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

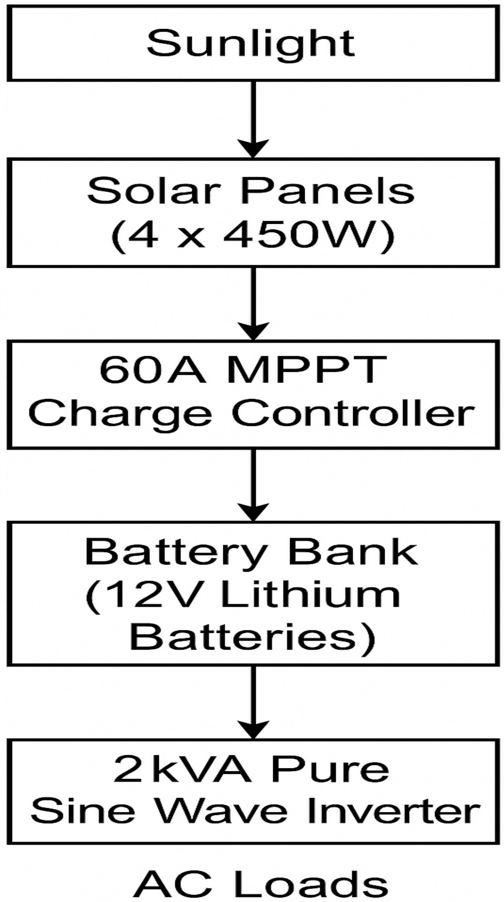

Figure 3.2

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 appliances)
- **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

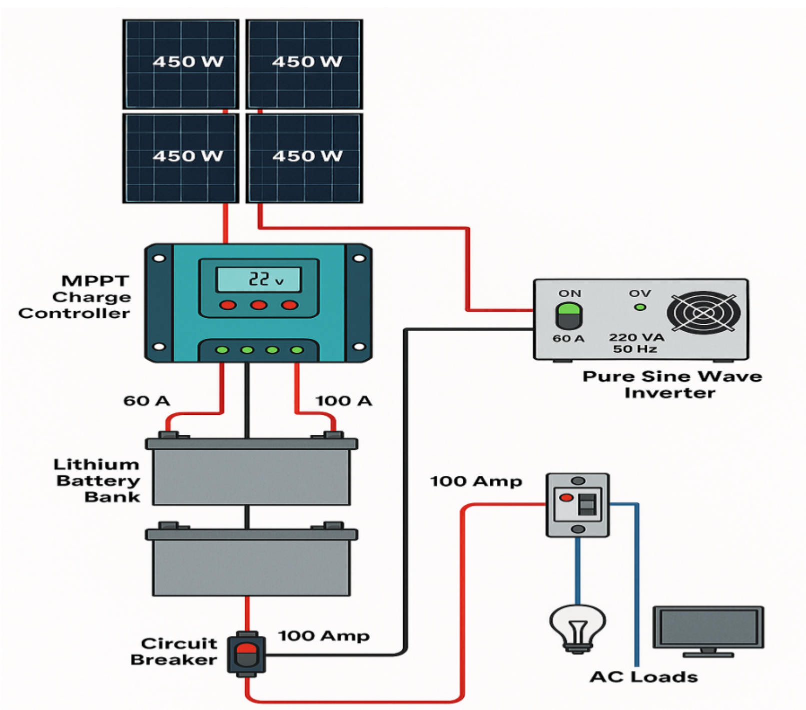

Figure 3.4

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 AC output.

3.5.0 Software Tools

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

1. **Proteus Design Suite**

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

2. **MATLAB/Simulink**

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

3. **PVsyst**

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

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 protection.

3.6.0 Safety Considerations

Ensuring the safety and reliability of the solar-powered inverter system is paramount.

The following measures were implemented during design and construction:

1. Proper Component Selection

- **Certified components** were chosen (solar panels, charge controller, lithium batteries, inverter) to ensure high-quality and reliability.
- **Overcurrent ratings** and compatibility checks were conducted to prevent system 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) were **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 risk of loose connections.

6. Environmental Protection

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

7. Load Management

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

8. Periodic Maintenance

Recommendations for **regular inspection** of:

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