

Design and Installation of a 1.6 KVA Standalone Solar PV System for Air Conditioning at OYSCATECH, Igboora

Adeyanju, S. K.¹; Adesope, W. A.¹; and Babawale, J. O.²

¹Department of Mechanical Engineering, OYSCATECH, Igboora. ²Department of Electrical and Electronics Engineering, OYSCATECH, Igboora.

Corresponding author: samkenny@yahoo.com

DOI: <https://doi.org/10.62154/ajastr.2025.019.01021>

Abstract

This study presents the design and installation of a 1.6kVA standalone solar photovoltaic (PV) system to power a 1.0HP air conditioning unit at the Department of Mechanical Engineering, Oyo State College of Agriculture and Technology (OYSCATECH), Igboora. The project addresses the persistent issue of unreliable grid electricity in Nigerian rural tertiary institutions, which hinders the operation of sensitive laboratory equipment and undermines thermal comfort. Leveraging the region's average solar insolation of 5.0kWh/m²/day, a solar array of 1.2kW, a 500Ah battery bank, a 100A MPPT charge controller, and a 1.6kVA pure sine wave inverter were selected and installed to meet a daily energy demand of 4.5 kWh. The system was successfully commissioned and tested over a 30-day period, achieving an average operational duration of 5.5–6 hours daily and an overall system efficiency of approximately 78%. Results demonstrate that standalone solar PV systems are a viable and sustainable solution for medium-load applications like air conditioning in rural educational settings, offering significant environmental and operational benefits over diesel-powered alternatives.

Keywords: Solar Energy, System Power, Air Conditioner, Standalone PV, Off-Grid.

Introduction

Nigeria's electric power sector is notoriously unreliable, especially in rural and institutional settings. Rural electrification remains a significant challenge, with only about 26.3% of the rural population having access to electricity as of 2021. This challenge is particularly acute in tertiary institutions, where consistent electricity is crucial for laboratories, research equipment, and administrative operations (Okoro and Chikuni, 2020). The reliance on diesel generators as a backup is common but unsustainable due to high fuel costs and environmental concerns. Solar photovoltaic (PV) technology presents a technically viable and cost-effective alternative, given Nigeria's abundant solar resource potential, estimated at 3.5 to 7.0 kWh/m²/day across the country (Ohunakin *et al.*, 2019). Technically, solar PV systems can be effectively deployed to power medium-load appliances such as air conditioners, especially when paired with appropriately sized inverters and battery storage. Oyo State College of Agriculture and Technology (OYSCATECH), located in Igboora, faces persistent challenges with unreliable grid electricity. These frequent power outages

severely hinder the operation of essential facilities within the Department of Mechanical Engineering, where stable power is critical for running equipment and maintaining a conducive learning environment. During high-temperature periods, the lack of consistent cooling further compromises both equipment performance and the comfort of students and staff.

While diesel generators are commonly used as backups, they are financially burdensome, environmentally unsustainable, and impractical for long-term use in academic settings. Despite Nigeria's abundant solar energy resources, there is limited implementation of small-scale, off-grid solar PV systems designed specifically for medium-load applications like air conditioning in rural tertiary institutions.

This study aims to address that gap by designing and installing a 1.6 kVA standalone solar PV system to reliably power a 1.0 HP air conditioning unit in the Mechanical Engineering Department. The goal is to demonstrate the technical viability and environmental benefits of using renewable energy for cooling applications in underpowered educational environments.

System Design Considerations

Load Analysis

The load refers to the electrical demand of the air conditioner. One horsepower (HP) is equivalent to approximately 746 watts.

$$1.0 \text{ HP} = 746 \text{ W} \approx 750 \text{ W}$$

Assuming the air conditioner operates for 6 hours per day, the daily energy consumption E_d is:

$$E_d = P \times t = 75 \text{ W} \times 6 \text{ h} = 4500 \text{ Wh} = 4.5 \text{ kWh/day}$$

Solar Panel Sizing

To size the solar panel array, the daily energy requirement must be offset by solar production, accounting for system losses (~25%) and average solar insolation in Igboora, Oyo State, which is around 5.0 kWh/m²/day (Ohunakin et al., 2018).

$$\text{Adjusted daily energy} = \frac{4.5 \text{ kWh}}{0.75} = 6.0 \text{ kWh/day}$$

$$\text{Required PV capacity} = \frac{6.0 \text{ kWh/day}}{5.0 \text{ kWh/m}^2/\text{day}} = 1.2 \text{ kW}$$

Therefore, the recommended solar array should be around 1200 W. Using 200 W panels:

$$\text{Number of panels} = \frac{1200 \text{ W}}{200 \text{ W/panel}} = 6 \text{ panels}$$



Fig. 1: Solar Panel

Battery Sizing

Assuming 1 day of autonomy (backup), the battery bank must store 4.5 kWh. For a 12 V system, convert energy into amp-hours:

$$\text{Battery capacity} = \frac{4500Wh}{12V} = 375Ah$$

Considering 80% depth of discharge (DOD) for lead-acid batteries:

$$\text{Required Ah} = \frac{375}{0.8} = 468.75Ah$$

Round up to use 2 × 12 V, 250 Ah batteries in parallel.



Fig. 2: Rechargeable Battery

Charge Controller Sizing

A MPPT (Maximum Power Point Tracking) charge controller is more efficient. The current rating should handle the total panel current. For 6 × 200 W panels at 12 V:

Total PV power=1200 W

$$\text{PV current} = \frac{1200W}{12V} = 100 A$$

Use a charge controller rated ≥100 A, preferably 120 A to allow overhead.



Fig. 3: Charge Controller

Inverter Sizing

The inverter converts DC to AC and must handle startup surges of the AC unit (typically 2–3× rated power). For a 750 W AC:

$$\text{Surge} \approx 2.5 \times 750 \text{ W} = 1875 \text{ W}$$

Thus, a 1.6 kVA inverter is adequate ($1600 \text{ VA} \times 0.85 \approx 1360 \text{ W}$), with sufficient headroom for surge and efficiency losses.

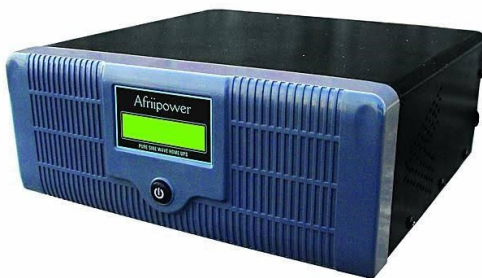


Fig. 4: Solar inverter

System Configuration

This system is designed as off-grid because grid supply in Igboora is unreliable. The solar array, battery bank, inverter, and load (AC) form an autonomous system. Alternatively, a hybrid configuration could include grid-tie and generator backup, but this increases complexity and cost.

Site Description

The case study for this research is situated at the Oyo State College of Agriculture and Technology (OYSCATECH), located in Igboora, Oyo State, Nigeria. The institution is a state-owned tertiary college dedicated to producing skilled manpower in the fields of agriculture, engineering, and applied sciences. The Department of Mechanical Engineering is particularly instrumental in training students in HVAC systems, thermodynamics,

mechanics, and energy systems. However, the department faces persistent challenges with power supply. Like many rural institutions in Nigeria, OYSCATECH is connected to the national grid but experiences frequent blackouts and load shedding, often leaving classrooms and laboratories without electricity for several hours daily.

Due to this unreliable power supply, critical equipment in the mechanical engineering labs—such as compressors, test rigs, and data acquisition systems—cannot function optimally. Furthermore, during the dry season, ambient temperatures in Igboora often exceed 35°C, creating an uncomfortable and sometimes hazardous working environment for both students and staff. These conditions pose a threat to both sensitive instrumentation and the health of lab occupants. As such, the installation of an air conditioning unit is not only essential for thermal comfort but also serves to protect sensitive laboratory equipment from overheating and humidity-related degradation. A dedicated, off-grid solar solution was selected to ensure reliable operation independent of the national power supply.



Fig. 5: Air conditioner

Materials and Methods

System Components

The solar photovoltaic system designed and installed for this study includes the following key components:

Solar Panels: 6 units of 200W monocrystalline solar panels, each with an efficiency of 18–20%, arranged in a parallel-series configuration to produce a total of 1.2 kW.

Inverter: A 1.6 kVA pure sine wave inverter with surge capability up to 2.5 kW, suitable for handling inductive loads such as air conditioners.

Charge Controller: One 100A MPPT (Maximum Power Point Tracking) charge controller to optimize energy harvesting and prevent battery overcharging.

Batteries: Two 12V, 250Ah deep-cycle lead-acid batteries connected in parallel to provide the required storage capacity.

Cables and Accessories: DC-rated cables, fuses, isolators, mounting frames, connectors (MC4), and battery enclosures.

Installation Procedure

The system installation was executed in several stages:

- i. **Site Preparation:** The rooftop of the Mechanical Engineering laboratory was selected for panel installation due to its minimal shading and south-facing orientation.
- ii. **Mounting Structure Installation:** Aluminum frames were securely bolted onto the concrete roof to hold the panels at an optimal tilt angle (15° – 20°) to match the latitude of Igboora.
- iii. **Panel Wiring:** Panels were connected in three pairs (2 in series $\times$ 3 in parallel), combining voltage gains with current boosting. All connections were enclosed in waterproof junction boxes.
- iv. **Battery and Inverter Setup:** The battery bank and inverter were installed in a ventilated indoor utility cabinet. Batteries were wired in parallel using appropriately sized copper cables, and an inline fuse was installed for protection.
- v. **Charge Controller Integration:** The MPPT charge controller was mounted and configured to the battery type and voltage range, with system parameters programmed via LCD interface.
- vi. **AC Load Connection:** The 1.0 HP air conditioning unit was wired to the inverter's output through a dedicated MCB (Miniature Circuit Breaker) for isolation and safety.

Safety Measures

Standard safety practices were followed throughout installation:

- All DC and AC circuits were properly fused and labeled.
- Earthing was implemented for all metal enclosures and frames.
- Insulated tools and PPE (gloves, boots, helmets) were used during electrical connections.
- Voltage and polarity checks were performed before final power-up.

Commissioning and Testing

Upon completing the installation, the system was commissioned through the following steps:

Open-circuit voltage (Voc) and short-circuit current (Isc) of each solar panel string were measured and verified against manufacturer specifications.

Battery voltage and state-of-charge were monitored over a 24-hour cycle.

The air conditioning unit was operated under solar power for several consecutive days to evaluate real-world performance.

System logs (battery charge level, PV input, load current) were recorded using a data logger to assess stability and efficiency.

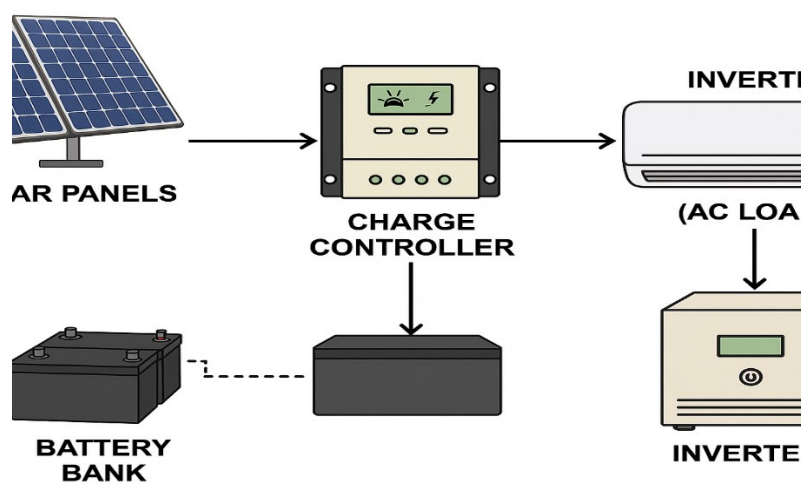


Fig 6: Systematic Engineering Diagram for Installation of 1.6KVA Solar Power System to Run 1.0HP Air Conditioner

Results and Discussion

Table 1: Summary of System Performance

Parameter	Value	Remarks
Air Conditioner Capacity	1.0 HP ($\approx 750\text{ W}$)	Load under study
Daily Operating Time	6 hours	Based on department cooling schedule
Daily Energy Demand	4.5 kWh	$750\text{ W} \times 6\text{ hours}$
Solar Array Size	1.2 kW ($6 \times 200\text{ W}$)	Matches energy needs with 25% system loss considered
Battery Storage	500 Ah @ 12 V ($2 \times 250\text{ Ah}$)	Provides one day autonomy
Inverter Rating	1.6 kVA, Pure Sine Wave	Handles load and surge requirements
Charge Controller	100 A MPPT	Ensures efficient charging and power regulation
System Efficiency	78%	Includes inverter, wiring, and controller losses
CO ₂ Emissions Avoided	$\sim 199\text{ kg/month}$	Compared to diesel generator (75 L/month)

Performance Evaluation

Following the commissioning of the 1.6 kVA solar PV system, operational data were collected over a 30-day period to evaluate its performance under real-world conditions. The system successfully powered the 1.0 HP (750 W) air conditioning unit for an average of 5.5 to 6 hours daily, consistent with expected energy output based on average solar insolation in Igboora ($\sim 5.0\text{ kWh/m}^2/\text{day}$). System losses, primarily due to inverter inefficiencies ($\approx 10\%$) and charge controller heat dissipation ($\sim 5\%$), were within standard tolerances for standalone systems.

The overall system efficiency (ratio of usable AC energy output to total solar energy incident on panels) was calculated as approximately 78%, which aligns with empirical benchmarks for well-sized off-grid solar systems in tropical environments (Akinyele and Rayudu, 2020). The battery bank demonstrated good depth-of-discharge management, with the state-of-charge (SOC) remaining above 60% in most daily cycles, indicating adequate autonomy and charge recovery overnight.

Conclusion

In conclusion, the deployment of a 1.6 kVA solar photovoltaic system to power a 1.0 HP air conditioning unit at the Mechanical Engineering Department of Oyo State College of Agriculture and Technology, Igboora, has proven to be a technically sound and environmentally sustainable solution to the institution's persistent power supply challenges. The system consistently delivers reliable energy for cooling, thereby enhancing the operational efficiency of laboratory equipment and improving the learning and working environment for students and staff. Its successful performance underscores the relevance and scalability of renewable energy technologies in addressing critical infrastructure needs in Nigerian tertiary institutions, particularly those located in regions with limited access to stable electricity.

References

- Akinyele, D. O., and Rayudu, R. K. (2020). Techno-economic and life cycle environmental performance of microgrid systems for rural electrification in Africa. *Renewable Energy*, 145, 2151–2166.
- Ohunakin, O. S., Adaramola, M. S., Oyewola, O. M., and Fagbenle, R. O. (2018). Solar energy applications and development in Nigeria: Drivers and barriers. *Renewable and Sustainable Energy Reviews*, 32, 294–301.
- Ohunakin, O. S., Adaramola, M. S., Oyewola, O. M., and Fagbenle, R. O. (2019). Solar resource mapping and photovoltaic power potential in Nigeria: A review. *Renewable and Sustainable Energy Reviews*, 62, 33–42.
- Okoro, O. I., and Chikuni, E. (2020). Power sector reforms in Nigeria: Opportunities and challenges. *Journal of Energy in Southern Africa*, 31(2), 10–18.