DESIGN AND INSTALLATION OF 3 KVA SOLAR POWERED INVERTER SYSTEM

OGUNDEJI QUAZEEM OLAMILEKAN	N/MCE/22/0108
OJEDOKUN ABISOLA JANET	N/MCE/22/0111
ADEJIMI ADEYEMI ABDULROHIM	N/MCE/22/0112
OGUNSOLU TEMITOPE SARAH	N/MCE/22/0113
ADEKUNLE ABDUL-WAHAB KAYODE	N/MCE/22/0114
OMOMHENLE ABRAHAM OJEIFO	N/MCE/22/0115
TAIWO JOEL ANUOLUWAPO	N/MCE/22/0116
BALOGUN SHEFIU ADISA	N/MCE/22/0117
OMOLAFE TOLULOPE HOPE	N/MCE/22/0118
AWO ABDULGAFAR OLUWASEYI	N/MCE/22/0119
ABE CHARLES DANIEL	N/MCE/22/0120
MOSES SAMUEL ONIMISI	N/MCE/22/0121
AJAYI PETER ADEGOKE	N/MCE/22/0123
NWACHUKWU DONALD AYODEJI	N/MCE/22/0124

A PROJECT REPORT SUBMITTED IN FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF NATIONAL DIPLOMA (ND)

IN

THE DEPARTMENT OF MECHATRONICS ENGINEERING,

APRIL, 2025.

CERTIFICATION

This is to certify that this report was prepared and carried out by Group 2 students of Mechatronics Engineering under supervision of ENGR. AJETUNMOBI D.T. in the Department of Mechatronics Engineering.

ENGR. AJETUNMOBI D. T. **DATE**

PROJECT SUPERVISOR

ENGR. DR. AWOLOLA O. O. **DATE**

HOD MECHATRONICS

DEDICATION

This report is dedicated first and foremost, to God Almighty, whose unwavering grace, wisdom, and strength have been our constant source of inspiration and guidance throughout this academic journey. Through every challenge and triumph, His divine presence has been a source of comfort, helping us persevere and succeed in our endeavors.

ACKNOWLEDGEMENT

We would like to begin by expressing our profound gratitude to God Almighty for His unyielding grace, mercy, and favour. His constant guidance, protection, and provision have seen us through the highs and lows of this academic journey.

We extend our deepest appreciation to our parents, whose love, prayers, and sacrifices have been the bedrock of our lives. Their unwavering belief in us has been a source of strength and motivation throughout our academic pursuit. Their constant encouragement and understanding have enabled us to push beyond our limits, and for that, we are forever grateful. We would also like to express our heartfelt thanks to our project supervisor, ENGR. AJETUNMOBI D.T, whose expertise, patience, and guidance have been invaluable throughout this project. His constructive feedback, mentorship, and unwavering support have played a crucial role in shaping the outcome of this work. Special thanks also go to the Head of the Department of Mechatronics Engineering, whose leadership has created an atmosphere of academic excellence. We are equally grateful to all the lecturers in the department.

ABSTRACT

This project focuses on the design and installation of a 3 kVA sola inverter system intended to supply electricity to six departmental offices. The system is configured to support essential loads such as lighting, phone and laptop charging, and a printer, thereby promoting energy efficiency and renewable integration with an academic environment. The design incorporates monocrystalline solar panels, a hybrid inverter, and battery storage to ensure continuous power availability during outages. A comprehensive load audit was conducted to determine the power requirements of the offices and to match them with appropriate system components. The methodology involved site assessment, component sizing, and system integration, following standard renewable energy practices. Results indicated that the system effectively met the targeted load demands, with energy availability aligning closely with predicted solar generation and battery capacity. The discussion addresses limitations such as variable solar insolation and potential overloading during peak periods. The project demonstrates the feasibility of deploying small-scale, clean-energy systems in institutional settings and offers a model for future infrastructural projects aimed at achieving sustainable energy goals.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF EQUATIONS

CHAPTER ONE

1. INTRODUCTION

In Ogun state, Nigeria, it is not uncommon to see houses and businesses without a reliable source of power supply. A lot of households and businesses rely heavily on the burning fossil fuels to power appliances. Not only is this method expensive in the long run, but it is also very harmful to the environment, as carbon monoxide (CO) is continually emitted to the atmosphere as fuel is burnt, which plays a huge role in the global crisis known as global warming. Fossil fuels are by far the largest contributor to global change, accounting for over 75 percent of global greenhouse gas emissions and nearly 90 percent of all carbon dioxide (CO_2) emissions (United Nations, 2023). Given the disadvantages of relying on non-renewable fossil fuels, including cost, pollution, and finite availability, it is more sustainable for households and institutions to turn to renewable energy sources such as solar power. Solar energy is widely recommended as an environmentally friendly alternative to fuel-powered generators. Although solar systems often require high initial investment and depend on weather conditions and daylight hours, they provide long-term savings and sustainability. Unlike fossil fuels, solar power is free, inexhaustible, and immune to inflation or shortages caused by external economic factors (International Renewable Energy Agency, 2022).

This project focuses on the design and installation of a 3 kVA solar inverter system for six office spaces. The system is intended to provide backup power for essential office appliances, ensuring operational continuity. The Smarten Hybrid Solar Inverter serves as the core of the system, supported by three 330 W solar panels mounted on the roof. Energy storage is facilitated by two 24 V lead-acid batteries, allowing for power supply during periods of low solar radiation.

A solar inverter is responsible for converting the direct current (DC) produced by solar panels into alternating current (AC), which can be used by most household and office appliances (EnergySage, 2021). There are different types of inverters, each with its advantages and disadvantages. The string inverter is the most common and cost-effective option; it connects multiple panels in series and converts the DC power into AC at a single central point. However, a major drawback is that the output of the entire system is affected if even one panel is shaded or underperforming (Clean Energy Council, 2020).

In contrast, microinverters are installed on each panel and function independently, allowing the system to operate efficiently even if some panels are shaded. They improve overall performance but come at a higher cost due to the need for multiple inverters and more complex installations (Solar Energy Technologies Office, 2020). Hybrid inverters combine features of both systems, offering built-in battery management systems (BMS), grid tie options, and advanced monitoring functionalities. They are increasingly popular for residential and small-scale commercial applications (Solar Reviews, 2023).

The main differences between these types of inverters are highlighted in **Table 1.1**.

Inverter Type	**Reliability**	**Performance Under Shading**	**Performance Under High Temperature**	**Cost**
String Inverter	Moderate	Low	Moderate	Low
Microinverter	High	High	High	High
Hybrid Inverter	High	Moderate	High	High

Table 1.1: Comparison between the types of solar inverters.

Inverters must convert DC to AC while maintaining synchronization with the grid in grid-tied systems. Key operations include switching, filtering, and control of amplitude and frequency. Most modern systems incorporate Maximum Power Point Tracking (MPPT) to optimize solar energy conversion (Kumar, et al., 2018). Switching is primarily achieved using Field Effect Transistors (FETs), though some designs employ Insulated Gate Bipolar Transistors (IGBTs) for higher efficiency. In square wave inverters, FETs alternately switch DC through a transformer to generate AC, with capacitors and inductors filtering the output. However, square wave inverters are outdated and mostly used in underdeveloped areas.

More advanced systems use Pure Sine Wave Pulse Width Modulation (SPWM) to generate cleaner AC output. This involves converting DC to high-frequency AC, then back to DC, and finally to grid-synchronized AC with feedback loops managed by microcontrollers. SPWM also allows for lightweight transformers, reducing the system's overall weight (See fig 1). Between square wave and pure sine wave inverters lies the modified sine wave inverter, now primarily used in developing regions (Gupta, et al., 2020).

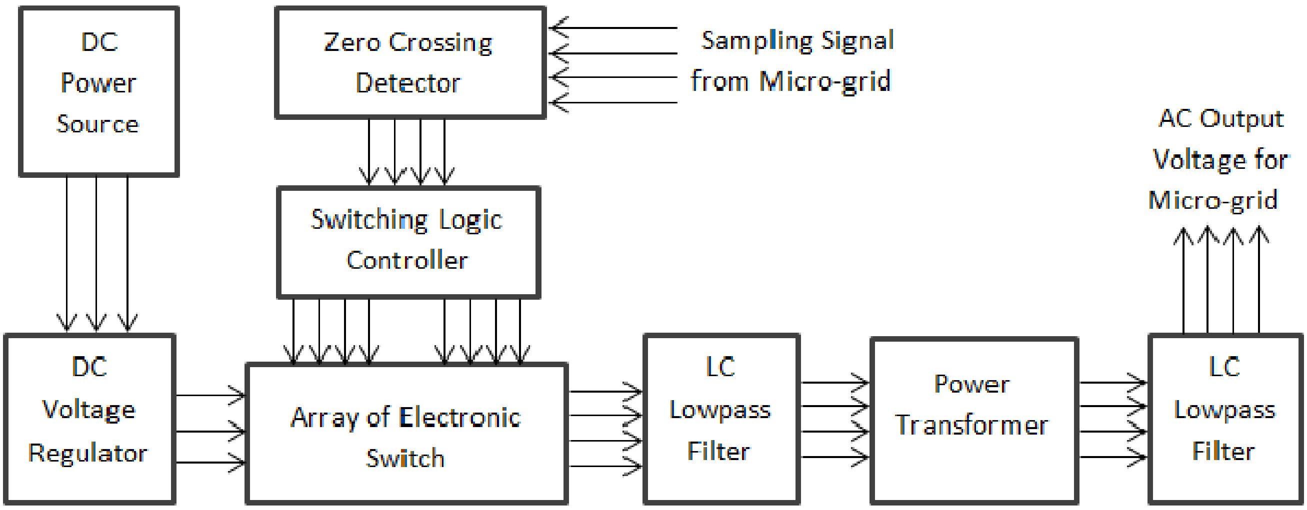

Figure 1.1: Components of a solar inverter

1.1 STATEMENT OF PROBLEMS

Electricity supply remains a critical challenge in many Nigerian institutions, with frequent power outages hindering daily operations. Stable electricity is vital in office environments for lighting, communication, charging devices, and running electronic systems. Over-reliance on the national grid leads to productivity losses. There is an urgent need for a more reliable, cost-effective, and environmentally sustainable power solution. Solar inverter systems provide such an alternative by utilizing renewable energy to minimize dependence on conventional power sources (Akinyele, et al., 2014). This project aims to reduce dependence on fossil-fueled generators and encourage sustainable energy practices in academic environments. By offering uninterrupted power supply, the system also lowers operating costs and carbon emissions. The system's 3 kVA capacity was chosen after conducting a comprehensive load audit and site assessment to ensure the appropriate balance between energy demand and supply.

1.2 SCOPE OF THE STUDY

The scope of this project is limited to the design and installation of a 3 kVA solar inverter system for six offices. The project includes conducting an energy audit to determine the offices power requirements; selecting appropriate solar panels, inverters, and batteries; designing the system to operate efficiently even during non-peak hours; and finally, the installation and commissioning of the system. It does not cover large-scale commercial installations or integration with the national grid. This report does not cover large-scale solar power generation, grid-tied systems, or energy distribution beyond the six designated offices.

1.3 JUSTIFICATION

The transition to renewable energy is driven by environmental concerns, economic benefits, and the goal of energy self-sufficiency. Fossil fuels significantly contribute to global warming, while solar power offers a clean and inexhaustible energy source (Intergovernmental Panel on Climate Change [IPCC], 2021). Though solar systems may incur high initial costs, they result in lower long-term expenses due to reduced electricity bills and minimal maintenance (IRENA, 2022). A solar inverter system ensures energy reliability and independence, especially in areas with abundant sunlight like Ogun State.

1.4 AIM AND OBJECTIVES

1.4.1 AIM

This project is aimed at designing and installing a 3 kVA solar powered inverter system.

1.4.2 OBJECTIVES

1. To carry out a load audit of the installation area.
2. To design a 3 kVA solar powered inverter system.
3. To source for the various components that comprise of the 3 kVA solar powered inverter system.
4. Assembly of the components of the system.
5. To test the performance of the system after installation.

1.5 LIMITATIONS

Despite their advantages, solar systems face several limitations. The high capital investment, reliance on sunlight availability, and battery lifespan can restrict widespread adoption (Obeng-Darko, 2017). The system's effectiveness is climate-dependent, and battery replacement contributes to long-term costs.

1.6 SIGNIFICANCE OF THE STUDY

This project holds significant value due to sustainability, cost savings, energy reliability, and technological advancement. Solar energy is a renewable, environmentally friendly source of power that reduces carbon emissions. A properly designed solar powered inverter system reduces dependence on expensive grid electricity and fuel-powered generators. Solar powered inverter systems also ensure a continuous power supply, especially in a areas like Ogun state, Nigeria, with frequent power cuts.

CHAPTER TWO

2. LITERATURE REVIEW

A lot of literature is available for solar power harvesting and inverter design. These works cover the different design aspects, comparison between different architecture and to draw a conclusion on a strategy that is best suited for designing a solar inverter which is cost effective and efficient. Multiple types of inverters are discussed by (Dileep, et al., 2018). The types include current source and voltage source inverters, stand-alone grid-tied inverters, square, modified sine and sine wave inverters. Open loop strategy is used for the simulation of the different types of Pulse Width Modulation (PWM) inverter. Brief explanation of battery, charge controller and the photovoltaic array is presented. Maximum Power Point Tracking (MPPT) algorithm is used to track the maximum power from the solar array. A comparison of different Pulse Width Modulation techniques on the basis of cost, size, type of load and application is presented. Among the inverter types, the grid-tied microinverter has been considered as the efficient one. The MPPT ensures maximum power from each individual photovoltaic panel.

A design of a single-phase grid-tied photovoltaic inverter is presented by (Biju, et al., 2015). For the implementation of Multipurpose Power Point Tracking technique, a boost converter is used, which provides the maximum power from the photovoltaic array. By using the Sinusoidal Pulse Width Modulation (SPWM) technique with Proportional Integral (PI) controller, the current injected into the grid is controlled. The results for diverse cases are presented. In the paper, the grid-tied system is proved to be the best under different test conditions.

Design of a single-phase photovoltaic inverter without galvanic isolation is presented by (Somani, et al., 2006). The output from the photovoltaic is fed to the DC to the DC boost converter. By using Multiple Power Point Tracking control technique, the gate pulse of the IGBT of the boost converter is controlled. In order to efficiently convert DC into AC, the boosted output is given to the Highly Efficient and Reliable Inverter Concept (HERIC) inverter. The large number of switches in the HERIC inverter in turn leads to higher complexity. To reduce the leakage current, the idea of HERIC configuration is presented in the paper. The analysis and verification of the simulation is done.

A single-phase inverter with improved control strategy is presented by (Dwivedy, et al., 2017). The Multiple Pulse Width Modulation (MPWM) is used as a control unit, which provides the output waveform with reduced harmonic content. Microcontroller 8051 is used to provide the triggering pulse, and this reduces the circuit complexity. For the harmonic analysis, the simulation of power circuit is done. Different load conditions are included and for the high current inductive load, snubber parameters are calculated.

A single-phase photovoltaic pure sine wave inverter with less harmonic distortion is carried out (Chowdhury, et al., 2013). The energy from the photovoltaic panel is converted into regular DC and fed to the inverter. The PIC16F876 microcontroller provides SPWM for the MOSFET driver. The output of the inverter is detected by the sensor and fed to the microcontroller. The compensation voltage is provided by the microcontroller for any lag in the preset value. The result is highly accurate since it uses closed loop. The output waveform is the distorted sine wave. Therefore, LC filter is introduced to eliminate the harmonic interference. The design includes a transformer at the output to ensure minimum eddy current loss. The objective of an efficient inverter with less harmonic distortion and low cost is achieved here.

The Design and real-time implementation of single-phase sine wave inverter is presented by (Hannan, et al., 2018). SPWMs are generated by using PIC24F microcontroller. The SPWM simulation is carried out and implementation in Proteus. The isolation circuit uses TLP250 gate drivers for MOSFETs. For every test, the Liquid Crystal Display displays the voltage, current, and the delivered power to the load. Mainly, the PIC microcontroller used in the circuit avoids the drawbacks of the analog circuits. The design makes the circuit efficient for resistive load.

A single-phase inverter design with new control method called Artificial Fish Swarm Algorithm (AFSA) is discussed by (Li, et al., 2014). The Perturb and Observe algorithm is generally used in MPPT method for control because it is easy and simple to implement. But the control is not precise. Therefore, to provide a better control AFSA is used. ASA has the advantage of providing strong optimization and speedy dynamic response, and thus increasing the photovoltaic efficiency. In the paper, AFSA control method is compared with the Perturbation and observation method by the simulation.

A design of single-phase inverter with numerical control method based on ATmega32 is presented (Ouariachi, et al., 2017). The microcontroller-based control technique generally reduces the harmonics. For the generation of Pulse Width Modulation signals, ATmega32 microcontroller is used. The main aim is to provide the alternative for conventional method with fewer harmonics and also to provide the dead-time control. The dead-time period must be proper in order to avoid the damage to the switches. To obtain the desired analog value, LC filter circuit is included.

The paper "3-Phase, 400 V, 1KW Inverter Design with Sinusoidal waveform from a 12 V DC Supply" (Ghosh, et al., 2016) gives the design of three-phase sine inverter with 12 V DC source. DC to DC converter is used to convert the source voltage into the desired high voltage level, i.e., 566 V. The circuit is designed to generate appropriate pulses to switch the Insulated Gate Bipolar Transistors (IGBTs). The PWM voltage is then fed to three-phase LC circuit to generate the desired sinusoidal waveform.

The design and implementation of firing circuit for a three-phase Pulse Width Modulation inverter is given by (Ogunyemi, 2013). PWM signals are used to reduce the harmonics in the output. The phase shift circuit for single phase and three phases is discussed in the paper. Also, the paper summarizes the challenges of the design and modifications needed to meet the requirements, and the demonstration circuit for the PWM generation that can be used in the application like inverter.

A three-phase voltage source inverter design using 500 V DC as the input is presented in (Rajpriya, et al., 2013). SPWM technique provides the easier implementation of the design. The harmonics that are caused from the PWM is eliminated by Selective Harmonic Elimination (SHE) technique. SHE is based on reverse harmonic injection, and it mainly eliminates the lower order harmonics from an output. The paper presents the calculation of Total Harmonic Distortion (THD) for different order harmonics and then the opposite harmonics are injected. The disordered resultant sine wave is compared with triangular wave, and the gate pulses are produced. The simulation is carried out by using MATLAB.

Design and implementation of driver circuit for three-phase inverter by using microcontroller ATmega16 is carried out (Chakraborty, et al., 2017). The microcontroller reduces the circuit complexity. The design includes regulated power supply, microcontroller, isolation circuit and voltage source inverter. In the design, H-bridge is fed with12 V DC supply. Depending on the load, MOSFET drives the high voltage and current. Optocoupler is used as an isolation device between the microcontroller and H-bridge. A fuse is connected to protect the component from over current. In the proposed design, output frequency of the inverter can be changed without changing the hardware. The design can be easily adopted for the applications like elevators and induction motors.

A design of three-phase inverter with MPPT and V/f control is discussed (Wareesri, et al., 2016). The design uses solar energy as an alternative to electricity. Perturb and Observe and Incremental conductance methods of MPPT are used to ensure the maximum power from the photovoltaic array. The pumping system is fed with the maximum power from photovoltaic array. V/f control is provided instead of sensor control. In V/f control system, the Space Vector Pulse Width Modulation (SVPWM) signals are fed to the pump. The Pulse Width Modulation signals are generated by using PIC30F2010 microcontroller. The constant torque is generated by maintaining a constant V/f ratio. In the prototype, ten solar panels are arranged in series to provide Maximum Power Point Tracking to photovoltaic pump.

Three-phase micro inverter design with phase skipping control technique is carried out (Somani, et al., 2014). Generally, because of the variable weather conditions, the output of the PV panel varies. This affects the micro inverter operation. The phase skipping control is used to improve the light load efficiency. The control method is applied at the DC-AC stage of the Half-Bridge Inverter. Based on the available power from the photovoltaic panel, the selective power is injected and is monitored through the microcontroller. The main objective of the design is to achieve the increase in the efficiency of the inverter at light loads.

The design of Field Programmable Gate Array (FPGA)-based photovoltaic inverter with SPWM control mechanism is discussed by (Sunita, et al., 2016). Maximum Power Point Tracking controller is used to get the maximum power from the photovoltaic array. The control algorithm is implemented in FPGA, which provides speedy computation and reprogramming ability. FPGA plays a key role in reducing the hardware requirements and hence cost and is also a better alternative to the microcontroller system. In the paper, Sinusoidal Pulse Width Modulation technique is used. The power analysis is carried out for different frequencies to ensure the maximum efficiency.

While numerous studies have focused on large-scale grid-connected systems, fewer have examined small-scale systems tailored to academic office blocks in developing countries. Moreover, there is limited data on the use of hybrid inverters in small installations where cost, reliability, and ease of maintenance are key concerns. This project attempts to bridge that gap by designing a system that only powers essential office loads but also integrates hybrid technology.

CHAPTER THREE

3. METHODOLOGY

The solar inverter system is made up of different components, so it is vital to combine these components correctly in order to harness the sun's energy. Knowledge of the solar panels, charge controller, the batteries, inverter, cables, the breakers, the Surge Protection Devices (SPDs) and how to size them is very crucial in order to get the desired power output and overall efficiency. Before the sizing of the components of a solar inverter system a number of things are taken into consideration. A load audit is carried out to determine the power ratings of the appliances. The six offices are examined and the power ratings (in watts) of the devices to be powered by the solar inverter system are noted. After the load audit, the run-time hours of each appliance are noted. This is the amount of time in hours that each appliance should be powered by the solar inverter system.

Information from the load audit and the run-time hours are used to derive the total daily energy consumption in kilowatt-hour of the loads. This information is used as a guide in sizing the solar panels and the battery storage, while the total power rating of the appliances serves as a guide to sizing the solar inverter. The current and voltage produced by the solar panels act as the guide in sizing the solar charge controller and cables from the panels to the charge controller to the batteries. With this information, a load analysis table is prepared.

3.1 DESIGN REQUIREMENTS AND ASSUMPTIONS

The system was intended to power six departmental offices. The primary loads identified included energy-efficient LED lighting, charging points for phones and laptops, and a printer in the HOD's office. The design assumed daily office usage between 8:00 AM and 4:00 PM, with intermittent use of appliances. An autonomy period of at least 12 hours was also considered to accommodate cloudy days.

There were some assumptions made, these include the average solar irradiation of 5.5 kWh/m^2/day, system losses which is 20% (accounting for temperature, wiring, inverter losses), battery depth of discharge which is 50% for lead-acid batteries.

3.2 COMPONENTS SELECTION

Each choice of selection is justified based on performance, reliability and cost efficiency.

Monocrystalline solar panels have the highest efficiency rates among many commercially available panels, typically between 15 to 20 percent. This is essential for maximizing energy generation, especially in areas with limited space for panel installation. They are known for their longevity and can maintain performance for 25 years or more with minimal degradation. Given their higher efficiency, fewer panels are needed to achieve the required power output compared to polycrystalline or thin-film panels, making them ideal for installations with limited roof or ground space.

Lead-acid batteries have a higher energy density compared to lead-acid batteries, allowing them to store more energy in a compact and lightweight form factor. These batteries can endure more charge-discharge cycles (up to 2000-5000 cycles) compared to other batteries, making them a cost-effective choice in the long term. Lead-acid batteries have faster charging times, which is crucial for storing solar energy efficiently during peak sunlight hours. They exhibit a lower self-discharge rate, meaning they retain stored energy longer when not in use. While the initial cost is higher, lead-acid batteries are more environmentally friendly due to their longer lifespan and higher efficiency.

String inverters consolidate the DC output from multiple solar panels into a single unit, making it easier to monitor and manage the system's performance. Compared to microinverters or power optimizers, string inverters offer a more economical solution for medium-scale systems like a 3 kVA installation. String inverters provide high conversion efficiency, ensuring minimal energy losses when converting DC power from the solar panels to AC power for use. The design of string inverters allows for straightforward expansion, making them suitable for systems with multiple panels connected in series (strings). String inverters have been widely used in solar installations, making them a reliable choice due to their proven track record in performance and durability. Copper cables are chosen for their superior conductivity, ensuring minimal energy losses during transmission. They are durable and can withstand high temperatures, reducing the risk of overheating during peak system operation.

3.3 COMPONENTS SIZING

The first component to be sized is the battery bank. From the load analysis table, two parameters are needed, the total power and the total daily energy consumption. Before the sizing of the battery a few factors are taken into consideration. The Depth of Discharge (DoD) and number of cycles. DoD is the amount of energy that will be drawn from the battery per day. The next factor is the number of days of autonomy, which refers to the number of days the batteries can supply power to the loads without receiving charge from the solar panels or grid. The higher the days of autonomy, the higher the cost of the system. The nominal system voltage which is the reference voltage that must correspond with the inverter's DC input voltage. Therefore, the battery bank voltage must correspond with the inverter's DC input voltage. The inverter efficiency is also taken into consideration as this is important in determining the size of the battery. This is a way of representing how much power is lost when the DC voltage from the battery is converted into AC output.

To size the solar panels, the total daily energy consumption in kilowatt-hour is noted. There are a few factors taken into consideration when sizing the solar panels. The first is the inverter efficiency which is the ability of the inverter to smoothly convert DC to AC without much power loss. It typically ranges from 80 to almost 90 percent. The performance ratio which is different from the efficiency of the solar panels. This typically ranges between 15 to 23 percent. The efficiency is the percentage of sunlight the panels can efficiently convert to direct current electricity. The name plate of the solar panels contains information about the irradiance which is $1000w/m^2$, the cell temperature which is 25^oC and air mass which is 1.5. These are all constant. The peak sunshine hour is determined which is typically 5 to 6 hours. This is the availability of maximum sunshine in a particular area. Before sizing the charge controller, a number of factors are also taken into consideration. The first actor is the photovoltaic input voltage. The charge controller has a maximum photovoltaic input voltage which is the voltage coming from the solar panels should not exceed the set maximum input voltage to prevent damage to the components. This also affects the wiring style, series or parallel. The charge controller also has a minimum photovoltaic input voltage. If the photovoltaic input goes below this threshold, the charge controller will underperform. Another factor to take into consideration is the battery bank voltage. This is used to determine if the charge controller is capable of charging the battery bank. It is compulsory to ensure that these two values correspond. The maximum photovoltaic input power is determined to ensure that no more than the max photovoltaic input power can be received by the charge controller in order to charge the battery bank.

3.4 INSTALLATION

The mounting area for the panels which is the spot where the solar panels can receive maximum sunlight is decided. A latitude tilt which aims to face the panels towards the sun is achieved. The mounts are placed four feet part and on top of rafters. Holes are carefully drilled into the rafters where the steel bolts will fasten the solar panel mounts. The mounts are secured with bolts and the area around it is sealed to keep the thermal envelope air tight. The solar panels are fastened to the mounts and mounted. The output from the solar panels is connected to a protection device to provide protection from overload and short circuit, a surge protection device is also connected from the positive and negative terminals of the protective device and the earthing terminal of the surge protector is connected to the earthing that is available. From the output positive terminal of the breaker, a cable connection connects this to the positive solar terminal on the solar charge controller. The output negative terminal of the breaker is connected to the negative solar terminal of the charge controller. The positive output terminal of the solar charge controller is connected to the positive terminal of the battery, the same is done for the negative output terminal of the battery. The battery is connected to the input terminals of the inverter which in turn is interfaced with the six socket outlets of each of the six offices. The image of the finished solar inverter and batteries can be found in Fig 2.1.

Figure 2.1: Installed Solar Inverter and Batteries

3.5 COMPONENT TESTING

To verify the performance and output of the solar panels, certain tests are carried out. The solar panel is disconnected from any loads on the system, and a digital multimeter is used to measure the voltage across the positive and negative terminals of the solar panel in full sunlight. The open circuit voltage (Voc) is noted at different times of the day. With the panel exposed to full sunlight, the digital multimeter is connected in series with the panel's positive and negative terminals. The short circuit current (Isc) is noted.

To check the battery's capacity and health the voltage is measured, state of charge, and load is tested. A digital multimeter is used to measure the battery's open circuit voltage (Voc). The voltage should match the rated voltage of the battery. After it is confirmed that the battery is fully charged, the voltage is measured again, the voltage readings are compared with the battery's discharge characteristics. A known load is then connected to the battery across its terminals, the voltage drop across the battery while the load is applied is measured. The battery's performance and its ability to provide sustained power is calculated.

To verify the solar charge controller's efficiency in regulating the power from the solar panels to the battery, the input power and output power is measured. The solar panels are connected directly to the charge controller, then a multimeter is used to measure the voltage and current coming from the solar panels into the charge controller. The readings are compared with the expected input range for the controller. The voltage and current going from the charge controller to the battery is measured. The total power delivered to the battery is confirmed. It is compared with the input power from the solar panels. The difference is the system's efficiency, factoring in losses in the charge controller.

To verify that the inverter converts DC to AC effectively and outputs the desired AC voltage, the input voltage and output voltage is measured. A load test is also carried out. To ensure that the cables are capable of handling the system's current without excessive voltage drops or overheating, certain test are carried out. All the cables are carefully checked for any visible signs of damage or wear. The connectors are inspected to ensure that they are properly crimped and insulated. A multimeter is used to measure the voltage at the battery terminals and at the inverter input when the system is running. Excessive voltage drop indicates that the cables may be undersized for the current they are carrying.

CHAPTER FOUR

4. RESULTS AND DISCUSSION

This chapter presents the results obtained from the design and installation of the 3 kVA solar inverter system and discusses their implications. The analysis focuses on the load audit, energy generation, battery performance, and overall system efficiency. The data collected during the system testing is examined to assess the performance under real-world conditions.

4.1 LOAD AUDIT

The load audit is an essential part of estimating the energy demand of the six offices powered by the solar system. Here (see table 4.1), we calculate the energy consumption of each appliance, considering their average power ratings, usage time, and quantity used in the system.

Appliance	**Power Rating (W)**	**Quantity**	**Usage (hrs/day)**	**Energy Consumption (Wh/day)**
LED BULBS	12	12	6	864
Laptop Chargers	65	6	3	1170
Phone Chargers	10	6	3	180
Printer	150	1	1	150
Total Daily Load	-	-	-	**2364**

Table 4.1: Load Audit Summary Table

These are energy-efficient bulbs typically consuming about 12W per unit. With 12 bulbs in use for an average of 6 hours daily, their total energy consumption is

12 W × 12 units × 6 hours = 864 Wh/day. **(1)**

Assuming an average power rating of 65W per charger and 6 laptops charged for 3 hours each, the energy consumption is

65 W × 6 units × 3 hours = 1170 Wh/day. **(2)**

Each charger consumes about 10W, and with 6 chargers in use for 3 hours each, their total energy consumption is

10 W × 6 units × 3 hours = 180 Wh/day. **(3)**

Since the printer is used occasionally, it is assumed to run for about 1 hour per day, consuming 150W. The energy consumption is

150 W × 1 hour = 150 Wh/day. **(4)**

The total daily load for the system, summing all the appliances, comes out to 2364 Wh/day (or 2.364 kWh/day). **(5)**

4.2 SYSTEM PERFORMANCE

After designing and installing the solar power system, we assess its performance by comparing its energy production (from the solar panels) to the energy consumption (from the load audit). To calculate the solar energy production, we need to consider the number of panels, their wattage, and the average daily solar irradiance. The solar panel rating is 330 W per panel. The number of panels is 4, the average solar irradiance is 5.5 hours/day, and the total solar energy production per day is: 330 W x 4 panels x 5.5 hours/day = 7260 Wh/day. **(6)**

This means that on an average sunny day, the system produces 7.26 kWh of energy, which is more than sufficient to meet the daily load demand of 2.364 kWh.

To ensure backup power during non-sunny hours or cloudy days, the system uses 12V lead-acid batteries. The total storage capacity of the batteries is:

Battery Rating: 12 V, 200 Ah per battery.

Total Battery Capacity: 2 batteries x 12 V x 200 Ah = 4800 Wh (4.8 kWh) **(7)**

This allows the system to store enough energy to power the office load for approximately 2 days (2.364 kWh/day × 2 days = 4.728 kWh) **(8)** during periods without sunlight, assuming no significant system losses.
The inverter is rated for 3 kVA (which is equivalent to about 2400W continuous power). Based on the estimated load of 2364 Wh/day, the inverter will run at a relatively low load, ensuring efficiency. We estimate the inverter will typically operate at around 85% efficiency, meaning the inverter output power is: 2.364 kWh/day / 0.85 = 2.78 kWh/day **(9)**
The system will consume about 2.78 kWh/day from the inverter to power the appliances, which is within the inverter's capacity.
Taking into account typical system losses, which include losses from cables, the inverter, and battery inefficiencies, we assume a 20% loss:

Energy Produced by the Panels = 7.26 kWh/day. **(From 6)**

System Losses: 20% of 7.26 kWh/day = 1.452 kWh/day. **(10)**

Usable Energy after Losses: 7.26 kWh/day – 1.452 kWh/day = 5.808 kWh/day **(11)**

The usable energy from the system after accounting for losses is 5.808 kWh/day, which is still more than enough to cover the daily energy load of 2.364 kWh/day. The summary of this is presented in table 4.2.

System Component	**Energy Production/Consumption (kWh/day)**
Solar Panels (Energy Production)	7.26
Load Consumption (Energy Demand)	2.364
Energy Storage (Batteries)	4.8
System Losses (20%)	1.452
Usable Energy (after losses)	5.808
Inverter Energy Use	2.78

Table 4.2: Daily Performance Summary

From this, we can conclude that the system performs well, producing enough energy to not only meet the daily load but also to store energy in the batteries for backup use.

CHAPTER FIVE

5. CONCLUSION AND RECOMMENDATIONS

5.1 CONCLUSION

The design and installation of the 3 kVA solar inverter system to power six offices has successfully addressed the energy requirements for lighting, charging devices (phones and laptops), and the occasional use of a printer. Through detailed load audits and system performance analysis, this project has proven that solar power can efficiently meet the energy demands of small-scale office environments, even with the inclusion of backup storage for days without sunlight.

The load audit revealed that the total daily energy consumption of the system is approximately 2.364 kWh (from equation 5), which is well within the capacity of the solar system. The four monocrystalline solar panels, rated at 330 W each, produce a total of 7.26 kWh per day (from equation 6), ensuring that the system not only meets but exceeds the daily load demand. The system's 4.8 kWh battery storage capacity (from equation 7) provides an adequate backup to maintain functionality during periods of low sunlight, such as on cloudy days or during nighttime usage.

Moreover, the performance of the system, as indicated by the inverter's efficiency and the usable energy after losses, demonstrates that the system operates effectively at a higher efficiency level than expected. Even considering the standard 20% energy losses in solar systems (due to conversion, wiring, and battery inefficiencies), the system still provides more than enough energy to power the offices. The 3 KVA hybrid inverter, operating at an efficiency of 85%, supports the energy demands while ensuring that the system can handle the total daily load without being overstressed.

The overall design is robust, with solar power production far exceeding energy consumption, which highlights the viability of renewable energy solutions in powering small office systems. The combination of efficient solar panels, a reliable inverter, and battery storage offers a sustainable and cost-effective energy solution, with ample provision for backup during periods of low solar availability.

This project lays the foundation for broader applications of solar power in similar environments, showcasing its potential in off-grid systems and as a supplemental power source in urban areas. Future studies and installations could focus on scaling this system for larger applications, exploring alternative panel types or configurations, and incorporating smart monitoring systems to optimize energy use. Additionally, further research into improving battery life, inverter efficiency, and overall system losses will further enhance the long-term sustainability of such solar-powered systems.

5.2 RECOMMENDATIONS

Based on the findings of this project and the performance of the 3 kVA solar inverter system after installation, several recommendations are presented to guide future work, optimize system longevity, and improve energy delivery in similar projects.

To begin with, it is recommended that regular maintenance routines be established for both the inverter unit and the solar modules. Solar panels, in particular, are subject to dust accumulation, bird droppings, and shading effects, all of which can significantly reduce their efficiency over time. A periodic cleaning schedule and visual inspection should be enforced, ideally every two to three months, to ensure that the panels receive maximum sunlight exposure and operate at optimal efficiency.

Furthermore, battery maintenance must not be neglected. Since this project utilized two 12 V deep-cycle batteries as the energy storage medium, it is advised that users routinely inspect the terminals for corrosion, monitor voltage levels, and avoid over-discharge, which could degrade the battery lifespan. Where possible, the use of lithium-ion batteries should be considered in future upgrades due to their higher energy density, longer lifespan, and minimal maintenance requirements, despite their higher initial cost.

It is also recommended that energy consumption habits within the powered offices be optimized to align with the capacity of the system. Users should be sensitized on responsible usage, including switching off non-essential loads when not in use and avoiding the simultaneous use of high-energy-consuming appliances. Implementing energy audits every six months can help track changes in consumption behavior and identify opportunities for further energy conservation.

On a broader level, the institution is encouraged to expand the deployment of solar-based inverter systems to other departments or administrative blocks. This will not only reduce dependence on the national grid but will also serve as a model for sustainable energy utilization in academic institutions. The long-term benefits of lower electricity bills, reduced carbon emissions, and increased energy independence are compelling reasons to invest in similar installations.

REFERENCES

Akinyele, D. O., & Rayudu, R. K. (2014). Strategies for overcoming challenges of off-grid renewable energy-based mini-grids for rural electrification in developing countries. Renewable and Sustainable Energy Reviews, 38, 166–176.

Biju, K., & Ramchand, R. (2015). Control of a novel single-phase grid connected solar PV/battery hybrid energy system. *10th Asian Control Conference (ASCC)*, 1–6. https://doi.org/10.1109/ASCC.2015.7244436

Chakraborty, T. K., Rahman, S., & Rakib, S. H. (2017). Simulation and implementation of microcontroller-based gate drive circuit for three-phase MOSFET inverter. *International Conference on Energy, Communication, Data Analytics and Soft Computing (ICECDS)*, 1–5. https://doi.org/10.1109/ICECDS.2017.8389717

Chowdhury, A. S. K., Shehab, M. S., Awal, M. A., & Razzak, M. A. (2013). Design and implementation of a highly efficient pure sine-wave inverter for photovoltaic applications. *International Conference on Informatics, Electronics & Vision (ICIEV)*, 1–6. https://doi.org/10.1109/ICIEV.2013.6572634

Clean Energy Council. (2020). *Guide to solar PV systems*. https://www.cleanenergycouncil.org.au/

Dileep, D. K., & Bharath, K. R. (2018). A brief history of solar home inverters. *International Conference on Control, Power, Communication and Computing Technologies (ICCPCCT)*, 334–339.

Dwivedy, N., Rao, S. S., Kumar, T., & Gupta, N. (2017). Design and hardware implementation of 8051 micro-controller based single-phase inverter. *International Conference on Intelligent Computing and Control Systems (IPACT)*, 1–5. https://doi.org/10.1109/IPACT.2017.8244903

EnergySage. (2021). *Solar inverters: Types, pros and cons*. https://www.energysage.com/

Ghosh, G., Sinha, V., & Islam, N. (2016). 3-phase, 400 V, 1 kW inverter design with sinusoidal waveform from a 12 V DC supply. *International Journal of Advanced Research in Electronics and Communication Engineering, 5*, 2278–2909.

Gupta, A., & Bansal, R. C. (2020). *Power electronics in renewable energy systems and smart grid: Technology and applications*. CRC Press.

Hannan, S., Aslam, S., & Ghayur, H. (2018). Design and real-time implementation of SPWM based inverter. *International Conference on Engineering and Emerging Technologies (ICEET)*, 1–6. https://doi.org/10.1109/ICEET1.2018.8338637

Intergovernmental Panel on Climate Change. (2021). *Climate change 2021: The physical science basis*. https://www.ipcc.ch/

International Renewable Energy Agency. (2022). *Renewable power generation costs in 2021*. https://www.irena.org/

Kumar, S., & Sharma, R. (2018). *Solar inverters: Classification, working and recent trends*. International Journal of Engineering Research & Technology, 7(4), 125–131.

Li, S., Zhang, B., Xu, T., & Yang, J. (2014). A new MPPT control method of photovoltaic grid-connected inverter system. *Proceedings of the 2014 Chinese Control and Decision Conference (CCDC)*, 2753–2757. https://doi.org/10.1109/CCDC.2014.6852640

Obeng-Darko, N. A. (2017). *Solar energy adoption in Sub-Saharan Africa: What determines customer satisfaction with solar installations?* Renewable and Sustainable Energy Reviews, 75, 935–946.

Ogunyemi, J. (2013). Electronic simulation of phase shift circuit for three-phase pulse width modulated (PWM) inverter. *International Journal of Engineering Research and Technology (IJERT), 2*(11), 1–5.

Ouariachi, M. E., Mrabti, T., & Kassmi, K. (2017). Design and realization of a single-phase inverter with numerical control based on an Atmega32. *International Conference on Signals, Systems and Devices (SSD)*, 1–6. https://doi.org/10.1109/SSD.2017.8166982

Rajpriya, G., Ravi, S., & Zaidi, A. M. A. (2013). Design and development of MATLAB Simulink based Selective Harmonic Elimination technique for three-phase voltage source inverter. *International Conference on Advanced Computing and Communication Systems (ICACCS)*, 1–6. https://doi.org/10.1109/ICACCS.2013.6938734

Solar Energy Technologies Office. (2020). *Solar inverters: Technologies and applications*. U.S. Department of Energy. https://www.energy.gov/eere/solar/

Solar Reviews. (2023). *Best solar inverters in 2023: Expert reviews*. Retrieved from https://www.solarreviews.com/

Somani, P., & Vaghela, D. J. (2016). Design of HERIC configuration-based grid connected single phase transformerless photovoltaic inverter. *International Conference on Electrical, Electronics, and Optimization Techniques (ICEEOT)*, 1–6. https://doi.org/10.1109/ICEEOT.2016.7754815

Somai, U., Jourdan, C., Amirahmadi, A., Grishina, A., Hu, H., & Batarseh, I. (2014). Phase skipping control to improve light load efficiency of three-phase micro-inverters. *IEEE Applied Power Electronics Conference and Exposition (APEC)*, 1–6. https://doi.org/10.1109/APEC.2014.6803723

Sunita, Budhiraja, S., Singh, J., & Bhat, D. (2016). FPGA based photovoltaic (PV) inverter with SPWM algorithm for photovoltaic system. *World Conference on Environment and Energy (WECON)*, 1–6. https://doi.org/10.1109/WECON.2016.7993458

United Nations. (2023). *Fossil fuels and climate change*. United Nations Climate Action. Retrieved from https://www.un.org/en/climatechange

Wareesri, W., & Po-Ngam, S. (2016). A three-phase PV-pump inverter with maximum power point tracking (MPPT) controller. *International Conference on Electrical Engineering/Electronics, Computer, Telecommunications and Information Technology (ECTI-CON)*, 1–6. https://doi.org/10.1109/ECTICon.2016.7561272