PROJECT

ON

DESIGN AND CONSTRUCTION OF 3KV A SOLAR INVERTER USING 24.VOLTBATTERY

JAYEOLA TOSIN ODUNAYO

HND/23/SLT/FT/0879

SUBMITTED TO THE

DEPARTMENT OF SCIENCE
LABORATORY TECHNOLOGY
[PHYSICS AND ELECTRONICS UNIT]
INSTITUTE OF APPLIED SCIENCE,

KWARA STATE POLYTECHNIC,ILORIN

IN PARTIAL FULFILLMENT FOR THE

AWARD OF HIGHER NATIONAL

DIPLOMA [HND] IN SCIENCE

LABORATORY TECHNOLOGY

SUPERVISED BY

MR. AGBOOLA A.O

2024/2025 SESSION

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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.).

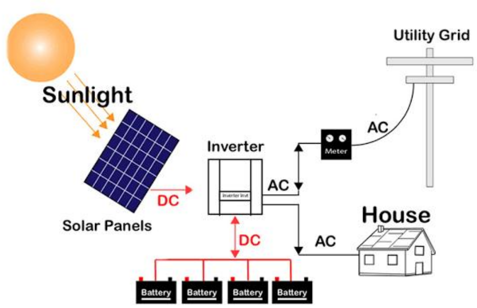

Figure 1: image of a solar power system

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).

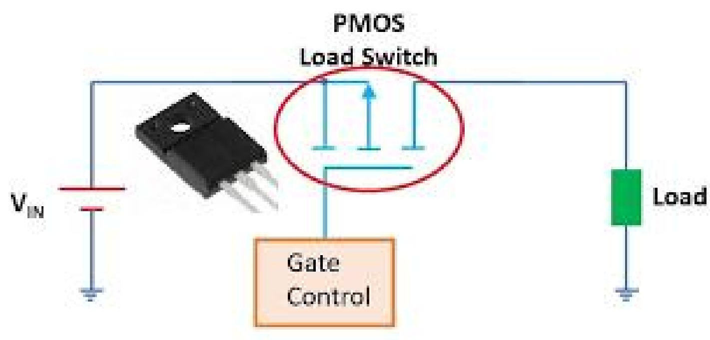

Figure 2: image of a MOSFETs and Power Switching Devices

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.

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