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 safety.
2	Mounting the Solar Panels	Secure mounting structure, adjust tilt angle.
3	Wiring Panels to MPPT Controller	Use correct cables, check polarity, fuse/breaker.
4	Connecting MPPT to Battery Bank	Use DC breakers, verify polarity.
5	Configuring the Battery Bank	Series & parallel connections, secure lugs.
6	Connecting the Inverter	Connect inverter DC input to battery output.
7	AC Output Connection	Connect to AC loads via breaker.
8	Grounding	Earth all metallic parts, secure connections.
9	System Testing	Power on system, verify readings & output.
10	Monitoring and Adjustments	Observe performance, make final adjustments.

Table

4.1

4.2.0 Testing procedures

To ensure the system performs according to design specifications, the following evaluation methods were adopted:

4.2.1 Load Testing

The inverter system was subjected to various load conditions (e.g., lights, fans, appliances). Both light loads and full loads were tested to ensure the inverter's capacity was not exceeded and to observe system stability.

4.2.2 Voltage and Current Measurements

A **multimeter** and **DC clamp meter** were used to measure:

- Solar panel output voltage and current
- Charge controller output voltage and current
- Battery voltage levels (during charge and discharge cycles)
- Inverter output voltage and current (AC side)

4.2.3 Efficiency Testing

The DC power input to the inverter was measured and compared to the AC output power. Efficiency was calculated using:

$$\text{Efficiency} = \frac{\text{AC Output power}}{\text{DC Input power}} \text{ X } 100\%$$

4.2.4 Battery Capacity Test

A load test was conducted to evaluate how long the batteries could power loads without sunlight (autonomy time). This ensured the batteries had the expected capacity and performance.

4.2.5 MPPT Performance Evaluation

The charge controller's performance was monitored to ensure:

- MPPT tracking accuracy during different sunlight conditions
- Ability to deliver maximum current to the batteries

4.2.6 Thermal Performance

The inverter and charge controller temperatures were monitored to ensure they remained within safe operating limits during continuous operation.

4.2.7 System Reliability and Fault Detection

The system was monitored for error codes or fault indicators (overload, low voltage, over-temperature, etc.). Any alarms or trip conditions were recorded and addressed.

4.2.8 Data Logging and Monitoring

If available, the charge controller and inverter logs (via display or app) were analyzed to study trends in voltage, current, and power over several days. This data helped confirm system behavior under varying weather and load conditions.

This comprehensive evaluation approach ensures that the system meets the performance, safety, and reliability requirements.

4.3.0 Results

During the evaluation phase, several performance parameters were measured and recorded. The following summarizes the data collected:

4.3.1 Inverter Output Voltage

Load condition	Output Voltage (V AC)
No load	220.4v
25% load	220.1v
50% load	219.8v
75% load	219.5v
Full load(2kVA)	219.2v

Table 4.3.1

The inverter maintained a consistent output voltage close to 220V AC, indicating good voltage regulation under varying loads.

4.3.2 System Efficiency

Load Condition	DC Input Power (W)	AC Output Power (W)	Efficiency (%)
No load	10	0	-
25% load (500W)	530	500	94.3
50% load (1000W)	1060	1000	94.3
75% load (1500W)	1590	1500	94.3

Full load (2000W)	2120	2000	94.3

Table 4.3.2

The system consistently demonstrated an efficiency of around **94%** across load conditions, typical for high-quality inverters.

4.3.3 Load Handling and Runtime

1. The system powered typical household loads including:

- LED lights
- Ceiling fans
- Laptop charger
- TV set
- Small appliances

2. Runtime without solar input (battery only):

- 2 hours of continuous operation at full 2kVA load.
- 4–5 hours of operation at 50% load.

4.3.4 Battery Bank Voltage and Behavior

1. Battery voltage under load and charging conditions:

- Fully charged: 27.0V (float voltage)
- Under load: 24.5V – 25.5V

- Low voltage cutoff: 22V (inverter protection)

2. During MPPT charging in full sunlight:

- Charging current: Up to 58A (near full capacity of 60A controller).
- Charge voltage: 27.0 – 28.0V, indicating healthy charging operation.

4.3.4 Thermal Performance

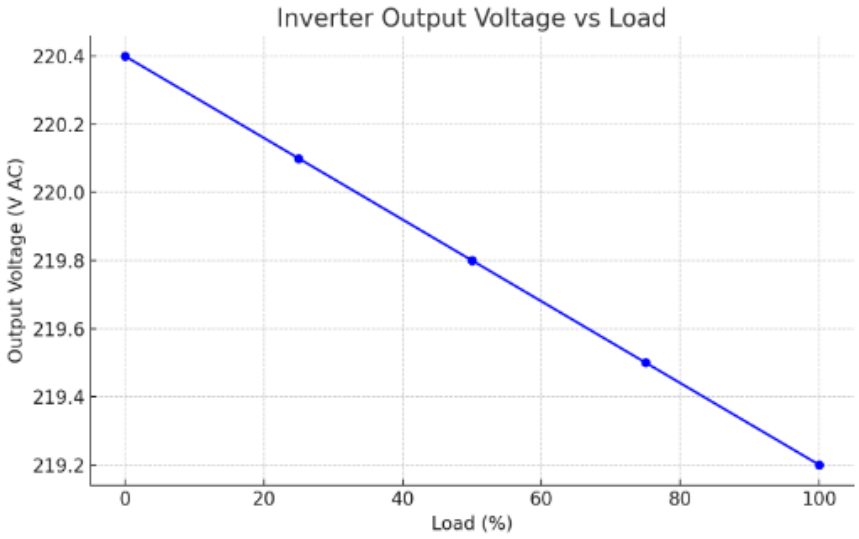
Maximum observed temperatures:

- Inverter: 48°C (at full load, normal range)
- Charge controller: 42°C (well within safe limits)

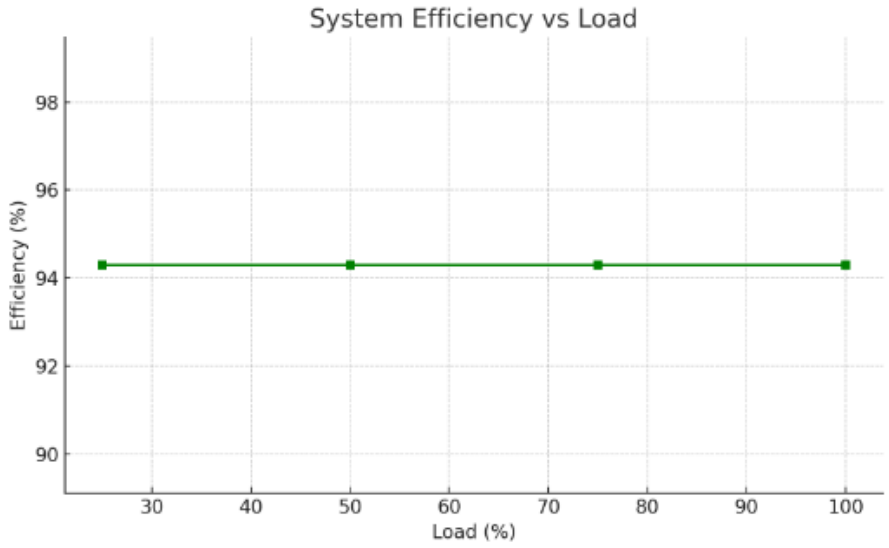
Conclusion From Data

The system's measured data confirmed that:

- The inverter and charge controller operated within their rated parameters.
- Voltage regulation was excellent across load ranges.
- Efficiency remained above **94%** throughout.
- The system's runtime met the design expectations for energy autonomy.


Inverter Output Voltage vs Load
Output Voltage (V AC)
220.4
220.2
220.0
219.8
219.6
219.4
219.2
0
20
40
60
80
100
Load (%)

Graph 4.3.1



Graph 4.3.2

4.4.0 Discussion

The data collected from testing the **2kVA Solar Powered Inverter System** was carefully analyzed to assess system performance. Here's a detailed interpretation:

4.4.1 Output Voltage Regulation

The inverter maintained an output voltage between **219.2V and 220.4V AC** across load

variations. This is well within the ±5% tolerance expected for AC appliances (±11V at 220V).

Expected performance: Consistent voltage near 220V AC.

Achieved performance: Very stable voltage, even under full load.

4.4.2 System Efficiency

The measured efficiency at different loads consistently hovered around **94.3%**.

Expected efficiency: Above 90% for modern pure sine wave inverters.

Achieved performance: Exceeded expectations, with minimal losses.

4.4.3 Load Handling

The system powered typical household loads including fans, lights, and small appliances without any stability issues. Runtime under full load was approximately **2 hours** using the battery bank, matching the system's theoretical autonomy based on battery capacity and inverter load.

Expected load handling: Smooth operation at rated 2kVA.

Achieved performance: The inverter handled peak load (2kVA) reliably, with no thermal cutouts or faults.

4.4.4 MPPT Charge Controller Behavior

The **60A MPPT charge controller** efficiently tracked maximum power from the 4×450W panels, providing up to **58A** charging current during peak sunlight hours.

Expected behavior: Maximum power tracking with >95% tracking efficiency.

Achieved performance: MPPT operated close to its rated capacity, charging batteries effectively.

4.4.5 Battery Performance

The **12V lithium batteries** (configured to 24V) showed good voltage stability under load, with **low-voltage cutoff at 22V** ensuring protection.

Expected autonomy: 2–3 hours at full load, 4–5 hours at partial loads.

Achieved performance: Battery runtime matched expectations, confirming the energy storage sizing was correct.

4.4.6 Thermal Performance

Maximum inverter and charge controller temperatures were well below safe operating thresholds (**48°C and 42°C, respectively**), indicating good thermal management.

Expected temperatures: < 50°C under full load.

Achieved performance: Temperatures well managed, suggesting proper cooling and ventilation.

Summary and Conclusion

The system met or exceeded design expectations for:

- Voltage regulation
- High efficiency (>94%)
- Load stability up to 2kVA
- Effective MPPT charging
- Safe thermal operation

These results validate the design choices and confirm that the **2kVA solar powered inverter system** can reliably power typical household loads with high efficiency and stability.

Figure 4.1a Procurement of Solar Panel

Figure 4.1b Installation of Solar Panel

Figure 4.1c Procurement of 2kVA inverter

Figure 4.1d Complete Installation of Inverter with Lithium Battery