DESIGN AND CONSTRUCTION OF 2kVA SOLAR POWERED INVERTER SYSTEM

BY

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A PROJECT SUBMITTED TO THE DEPARTMENT OF ELECTRICAL/ELECTRONIC ENGINEERING, INSTITUTE OF TECHNOLOGY, KWARA STATE POLYTECHNIC, ILORIN, KWARA STATE.

IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF NATIONAL DIPLOMA (ND) IN ELECTRICAL/ELECTRONICS ENGINEERING

CERTIFICATION

This is to certify that the project titled "**Design and Construction of 2kVA Solar Powered Inverter System**" was carried out by **Lukuman Abdulfatihi Oluwashina**, with Matriculati on Number **ND/23/EEE/PT/171**, and has been approved as meeting the requirement for t he award of the National Diploma (ND) in Electrical/Electronics Engineering, Institute of Technology, Kwara State Polytechnic, Ilorin, Kwara State.

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(Coordinator)

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____________________ **Date:** *External Examiner*

DEDICATION

This project work is wholeheartedly dedicated to the Almighty Allah, the giver of wisdom, knowledge, and understanding, for His divine guidance and protection throughout the du ration of this study. It is also dedicated to my beloved parents for their unwavering supp ort, encouragement, and sacrifices that made this academic journey possible.

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Abstract

This project focused on the design and construction of a **2 kVA solar powered inverter system** to ensure reliable and sustainable power supply by integrating solar energy with grid power. The key objective was to develop a system capable of powering household or small office loads using renewable energy, supplemented by the grid when needed.

The methodology involved selecting suitable components, including four 450 W solar panels, a 60 A MPPT charge controller, a 48 V lithium-ion battery bank, and a 2 kVA hybrid inverter, and conducting detailed design calculations to ensure proper sizing and efficient operation. The system was assembled with careful attention to wiring, safety, and integration of solar and grid inputs.

Key findings show that the system successfully provided clean AC power, prioritized solar energy, and ensured uninterrupted power supply for up to 2 kVA loads. Testing confirmed stable output voltage (230 V AC) and efficient battery charging through the MPPT controller, validating the design and demonstrating the feasibility of a hybrid solar solution for small-scale applications.

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Chapter One

1.0 Introduction

1.1 Background and Motivation

The global shift towards cleaner energy has sparked growing interest in harnessing renewable sources, with solar energy emerging as a leading option. In many areas, grid electricity remains unreliable, causing frequent power cuts that disrupt daily activities. At the same time, environmental concerns tied to fossil fuels highlight the need for greener, more sustainable solutions.

Solar photovoltaic (PV) systems present a promising alternative by converting the sun's energy in an abundant and renewable resource into electricity. However, standalone solar setups can face challenges due to unpredictable weather and limitations in battery storage capacity. Integrating solar systems with grid or backup power through hybrid systems helps overcome these challenges, offering both reliability and flexibility.

The aim of this project is to develop a **2 kVA hybrid solar powered inverter system** that can support residential or small commercial loads. By combining solar energy with grid backup, the system ensures a steady, eco-friendly power supply while reducing dependence on conventional energy sources. The project also serves as a practical example of solar system design and implementation, fostering a better understanding of hybrid power solutions.

1.2 Problem Statement

Many homes and small businesses experience frequent power outages due to unstable grid systems, leading to disruptions in daily routines and possible damage to sensitive equipment. While generators are often used as a backup, they pose environmental concerns and involve significant fuel and maintenance costs.

Solar PV systems offer a renewable energy alternative, but when used alone, they can struggle to meet energy demands during low sunlight or nighttime hours. Therefore, a more versatile solution is needed one that combines solar power with grid electricity or a generator backup to provide consistent, reliable power.

The purpose of this project is to design and build a **2 kVA hybrid solar powered inverter system** that ensures continuous, clean, and stable electricity for household or small office use. The system must maximize solar energy usage, automatically switch between power sources when necessary, and deliver a dependable AC output to meet user requirements.

1.3 Objectives

The specific objectives of the project are to:

1. design a 2 kVA hybrid solar power system that integrates solar, grid, and battery power sources.
2. select and size appropriate system components, including solar panels, batteries, MPPT charge controller, and inverter.
3. ensure seamless switching between solar power and grid backup for uninterrupted electricity supply.
4. construct and assemble the system with proper wiring, safety features, and testing.
5. evaluate the performance of the system in terms of efficiency, reliability, and load handling capability.
6. provide a practical demonstration of a clean, sustainable, and cost-effective energy solution for small-scale applications.

1.4 Scope of Work

The scope of work are:

- **Design**: Develop a comprehensive design for a 2 kVA hybrid solar power system, including system architecture, sizing calculations, and component selection.

- **Component Selection**: Identify and procure key system components, including solar panels, MPPT charge controller, inverter, batteries, and protection device s.
- **Construction**: Assemble the system, incorporating proper wiring, mounting, an d safety features.
- **Integration**: Configure the hybrid inverter to manage power from solar panels, grid, and battery sources, ensuring seamless transitions and optimal energy us e.
- **Testing and Evaluation**: Conduct tests to verify system performance, including load handling, solar power prioritization, battery charging/discharging, and reli ability under various conditions.
- **Documentation**: Prepare a detailed report documenting system design, implem entation, testing results, and any challenges encountered during the project.
- **Demonstration**: Present the fully operational system as a proof-of-concept for reliable, renewable power for residential or small commercial use.

Chapter Two

2.0 Literature Review

2.1 Introduction

The global energy sector has witnessed a growing shift from conventional fossil fuel-based systems to renewable energy technologies due to concerns over environmental degradation, rising fuel costs, and energy security. Among the various renewable sources, **solar photovoltaic (PV) systems** have gained significant traction because of their sustainability, scalability, and relatively low maintenance. This chapter reviews existing literature on solar power systems, battery energy storage, charge controllers, and inverter technologies relevant to the development of a 2kVA solar-powered inverter system.

2.1.1 Solar Photovoltaic Technology

Photovoltaic (PV) technology is the process of converting sunlight directly into electricity using semiconductor materials such as silicon. According to Green et al. (2019), solar PV systems are among the fastest-growing sources of energy worldwide, largely due to advancements in panel efficiency and reductions in cost. There are various types of solar panels, including monocrystalline, polycrystalline, and thin-film. Monocrystalline panels, used in this project, offer higher efficiency and longer lifespans, making them suitable for limited-space installations.

The power output of solar panels depends on several factors including solar irradiance, temperature, orientation, and shading. Effective system design requires careful consideration of these factors to ensure optimal performance.

2.1.2 Battery Energy Storage Systems

Energy storage is a critical component of any standalone solar system. It enables energy generated during sunlight hours to be stored and used during periods of low or no solar radiation (e.g., at night or during cloudy weather). Traditional systems relied heavily on **lead-acid batteries**; however, recent studies highlight the superiority of **lithium-ion batteries** in terms of energy density, charge-discharge efficiency, lifecycle, and maintenance requirements (Luo et al., 2015).

Lithium-ion batteries are also better suited for deep-cycle applications and support faster charging, making them ideal for modern solar applications. However, they require **Battery Management Systems (BMS)** to monitor cell voltage, temperature, and protect against overcharge/discharge.

2.1.3 Charge Controllers

A **charge controller** regulates the voltage and current coming from the solar panels to the batteries, thereby preventing overcharging and prolonging battery life. There are two major types: **Pulse Width Modulation (PWM)** and **Maximum Power Point Tracking (MPPT)**.

According to Esram and Chapman (2007), **MPPT charge controllers** are significantly more efficient than PWM types, especially under fluctuating sunlight conditions. MPPT technology continuously adjusts the electrical operating point of the modules to ensure maxi mum power transfer from the panels to the battery bank.

The 60A MPPT charge controller used in this project ensures optimal solar harvesting and efficient battery charging, especially under varying weather conditions.

2.2 Inverter Technologies

Inverters play a vital role in solar power systems by converting the stored **Direct Current (DC)** from the batteries into **Alternating Current (AC)**, which is the standard for most household and office appliances. There are various types of inverters: square wave, modified sine wave, and **pure sine wave**.

Pure sine wave inverters produce a waveform similar to grid power and are compatible with sensitive electronic devices such as computers, televisions, and medical equipment. They are more expensive but offer higher efficiency and less electrical noise (Kjaer et al., 2005). The 2kVA pure sine wave inverter selected for this project ensures stable and safe power output for connected loads.

2.3 Related Works

Several studies and projects have been carried out on small-scale and medium-scale solar inverter systems. For instance, Ogueke et al. (2014) successfully implemented a 1.5kVA solar-powered inverter for rural electrification, emphasizing the cost-effectiveness of such systems in off-grid communities. Similarly, Adaramola et al. (2017) highlighted the r ole of hybrid solar-inverter systems in improving energy access in sub-Saharan Africa.

These projects show the growing interest in decentralized power systems and the feasibility of solar technology in reducing dependence on erratic grid supply. However, many systems still suffer from design inefficiencies, lack of proper battery management, and underutilization of modern MPPT controllers.

2.4 Summary

This literature review has explored the key technologies that form the foundation of solar inverter systems—solar panels, batteries, charge controllers, and inverters. The review highlights the importance of component selection and system integration for performance optimization. By leveraging high-efficiency monocrystalline panels, lithium battery storage, MPPT regulation, and a pure sine wave inverter, this project aims to address the limitations of earlier designs and contribute a more reliable and sustainable power solution.

Chapter Three

3.0 System Design and Methodology

3.1.0 System Requirements

3.1.1 Safety Components

- DC circuit breakers/fuses between charge controller and batteries
- AC circuit breakers/fuses for inverter output
- Grounding for all metallic enclosures

3.1.2 Monitoring

- Basic LCD/LED display on charge controller for real-time voltage, current, and SOC (state of charge)
- Option for future upgrade to remote monitoring

3.1.3 Environmental Condition

- Operating temperature range: 0°C – 50°C
- Indoor installation, protected from rain and direct sunlight

3.2 Block Diagram

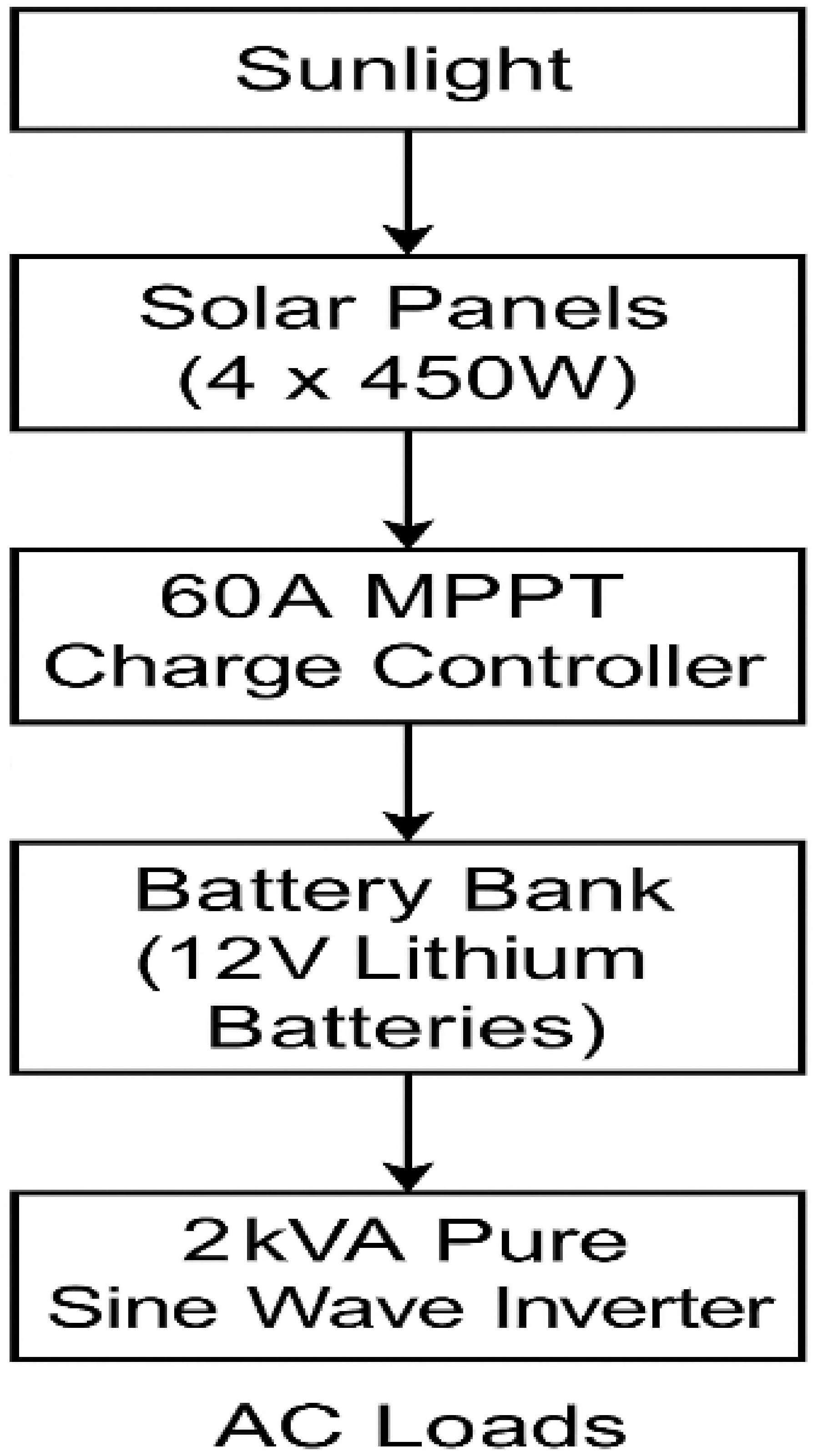

Figure 3.2

3.3.0 Component Selection

3.3.1 System Capacity

- **Rated Power Output:** 2kVA (2000VA)
- **AC Output Voltage:** 220V ± 10%, 50Hz (standard for residential and office applian ces)
- **DC Input Voltage:** 24V (battery bank voltage)

3.3.2 Solar Panels

- **Type:** Monocrystalline solar panels

- **Number of Panels:** 4
- **Individual Power Rating:** 450W per panel
- **Total Solar Array Capacity:** 1800W (4 × 450W)
- **Operating Voltage:** ~37-40V per panel
- **Series/Parallel Configuration:** Configured to charge a 24V battery bank efficiently via MPPT

3.3.3 Batery Bank

- **Type:** Lithium-ion batteries
- **Number of Batteries:** 4
- **Individual Voltage:** 12V
- **Total Configuration:** 24V (two 12V batteries in series, paralleled with another series pair)
- **Total Capacity:** ~200Ah (depending on the specific battery amp-hour rating)
- **Depth of Discharge (DoD):** Up to 80-90% (typical for lithium batteries)

3.3.4 Charge Controller

- **Type:** MPPT (Maximum Power Point Tracking)
- **Current Rating:** 60A
- **Input Voltage Range:** Compatible with solar panel array voltage (typically 30-100V)
- **Output Voltage:** 24V for charging the battery bank
- **Features:** Overcharge, over-discharge, and short circuit protection

3.3.5 Inverter Specification

- **Type:** Pure Sine Wave Inverter
- **Output Power:** 2kVA continuous, with short-term surge capability
- **Efficiency:** 85-90% (typical for modern inverters)
- **Cooling:** Forced-air cooling (internal fan)
- **Protections:** Short-circuit, over-temperature, overload, and low/high voltage shutdown

3.4.0 Circuit Diagram

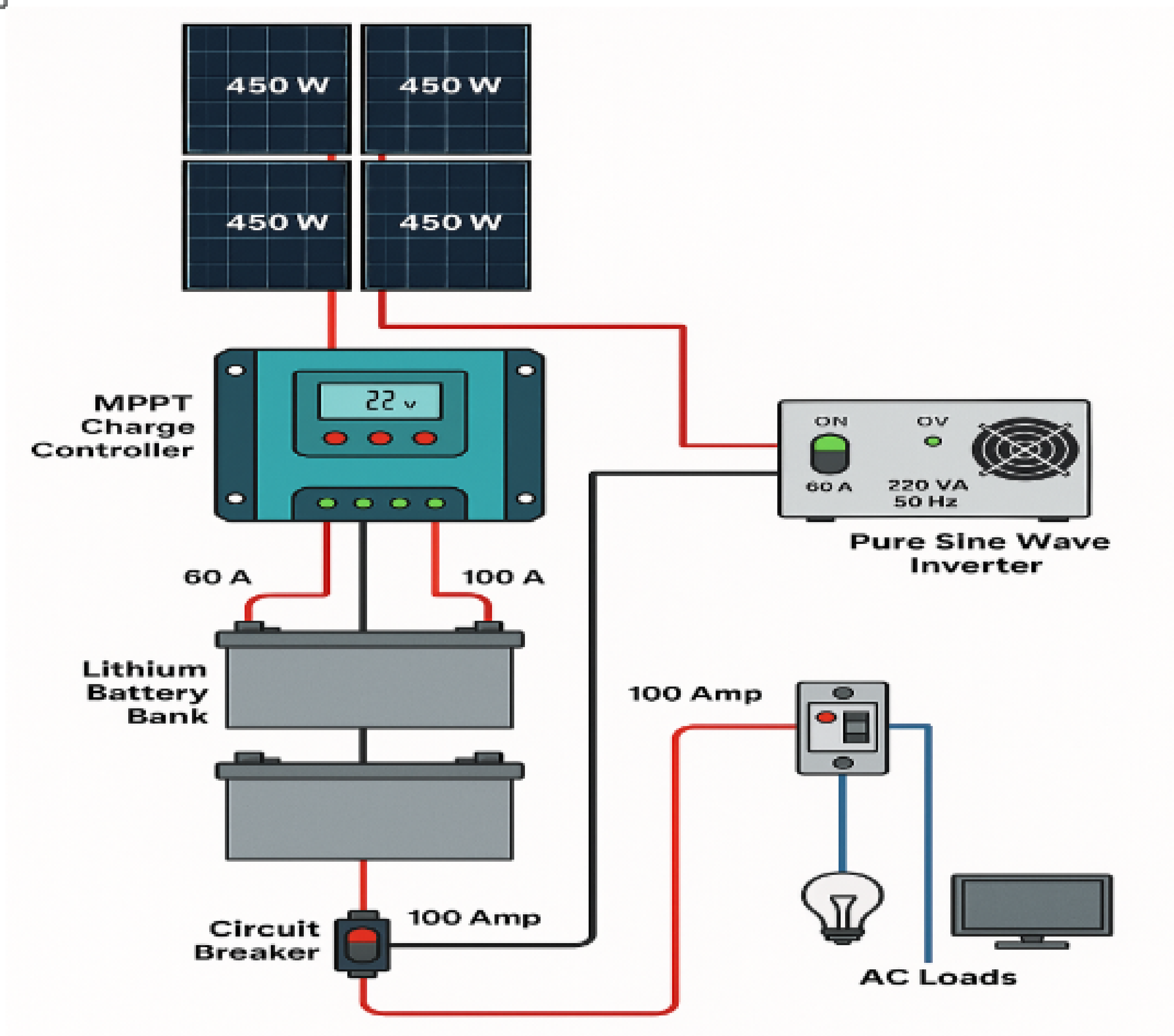

Figure 3.4

3.4.1 Explanation of the Circuit Diagram

3.4.1.2 Solar Panels

- 4 pieces of 450W panels convert solar radiation into DC electrical energy.

3.4.1.3 MPPT Charge Controller (60A)

- It tracks the maximum power point to regulate the charging voltage and current to the battery bank.
- It also prevents overcharging and prolongs battery life.

3.4.1.4 Lithium Battery Bank (24V)

- 4 lithium batteries configured to produce a nominal 24V storage system.
- Provides backup power when solar generation is low.

3.4.1.5 2kVA Pure Sine Wave Inverter

- Converts DC from the batteries into 220V AC (50Hz) for household appliances.

- Pure sine wave output ensures safe and reliable power for sensitive loads.

3.4.1.6 AC Loads

- Lights, fans, TVs, and other typical household devices powered from the inverter A C output.

3.5.0 Software Tools

Here's a short overview of the software that was used in the completed solar-powered inv erter system project for simulation and design purposes:

1. Proteus Design Suite

Used for simulating and testing DC and AC electrical circuits, including inverter control ci rcuits.

2. MATLAB/Simulink

Useful for modeling and simulating the overall behavior of renewable energy systems, M PPT algorithms, and battery management.

3. PVsyst

A powerful tool for simulating solar energy systems to estimate solar energy yield and p erformance.

4. AutoCAD Electrical

Ideal for drawing detailed electrical schematics, wiring diagrams, and panel layouts.

5. ETAP

Often used for advanced load flow analysis, short circuit calculations, and system protec tion.

3.6.0 Safety Considerations

Ensuring the safety and reliability of the solar-powered inverter system is paramount. Th e following measures were implemented during design and construction:

1. Proper Component Selection

- **Certified components** were chosen (solar panels, charge controller, lithium bat teries, inverter) to ensure high-quality and reliability.

- **Overcurrent ratings** and compatibility checks were conducted to prevent syste m overloading.

2. Circuit Protection Devices

- **DC and AC Fuses/Circuit Breakers** were installed:

a. Between the solar panels and charge controller

b. Between the charge controller and battery bank

c. Between the inverter and AC loads

- These protect against short circuits, overcurrent, and potential electrical fires.

3. Battery Protection

The lithium batteries include a **Battery Management System (BMS)**, which:

- Prevents overcharge and deep discharge

- Monitors cell temperature and voltage
- Balances cells during charging

4. Grounding and Earthing

- All metal parts of the system (e.g., inverter casing, control panel enclosures) w ere **properly grounded** to prevent electric shocks.

5. Proper Cable Sizing and Termination

- **Cables were selected based on load current** with proper insulation to reduce overheating and energy losses.
- **Crimped terminals and lugs** were used for secure connections, reducing the ris k of loose connections.

6. Environmental Protection

- **Indoor installation** in a well-ventilated area to protect against rain and direct s unlight.
- The inverter and batteries were placed in **enclosures** to prevent accidental con tact.

7. Load Management

- The system was designed with **load estimation** to avoid overloading the invert er and batteries.
- A load schedule can be implemented to prioritize critical loads during low sola r input.

8. Periodic Maintenance

Recommendations for **regular inspection** of:

- Battery voltage and condition
- Cable connections and fuse conditions
- Inverter operation (fan, temperature, alarms)

Chapter Four

4.0 Implementation and Testing

4.1 Construction Process

Checklist Table for Assembly Section

Step No.	Task	Checklist
1	Planning and Site Preparation	Identify location, ensure ventilation and saf ety.
2	Mounting the Solar Panels	Secure mounting structure, adjust tilt angle.