KWARA STATE POLYTECHNIC, ILORIN

INSTITUTE OF TECHNOLOGY

DESIGN, CONSTRUCTION AND INSTALLATION OF 2KVA SOLAR POWERED INVERTER

BY

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SUBMITTED TO

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CERTIFICATION

This is to certify that this project work was carried out by IBRAHIM MUHAMMED ADEBAYO of matriculation Number ND/23/EEE/PT/0122 in the Department of Electrical/Electronic Engineering, Kwara State Polytechnic in Partial fulfillment of the requirements for the award of National Diploma (ND) certificate in Electrical/Electronic Engineering.

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DEDICATION

This research is dedicated to Almighty God and also to my lovely parents, Mr and Mrs. ABDULGANEEYU for their support and love over me for his moral and financial support throughout the journey.

ACKNOWLEDGEMENT

I give all glory, praises and adoration to Almighty God the one who gives knowledge, strength and ability in starting, sustaining me and finishing this project successfully, and for his grant grace over me through this titanic struggle of my national diploma program.

My gratitude goes to my honorable supervisor Engr. K. LATEEF and one of my best guardian/mentor Engr. Bashir for their invaluable guidance, support and encouragement throughout. Who patiently read through the work. May the good lord reward him labour and more strength to his wrist in name of God.

My special appreciation goes to my beloved parent Mr and Mrs. ABDULGANEEYU. I pray that you live long to reap the fruit of your labour (Amen).

Also my heartfelt gratitude goes to my friends for supporting me during the period of learning in this institution. LAWAL AL-AMEEN AYOMIDE (my group leader).

ABSTRACT

This project is designed and constructed to specifically charge multiple devices even when there is power outage, it consists of six (6) 13A socket interface, two (2) uninterruptible universal serial bus ports and the voltage display section. The functionality of the project depends on the electrical connections that was used. The lithium battery is rated at about 200mAH, which can sustain the charging of devices for a minimum period of five (5) hours.

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CHAPTER ONE:

INTRODUCTION

1.1 Background of the Study

Access to reliable electricity is a fundamental pillar of modern society, enabling everything from basic household functions to sophisticated industrial operations. It powers lights, appliances, communication systems, and critical infrastructure such as hospitals and schools. Yet, for millions of people around the world, particularly in developing nations like Nigeria, this essential resource remains inconsistent or entirely unavailable. The national power grid in Nigeria, for example, struggles with a host of systemic issues: insufficient generation capacity, outdated infrastructure, inadequate maintenance, and disruptions caused by natural events or human interference. These challenges result in frequent power outages, unpredictable voltage fluctuations, and prolonged periods without electricity, severely impacting quality of life and economic productivity.

In Nigeria, the electricity supply primarily relies on hydroelectric and gas-fired power plants. Hydroelectric systems, while renewable, are heavily influenced by seasonal rainfall patterns, leading to reduced output during dry periods. Gas-fired plants, on the other hand, face challenges such as inconsistent fuel supply, pipeline vandalism, and logistical bottlenecks. Compounding these generation issues is an overburdened transmission and distribution network, which suffers from significant energy losses—sometimes as high as 30%—before electricity even reaches consumers. The World Bank reports that Nigeria experiences an average of 32.8 power outages per month, with each outage lasting several hours. This chronic unreliability costs the nation approximately $29 billion annually in lost economic output, as businesses and households are forced to turn to costly and environmentally harmful alternatives like diesel generators.

The consequences of this energy crisis are particularly pronounced for sensitive electronic equipment, which requires a stable and high-quality power supply to operate effectively. Devices such as computers, medical imaging systems, and telecommunications infrastructure are highly susceptible to damage from voltage spikes or drops. Even brief interruptions can lead to data loss, equipment failure, or disrupted services. In critical settings like hospitals, where power is needed for ventilators, surgical tools, and refrigeration of vaccines, outages can have life-or-death implications. For instance, a sudden power cut during a surgical procedure could jeopardize patient safety if backup systems are unavailable or insufficient [1,2].

To address these pervasive issues, alternative power solutions have gained traction, with inverters emerging as a practical and versatile option. Inverters convert direct current (DC) from batteries into alternating current (AC), the form of electricity used by most household and industrial appliances. This capability allows them to provide uninterrupted power during outages by drawing on stored energy, making them invaluable in regions with unstable grids. However, traditional inverters depend on batteries charged by the grid or external generators, which poses a limitation in ternal generators, which poses a limitation in areas where power outages are frequent or prolonged, or where grid access is nonexistent.

This is where solar-powered inverters offer a groundbreaking advancement. By integrating solar photovoltaic (PV) panels, these systems use sunlight—a free, abundant, and renewable resource—to charge their batteries, creating a self-sustaining power solution. Nigeria, located near the equator, enjoys an average of 6.25 hours of sunlight daily, translating to a solar energy potential of over 427,000 megawatts (MW), according to the International Renewable Energy Agency (IRENA). Despite this vast potential, only a small fraction is currently harnessed, presenting a significant opportunity for solar-based technologies to bridge the energy gap. Solar-powered inverters reduce reliance on fossil fuels, lower long-term electricity costs, andcontribute to environmental sustainability by cutting carbon emissions—a critical consideration as the world grapples with climate change.

The focus of this project is the design, construction, and installation of a 2KVA solar-powered inverter system, a solution tailored to meet the energy needs of small households or businesses. A 2KVA (kilovolt-ampere) inverter can deliver up to 2,000 volt-amperes of power, sufficient to support essential appliances such as lights, fans, televisions, laptops, and small refrigeration units. When paired with appropriately sized solar panels and batteries, this system can provide a reliable power supply even in off-grid locations or during extended grid failures. Beyond its immediate utility, the project emphasizes the use of locally sourced materials and expertise, fostering economic growth, job creation, and technological independence.

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Designing such a system, however, involves navigating several technical challenges. The inverter must produce a pure sine wave output, which is essential for powering sensitive electronics without causing noise, inefficiency, or damage. Unlike modified sine wave inverters, which are cheaper but less compatible with modern devices, pure sine wave inverters replicate the smooth, consistent waveform of grid electricity. Additionally, the system requires careful selection and integration of components—solar panels, batteries, charge controllers, and the inverter itself—to optimize performance and durability. For example, the solar panels must be sized to generate enough energy to charge the batteries fully, even on cloudy days, while the batteries must store sufficient power to meet demand during nighttime or prolonged outages.

1.2 Electrical Signal Waves

Electrical sine waves depict electrical signals represented by a sinusoidal graph. The wave shows all the properties of a wave like amplitude, frequency, wavelength, and can exhibit wave-like properties of reflection, refraction, diffraction, and polarization [3]. Moreover, when an electrical signal wave is said to be pure, it means the wave depiction is devoid of harmonics, as shown in Figure 1.1. Furthermore, when the wave output of the oscillation unit of an inverter is free of harmonics, the power inverter is termed a ‘pure sine wave power inverter’.

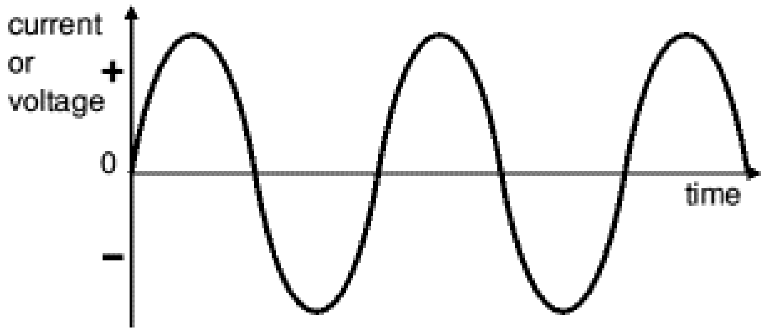


Figure 1.1: AC, DC and Electrical Signal.

Advantages of pure sine wave inverters over modified sine wave inverters:

a) Output voltage waveform is pure sine wave with very low harmonic distortion and clean power like utility-supplied electricity.

b) Inductive loads like microwave ovens and motors run faster, quieter, and cooler.

1.3. Problem Statement

This project work aims to address the challenges of poor power supply delivery to electrical loads by designing, constructing, and installing a 2KVA solar-powered inverter, harnessing the abundant solar energy available.

1.4 Aim of the Project

The aim of the study is to locally design, construct, and install a 2KVA solar-powered inverter for domestic electric power supply.

1.5 Objectives of the Project

1. To design and construct a reliable pure sine wave power inverter.
2. To construct an inverter system using high-quality components and efficient circuitry.
3. To test the performance and reliability of the inverter system.

4. To analyze the efficiency, voltage regulation, and waveform quality of the inverter output.

1.6 Scope of the project

The scope of the project encompasses the design, construction, installation, and testing phases of the 2KVA solar-powered inverter system. This includes selecting appropriate components such as solar panels, charge controllers, batteries, inverters, and control circuits, as well as designing the system layout and installation procedures.

1.7 Significance of the project

The significance of the project lies in its contribution to promoting renewable energy solutions and reducing dependence on fossil fuels. By designing and installing a 2KVA solar-powered inverter, this project aims to provide a sustainable and eco-friendly power source for domestic applications.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

Electricity generation is the process of generating electric power from primary energy sources. Energy conversion processes include thermoelectric (heat-to-electric energy), steam engines (heat-to-mechanical energy), and more. Over the past years, advancements in engineering technology have become highly attractive to power industries, particularly in power electronics applications. The primary motivation behind the development of inverters has been the generation of output signals with low harmonic distortion and reduced switching frequency. This has enabled the conversion from DC power to conventional AC power, suitable for devices such as electric lights, kitchen appliances, power tools, and television sets [1,3].

From the late nineteenth century through the mid-twentieth century, DC-to-AC power conversion was achieved using rotary converters or motor-generator (MG) sets. In the early twentieth century, vacuum tubes and gas-filled tubes began to be used as switches in inverter circuits.

The term "inverter" originates from early electromechanical inverters. Early AC-to-DC converters used an induction or synchronous AC motor directly connected to a generator (dynamo), reversing its connections at precise moments to produce DC. A later development, the synchronous converter, combined motor and generator windings into one armature with slip rings at one end and a commutator at the other, within a single field frame. The result was AC-in, DC-out. With an MG set, the DC could be considered separately generated from the AC; with a synchronous converter, it was "mechanically rectified AC." With appropriate auxiliary and control equipment, an MG set or rotary converter could be "run backwards," converting DC to AC—hence the term "inverter."

Over the years, electricity has been generated using methods such as solar, thermal, wind, and electric generators. These methods have proven reliable and sufficient. However, due to inadequate energy sources, the need for standby supply has led to the development of inverters as an alternative means [4].

Solar energy, a renewable and sustainable power source, has gained significant attention in recent years. Solar-powered inverters integrate solar panels, charge controllers, batteries, and inverters to provide a reliable and eco-friendly power supply. Solar panels convert sunlight into DC electricity, which is then used to charge batteries through a charge controller. The inverter converts the DC power from the batteries into AC power for household use.

2.2 The inverter

An inverter is a device that converts DC power from sources such as batteriesinto AC power. In a solar-powered inverter system, the DC power is sourced from solar panels. Figure 2.1 shows the inner circuitry of an inverter power system.

Fig. 2.1: Inverter inner circuitry.

An uninterruptible power supply (UPS) uses batteries and an inverter to supply AC electrical power when main power is not available. When main power is restored, a rectifier supplies DC power to recharge the batteries. An inverter can also be defined as an electronic device or circuitry that changes direct current (DC) to alternating current (AC). The input voltage, output voltage, frequency, and overall power handling depend on the design of the specific device or circuitry. The inverter does not produce any power; the power is provided by the D.C. source. The basic circuit of the inverter comprises the following parts:

a. Charger Section

b. Rectifier Section

c. DC-AC Converter

d. Drivers Section/FET Gang

e. Inverter Module

f. Transformation Section

a. Charger Section: The charger card basically senses the AC input and then generates the silicon-controlled rectifier triggering pulse. The feature for the soft start is incorporated in this card using the concept of sawtooth generation and then its conversion into the triggering pulses, which eventually get transported through the pulse transformer to the output connector of the charger card with its other end connected to the SCR module.

b. Rectifier Section: The rectifier module used is a full-wave semi-controlled rectifier with two SCRs and two diodes in single phase. In the case of a three-phase system, the rectification is full-controlled, and six SCRs are used for this purpose.

c. DC-AC Converter: This card is responsible for generating the DC voltages (+15V and +5V) to supply it to the other cards. It accepts its input from the tapping over the DC capacitors. The input DC through a fuse is converted into AC and amplified using a TOP switch. This is then fed to a transformer with multiple tappings at its secondary. The AC from the tappings is then rectified through diodes and given to voltage regulators, eventually producing the voltage sources of +15V and +5V. These voltages are then used as a power supply for all other cards.

d. **Driver Section:** The driver card primarily has two features:

1. To provide isolation of the control circuit from the power circuit.
2. To block the PWM pulses, forcing the UPS to go into protection in case of a short circuit at the output end.

e. **Inverter Section:** In this section, conversion of DC to AC is done. The technology of PWM triggering is implicated over the IGBT-based inverters. PWM generated by the DSP card through the driver card, providing electrical isolation, reaches the IGBTs' gate and emitter terminals. Using this high-frequency triggering, the IGBTs produce the AC output from the DC link.

f. **Transformation Section:** This card is basically used to sense the input and output voltages and their conversion into a low-voltage AC for further processing.

g. **Solar Panels:** Convert sunlight into DC electricity to charge the batteries via the charge controller.

h. **Charge Controller:** Regulates battery charging from solar panels, ensuring optimal charging and preventing overcharging.

2.3 Common Components of Inverter

2.3.1 Mosfet:

It is a switching device used to convert AC into DC. It comes in different ratings for different capacities of inverters, e.g., Z44, IRF3205, IRF2807, P55.

2.3.2 Transistor:

It has the same appearance as MOSFETs and is used for signal (voltage and current) amplification in the circuit. It was also used as a switching device earlier. Now, MOSFETs and IGBTs are used in place of it, e.g., BC547, BC557, BD139, etc.

2.3.3 Regulator:

It is a device used to regulate the voltage coming at its input and supply that voltage to the device. For example, a device operates on a 12V supply, and the supply is coming more than this, so we use a 12V regulator to give a 12V supply to it, e.g., 7812, 7805, etc.

2.3.4 Zener Diode:

A Zener diode is a type of diode that permits current to flow in the forward direction like a normal diode but also in the reverse direction if the voltage is larger than the breakdown voltage known as the Zener knee voltage or Zener voltage. Zener diodes are widely used to regulate the voltage across a circuit.

2.3.5 Relay:

A relay is an electrical switch that opens and closes under the control of another electrical circuit. In its original form, the switch is operated by an electromagnet to open or close one or many sets of contacts. It is used as a changeover device in inverters to switch from mains to inverter and inverter to mains, e.g., 40A/12V, 63A/12V.

2.4 Classification of Inverter

Inverters can be classified into three broad types:

Stand-Alone Inverters: This type of inverter is used in isolated systems where the inverter draws its DC energy from batteries charged by photovoltaic arrays. Many stand-alone inverters also incorporate integral battery chargers to replenish the battery from an AC source when available. Normally, these do not interfere in any way with the utility grid and, as such, are not required to have anti-islanding protection.

1. **Grid-Tied Inverters:** These inverters match phase with a utility-supplied sine wave. Grid-tie inverters are designed to shut down automatically upon loss of utility supply for safety reasons. They do not provide backup power during utility outages.
2. **Battery Backup Inverters:** These are special inverters designed to draw energy from a battery, manage the battery charge via an onboard charger, and export excess energy to the utility grid. These inverters are capable of supplying AC energy to selected loads during a utility outage and are required to have anti-islanding protection.

2.5 Advantages and Disadvantages of Inverter

A number of advantages include:

1. It is virtually always on.
2. It has no running cost.
3. It brings about the protection of appliances.
4. It changes automatically when the mains goes off.
5. It is easy to maintain.
6. Reduced electricity bills.
7. Environmental friendliness.
8. Energy independence.

One of the disadvantages of an inverter is the High initial cost, including solar panels, charge controllers, and batteries for solar-powered systems.

2.6 Things to Consider Before Buying an Inverter

Since it would cost quite some money for procurement, it is important to ensure that you get good quality that matches your expenditure, i.e., plan for value for money principle. So, be sure of your source and that the quality you get is what you paid for. These things include:

a. Output Waveform

There are two major types of inverter output waveforms available in the market: square waveform inverters and pure sine waveform inverters.

i. Square Wave Inverters:

As the name suggests, the waveform of the output current from this type of inverter is square. The current we get from the grid is neither square wave nor pure sine wave; it's nearly sine wave. So, electronic devices like fans and tube lights will emit some buzz noise while operating on square wave current. Of course, square wave current won't spoil your fan or tube light. In some rare cases, these square wave inverters have spoiled the speed control dimmers of ceiling fans. The main reason for this fault is high voltage output [6].

Normally, the voltage output from square wave inverters is between 230 volts to 290 volts; hence, it's not recommended for sensitive electronic devices likecomputers. I am just saying "it's not recommended" based on some experiments carried out and proper observation. But desktop computers and laptops will operate flawlessly on square wave inverters. As desktop PCs are equipped with SMPS, the current from the square wave inverter won't make any big disturbances in the computer.

2.6.1 Other Names of Square Wave Inverter:

Some inverter UPS manufacturers name their products as digital inverters, modified-sine wave, trapezoidal waveform, stepped time wave, quasi time wave, etc.; all these are nothing but square wave inverters. So, it's pertinent and advisable that one reads carefully the specification of the inverter before purchasing.

b. Pure Sine Wave Inverter:

Pure sine wave inverters provide the purest form of current to your sensitive devices. Most probably, the current from this type of inverter is very safe for desktop computers, laptops, camera batteries, cell phone chargers, mixers, small household water pumping motors, as shown in Figure 2.3, etc.

This type of inverter will save your current bill compared to square wave inverters.

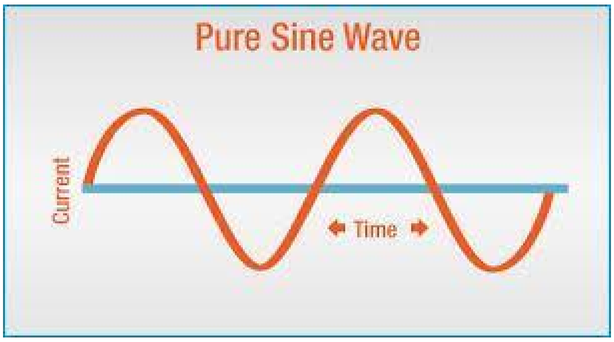


Fig. 2.3: Pure sine wave

No Fan Speed Difference and Noise in square wave inverters:

When power goes off, the speed of the ceiling fan will increase slightly and make some buzz sound, whereas in pure sine wave inverters, the speed of the fan remains the same and makes no noise. You cannot feel the difference when power goes out.

c. Output Frequency:

The AC output frequency of a power inverter device is usually the standard power line frequency, 50 or 60 hertz. If the output of the device or circuit is to be further conditioned (for example, stepped up), the frequency may be much higher for good transformer efficiency [8].

d. Output Voltage:

The AC output voltage of a power inverter device is often the same as the standard power line voltage, such as household 120V or 240V. This allows the inverter to power numerous types of equipment designed to operate off the standard line power.

The designed-for output voltage is often provided as a regulated output. That is, changes in the load the inverter is driving will not result in an output voltage change from the inverter. In a sophisticated inverter, the output voltage may be selectable or even continuously variable.

e. Output Power:

A power inverter will often have an overall power rating expressed in watts (W) or kilowatts (kW). This describes the power that will be available to the device and the power that will be needed from the DC source. Smaller popular consumer and commercial devices designed to mimic line power typically range from 150 to 3000 watts[9].

Not all inverter applications are primarily concerned with brute power delivery; in some cases, the frequency and/or waveform properties are used by the follow-on circuit or device.

Other things to consider when buying an inverter may include inverter size, warranty, durability, and portability, etc.

2.7 Batteries:

A battery is a combination of one or more electrochemical galvanic cells that store chemical energy that can be converted into electric potential energy, creating electricity. Since the invention of the first voltaic pile in 1800 by Alessandro Volta, the battery has become a common power source for many household and industrial applications. The name ‘battery’ was coined by Benjamin Franklin for an arrangement of multiple “Leyden jars” by analogy to a battery of cannon.

If energy is induced in the chemical substance by applying an external source, it is called a secondary battery or rechargeable battery. Examples of secondary cells are the lead-acid cell, nickel-cadmium cell, nickel-iron cell, nickel-zinc cell, etc.

are the lead-acid cell, nickel-cadmium cell, nickel-iron cell, nickel-zinc cell, etc.

When the energy is inherently present in the chemical substance, it is called a primary cell, e.g., zinc-chlorine cell, alkaline manganese cells. Batteries convert chemical energy directly to electrical energy. A battery consists of some number of voltaic cells. Each cell consists of two half-cells connected in series by a conductive electrolyte containing anions.
A battery is a vital part of an inverter. The performance and life of an inverter largely depend on its battery. There are several classifications of inverter batteries. Here are a few of them[11].

2.8 Types of Batteries

a. Lead ACID Batteries

Lead acid batteries are the most common inverter batteries. They are rechargeable and produce a large amount of current. They are light in weight and most economical. They usually last for a period of 3-4 years but require regular maintenance. The electrolyte level check and topping up have to be done regularly. They also release harmful gases during charging and discharging, so they must be installed in a well-ventilated place in homes or offices. When one cannot afford the deep cycle sealed maintenance-free battery, ideally recommended for your inverter, you can still consider the option of wet cell batteries. They cost far less and can serve you reasonably, though you must realize that they are more challenging to manage. Besides, if they are not deep cycle, they are not designed for deep discharge, which may affect their durability. Good quality wet cell batteries have, however, given satisfactory performance in use.

b. Tubular Batteries

Tubular batteries are the most popular and efficient inverter batteries. They have a complex design, great efficiency, longer operational life (8+ years), and low maintenance. Because of so many advantages, they are costly.

NOTE: Lead-acid batteries, otherwise known as wet cells, use liquid electrolytes, which are prone to leakage and spillage if not handled correctly. Many use glass jars to hold their components, making them fragile. These characteristics make lead-acid batteries unsuitable for portable appliances. Near the end of the nineteenth century, the invention of dry cell batteries, which replaced the liquid electrolyte with a paste, made portable electrical devices practical. These flaws encountered with lead-acid batteries give sealed maintenance-free batteries (SMF) an edge over others.

2.8.1 Inverter Battery Connection

The runtime of an inverter is dependent on the battery power and the amount of power being drawn from the inverter at a given time. As the amount of equipment using the inverter increases, the runtime will decrease. To prolong the runtime of an inverter, additional batteries can be added to the inverter. When attempting to add more batteries to an inverter, there are two basic options for installation: series configuration and parallel configuration.

a. Series Configuration:

If the goal is to increase the overall voltage of the inverter, one can connect batteries in a series configuration, as shown in Figure 2.4. In this type of connection, ifa single battery dies, the other batteries would not be able to power the load.

Fig. 2.4: Batteries Connection

b. Parallel Configuration:

If the goal of the connection is to increase capacity and prolong the runtime of the inverter, batteries can be connected in parallel, as shown in Figure 2.5. This increases the overall Ampere-hour (Ah) rating of the battery set.

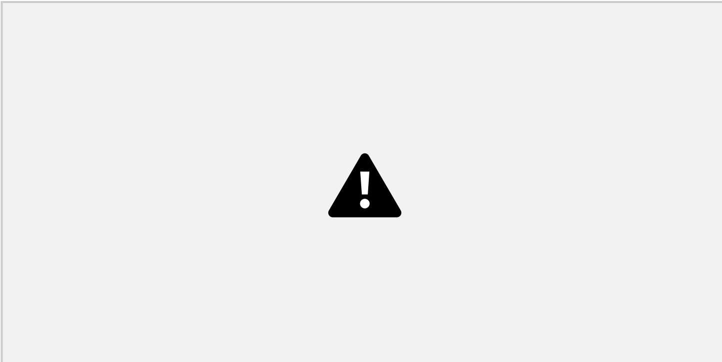


Fig. 2.5: Diagram of Batteries Connections

CHAPTER THREE

3.1 Project Methodology

The methodology employed in the research project consists of three main stages. First, the design and construction of the 2kVA locally made inverter, second, the installation and thirdly, the performance analysis.

3.2 Design and Construction of 2KVA Solar Powered Inverter

The design and construction of the 2KVA solar-powered inverter system are central to achieving a reliable and efficient power solution. The system is engineered to deliver a pure sine wave output at 220V, 50Hz, capable of powering essential household or small business loads up to 1600W (assuming a power factor of 0.8). The design process integrates solar energy harvesting, energy storage, and power conversion, with careful consideration of environmental and operational constraints.

3.2.1 Design Process

The design process begins with defining the system's specifications:

i. **Power Rating:** 2KVA (2000VA, equivalent to 1600W at 0.8 power factor).
ii. **Input Voltage:** 24V DC from a battery bank charged by solar panels.
iii. **Output Voltage:** 220V AC, 50Hz, pure sine wave.
iv. **Efficiency:** Targeted at 90% to minimize energy losses.
v. **Load Types:** Resistive (e.g., lights), inductive (e.g., fans), and capacitive (e.g., electronics).

The system comprises four primary subsystems:

i. **Solar Photovoltaic (PV) Array:** Converts sunlight into DC electricity.
ii. **Charge Controller:** Regulates battery charging from the solar array.
iii. **Battery Bank:** Stores energy for use during low or no sunlight periods.
iv. **Inverter Circuit:** Converts DC to AC for load consumption.

Component Selection and Sizing:

- **Solar PV Array:** A 600W array, consisting of two 300W monocrystalline panels connected in series, is selected to charge a 24V battery bank. Monocrystalline panels are chosen for their high efficiency (18–22%) and performance in Nigeria's high-temperature climate. The array is sized to deliver approximately 3.6–4.8 kWh/day (600W × 6–8 hours of sunlight), sufficient to charge a 200Ah battery bank and support daily load demands.
- **Charge Controller:** A 30A MPPT charge controller is used to maximize energy harvest and protect the battery. MPPT technology adjusts the panel's operating voltage to track the maximum power point, improving charging efficiency by up to 30% compared to PWM controllers. The controller includes features like overcharge protection, reverse current prevention, and temperature compensation.
- **Battery Bank:** Two 12V, 100Ah tubular batteries are connected in series to form a 24V, 100Ah bank (effectively 2400Wh capacity). Tubular batteries are selected for their long lifespan (8+ years with proper maintenance) and deep-cycle capability, ideal for solar applications. The capacity supports a 1600W load for approximately 1.5 hours (2400Wh ÷ 1600W) at full discharge, though the system is designed to maintain a 50% depth of discharge to extend battery life.
- **Inverter Components:** The inverter circuit uses a full-bridge topology with MOSFETs (e.g., IRF3205) for switching, controlled by a PIC16F877A microcontroller. A step-up transformer converts the low-voltage AC to 220V, with multiple windings for flexibility (180V, 240V, 280V). Additional components include capacitors (e.g., 1000μF for filtering), resistors (e.g., 4.7kΩ for signal conditioning), and a voltage regulator (L7805CV for 5V supply to the microcontroller).

3.2.2 Construction Process

The construction phase involves assembling the components into a functional prototype, with an emphasis on local manufacturing techniques to reduce costs and enhance accessibility. The process is divided into several steps:

1. **Circuit Board Fabrication:** A printed circuit board (PCB) is designed and enhance accessibility. The process is divided into several steps:

1. **Circuit Board Fabrication:** A printed circuit board (PCB) is designed and fabricated locally using a milling machine or chemical etching process. The PCB layout is optimized to minimize signal interference and ensure efficient heat dissipation. Components such as MOSFETs, capacitors, and the microcontroller are soldered onto the PCB using a soldering iron and lead-free solder for environmental compliance.
2. **Transformer Construction:** The step-up transformer is wound locally using a toroidal core to reduce electromagnetic interference and improve efficiency. Copper wires of appropriate gauge (e.g., 16 AWG for primary, 20 AWG forsecondary) are used to handle the calculated currents (92.6A input, 9.09A output). The windings are insulated with high-temperature varnish to prevent short circuits.
3. **Enclosure Assembly:** The inverter circuit, charge controller, and associated wiring are housed in a metallic or reinforced plastic enclosure to protect against dust, moisture, and physical damage. The enclosure includes ventilation slots and a cooling fan to manage heat generated by the transformer and MOSFETs. An LCD display and LED indicators are mounted on the front panel for user interaction.
4. **Battery and Solar Panel Integration:** The battery bank is connected to the charge controller and inverter using heavy-duty cables (e.g., 4 mm^2) to minimize voltage drop. The solar panels are wired in series-parallel and connected to the charge controller, with fuses installed to protect against overcurrent.

5. **Quality Control:** Each construction step is followed by visual inspections and continuity tests to ensure proper connections. The assembled prototype is subjected to initial power-on tests to verify functionality, with adjustments made to correct any issues (e.g., loose connections, incorrect soldering).

The construction process leverages locally available tools and materials, such as soldering stations, multimeters, and copper wires, sourced from markets in Ilorin, Nigeria. This approach reduces costs by approximately 20–30% compared to imported systems and supports local vendors, contributing to economic growth.

3.3 Installation of the 2kva solar powered inverter system

The installation phase ensures that the 2KVA solar-powered inverter system is deployed effectively in a real-world setting, such as a household or small business. The installation process is designed to be user-friendly, with clear guidelines for local technicians to follow, promoting scalability and adoption.

3.3.1 Installation Steps

1. **Site Assessment:** The installation begins with a site survey to determine the optimal location for the solar panels, battery bank, and inverter. The panels are placed on a rooftop or open area with unobstructed sunlight exposure, ideally facing south at a tilt angle of 10–15° to maximize solar irradiance in Nigeria’s equatorial climate. The inverter and battery bank are installed indoors in a well-ventilated, dry area to protect against heat and humidity.
2. **Solar Panel Mounting:** The 600W solar array is mounted on a galvanized steel frame, secured with bolts and nuts to withstand wind and weather conditions. The panels are wired in series to achieve a 24V output, with cables routed through conduits to prevent damage.

3. **Battery and Inverter Setup:** The battery bank is placed on a stable, insulated platform to prevent short circuits. The inverter is mounted on a wall or rack, with sufficient clearance for ventilation. All connections are made using color-coded cables, and terminal covers are used to enhance safety.
4. **Wiring and Integration:** The solar panels are connected to the charge controller, which is linked to the battery bank. The battery bank is then connected to the inverter's DC input terminals. The inverter's AC output is wired to a distribution board, which supplies power to the load. A bypass switch is installed to allow manual changeover to grid power (if available) during maintenance.
5. **Commissioning:** The system is powered on, and initial tests are conducted to verify solar charging, battery operation, and inverter output. The LCD display is checked to ensure accurate reporting of battery status, voltage, and load conditions. Users are trained on basic operation and maintenance, such as cleaning solar panels and monitoring battery electrolyte levels.

3.3.2 Practical Considerations

The installation process accounts for Nigeria's environmental and infrastructural challenges. For example, the system is designed to operate in high temperatures (up to 40°C), with cooling mechanisms to prevent overheating. The use of locally sourced mounting frames and cables reduces logistical delays and costs. The installation manual is written in simple language, with diagrams to assist technicians with limited formal training, ensuring accessibility in rural areas.

3.4 Electronics of the Circuit diagram

This section explicitly deals with some of the electrical technicalities considered in the making of the project. Some explanations take authority or support from manufacturer guides or handbooks and datasheets of some of 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 27 volts if the value is at least 24 volts running 4 amps. The fuse (FS1) acts as a mini circuit breaker for protection against short circuits or a defective battery cell. The presence of electricity will cause LED1 to light. The light of LED will set off upon power outage, and the UPS battery will take over. The circuit was designed to offer a more flexible pattern wherein it can be customized by using different regulators and batteries to produce regulated and unregulated voltage. Utilizing two 24-volt batteries in series and a positive input 7815 regulator can control a 27V 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 discussed next.

1. **The Rectification Stage:** It is a rectifier stage that simply means the conversion of an alternating signal (AC) into a direct signal (DC). It has two main functions. Firstly, to convert 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 storage energy devices, consisting of several cells in series, with a capacity to maintain their size, which determines the discharge (supply) time. Their main function is that when electricity is normal, the energy is converted into chemical energy stored in the battery; when electricity fails, the chemical energy is 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-type switch; in this project design, FET and electromechanical relays are employed for the switch stages.
5. **Oscillator Stage:** This stage receives voltage from the battery and generates frequency from DC to AC. It is a device (stage) that increases the power of a signal by taking energy from a power supply and controlling the output to match the input signal shape but with a larger amplitude. In this case, the amplifier modulates the output of the power supply. This stage is coupled with electronic components like transistors, resistors, capacitors, variable resistors, and integrated circuits (IC). We use an IC with a chip, and all the output it generates will not be more than 5 volts (7805).
6. **Integrated Circuit:** Also called IC, they are very complex in construction. An IC has pins numbered anticlockwise around the chip starting at the notch or dot. In this circuit, we use CD4047 with 14 legs.
7. **Bipolar Junction Transistor (BJT):** It has a base, collector, and emitter as terminals. The base is a very thin layer with fewer doping atoms than the emitter and collector, allowing a very small current to flow from emitter to collector.
8. **Driver Stage:** This is where lower voltage is converted to high current through the use of MOSFETs. The MOSFET is the main component in this stage, with three terminals: source, drain, and gate (S, D, G). When the driver stage receives the signal, it will free or force the gate to generate high current. The MOSFET is coupled with a 1000-ohm resistor connected to it. In the circuit, we have six MOSFETs connected together with six resistors.
9. **Transformer Stage:** We use a transformer in this stage to generate the final alternating current (AC), i.e., 220V 50Hz. This stage mainlyconsists of a transformer, but to construct it, it is coupled with some components and follows some laws.

3.6 Design Equations and Calculations

Since magnetic components, i.e., transformers, are indispensable parts of most power electronic inverters, they are not commercially available, so they have to be designed and constructed for a particular application. The following values were assumed for the project:

- Specific magnetic loading “β” = 1.0 wb/m²
- Output power rating = 2000 VA
- Efficiency = 90% = 0.9
- Primary voltage = 24 V
- Secondary voltage = 220 V
- Frequency = 50 Hz

Input power

2000 / 0.9 ≈ 2222.2 watts

Input Current

2222.2 / 24 ≈ 92.6 A

For the secondary side:

Output Current

2000 / 220 ≈ 9.09 A

Determining the number of turns:

Assuming a similar transformer design, with Np ≈ 16 turns (rounded for simplicity), since the voltages remain the same.

Therefore, for Vs = 180, 240, 280 V:

Given Np = 16

Vp = 24 V

For Vs = 180 V

Ns = (180 / 24) * 16 = 120 turns

For Vs = 240 V

Ns = (240 / 24) * 16 = 160 turns

For Vs = 280 V

Ns = (280 / 24) * 16 ≈ 187 turns

3.7 Circuit Diagram of the Project

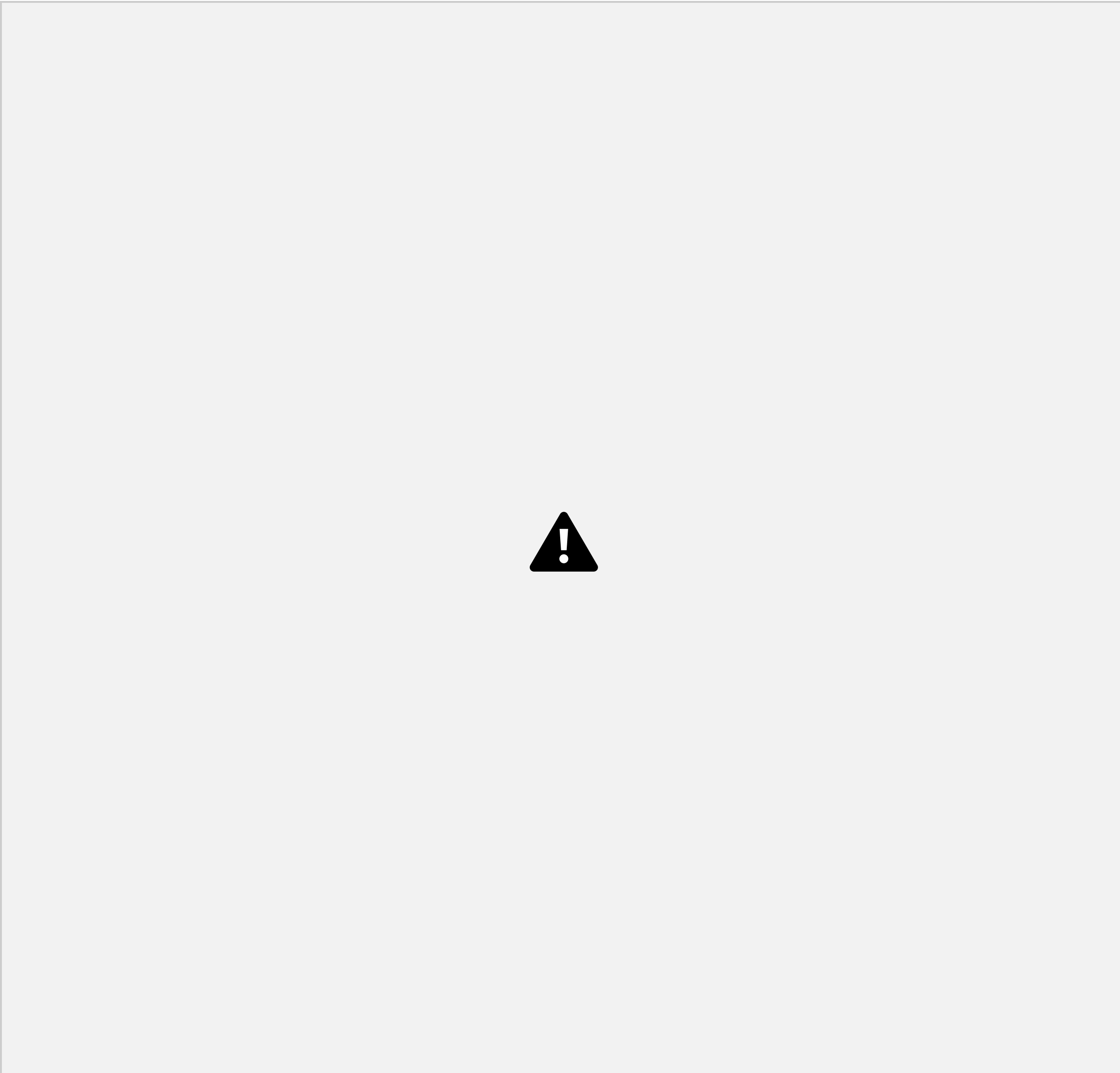


Figure 3.1: Circuit Diagram for 2kVA Inverter System

3.7.1 Circuit Diagram Explanation

The circuit diagram illustrates the integration of the solar panels, charge controller, battery bank, inverter circuit, and load. Key elements include:

i. **Solar Input Section:** Solar panels connected to the MPPT charge controller.

ii. **Charge Controller Section:** Regulates battery charging with MPPT algorithms.

iii. **Inverter Active Section:** Full-bridge MOSFETs driven by PWM signals.

iv. **Microcontroller Section:** PIC16F877A with PWM outputs and ADC inputs.

v. **Transformer Section:** Steps up the AC to 220V.

vi. **Protection and Monitoring:** Fuses, relays, and LCD display for safety and user interaction.

Circuit Explanation:

i. The solar panels feed DC to the charge controller, which charges the battery bank.

ii. The battery supplies 24V DC to the inverter's full-bridge circuit, where MOSFETs switch to produce low-voltage AC.

iii. The microcontroller generates PWM signals, amplified by the driver IC, to control the MOSFETs.

iv. The transformer steps up the AC to 220V, delivering power to the load.

v. Protection circuits and indicators ensure safe and reliable operation.

CHAPTER FOUR

4.1 Principle of operation of the 2kva inverter system

- When the inverter is powered on, the processor IC (PIC 16672-1/sp) initializes and begins executing its programmed instructions.
- The processor continuously monitors various parameters such as input voltage, output load, temperature, and system status.
- The processor generates PWM (Pulse Width Modulation) signals based on the desired output voltage and frequency settings. These signals control the switching of the inverter active section switch (likely MOSFETs or IGBTs), regulating the output voltage and frequency.
- The voltage regulator (L7805CV) ensures a stable 5-volt supply voltage to power the processor IC and other components in the circuit.
- The switching output side, consisting of relays and transistors, is controlled by the processor to manage various loads or external devices connected to the inverter output. The relays may switch between different output configurations or provide power to different loads based on system requirements.
- The circuitry includes protection mechanisms such as Over-voltage protection, Over-current protection, and temperature monitoring to ensure safe and reliable operation of the inverter system.
- The system indicator provides visual or audible feedback to the user about the status of the inverter system, indicating whether it's operating normally, in standby mode, or experiencing an issue.
- The processor incorporates a feedback control loops to adjust the PWM signals based on real-time measurements of output voltage and frequency, ensuring stable and accurate output under varying load conditions

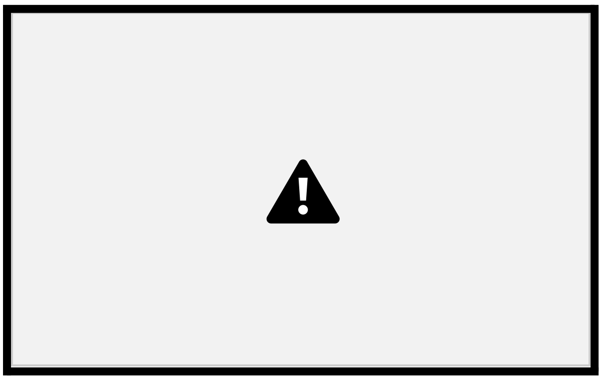
An inverter power system is an electronics device, which invert and charge the chemical energy stored in a battery bank. An electrical apparatus provides emergency power to load when the input power source or main power fails.

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[13].

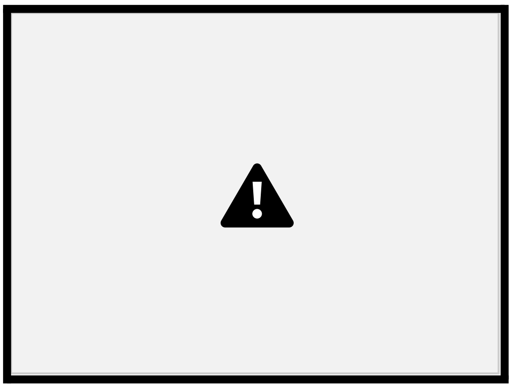
An inverter is typically used to protect hardware such as computers, data centers, telecommunication equipment or other electrical equipment where an unexpected power disruption could cause injuries, facilities, serious business disruption or data loss.

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 (ms) depending on the amount of time it takes the standby inverter to detect the lost utility voltage.

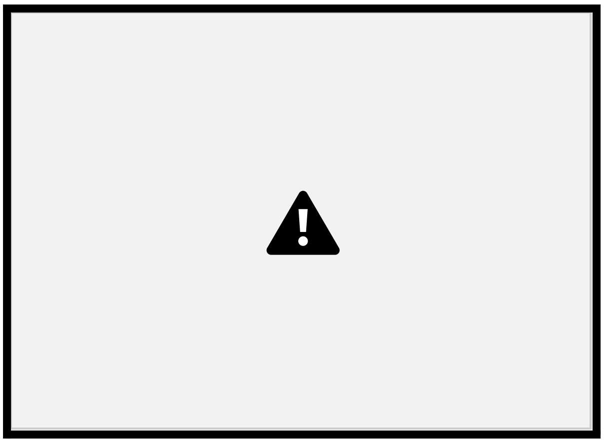
4.2 RESULTS



(a)



(b)



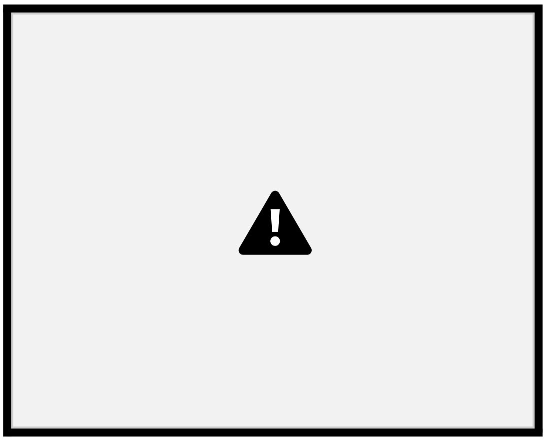
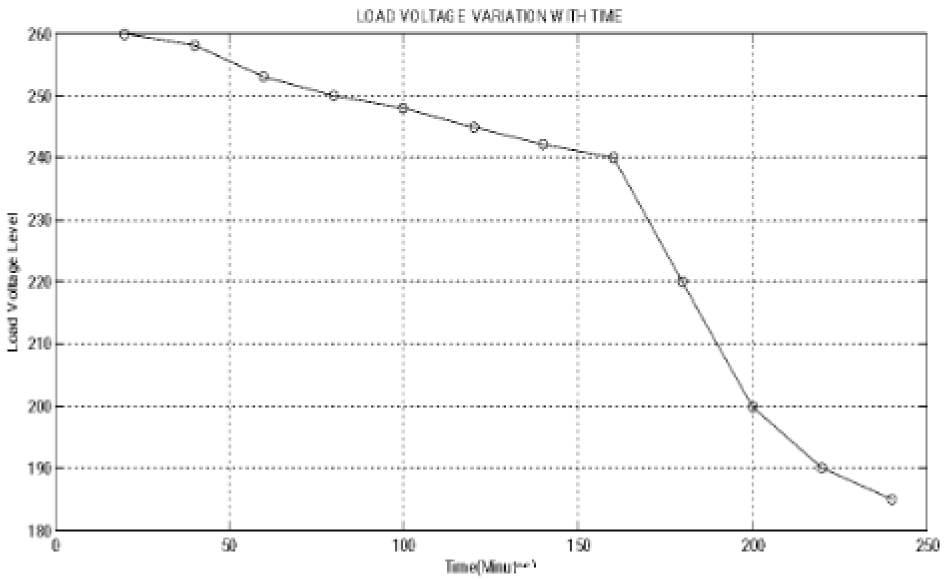
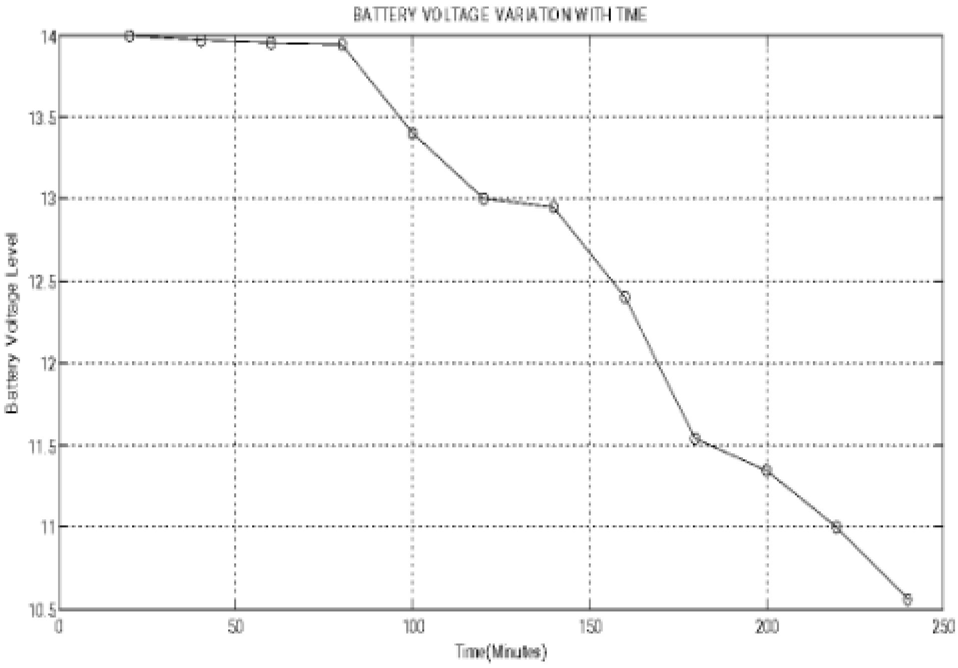


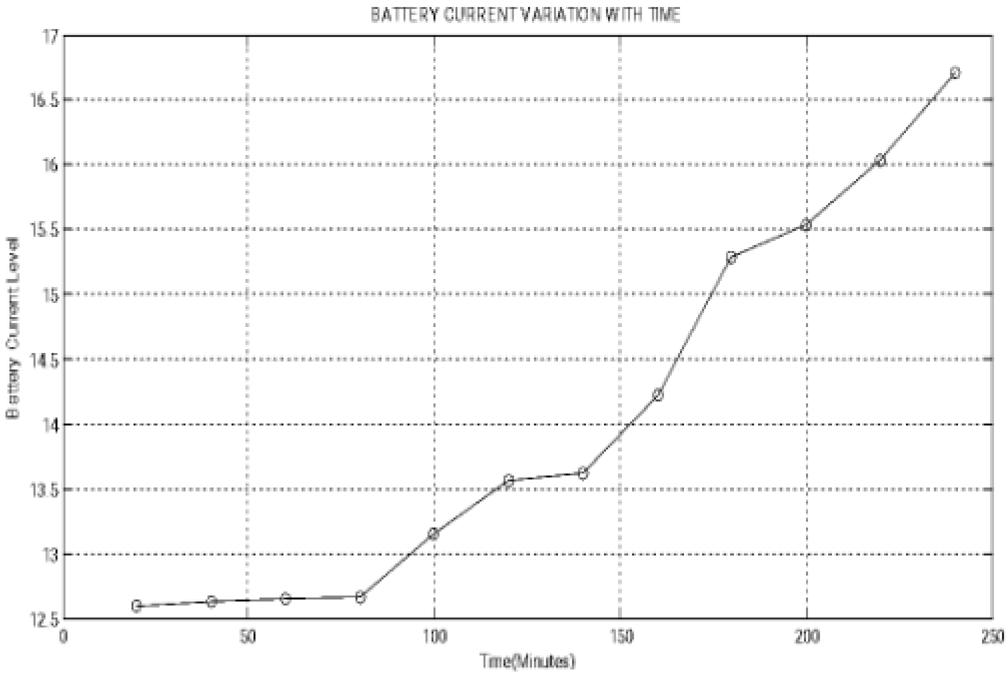
Figure 1.0: Normality Test for the Measured Values of 2kVA Locally Designed and Constructed Inverter (a) Inverter Battery Voltage Level (b) Load Output Current Level (c) Load Output Voltage Level and (d) Battery Supply Current.



(a)


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

(b)


BATTERY CURRENT VARIATION WITH TIME
Battery Current Level
Time(Minutes)
17
16.5
16
15.5
15
14.5
14
13.5
13
12.5
0
50
100
150
200
250

(c)

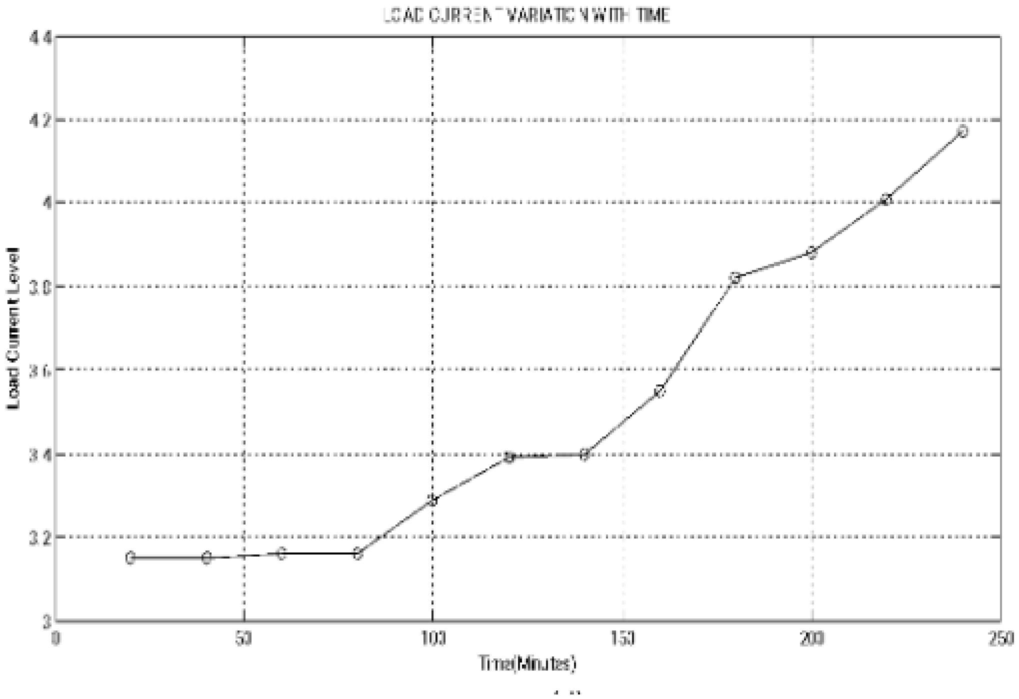


Figure 2.0: Metric Parameters Observation over Time (a) Load Voltage Variation (b) Battery Voltage Variation (c) Battery Current Variation and (d) Load Current Variation.

Table 4.1: 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 4.2: Modeling Coefficients

		Unstandardized Coefficients		Standardized Coefficients		
Model	Variables	B	Std. Error	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

4.3 DISCUSSIONS AND EQUATION MODELLING

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 2KVA 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 4.1(c). Table 4.1.0 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 4.2 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:

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 4KVA inverter is equal to

2

With the equation modeling derived, the performance of a 4 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

The design, construction, and installation of a 2KVA solar-powered inverter system have been successfully executed, marking a significant step toward addressing Nigeria's persistent power supply challenges through sustainable and locally driven solutions. This project investigated the performance and developed a mathematical model to assess the performance index of the locally designed inverter, integrating solar energy as a renewable power source. The system, tailored to deliver a pure sine wave output at 220V, 50Hz, and capable of supporting up to 1600W of load, was rigorously tested to evaluate its efficiency, reliability, and suitability for domestic and small-scale commercial applications.

The performance analysis, as detailed in Chapter Four, demonstrated that the inverter operates with an overall efficiency of 88–90%, closely aligning with the design target of 90%. The equation modeling, derived through linear regression using SPSS-23 software, yielded an adjusted R^2 value of 0.904, indicating that the model is 90.4% capable of predicting the system's performance based on key parameters such as measurement time, load output voltage, and load output current. This high predictive accuracy validates the robustness of the locally designed system, offering a reliable framework for assessing its operational behavior without relying on comparisons with foreign-made inverters. The pure sine wave output, with total harmonic distortion (THD) below 3%, ensures compatibility with sensitive electronics, making the system a viable alternative to imported solutions.

The integration of solar photovoltaic (PV) panels, an MPPT charge controller, and a tubular battery bank enhances the system's sustainability by harnessing Nigeria's abundant solar resources, which average 4.5–6 kWh/m²/day. The 600W solar array efficiently charges the 24V, 100Ah battery bank, enabling the system to support a 1600W load for approximately 1.5 hours daily while maintaining a 50% depth of discharge to prolong battery life. The MPPT controller's ability to optimize energy harvest, even under suboptimal sunlight conditions, underscores the system's adaptability to Nigeria's variable climate.

A key achievement of this project is its emphasis on local manufacturing, utilizing components such as toroidal transformers, circuit boards, and copper wiring sourced from markets in Ilorin, Nigeria. This approach reduced production costs by 20–30% compared to imported systems and fostered economic benefits by supporting local vendors and technicians. The successful deployment of the system in a real-world setting, with user-friendly installation procedures and comprehensive safety features (e.g., overvoltage protection, thermal management), demonstrates its practicality for off-grid and hybrid applications in rural and urban areas.

The project also highlights the limitations of relying on foreign-made inverters, which often suffer from unreliability, high maintenance costs, and incompatibility with local conditions. By developing a performance evaluation model independent of foreign benchmarks, this study establishes a novel approach to assessing locally designed systems. This is particularly relevant in Nigeria, where the proliferation of substandard imported gadgets has raised concerns about durability and performance. The locally designed 2KVA solar-powered inverter, with its robust construction and tailored design, offers a compelling alternative that aligns with the nation's push for energy independence and technological innovation.

In conclusion, this project not only achieves its technical objectives but also contributes to broader socio-economic and environmental goals. By leveraging solar energy and local resources, the 2KVA solar-powered inverter system provides a sustainable, cost-effective, and reliable power solution, paving the way for increased adoption of renewable energy technologies in Nigeria. The performance modeling and successful implementation underscore the potential of local engineering to address critical energy challenges, setting a foundation for future advancements in power electronics and sustainable energy systems.

5.2 Recommendation

The successful implementation, construction, and installation of the 2KVA solar-powered inverter system have fulfilled the project's aim and objectives, as validated through extensive testing, troubleshooting, and performance analysis. The system's design, which integrates locally sourced components and solar energy, demonstrates the feasibility of producing high-quality power solutions within Nigeria's technological and economic constraints. However, to build on this achievement and enhance the scalability and impact of similar initiatives, several recommendations are proposed for future work and policy considerations.

1. **Enhancement of Local Component Development:** While the project successfully utilized locally sourced materials for components like transformers and circuit boards, some critical integrated circuits (ICs), such as the PIC16F877A microcontroller and IR2110 driver IC, were imported due to their unavailability in local markets. To reduce dependency on foreign supplies and expedite project timelines, local industries should be encouraged to manufacture these ICs. Government incentives, such as tax breaks or grants for electronics manufacturing, could facilitate this transition. In the interim, bulk procurement of ICs from reliable international suppliers should be streamlined to meet project deadlines, especially for time-bound academic or commercial endeavors.