TITLE PAGE

DESIGN AND CONSTRUCTION OF 1.5KVA MOBILE INVERTER SYSTEM WITH MULTI-OUTPUT CAPABILITY AND ENERGY STORAGE OPTIMIZATION

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CERTIFICATION

Design and Construction of 1.5kVA Mobile Inverter System with Multi-Output Capability and Energy Storage Optimization"

was diligently carried out by ENIOLA TOSIN EMMANUEL (HND/23/EEE/FT/0091) a student of the Department of Electrical Electronics Engineering, Institute of Technology, in partial fulfillment of the requirements for the award of the Higher National Diploma (HND) in Electrical Electronics Engineering

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DEDICATION

All praise and gratitude are due to Almighty God, whose infinite mercy, guidance, and grace made this work possible.

I dedicate this project to my beloved parents, Mr. and Mrs. Eniola, for their unconditional love, prayers, and constant support throughout my academic journey.

I also extend my heartfelt appreciation to my supervisor, Engr. Jimoh A. A., whose valuable guidance, encouragement, and mentorship contributed greatly to the success of this project.

May this work reflect the efforts and sacrifices of all who stood by me.

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ABSTRACT

The increasing demand for reliable and portable power supply systems has driven the need for efficient inverter designs with energy storage optimization. This project focuses on the design and construction of a 1.5kVA mobile inverter system with multi-output capability and optimized energy storage to cater to various loads efficiently.

The system converts DC power from the battery bank to AC power, providing a stable 220V AC output suitable for household appliances, office equipment, and other electronic devices. The inverter incorporates advanced features such as multi-output terminals for simultaneous powering of multiple devices and an intelligent energy storage system to maximize battery life and performance.

Key components of the system include a modified sine wave inverter circuit, battery charging unit, automatic changeover switch, and energy management controller. The system was constructed using locally available components, making it cost-effective and easily maintainable.

Testing and performance analysis revealed that the inverter operates efficiently within the rated capacity, with minimal energy losses and improved energy utilization. The mobility of the system, combined with its optimized energy storage capability, makes it suitable for both residential and small-scale industrial applications where a stable power supply is needed during outages or in off-grid locations.

This project demonstrates the practicality of developing portable and sustainable power systems to meet the growing energy needs of modern society.

TABLE OF CONTENT

CHAPTER ONE

1.1 INTRODUCTION

Electrical power supply is one of the key prime mover of the local economy in Nigeria, its ranges of application in locals shops major in apprenticeship like: Salon, Welding, Grinding, Dry cleaning services, Computer Services, Hospital, Homes, Offices and Schools amongst other notables organizations that require electrical power systems to function are not exempted. Alternatively, electrical generator set has played tremendous roles in creating back up to the mains utility power system. However, the recent hike and fluctuation in the prices of the Motor Premium Spirit (PMS) in Nigeria and the quest for greener climate has necessitated the shift to renewable energy.

Solar energy system is one of the popular renewable energy system, and it applicability in providing alternative to the mains power system has been explore in recent years. This project will therefore take the exploration to another level by designing and constructing mobile inverter system with multi-input capability and energy storage optimization. The project aim to develop a versatile and efficient power system that will substitute the conventional gasoline generator set by addressing the growing need for reliable and sustainable energy in various applications, The project seeks to tackle the challenges of intermittent renewable energy sources, energy storage limitations, and the need for flexible power supply systems that can adapt to different input sources and loads. This innovative system will have far-reaching implications in areas such as remote power supply, emergency response situations and where access to reliable and efficient power is crucial. This project will help reduce carbon emissions, decrease dependence on fossil fuels, and improve energy access and security in various sectors.

There are existing mobile inverter systems that have been developed, but they often have limitations in terms of scalability, efficiency, and adaptability, For instance some systems are designed for specific applications, such as solar-powered water pumping systems, while others are limited by their inability to accept multiple input sources simultaneously. Moreover, many existing systems lack advanced energy storage optimization systems, leading to reduced efficiency and increased energy waste. In contrast, this project distinguishes itself through its modular design, allowing for easy scalability and adaptability to various applications. Additionally, the system's advanced energy storage optimization systems and ability to accept multiple input sources simultaneously set it apart from existing solutions.

Furthermore, the project's focus on compactness, lightweight design, and user-friendly interface makes it an innovative solution for mobile power supply needs. By addressing these limitations and incorporating cutting-edge technologies, this project offers a unique and comprehensive solution for efficient, reliable power supply and particularly timely and relevant due to the increasing global demand for sustainable energy solutions. As the Nigeria transitions towards renewable energy sources and grapples with the challenges of climate change, energy security, and grid resilience, innovative solutions like the mobile inverter system are crucial. The growing need for decentralized energy systems, remote power supply, and emergency response solutions further underscores the importance of this project. Moreover, advancements in technologies such as energy storage, power electronics, and Internet of Things (IoT) have created an opportune moment to develop and deploy a cutting-edge mobile inverter system that can optimize energy storage and multi-input capability.

1.2 Problem Statement

Electrical power supply is inevitable and has been adjudged as the prime mover and drive of our local economy. However, the recent hike in the prices, scarcity of PMS and the shady policies within the oil industry as created doubt for many small and medium scale enterprises on the reliance on gasoline generator set as alternative to mains. Therefore, a renewable based mobile inverter system with multi-input tendencies and energy system optimization will be designed and constructed leveraging high tech advances to create a robust and movable electrical power alternative to the mains.

1.3 Aim of the Project

The aim of the project is to design and construct a mobile inverter system with multi-input capability and energy storage optimization

1.4 Objectives of the Project

The following are the objective of the project and are to:

i. develop an efficient battery system of rating 13 volts, 40 AH in two separate phases using pieces of lithium cells of rating 3.7 volts and 3800 mAH cells.
ii. design and construct a mobile inverter system that can power multiple input devices (phones, power bank, laptop bulb, etc.) simultaneously.
iii. create a modular and scalable system that can be easily adapted to various applications and power requirements.
iv. validate the performance of the system through testing and application.

These objectives provide a clear direction for the project, ensuring that the final product meets the required specifications and performance criteria.

1.5 Scope of the Project

The project employed more in the powering of resistive loads type to inductive loads. This is because resistive loads are known for sourcing limited current while in operation to inductive loads that required three times their rated current has starting current. This scope is envisaged has a logical means to prolong the batteries operational lifespan by reducing the number of cycles of recharge. Therefore, the high numbers of cycle of recharge of the lithium batteries will ensure an optimize battery system for the mobile inverter system.

CHAPTER TWO

2.1 LITERATURE REVIEW

The availability of electrical power system involves the coordination of operations between the generating system, transmission system and the distributing system; where there is any misalignment in operation of any of this key system will resulted in power outage and downtime of the entire system. Therefore, the need for alternative source of power supply that is reliable, cheap and environmental friendly becomes sacrosanct.

2.2 Generating System

The generating system in an electrical power system refers to the combination of power plants, generators, and auxiliary equipment responsible for converting primary energy (such as fossil fuels, nuclear energy, wind, or solar energy) into electrical energy. This system is the first stage in the electrical power supply chain, followed by transmission, distribution, and consumption.

The generating system consists of different types of power plants, categorized based on the primary energy source they use:

a. Thermal Power Plants (Conventional):

These plants convert heat energy, usually from burning coal, natural gas, or oil, into electricity. Heat is used to produce steam that drives a turbine connected to an electrical generator.

- Coal Power Plants: Use coal combustion to heat water and produce steam.

- Gas Power Plants: Use natural gas to produce electricity, either by gas turbines or combined cycle plants.

- Nuclear Power Plants: Use nuclear reactions (fission) to generate heat, which is used to produce steam for turbines.

b. Renewable Power Plants:

Renewable energy plants generate electricity from natural sources like wind, sunlight, and water. These sources are abundant and environmentally friendly.

- Wind Power Plants: Convert the kinetic energy of wind into electrical energy using wind turbines.

- Solar Power Plants: Use photovoltaic (PV) cells to convert sunlight directly into electricity or use concentrated solar power (CSP) systems to heat fluids that generate steam for turbines.

- Hydroelectric Power Plants: Use the gravitational force of flowing or falling water to turn turbines and generate electricity.

- Geothermal Power Plants: Use heat from beneath the Earth's surface to produce steam and drive turbines.

- Biomass Power Plants: Convert organic materials into electricity, typically through combustion or gasification processes.

c. Distributed Generation Systems:

These are smaller-scale power generation systems located close to the point of consumption. Examples include rooftop solar systems, small wind turbines, and fuel cells. They help reduce transmission losses and enhance system reliability.

2.2.1 Key Components of generating systems

a. Prime Mover:

This is the mechanical component that converts thermal, kinetic, or potential energy into rotational motion. Common prime movers include steam turbines, gas turbines, water turbines, and wind turbines.

b. Generators:

Generators convert mechanical energy from the prime mover into electrical energy using electromagnetic inductioln. Most generators are synchronous machines, designed to run at constant speeds in coordination with the electrical grid.

c. Transformers:

Transformers are essential in generating systems to step up the voltage for efficient long-distance transmission. They minimize power losses by raising the voltage level before electricity is transmitted.

d. Auxiliary Systems

These include fuel handling systems, boilers (for thermal power plants), cooling systems, and pollution control systems like scrubbers and electrostatic precipitators (to control emissions). The generating system in an electrical power system is diverse, incorporating both traditional and renewable energy sources. It is critical for maintaining a balance between supply and demand, ensuring grid stability, and minimizing environmental impact. The future of power generation is moving towards greener and more sustainable solutions, with an emphasis on renewable energy and technological advancements.

2.3 Transmission System

The transmission system in an electrical power system is responsible for transporting electricity from generating stations to distribution networks, from where it is delivered to end-users. It operates at high voltages to minimize energy losses overq aww long distances, ensuring reliable and efficient power delivery. Below is a detailed discussion of the transmission system, its components, and key operational considerations.

2.3.1 Purpose and function of transmission system

The main function of the transmission system is to transport electricity over long distances at high voltage levels. By increasing voltage and lowering current, transmission systems minimize resistive losses (I^2R losses) in the transmission lines, ensuring that large amounts of power can be delivered efficiently. The system also plays a critical role in maintaining the stability and reliability of the overall power grid.

2.3.2 Key components of transmission systems

The transmission system consists of several critical components, each with a specific function to ensure the safe and efficient transport of electricity.

a. Transmission Lines

Transmission lines carry the electrical power from the generating plants to substations and eventually to distribution networks. They can be:

- Overhead Transmission Lines:

These are the most common and cost-effective transmission lines. They consist of conductors (often aluminum or copper) supported by towers or poles. Overhead lines operate at high voltages, typically ranging from 69 kV to 765 kV, depending on the distance and power capacity.

- Underground Transmission Lines:

Used in urban areas or environmentally sensitive regions where overhead lines are impractical. They are more expensive to install and maintain, but they offer aesthetic and environmental benefits.

b. Substations

Substations are facilities that help regulate and transform voltage levels in the transmission system. They contain transformers, circuit breakers, protective relays, and switchgear to manage power flow and protect the system from faults.

- Step-Up Substations:

Located at generating stations, they increase the voltage for efficient transmission.

- Step-Down Substations:

Located near load centers, they decrease the voltage before the electricity is sent to distribution networks for local use.

c. Transformers

Transformers are vital for adjusting voltage levels throughout the transmission system. Power is generated at lower voltages (typically 11-25 kV) and transformed to higher voltages (69-765 kV) for transmission. Step-down transformers reduce the voltage before power is distributed to consumers.

d. Transmission Towers and Poles

Transmission towers (for overhead lines) are designed to support conductors and insulators at a safe height above the ground. Different tower designs (e.g., lattice towers, monopole towers) are used depending on terrain, voltage levels, and environmental factors.

e. Circuit Breakers and Protective Relays

Circuit breakers and protective relays are used to detect and isolate faults (e.g., short circuits or overloads) in the transmission system. These devices ensure the system's safety by automatically disconnecting faulty lines or equipment to prevent damage and maintain grid stability.

f. Insulators

Insulators are critical components that prevent the transmission lines from coming into contact with grounded structures, such as transmission towers or poles. They are usually made from porcelain, glass, or composite materials.

2.3.3 Voltage levels in transmission

The transmission system operates at different voltage levels depending on the distance and power requirements:

High Voltage (HV): Typically, between 69 kV and 230 kV, used for regional power transmission over moderate distances.

Extra High Voltage (EHV): Ranges from 230 kV to 765 kV, used for long-distance transmission of large quantities of power.

Ultra-High Voltage (UHV): Voltages above 765 kV, used for extremely long distances in large interconnected grids to reduce losses even further.

Higher voltage levels are preferred for long-distance transmission to minimize energy losses, while lower voltages are used near distribution centers.

The transmission system is the backbone of the electrical power grid, ensuring that electricity generated at power plants is efficiently delivered to consumers. It operates at high voltages to minimize losses, and its reliability is critical to the stability of the entire power system. As the energy landscape shifts towards more decentralized and renewable energy sources, the transmission system must adapt to new challenges, ensuring security, efficiency, and flexibility.

2.4 Distribution System

The distribution system in an electrical power system is the final stage of delivering electricity from the transmission system to the end-users, such as homes, industries, and businesses. It typically operates at lower voltages compared to transmission systems and includes components such as transformers, distribution substations, feeders, and service lines.

2.4.1 Key components of the distribution system:

1. Distribution Substations:

These are the points where high-voltage electricity from the transmission system is stepped down to a lower voltage suitable for distribution.

Transformers at substations reduce the voltage to levels (usually 33kV, 11kV, or 6.6kV) that can be distributed to consumers.

2. Feeders:

Feeders are high-capacity power lines that carry electricity from substations to distribution transformers or secondary distribution systems.

They are typically operated at voltages like 11kV or 33kV and radiate out from the substation in different directions.

3. Distribution Transformers:

These transform medium-voltage electricity from the feeders down to lower voltage levels (typically 230V or 415V) for local distribution to consumers.

4. Primary Distribution Lines:

These are overhead or underground lines that carry electricity from distribution substations to distribution transformers.

They typically operate at voltages ranging from 11kV to 33kV.

5. Secondary Distribution Lines:

These are low-voltage lines that carry electricity from distribution transformers to homes, businesses, and industries.

The voltage level is generally reduced to 230V (single-phase) or 415V (three-phase) for end-user consumption.

6. Service Lines:

These are the final set of lines that deliver electricity directly to the user's premises.

Service lines are usually insulated wires that connect distribution poles or underground cables to individual consumers.

2.4.1 Types of distribution systems

1. Radial System:

- i. The most simple and economical configuration.
- ii. Power flows in one direction from the substation to consumers.
- iii. It has the drawback that a fault in the line can cut off power to all downstream customers.

2. Ring Main System:

- i. Power is supplied from two directions via a loop or ring, improving reliability.
- ii. If there is a fault in the system, the power can be redirected, minimizing outages.

3. Interconnected System:

- i. Multiple substations are interconnected, and power can be supplied from more than one source.
- ii. This system is highly reliable and efficient, often used in urban areas.

2.4.2 Functions of the distribution system

- I. Voltage Regulation: Ensure that the voltage levels remain stable despite varying demand across different areas.
- II. Load Balancing: Manage and distribute the electrical load to avoid overloading circuits and ensure efficient energy distribution.
- III. Protection: Implement devices such as circuit breakers and fuses to protect the system against faults like short circuits and overloads.

2.4.3 Challenges in distribution systems

a. Losses: Distribution systems experience losses due to resistance in the lines, which can lead to a reduction in efficiency.
b. Faults and Outages: Factors like equipment failure, weather conditions, and load imbalances can cause faults that disrupt power supply.
c. Integration with Renewables: Increasing integration of distributed generation (e.g., solar and wind) poses challenges in maintaining grid stability and managing bi-directional power flow.

The distribution system is vital for delivering electricity safely and reliably to end-users and plays a crucial role in overall grid management.

2.5 Alternative Source of Power Supply

The demand for reliable and sustainable energy solutions has spurred significant research and development into alternative sources of electrical power. Traditional power systems, largely dependent on fossil fuels such as coal, natural gas, and oil, have faced growing challenges related to environmental degradation, resource depletion, and energy security. As a result, alternative energy sources have gained attention as potential solutions to these issues, offering cleaner, more sustainable, and often more resilient power generation.

Among the most prominent alternatives are renewable energy sources such as solar, wind, hydropower, geothermal, and biomass. These energy sources are widely regarded for their minimal environmental impact and virtually inexhaustible supply.

a. Solar Power: Solar energy, derived from sunlight using photovoltaic (PV) panels or concentrated solar power (CSP) systems, has emerged as one of the fastest-growing renewable energy sources. Solar power systems are highly scalable, ranging from small-scale rooftop installations to large-scale solar farms, providing flexibility in addressing various energy demands. Technological advancements in PV materials, energy storage, and solar efficiency have made solar power increasingly viable in both residential and commercial applications.

b. Wind Energy: Wind power harnesses the kinetic energy of moving air masses using wind turbines. It has become a leading source of renewable energy globally, particularly in areas with high wind potential. Onshore and offshore wind farms can provide substantial electricity generation capacity. Improvements in turbine technology, along with cost reductions, have made wind energy one of the most cost-effective alternatives to fossil fuels.

c. Geothermal Energy: Geothermal power taps into the Earths internal heat to generate electricity. This energy source is highly reliable and provides a consistent power output, unlike solar or wind which are subject to weather variability. Geothermal plants are typically located in regions with significant volcanic or tectonic activity, making them less widely distributed compared to other renewable.

d. Biomass: Biomass energy is produced by converting organic materials such as agricultural waste, wood, and other plant-based materials into electricity through combustion or biochemical processes. Biomass offers the advantage of repurposing waste products into usable energy, contributing to waste management solutions while generating power. However, the environmental benefits of biomass are closely tied to the sustainability of the feedstock supply and production practices.

In addition to these renewable sources, alternative approaches such as nuclear power and hybrid systems combining renewable energy with traditional grid power or battery storage are gaining traction. Nuclear power, though not classified as renewable, offers a low-carbon energy source with significant energy output, though concerns about safety, waste disposal, and high costs remain.

The integration of alternative energy sources into modern electrical power systems is critical for ensuring a sustainable and resilient energy future. Advances in grid infrastructure, smart energy management, and energy storage technologies are essential to maximizing the potential of these alternative sources, enabling them to effectively meet the growing energy demands of a rapidly developing world.

2.6 Solar Inverter System

As the global shift towards renewable energy continues, solar power has emerged as a dominant alternative energy source due to its abundance, scalability, and environmental benefits. A critical component of any solar power system is the solar inverter, which plays a pivotal role in converting the direct current (DC) generated by solar panels into alternating current (AC) that is compatible with the electrical grid or for use in home appliances.

2.6.1 Basic Functionality of a Solar Inverter

Solar panels convert sunlight into DC electricity, which cannot be directly used by most household or commercial electrical systems that operate on AC. The solar inverter is responsible for converting this DC into AC with minimal power loss, making it a vital part of the solar power system. Without an inverter, the electricity generated by solar panels would be unusable for common applications like AC lighting, heating, and running electronic devices.

2.6.2 Types of Solar Inverters

There are several types of solar inverters, each designed to cater to different system configurations and needs:

a) String-Inverters: These are the most commonly used type in residential and commercial solar installations. In a string inverter system, multiple solar panels are connected in a series (a "string") to the inverter, which converts the combined DC electricity into AC. String inverters are efficient and cost-effective, though they can be impacted by shading or panel mismatch, as the performance of the entire string is influenced by the weakest panel

b) Micro-Inverters: Unlike string inverters, micro-inverters are installed on each individual solar panel. They convert the DC to AC at the panel level, which eliminates the issue of shading or panel mismatch and optimizes the output from each panel. While micro-inverters offer better performance and monitoring capabilities, they tend to be more expensive than string inverters.

c) Hybrid-Inverters: These inverters integrate the functionalities of a traditional inverter with a battery charging controller, allowing solar systems to store excess energy in batteries for later use. Hybrid inverters enable systems to function in off-grid or backup power mode, making them ideal for areas with unreliable grid access.

d) Power-Optimizers: Power optimizers are used in conjunction with string inverters. They are installed at the panel level, optimizing the DC voltage before sending it to the string inverter. This approach combines some of the benefits of micro-inverters, such as panel-level monitoring and shade mitigation, while maintaining the cost-effectiveness of string inverters.

2.7 Inverter Technological Advancements

Over the years, solar inverter technology has advanced significantly to improve energy conversion efficiency, enhance reliability, and integrate with smart grid systems. Modern inverters often come with Maximum Power Point Tracking (MPPT) capabilities, which ensure that solar panels are operating at their peak power output under various environmental conditions, such as changing sunlight intensity or temperature.

In addition, many solar inverters now include integrated monitoring systems that allow users to track the performance of their solar array in real-time via web platforms or mobile apps. This feature not only aids in system maintenance but also maximizes the overall efficiency of the solar installation by alerting users to any issues with specific panels or the inverter itself.

2.8 Role in Grid-Tied and Off-Grid Systems

Solar inverters are essential for both grid-tied and off-grid solar systems. In grid-tied systems, the inverter synchronizes the AC output from the solar panels with the local utility grid, allowing surplus energy to be sent back to the grid, often under net metering agreements. This allows users to offset their energy consumption, reduce utility bills, and contribute to the local power supply.

In off-grid systems, solar inverters are used alongside battery storage systems to ensure continuous energy supply. Since these systems are not connected to the utility grid, the inverter must also manage energy distribution to the batteries and provide backup power during nighttime or cloudy conditions

2.9 Challenges and Future Prospects

One of the ongoing challenges with solar inverter systems is ensuring high efficiency while minimizing energy loss during the DC-to-AC conversion process. Inverter efficiency has steadily improved, with most modern inverters achieving conversion efficiencies of 95% or higher. However, there is still room for optimization in areas such as heat management, component longevity, and integration with advanced energy storage systems.

Looking ahead, the future of solar inverters lies in their ability to seamlessly integrate with smart grids, Internet of Things devices, and decentralized energy systems. As energy storage becomes more widespread, inverters will also need to accommodate more complex energy flows, including bi-directional power conversion (for energy storage systems) and interaction with electric vehicles.

2.10 Review of Past Project Work on Solar Inverter System

The growing demand for renewable energy solutions, particularly in off-grid and rural locations, has spurred extensive research into standalone solar power systems. These systems operate independently of the utility grid, offering a reliable and sustainable source of energy in areas where grid extension is either impractical or too expensive. Over the years, various research projects have explored different aspects of solar standalone systems, including system design, optimization, and hybrid configurations. Here, this project will review some notable past projects to highlight advancements and challenges in the field.

Design and Implementation of a Solar Standalone System for Rural Electrification. A significant body of research has focused on designing solar standalone systems to electrify rural areas that lack access to grid electricity. One such study examined the design and implementation of a solar photovoltaic (PV) system for a small rural community in sub-Saharan Africa. The system, which consisted of a 2 kW PV array, a 24 V, 200 AH battery bank, and a 2 kW inverter, was tailored to meet the basic energy needs of households, including lighting, powering small appliances, and water pumping. The study demonstrated that solar standalone systems can provide a reliable energy source in remote locations, particularly when appropriately sized based on the community's energy consumption patterns. The use of mono-crystalline solar panels was found to be advantageous due to their efficiency in high-temperature climates. However, the project identified several challenges, most notably the high upfront cost of installation, which posed a financial barrier for rural communities. To address this, the study recommended financial interventions, such as subsidies or installment-based payment schemes, to make these systems more accessible to low-income populations (*Abdullahi et al., 2020*).

This project underscores the importance of proper system sizing, efficient energy storage, and the economic considerations necessary to make standalone systems viable for rural electrification.

Optimization of Standalone Solar Systems for Residential Use. Another key area of research has involved optimizing solar standalone systems for residential applications, with a particular focus on reducing costs and increasing energy efficiency. A study by Ibrahim et al. (2019) explored the optimization of a solar PV system for a residential household in a tropical region characterized by variable weather conditions. The system incorporated a 5 kW PV array, a 48V 400 Ah lithium-ion battery bank, and a 5 kW inverter.

The project applied simulation tools such as HOMER and MATLAB to model different system configurations, optimizing the size of the PV array and battery storage to ensure cost-effectiveness without compromising performance. Lithium-ion batteries were selected for their higher energy density and faster charging capabilities compared to traditional lead-acid batteries. The results of the study indicated that an optimized system can significantly reduce energy storage requirements, thus lowering costs. The system was capable of meeting the household's daily energy demands, even during periods of low solar irradiance. However, despite these optimizations, the cost of lithium-ion batteries remained a limiting factor, making the overall system more expensive than grid-supplied electricity. The study highlighted the need for ongoing advancements in battery technology to bring down costs and enhance the affordability of residential solar standalone systems (*Ibrahim et al., 2019*).

This research contributes to the broader understanding of how solar standalone systems can be optimized for residential use, particularly in regions with inconsistent sunlight, while identifying the high cost of advanced battery technologies as a challenge to wider adoption. Hybrid Solar-Wind Standalone Systems for Enhanced Reliability. Hybrid renewable energy systems, which combine solar energy with other renewable sources, have been studied as a means of improving the reliability of standalone systems. In one project, Kumar et al. (2021) developed a hybrid solar-wind standalone system designed for an off-grid agricultural facility. The system featured a 3 kW solar PV array and a 2 kW wind turbine, connected to a 48V 600 Ah battery bank and a 5 kW inverter. The primary advantage of the hybrid approach was its ability to provide continuous energy even during periods of low solar availability. By incorporating wind power, the system was able to compensate for the variability in solar energy generation, particularly during nighttime or cloudy conditions. This allowed the agricultural facility to maintain essential operations such as water pumping, refrigeration, and lighting without interruption. Despite its improved performance, the hybrid system introduced technical complexities in system design, particularly with respect to integrating different energy inputs and optimizing the charge controller. Additionally, the maintenance of the wind turbine proved to be more challenging than anticipated, highlighting the trade-offs involved in multi-source systems. Nonetheless, the project demonstrated the potential of hybrid systems in enhancing the resilience of standalone energy solutions, particularly in areas with inconsistent solar resources (*Kumar et al., 2021*).

Design and Implementation of a Solar Inverter System for Off-Grid Applications: This project focused on the development of a solar inverter system aimed at improving power conversion efficiency in off-grid systems. The study covered the design, component selection, and testing of the inverter, with a particular emphasis on minimizing power losses during DC-AC conversion. Smith (2018) highlighted the importance of selecting high-efficiency switching devices and optimizing cooling systems to enhance the longevity and performance of the inverter. This project focused on integrating IoT technology into a solar inverter system for real-time energy monitoring and control. The system allowed users to track energy production, consumption, and battery levels via a mobile app. The smart inverter was designed to optimize energy usage based on patterns and predictive algorithms. The project demonstrated the benefits of IoT for improving efficiency and user engagement with renewable energy systems *(Smith, J. 2018)*.

An Evaluation of Hybrid Solar Inverter Systems for Residential Energy Solutions: This work reviewed the performance of hybrid solar inverter systems that integrate solar energy with battery storage and grid connections. Rodriguez (2020) performed a comparative analysis of multiple commercial inverter systems, examining their efficiency, cost-effectiveness, and reliability under different environmental conditions. The research concluded that hybrid inverters could significantly reduce reliance on grid power and improve energy resilience during outages. This project combined solar and wind power generation with an inverter system to provide electricity to rural areas. The design integrated a hybrid charge controller and a 2kW inverter to manage the two energy sources. The system was designed to provide power to small rural communities. The study demonstrated that combining renewable sources improves power reliability and reduces the total cost of the system by balancing energy supply from solar and wind sources *(Rodriguez, L. 2020)*.

A Comparative Study of MPPT Algorithms in Solar Inverter Systems: In this study, Ahmed (2021) evaluated various Maximum Power Point Tracking (MPPT) algorithms used in solar inverters to optimize energy harvesting from photovoltaic systems. The research involved simulating different algorithms and comparing their performance in terms of tracking accuracy, convergence speed, and overall system efficiency. Ahmed found that advanced MPPT methods, such as Perturb and Observe (P&O) and Incremental Conductance, were most effective in improving the output of solar inverter systems under rapidly changing weather conditions. The project aimed to evaluate the performance of a solar inverter system for off-grid applications, specifically in remote areas. It included the design of a 1kW inverter with a 48V battery bank, powered by a 1.5 kW solar array. The system's reliability and efficiency were monitored over the course of a year. The study found that a well-sized solar inverter system can provide reliable power for remote homes, though seasonal variations in solar energy availability posed a challenge *(Ahmed, K. 2021)*.

2.8 Block Diagram of Mobile Inverter Systems

The subsections making up the inverter systems is as shown in the block diagram of Figure 2.1. The diagram shows the interconnection of one unit block to another, starting from the input solar panel to the output loads with various output ranges.

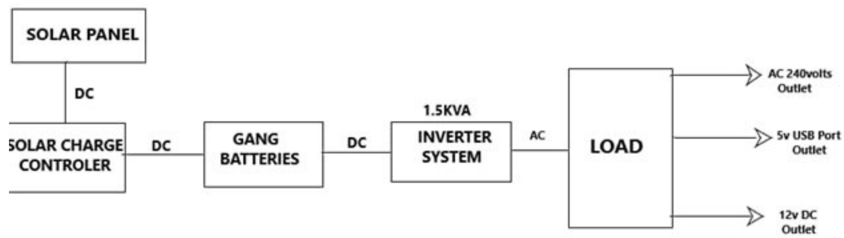


Figure 2.1: The Block Diagram of 1.5 kVA Mobile Inverter System

- Solar Panels: These photovoltaic (PV) panels are installed to harness sunlight. They convert sunlight into Direct Current (DC) electricity.
- Charge Controller: The DC electricity from the solar panels passes through a charge controller. This device regulates the voltage and current, preventing the batteries from overcharging.
- Batteries: The electricity is stored in batteries, usually deep-cycle types, for later use when sunlight is not available, such as during nighttime.
- . Inverter: The DC power stored in the batteries is converted into Alternating Current (AC) by the inverter, which is the type of electricity most household appliances use.
- Load: this is referring to the electrical devices or appliances that draw power from the system.

CHAPTER THREE

3.1 MATERIAL AND METHODOLOGY

The methodology employed in the research project consist of two main stages. First the design and construction of the 2 kVA locally made inverter and secondly, the performance analysis.

3.2 DESIGN AND CONSTRUCTION OF 2KVA MOBILE INVERTER

Most of us take the mains Ac supply for granted and use it almost casually without giving the slightest thought of Its inherent shortcomings and the danger posed to sophisticated and sensitive electronic instruments and equipment. For ordinary household appliances such as incandescent lamps, tubes, fan, TV and fridge, the mains ac supply does not make such difference, but when used for computers, medical equipment and telecommunication systems, a clean, stable interruption free power supply is of the outmost importance of the myriad of devices, processes and system which rely on ac power, computer are probably the most sensitive to power disturbances and failure. Interruptions in power supply may cause contents of memory to be lost or corrupt. The central processing unit of the system may malfunction or fail. In order to protect a sensitive system from power losses and blackouts, an alternative power source is required that can switch into operation immediately when disruption of the mains occurs. An uninterruptible power supply (UPS) is just such an alternative source. A UPS generally consists of a rectifier, battery charger, a battery bank an inverter .the rectifier should have its input protected and should be capable of supplying power to the inverter when the commercial supply is either slightly below the normal voltage or slightly above. There are three distinct types of uninterruptible power supply systems, namely, online UPS, offline UPS and electronic generators.

3.2 ONLINE INVERTER POWER SUPPLY SYSTEM

In the online inverter whether the mains power is on or off, the battery operating or connected to the inverter is on all the time and supplies the AC output voltage. When the mains power supply goes off, The UPS will be on only until the battery gets discharged, when the main power resumes, the battery will get discharged again.

3.3 OFFLINE INVERTER POWER SUPPLY SYSTEM

In the offline UPS and electronic generators UPS, their inverter is off when the power is present and the output voltage derived directly from the mains is the same as the mains supply voltage. The inverter turns on only when the main supply goes off. Recent demand survey shows that demand rate is in the order of electronic generators UPS, offline UPS and then online UPS. Although the offline and online UPS system are somewhat prefer in places where PC or computes are used, the demand for online ups systems is less than for offline UPS systems because of the online UPS system is higher. The circuit diagram of Figure 3.1 shows the circuit components and stages that are required in the designing of the 4 KVA uninterruptible power supply system. Some of the stages involve include, the rectification stage, batteries charging stage, oscillator stage, switching stage amplification and transformation stages.

3.4 ELECTRONIC OF THE CIRCUIT DIAGRAMS

This section dealt with some of the electrical technicalities that were considered in the making of the project. Some explanations take authority or support from manufacturer guide or handbook and datasheet of some the components used.

3.4.1 THE TRANSFORMER

The input to the primary winding of the transformer (T1) is 240V. The secondary winding can be raised up to 15 volts if the value is at least 12 volts running 2 amps, the fuse (FS1) acts as a mini circuit breaker for protection against short circuits or a detective battery cell in fact. The presence of electricity will cause the LED1 to light. The light of LED will set off upon power outage and UPS battery will take over. The circuit was designed to offer more flexible pattern where in it can be customized by using different regulators and batteries to produce regulated and unregulated voltage. Utilizing two 12volts batteries in series and positive input 7815 regulator can control a 15v supply.

3.5 THE ELECTRONICS OF AN INVERTER SYSTEM

The basic principle in terms of operation of a UPS is a device that can convert the chemical energy stored in a battery to electrical energy. Although the process of conversion (inverting) requires some stages to be fulfilled, some of the stages are discuss next.

1) THE RECTIFICATION STAGE: It is a rectifier stage which simply means the conversion of alternating signal (AC) into direct signal (DC). It has two main functions. Firstly the alternating current (AC) into direct current (DC), through the supply of filtered load, or the supply inverter. Secondly, to provide battery charging voltage, therefore it also plays a role in the charging section.
2) BATTERIES BANK: The batteries are used as a storage energy device, which consist of several cells in series, with a capacity to maintain its size which determine the discharge (supply) time. Its main function is that when electricity is normal, the energy converted into chemical energy stored in the battery interval; when the electricity tails, the chemical energy provided to the inverter or the load.
3) INVERTING STAGE- Generally, inverting is a direct current (DC) to alternating current (AC) process. It mainly consists of the oscillation stage.

4) STATIC SWITCH- It is a contact typed switch, in this project design, FET and electromechanical rely are employ for the switch stages.
5) OSCILLATOR STAGE:- this is a stage that receivers voltage from the battery, this is a stage where the circuit generate frequency from D.C to A.C .This is a device (stage) that increase the power of a signal. It does this by taking energy from a power supply and control the output this to match the impute signal shape but with lager amplitude.in this case (sense) from amplifier modulates the output of the power supply. This stage is couple with some electronic services like transistor, resistor, capacitor, variable resistor; integrate circuit (IC) etc. And we make use of IC with Chirp. All the output it will generate it will not more than 5volts (7805).
6) INTEGRATED CIRCUIT: - it can also called I.C in clip they are very complex in construction. An IC has a pin which in numbered anticlockwise round the chip starting at notch in dot. In this circuit we make use of CD4047 with 14 legs.
7) BIPOLAR JUNCTION TRANSISTOR (BJT): this has base, collector and emitter as a terminal. The base a very than layer, has server doping atom them emitter and connector, this very small current emitter collector flow.
8) DRIVER STAGE: - This is where lower voltage is converted to high current through use of Mosfet. This Mosfet is the main component in this stage, and

it has three terminal, the source, drain and gate, (S.D.G). When the drives stage received the signal it will free or force the gate in order to generate high current .This mosfet it couple with 1000ohms resistor connected to the mosphet. In the circuit we have six (6) mosfet connected together and 6 resistor as well.

9) TRANSFORMER TAGE: - We make use of transformer in this stage, this is a stage Where we generate and final (AC) alternative current i.e. 220V 50Hz. This stage is mainly made if transformer, but to know the transformer is been constructed it couple with some component and follows some laws that give it.

$$No\ of\ Turns = 45.0 * V$$

$$No\ of\ Turns = \frac{45.05 * V_S}{E * S}$$

V is the mains power supply, 45.05 is Constant, Vs is the secondary side voltage, E is the lamination breath and is the cross sectional area. Before the design the transformers lamination parameters will be measured, (i.e E and S) then they are multiply by the area and breath.

Therefore $4.4 * 5.5 = 24.2$, then substitute into the formula

$$\frac{45.05 * 220}{24.2}$$

$$= \frac{9,911}{24.2} = 409.545 turns\ for\ the\ \sec ondary\ side$$

For primary side because we want to generate 12V then our $V_P = 12V$

$$\frac{N_S}{N_P} = \frac{V_S}{V_P}$$

$$N_P = \frac{N_S * V_P}{V_S} = \frac{409*12}{220} = 22.309\, turns$$

= 22.309; 22 turns for the primary side

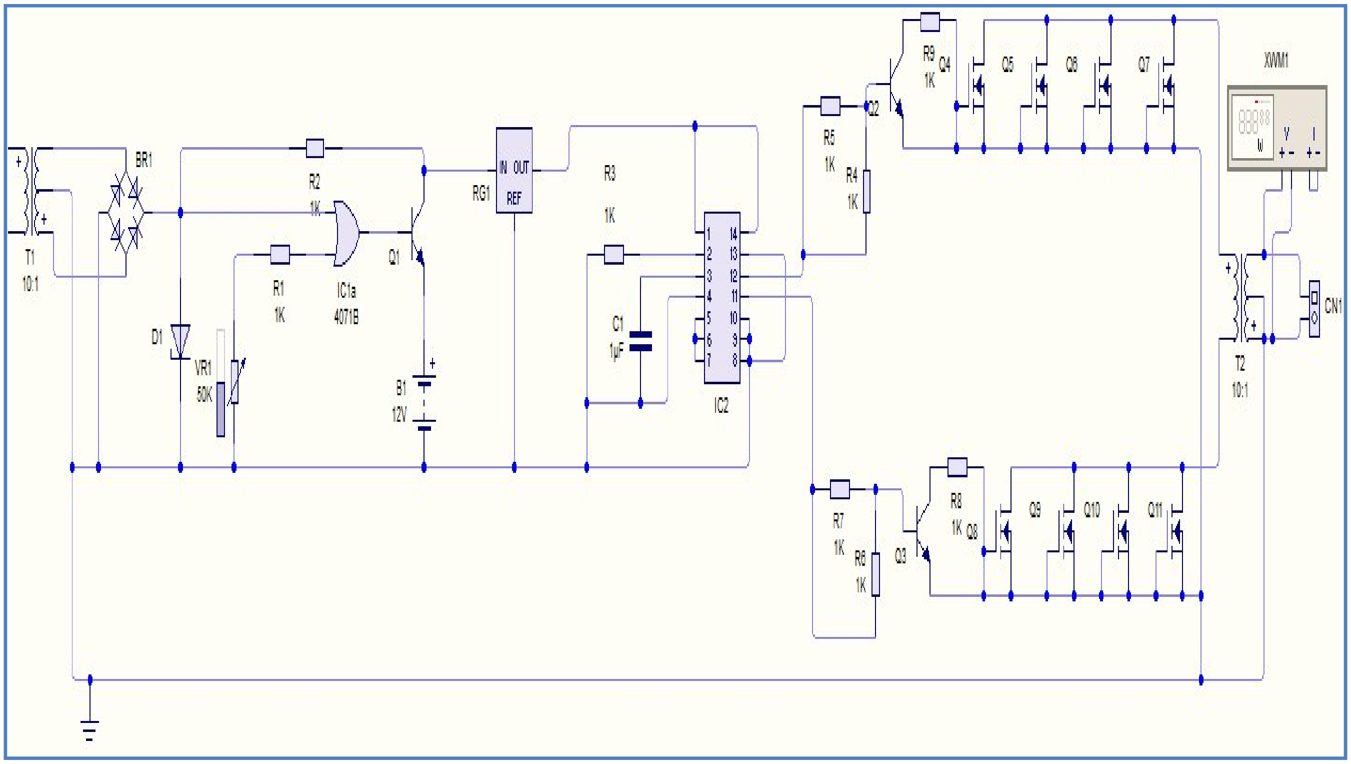


Figure 3.1 Circuit Diagram for 2KVA Mobile Inverter Systems.

CHAPTER FOUR

4.1 PRINCINPLE OF OPERATION OF AN INVERTER SYSTEM

An inverter power system is an electronics device which invert and charge the chemical energy stored in a battery bank. It is an electrical apparatus that provides emergency power to load when the input power source or main power fails.

An inverter differs from an emergency Power System or Standby generator in that it will provide near instantaneous protection from input power interruptions, by supplying energy stored in batteries the on – battery runtime of some uninterruptible power supply/sources is relatively short but sufficient to start a standby power source or properly shut down the protected equipment. The batteries are rated in certain period of time.

An inverter is typically used to protect hardware such as computers, data centers, telecommunication equipment or other electrical equipment where an unexpected power disruption could cause injuries, facilities, serious business disruption or data loss.

The most basic features of a ups is providing surge protection and battery backup. The protected equipment is normally connected directly to incoming utility power. When the incoming voltage falls below or rises above a predetermined level the ups turns on its internal DC – AC inverter circuitry, which is powered from an internal storage battery. The inverter then mechanically switches the connected equipment on to its DC- AC inverter output. The switch over time can be as long as 25 milli seconds depending on the amount of time it takes the standby inverter to detect the lost utility voltage.

5 RESULTS

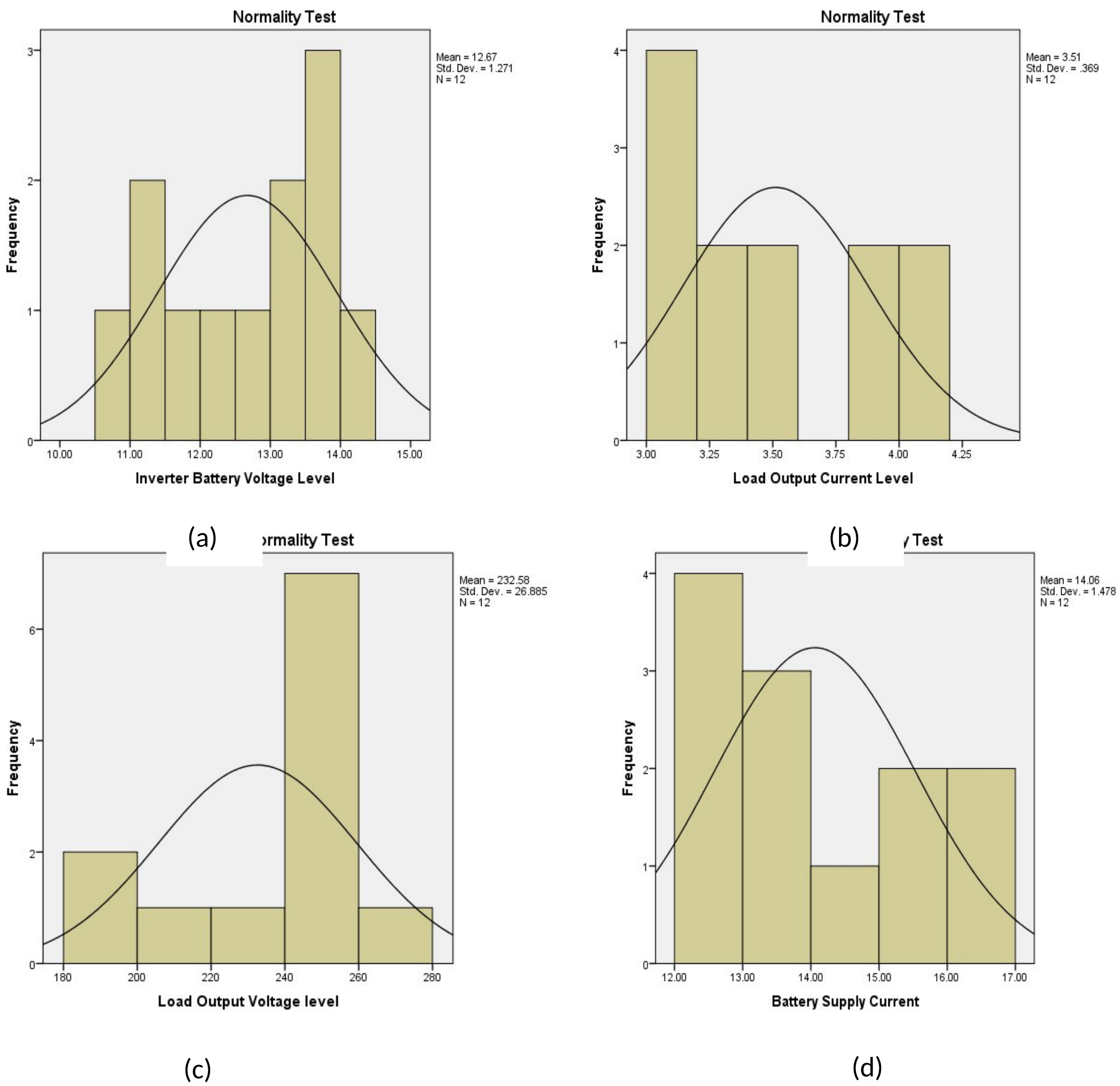
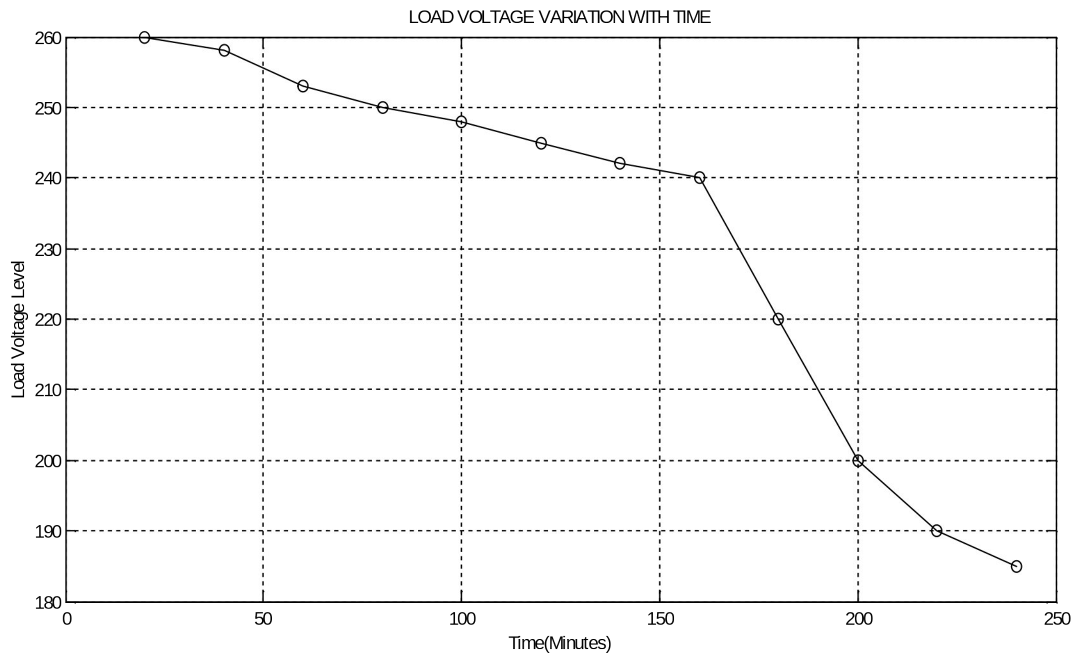
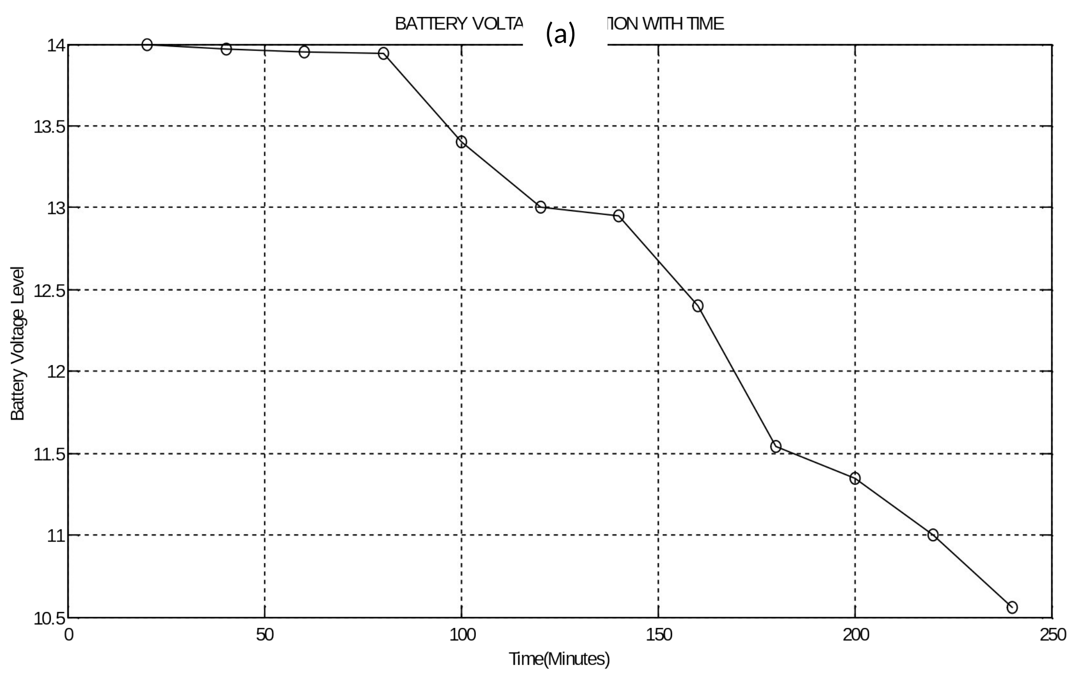


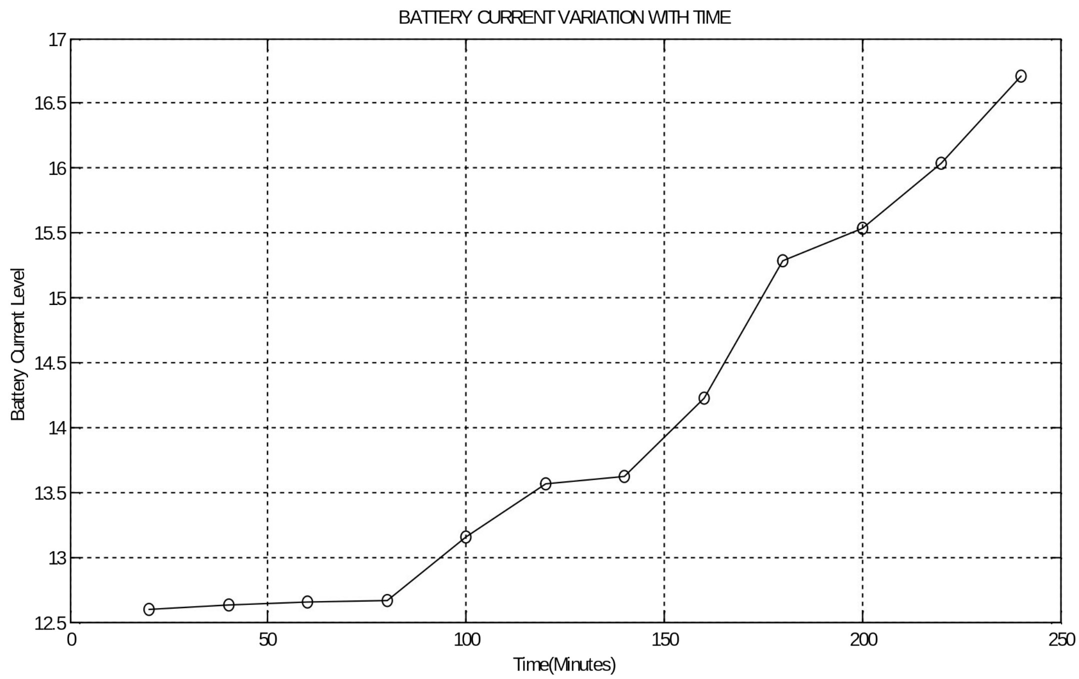
Figure 1.0: Normality Test for the Measured Values of 2 kVA Locally Designed Mobile Inverter (a) Inverter Battery Voltage Level (b) Load Output Current Level (c) Load Output Voltage Level and (d) Battery Supply Current.


LOAD VOLTAGE VARIATION WITH TIME
Load Voltage Level
260
250
240
230
220
210
200
190
180
0
50
100
150
200
250
Time(Minutes)

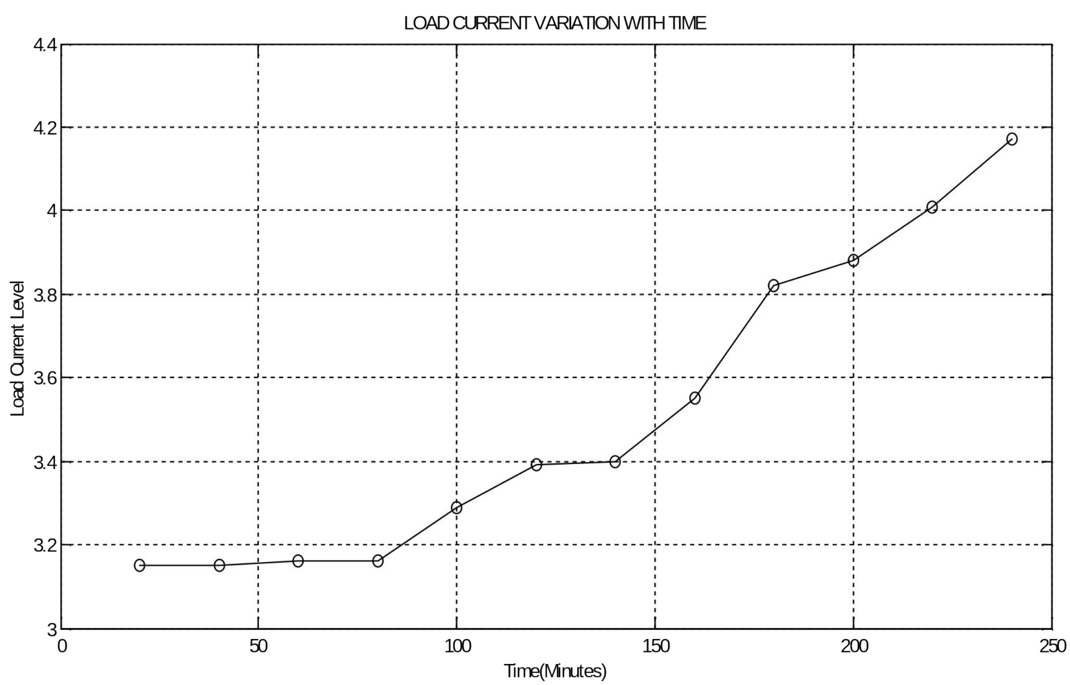
(a)


BATTERY VOLTA
TION WITH TIME
Battery Voltage Level
14
13.5
13
12.5
12
11.5
11
10.5
0
50
100
150
200
250
Time(Minutes)

(b)



(c)



(d)

Figure 2.0: Metric Parameters Observation over Time (a) Load Voltage Variation (b) Battery Voltage Variation (c) Battery Current Variation and (d) Load Current Variation.

Table 2.0: Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate

1	.965[a]	.930	.904	.22852

a. Predictors (Constant), Load Output Current Level, Measurement Time, Load Output Voltage Level

Table 3.0: Modeling Coefficients

Model	Variables	Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.
1	(Constant)	18.472	5.851		3.157	.013
	Measurement Time	.012	.003	1.184	3.582	.007
	Load Output Voltage level	-.034	.011	-1.216	-2.974	.018
	Load Output Current Level	-2.906	1.062	-1.453	-2.737	.026

a. Dependent Variable: Perfomance Level

Generally, measurements are known to be liable to outliers, sometimes called error. Errors arise due to imperfection on the part of human and machines that are used to obtain the numeric data. In this research work, a normality test was run on SPSS-23 software simulator to check for the normality test of the measured data in Table 1.0 as presented in Figure 1.0. The Figures show that the metric data are normal and they are completely devoid of outliers, hence they possess some level of credence when used in the investigation of the 2 kVA performance and equation modeling analysis. Figure 2.0 shows the depiction of the metric parameters variation with time. In Figure 2.0 (a), the graph depiction shows that the inverter provides support when maximally loaded for about four (4) hours, however, the inverter output voltage only drops by 20 volts in nearly two (2) hours. This indicates a very good performance by the inverter, although, afterward the output drops drastically with a compensation for the load sustainability through the corresponding increase in the battery current level as shown in Figure 2.0(c).Table

2.0 on the other hand comprises the model summary and it shows the Adjusted R square value, which indicate that the metric parameters that were keyed in to the SPSS-23 software were 90.4% capable of determining the success of the inverter performance and it was therefore adjudged okay. Table 3.0 shows the modeling coefficients for the metric parameter that was keyed in to SPSS software. At this stage, it is worth mentioning that, all the components used as well as the metric parameters obtained are all ohmic in nature (i.e they obey ohm's law, having a voltage – current linear relationship), with this credence, a linear regression equation was adopted for the equation modeling formulation. Fundamentally, the equation modeling therefore takes a form of general regression equation of the form: $P(invt) = K + K_1(t) + K_2(V_{OL}) + K_3(I_{OL})$ 1

where *P(invt)* is the inverter performance, *K* is the constant value in the modeling coefficient table, K_1 is the constant of measurement time at time *t*, K_2 is the constant of the load output voltage and K_3 is the constant of load output current. In this regard, the performance equation for the 2KVA inverter is equal to

$$P(invt) = 18.472 + 0.012\ (t) - 0.034\ (V_{OL}) - 2.906\ (I_{OL}) \quad 2$$

With the equation modeling derived, the performance of a 2 kVA locally designed and constructed inverter can be determined at any time t of operation of the inverter with the load output voltage measured (V_{OL}) at time t and the load output current (I_{OL}) at time t

CHAPTER FIVE

5.1 CONCLUSION, RECOMMENDATIONS, AND FUTURE WORK

The design and implementation of the 1.5kVA mobile inverter system with multi-output functionality and energy storage optimization has successfully addressed the key objectives of efficiency, portability, and operational versatility. The system demonstrated reliable performance in converting and distributing power to various output terminals while optimizing battery usage through an intelligent control mechanism. Its compact and mobile structure makes it suitable for use in both urban and rural environments, especially in regions with erratic power supply. The optimized energy storage ensures longer operation time, and the system's ability to handle multiple output devices simultaneously positions it as a valuable solution for domestic, fieldwork, and small business applications. Overall, the project has proven the feasibility and usefulness of a mobile inverter solution tailored for energy-deficient areas, contributing positively to energy accessibility and sustainability.

5.2 Recommendations

To enhance the performance, usability, and adaptability of the developed inverter system, the following recommendations are proposed:

- **Incorporation of Solar Charging with MPPT:** Future designs should integrate a solar charging unit equipped with a Maximum Power Point

Tracking (MPPT) controller to allow for efficient harnessing of renewable energy. This would reduce dependency on grid charging and further improve sustainability.

- **Development of a Mobile Application for Remote Monitoring:** A mobile app can be developed to facilitate real-time monitoring of battery level, output status, load consumption, and fault alerts. This can be achieved via Bluetooth or Wi-Fi, enabling users to control and supervise the system from a distance.
- **Adoption of Modular Battery Packs:** Implementing modular battery packs will make the system more flexible in terms of capacity expansion and maintenance. Users can easily upgrade or replace faulty modules without affecting the entire battery system, thus improving reliability and serviceability.

5.3 Future Work

In light of the outcomes and lessons learned from this project, several future improvements and research directions are suggested to further advance the system's capabilities:

- **Integration of IoT-Based Monitoring and Diagnostics:** The addition of Internet of Things (IoT) features will allow for cloud-based data logging, remote diagnostics, and performance analysis. This will enable predictive maintenance and enhance system availability.

- **AI-Driven Load Prediction and Management:** Artificial Intelligence (AI) techniques, such as machine learning algorithms, can be employed to predict user load patterns and optimize energy distribution accordingly. This could enhance efficiency and prolong battery life.
- **Deployment of Lightweight Lithium-Ion Battery Packs:** Transitioning from traditional lead-acid batteries to lithium-ion battery technology can significantly reduce system weight and size, improve energy density, and increase the overall lifespan of the energy storage unit.

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