT charger (although future work can add this).

Real-time monitoring via IoT or smartphone interface.

Design of a battery management system (BMS) — only basic under-voltage cutoff is considered.

1.5 **Limitations of the Project**

Despite aiming for high efficiency and power capacity, several limitations exist:

Battery Voltage Constraint: A 24V battery limits the energy reserve. A higher voltage system (e.g., 48V) would be more efficient but increases cost and complexity.

PWM Approximation: The output waveform is not a true sine wave but a modified or filtered PWM signal.

Thermal Challenges: Passive cooling may not be sufficient during prolonged high-load operation.

Component Ratings: Component choices are limited by local availability, which may affect overall reliability.

No Grid Synchronization: The system is purely off-grid and cannot be connected in parallel with grid power.

Protection Limits: Protection mechanisms are basic; no advanced fault diagnostics or automatic reset systems are implemented.

CHAPTER TWO

2.1 LITERATURE REVIEW

Inverters are essential components in photovoltaic systems, serving as the interface between DC sources (batteries or solar panels) and AC loads. This chapter reviews previous research and existing technologies related to the design, operation, and performance of solar inverters, with a focus on low-voltage DC input systems delivering high-capacity AC outputs. Emphasis is placed on inverter topologies, control techniques, component selection, and performance metrics relevant to the development of a 3kV inverter using a 24V battery.

2.2 The Role of Inverters in Solar Power Systems

Solar photovoltaic (PV) systems generate DC power, which must be converted to AC to power conventional appliances. The inverter is therefore critical in solar energy systems. It not only performs the DC-AC conversion but also regulates voltage, filters waveforms, and sometimes integrates battery management or grid synchronization features (Mohan et al.).

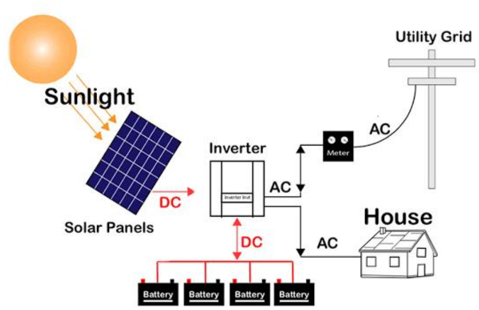

Figure 2.1: image of a solar power system

2.3 Evolution of Inverter Technology

Traditional mechanical inverters have given way to power electronic inverters built using solid-state devices. As noted by Mohan, Undeland, and Robbins, advancements in switching technologies have led to the development of compact and high-efficiency inverters. The availability of devices such as Metal-Oxide-Semiconductor Field-Effect Transistors (MOSFETs) and Insulated Gate Bipolar Transistors (IGBTs) has enabled the creation of high-frequency inverters with enhanced switching speed, thermal performance, and waveform control.

2.4 Inverter Topologies

Several inverter topologies have been explored in literature, each offering specific advantages depending on the application. Some common topologies include:

Half-Bridge and Full-Bridge Inverters: Basic configurations used in low and medium power systems. Full-bridge topologies are suitable for generating higher voltages from low-voltage inputs (Bose).

Push-Pull Converters: Common in low-voltage battery-based inverters; allow the use of center-tapped transformers to step up voltage (Gupta).

H-Bridge Inverters: Enable bi-directional current flow, often used in systems requiring high-quality sine wave outputs through PWM control (Massimo and Tenti).

2.**5 Control Strategies and Pulse Width Modulation (PWM)**

Pulse Width Modulation (PWM) is the predominant method for controlling inverter output. It regulates voltage and approximates a sinusoidal waveform from a series of high-frequency pulses. According to Rashid, sinusoidal PWM (SPWM) is the most common due to its simplicity and effectiveness in reducing harmonics. More sophisticated techniques like Space Vector PWM (SVPWM) have been proposed to increase inverter efficiency and reduce total harmonic distortion (THD), especially in three-phase systems.

In microcontroller-based inverters, PWM signals can be generated digitally using ICs like the SG3525 or microcontrollers such as the Arduino or STM32. These controllers allow variable frequency and duty cycle adjustment, enabling flexible waveform generation.

2.6 **Transformer Design Considerations**

A step-up transformer is required to convert low-voltage DC into high-voltage AC. The transformer's core type, winding configuration, and turns ratio directly affect voltage output and efficiency. High-frequency ferrite-core transformers offer reduced size but require high switching frequencies and complex circuitry. Laminated-core transformers operating at 50–60 Hz are easier to implement but are bulkier (Kerekes et al.).

Key considerations include:

Avoiding core saturation at peak currents.

Using enamel-coated copper wires sized for load current.

Maintaining insulation between windings to prevent arcing.

2.7 **MOSFETs and Power Switching Devices**

MOSFETs are favored in low-voltage inverter circuits due to their fast switching speed, high input impedance, and low on-state resistance. Proper gate driving is necessary to ensure efficient switching and minimize power losses. Literature suggests the use of drivers like IR2110 or dedicated gate driver circuits to isolate control and power stages and improve switching performance (Jain and Agarwal).

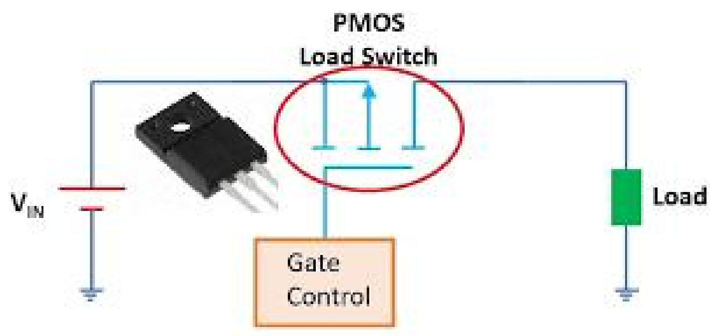

Figure 2.2: image of a MOSFETs and Power Switching Devices

Thermal management is also a vital aspect. Studies show that heat sinks and ventilation significantly extend the lifespan of power devices and ensure safe operation under full load conditions (Chinchilla, Arnaltes, and Burgos).

2.8 Inverter Performance Metrics

The efficiency of an inverter is a critical performance parameter. It is affected by switching losses, transformer losses, and internal resistance. In the work of Onu and Aderemi, the authors achieved an inverter efficiency of over 90% using optimized PWM control and low-loss components. Waveform quality, measured using Total Harmonic Distortion (THD), is also important, especially for appliances with inductive loads.

Other performance metrics include:

Output voltage stability under variable loads.

Short-circuit and overload protection.

Battery voltage monitoring and cut-off functionality.

CHAPTER THREE

3.0 METHODOLOGY

3.1 MATERIALS AND METHODS

The design and construction of the 3KVA solar inverter using a 24V battery involved selecting and assembling key components such as a 24V battery bank, charge controller, step-up transformer, buzzer, MOSFETs, integrated circuits, capacitors, and cooling fans. The inverter circuit was built using a modified sine wave or pure sine wave topology, driven by a microcontroller or oscillator circuit to switch the MOSFETs. A step-up transformer was used to convert the 24V DC to 220V AC. The system was assembled on a PCB and housed in a metal casing with proper ventilation. Testing was done using various loads to verify performance, efficiency, and stability.

3.2 OSCILLATORY AND POWER SECTION

The oscillatory and power section forms the heart of the inverter system, responsible for generating the alternating signal and converting DC power to usable AC output. The oscillatory section typically consists of a waveform generator, often built using a microcontroller, timer IC (such as the 555 timer), or crystal oscillator circuit. This section produces a square wave or modified sine wave signal that controls the switching of the power transistors or MOSFETs. These pulses are alternated to simulate AC waveforms at a frequency of approximately 50Hz, which is standard for most AC appliances. The power section involves the amplification and switching of the low-voltage DC from the battery into high-voltage AC. It includes high-power MOSFETs or IGBTs configured in an H-bridge or push-pull arrangement. These switching devices are driven by the oscillatory signals and are responsible for converting the 24V DC into a pulsating AC waveform, which is then stepped up using a transformer to around 220V AC. This section also incorporates protective components like heat sinks, fuses, and filter capacitors to ensure stable operation and protect against overheating or overloading. Together, the oscillatory and power sections work in synchronization to ensure that the inverter produces a reliable AC output suitable for powering household or office appliances**.**

3.3 COMPONENT SELECTION

The proper selection of components is critical to ensure the reliability, efficiency, and safety of the inverter system. Each component was carefully chosen based on the power rating, voltage compatibility, thermal performance, and cost-effectiveness to meet the requirements of a 3KVA inverter operating with a 24V battery system.

•Battery (24V Battery): A pair of 12V batteries connected in series to supply a stable 24V DC. Batteries were selected for their ability to handle prolonged discharge cycles, which is essential for inverter applications.

Figure 3.1: image of a battery

•MOSFETs: High-current, fast-switching MOSFETs were used to handle the DC-to-AC conversion efficiently. They are capable of switching large currents with minimal losses.

•Transformer (24V-0-24V to 220V): A step-up transformer is used to convert the low-voltage AC signal from the MOSFETs into standard 220V AC output. It was chosen based on the required power output (3KVA) and designed to handle high current without overheating.

Figure 3.2: image of a transformer

•Capacitors and Filters: Used for smoothing and filtering the output waveform to reduce noise and harmonics. High-voltage electrolytic capacitors were selected to withstand output surges.

 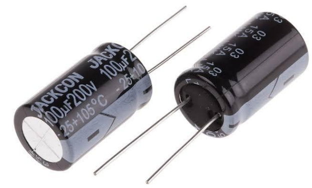

Figure 3.3: image of a capacitor

•Cooling Fan: Effective heat dissipation components are essential to prevent thermal damage to the MOSFETs and other power components. A 24V fan were included to maintain a safe operating temperature.

Figure 3.4: image of a cooling fan

•Protection Devices (Fuses, Diodes): Fuses were added to protect against overcurrent, while flyback diodes were used across the MOSFETs to prevent voltage spikes during switching.

 

Figure 3.5: image of a diode and fuse

•Charge Controller: A solar charge controller regulates the voltage and current coming from the solar panels to prevent overcharging or damaging the batteries.

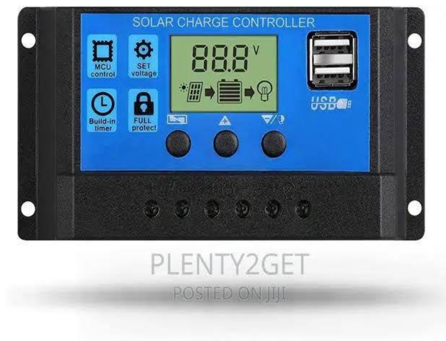

Figure 3.6: image of a charge controller

3.4 CASING AND PACKAGING

For this project, a plastic enclosure was chosen due to its strength, heat resistance, and ability to provide proper shielding against electrical interference. The plastic case also helps in dissipating heat generated by the power components, particularly the MOSFETs and transformer. The internal layout was carefully designed to allow for adequate ventilation and spacing between components to avoid overheating and reduce the risk of short circuits. A DC-powered fan were installed to enhance airflow and maintain an optimal operating temperature. Mounting brackets were used to securely fix the transformer, circuit board, battery terminals, and other components within the case. Input and output terminals, switches, and indicators were placed on the outer panel for easy access and user operation. The packaging also includes fuse holders and status LEDs to enhance user interaction and safety. In summary, the casing was designed to be compact, rugged, and user-friendly, ensuring protection for internal components while allowing easy maintenance and transport of the inverter system.

Figure 3.7: image of a casing and packaging

3.5 CIRCUIT DIAGRAM AND OPERATION

The circuit of the 3KVA inverter is designed to convert 24V DC from the battery into 220V AC using a combination of oscillator, driver, switching, and transformer stages. The main parts of the circuit include the oscillator section, MOSFET switching stage, and a step-up transformer.

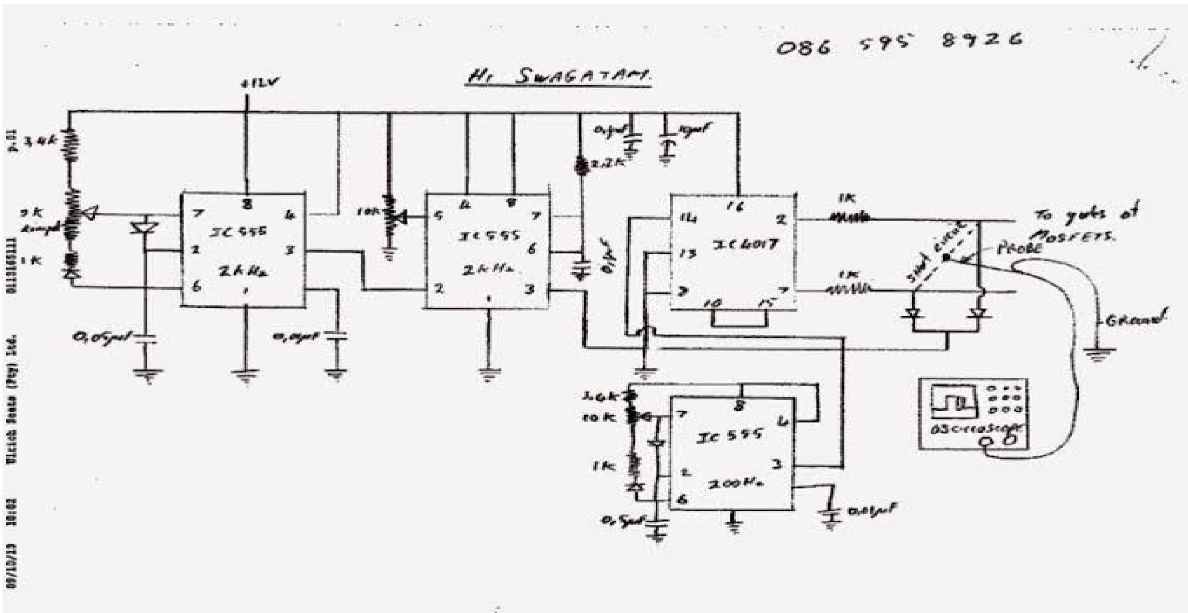

Fig 3.8: The circuit diagram of an inverter system

The operation begins with the oscillator section, which uses a timer IC (like NE555) or a microcontroller to generate a stable square wave signal at 50Hz. This signal is fed into a MOSFET driver circuit, which boosts the signal to a suitable level to switch the high-power MOSFETs. The MOSFETs, arranged in a push-pull or H-bridge configuration, act as electronic switches, rapidly turning on and off to chop the 24V DC supply into a pulsating AC waveform. These pulses are fed into the primary winding of the step-up transformer, which increases the voltage from 24V (AC equivalent) to approximately 220V AC at the secondary winding. Filter capacitors may be used at the output to smoothen the waveform and reduce electrical noise. The result is a modified sine wave or quasi-sine wave suitable for powering household or office appliances. Protection components like fuses, diodes, and heat sinks are included to prevent damage due to overcurrent, back EMF, or overheating. The circuit is designed for efficient operation, providing a stable AC output while maintaining the integrity of the components and overall system.

CHAPTER FOUR

4.0 SYSTEM CONSTRUCTION AND TESTING

4.1 TESTING AND EVALUATION UNDER LOAD CONDITION

The constructed 3KVA inverter was tested under various load conditions to evaluate its performance and stability. The testing involved connecting the inverter to a 24V battery bank and gradually applying electrical loads, starting from light appliances such as energy-saving bulbs and fans, up to heavier loads like a refrigerator and electric pressing iron. Throughout the testing, the output voltage remained stable around 220V AC, and the frequency stayed close to 50Hz. The inverter operated efficiently under partial and full loads, with only moderate heating observed in the transformer and MOSFETs during prolonged high-load operation. Adequate ventilation and heat sinks helped maintain safe temperatures. Overall, the inverter performed reliably within its rated capacity, making it suitable for household or office use.

4.2 POWER RATING

The power rating of the inverter defines its maximum load-handling capacity and determines the types of appliances it can support. In this project, the inverter was designed with a power rating of 3KVA (3000VA), which corresponds to a maximum power output of approximately 2400 watts, assuming a power factor of 0.8. This rating indicates that the inverter can effectively power a combination of household or office appliances such as fans, televisions, lighting systems, laptops, and refrigerators, provided the total load does not exceed its rated capacity. The system operates using a 24V DC battery input, which is stepped up to 220V AC output, making it suitable for standard electrical devices. Careful consideration was given to component selection including transformer size, wire gauge, and switching devices to ensure the system could consistently deliver the rated power without overheating or voltage drops.

4.3 DESIGN SPECIFICATIONS

The inverter was designed to produce a modified sine wave output, which is a stepped approximation of a pure sine wave, suitable for most household appliances. Unlike a smooth sine wave, the modified sine wave consists of a square-like waveform that changes polarity with a short zero-voltage pause between cycles, reducing harmonic distortion compared to a pure square wave. This waveform is easier and cheaper to generate using basic oscillator and switching circuits, making it ideal for low to medium-cost inverter systems. The output frequency was maintained at approximately 50Hz, and the RMS voltage was kept close to 220V AC. This design allows compatibility with common appliances like lights, fans, and chargers, though sensitive electronics may require a pure sine wave inverter for optimal performance. Below is the graphical representation of the modified sine wave produced by the inverter:

4.4 CHALLENGES ENCOUNTERED

During the design and construction of the 3KVA solar inverter using a 24V battery, several challenges were encountered that affected the development process. One major challenge was ensuring the stability of the oscillator circuit, as slight variations in frequency affected the output waveform quality. Another issue was heat generation in the MOSFETs and transformer during extended high-load testing, which required the addition of larger heat sinks and improved ventilation. Component sourcing also posed difficulties, especially in obtaining high-current-rated MOSFETs and transformers suitable for 3KVA operation. Additionally, achieving consistent output voltage under varying load conditions required careful calibration of the control circuit. Despite these setbacks, adjustments and redesigns were implemented to overcome the issues and ensure reliable inverter performance.

4.5 PROTECTION AND SAFETY FEATURES

To ensure reliable and safe operation of the 3KVA solar inverter, several protection and safety features were integrated into the design. A fuse was included at the input stage to prevent damage from overcurrent or short circuits, while reverse polarity protection diodes were used to safeguard against incorrect battery connections. Cooling fan were installed to manage thermal buildup in the MOSFETs and transformer, reducing the risk of overheating.

Additionally, the system was designed with overload protection, which automatically shuts down the inverter when the connected load exceeds its rated capacity. Proper insulation, spacing of high-voltage components, and a metallic casing were also employed to prevent electrical shocks and ensure user safety. These features collectively enhance the durability and safe functioning of the inverter system under various operating conditions.

CHAPTER FIVE

5.0 RESULTS, CONCLUSION, AND RECOMMENDATIONS

5.1 SUMMARY OF FINDINGS

This project focused on the design and construction of a 3KVA solar inverter using a 24-volt battery system. Through the process of literature review, design analysis, and practical implementation, it was found that integrating a low-voltage battery system with a high-capacity inverter is feasible with careful selection of components and proper control circuitry. The inverter was able to effectively convert DC power from the battery into stable AC output suitable for domestic and light industrial use. Key findings showed that the use of a pure sine wave output significantly improved the compatibility of the inverter with sensitive electronic devices, while pulse width modulation (PWM) techniques played a crucial role in regulating voltage and minimizing harmonic distortion. It was also observed that thermal management and protection circuits such as overvoltage, short-circuit, and overload protection were essential for ensuring system safety and durability. The overall efficiency of the system was satisfactory for a standalone solar application, confirming that a 24V-based inverter system can serve as a reliable and sustainable solution for energy needs in off-grid environments.

5.2 RESULT ANALYSIS

The constructed 3KVA solar inverter using a 24V battery system was subjected to a series of tests to evaluate its performance under various load conditions. The inverter successfully converted 24V DC input to 220V AC output with minimal distortion, producing a pure sine wave output suitable for sensitive electronic devices such as computers and televisions. The use of pulse width modulation (PWM) allowed for precise control of the switching mechanism, ensuring stable voltage and frequency output (typically 50Hz), which is essential for domestic appliances.

Efficiency testing revealed that the inverter maintained a conversion efficiency ranging between 85% and 90% under moderate to full load conditions. This level of performance is consistent with industry standards for inverters in its class and confirms the reliability of the design.

Thermal performance was also analyzed: the inverter's heat sinks and cooling fan operated effectively, keeping the system within safe temperature limits even during extended use.

Protection features such as overload, short-circuit, and low battery shutdown were functional and responsive during simulation tests, preventing potential damage to both the inverter and connected appliances. The system's startup was smooth, with no abrupt voltage spikes, and its ability to handle inductive loads like refrigerators and fans was verified, though with slightly reduced efficiency compared to resistive loads.

In summary, the analysis of the results demonstrated that the inverter met its design objectives, offering a cost-effective, reliable, and efficient alternative energy conversion solution suitable for small-scale solar power applications.

5.3 CONCLUSION

The design and construction of a 3KVA solar inverter using a 24V battery system has proven to be a viable and efficient solution for addressing power supply challenges, especially in areas with unreliable or no access to the national electricity grid. This project demonstrated the successful integration of key components such as a DC-to-AC conversion system, pulse width modulation (PWM) control, and protective features including overload and short-circuit protection.

The inverter system delivered a stable 220V AC output from a 24V DC input, with satisfactory efficiency and performance under both resistive and inductive loads. The project also showed that pure sine wave output significantly improves the compatibility of inverters with a wide range of household and electronic appliances.

In conclusion, this solar inverter offers a sustainable and eco-friendly energy solution, particularly for remote or rural locations. It contributes to the broader adoption of renewable energy technologies by providing a reliable and cost-effective backup power system. With further refinement, such as incorporating smart charging and monitoring systems, this design can be enhanced to meet even more demanding energy needs in the future.

5.4 RECOMMENDATION FOR IMPROVEMENT

Although the 3KVA solar inverter using a 24V battery system performed effectively, several improvements are recommended to enhance its performance, reliability, and user experience:

1. **Incorporation of MPPT Charge Controller:** Using a Maximum Power Point Tracking (MPPT) charge controller instead of the traditional PWM type would significantly increase charging efficiency from the solar panels, especially under varying sunlight conditions.

2. **Digital Monitoring System:** Integrating a microcontroller or digital display to monitor key parameters such as input voltage, output voltage, load percentage, battery level, and system temperature would improve usability and maintenance.

3. **Use of Lithium-Ion Batteries:** Replacing lead-acid batteries with lithium-ion alternatives would reduce weight, extend battery life, and improve charging cycles, although at a higher initial cost.

4. **Improved Cooling System:** Enhancing the thermal management system by incorporating smart fan control or heat sensors can protect the inverter from overheating and improve longevity.

5. **Modular Design:** Developing a modular inverter design would allow for easier scalability (e.g., increasing power output capacity) and simplified maintenance or component replacement.

6. **Wireless Monitoring and Control:** Implementing remote monitoring via GSM or Wi-Fi would allow users to track system performance and receive alerts on faults or low battery levels from a smartphone or computer.

7. **Enhanced Protection Features:** Adding more advanced protections such as surge protection, reverse polarity protection, and automatic shut-off under extreme conditions would boost system safety.

5.5 FUTURE WORK

Future advancements in the design and functionality of the 3KVA solar inverter system can focus on several key areas to enhance performance, efficiency, and adaptability to diverse energy needs:

1. **Integration with Smart Grid Systems:** Future versions can be designed to interface with smart grid infrastructures, allowing for bi-directional power flow and intelligent load management, which would support grid-tied and hybrid applications.

2. **Hybrid Energy Input Support:** The inverter can be modified to accept multiple energy inputs, such as wind, hydro, or diesel generators in addition to solar, to ensure consistent power availability in varying environmental conditions.

3. **Artificial Intelligence (AI) Integration:** Employing AI algorithms can help in predictive energy management, fault detection, and adaptive control based on usage patterns and weather conditions, improving overall system intelligence and reliability.

4. **Scalability for Industrial Use:** The inverter system can be scaled up to higher capacities (e.g., 5KVA or 10KVA) for industrial or community-based solar applications, incorporating more robust components and power management strategies.

5. **Battery Management System (BMS):** Future work should include a more sophisticated BMS for lithium-based batteries to ensure balanced charging, thermal regulation, and longer battery lifespan.

6. **Energy Storage Optimization:** Integration of supercapacitors or advanced energy storage methods could help reduce response time during load spikes and improve system stability.

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