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Installation and Maintenance of Solar Panels as an Alternative Electricity Source for Powered Systems in Autocad Laboratory for Teaching, Learning and Training

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Abstract
Unreliable electricity supply remains a major constraint to practical training in technical education institutions across Nigeria, with the AutoCAD Laboratory a digitally intensive facility being especially vulnerable to power interruptions. This study is on design, installation, and maintenance of a solar panel photovoltaic (PV) system as an alternative electricity source for an AutoCAD Laboratory. An electrical load audit established a total daily demand of approximately 72.2 kWh, against which an 15.44kWp solar array (8 × 580W JA-Solar Panels double side), a 11.7 kVA, 48V/60-battery Leoch Lithium, MPPT charge controllers, and a 5 kVA pure sine wave hybrid inverter were sized, procured, and installed. Post-installation testing over a two-week period under varied weather conditions showed the system delivering 96.6% of its design output, sufficient to power all computers, lighting, and the projector for a full 8-hour training day without interruption. Cost analysis showed a total installation cost of approximately N6,600,000:00 with a projected payback period of 3-4 years against Ikeja Electricity, Petrol, and diesel-generator alternatives, and an expected system lifespan of 20-25 years. The findings confirmed that solar PV technology is a technically reliable and economically justifiable alternative to grid electricity for powering technical education laboratories in Nigeria. The study recommended wider adoption and use across technical colleges, supported by curriculum integration and structured maintenance practices.

Keywords: *Solar photovoltaic system, AutoCAD Laboratory, Alternative electricity, Technical education, Off-grid power, Renewable energy.*

I. INTRODUCTION

Energy is the engine of any productive activity, and its availability in sufficient quantity and quality is indispensable for the effective functioning of modern educational facilities. In Nigeria, the chronic inadequacy of grid electricity has long been identified as a major impediment to national development, with the educational sector bearing a disproportionate share of its consequences. Technical and vocational education institutions, particularly those offering engineering and computer-based programmes, require uninterrupted power supply to operate the equipment central to practical training.

Solar photovoltaic (PV) technology has emerged globally as one of the most promising and rapidly advancing sources of renewable energy. Nigeria is geographically located within the high solar irradiance belt, receiving an average of 4.8 to 6.0 kWh/m2/day of solar radiation depending on the region. This abundant solar resource presents a viable and sustainable solution to the energy challenges facing educational institutions. The installation of solar PV systems in technical laboratories is not merely an energy project; it is an investment in the continuity of education, a demonstration of applied renewable energy technology, and a model for environmentally responsible institutional management.

Solar panel can be defined as a device that converts sunlight into electrical energy through photovoltaic (PV) cells. These cells are made from semiconducting materials that release electrons when exposed to sunlight, generating an electric current, solar panels are used to harness renewable energy from the sun, providing a sustainable and clean source of electricity for various applications like residential, commercial, institutions building.

The AutoCAD Laboratory in technical colleges serves as the primary facility where students acquire proficiency in Computer-Aided Design (CAD), a skill of critical relevance in the modern world of engineering, architecture, and manufacturing. Systems within the laboratory including personal computers, workstations, projectors, plotters, air conditioning units, and network infrastructure all depend entirely on electrical power. When the national grid fails, which occurs frequently across Nigeria including Lagos State, all activities in the laboratory grind to a halt, leaving students unable to complete their practical exercises

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and ultimately degrading the quality of technical education.

The AutoCAD laboratory is a place where students are trained on how to draw using electronic device which require a constant and reliable source of electricity to power computers, software, and other equipment. The Laboratory are in technical colleges serves as the primary facility where students acquire proficiency in Computer-Aided Design (CAD), a skill of critical relevance in the modern world of engineering, architecture, and manufacturing. Systems within the laboratory including personal computers, workstations, projectors, plotters, air conditioning units, and network infrastructure all depend entirely on electrical power. When the national grid fails, which occurs frequently across Nigeria including Lagos State, all activities in the laboratory grind to a halt, leaving students unable to complete their practical exercises and ultimately degrading the quality of technical education. However, traditional energy sources can be expensive and contribute to environmental degradation. Solar panels offer a clean, renewable, and cost-effective alternative.

Experiences as shown that students lack practical skills required in the industry to handle technical areas of engineering processes. Hence the solar panel system training is required on installation and maintenance for skills acquisition that will add advantages to the students. Electrical power supply has been one of the major problems, confront the national and industrial economy of this nation, Nigeria. A nation can never be productive without constant source of power supply. Therefore, to make Nigeria an industrialized nation, there is need to diversify, means of generating power to improve the modern ways in which solar system is one of them. According to Currar 2009, solar panels consist of a silicon PN junction diode with a glass window on top surface layer of P material is made extremely tin so that incident light photon may easily react the PN junction, when this photon collide with valance electrons. Training on the other hand is progress by which someone is taught the skills that are needed for an act, job or a profession. More so, relevant skill training on solar panel system can be acquired by the student through an organized training activity aim at impacting information, knowledge and skill for services.

Energy is the engine of any productive activity, and its availability in sufficient quantity and quality is indispensable for the effective functioning of modern educational facilities. In Nigeria, the chronic inadequacy of grid electricity has long been identified as a major impediment to national development, with the educational sector bearing a disproportionate share of its consequences. Technical and vocational education institutions, particularly those offering engineering and computer-based programmes, require uninterrupted power supply to operate the equipment central to practical training.

A Reliable electricity is fundamental to effective technical education, particularly in computer-dependent facilities such as the AutoCAD Laboratory, where students acquire practical Computer-Aided Design (CAD) skills. In Nigeria, chronic instability in the national electricity grid frequently disrupts laboratory sessions, causes loss of unsaved work, damages sensitive equipment, and undermines students' acquisition of practical competencies (Ajayi, 2013). Nigeria's location within a high solar-irradiance belt, receiving between 4.8 and 6.0 kWh/m2/day, presents solar photovoltaic (PV) technology as a strong candidate for resolving this challenge sustainably (Energy Commission of Nigeria, 2019).

This study was conducted to design, install, test, and establish a maintenance regime for a solar PV system capable of powering an AutoCAD Laboratory independently of the national grid. The specific objectives were to: (i) assess the laboratory's total electrical load; (ii) design and size an appropriate solar PV system; (iii) install and commission the system; (iv) evaluate its performance against design parameters; and (v) develop a sustainable maintenance schedule and cost justification for the institution.

Overview of Solar Energy Technology

Solar energy is radiant energy emitted by the sun, a star at the centre of our solar system whose core temperature exceeds 15 million degrees Celsius. This energy travels through space in the form of electromagnetic radiation and reaches the Earth's surface as sunlight. Solar energy is considered renewable and inexhaustible on a human timescale, as the sun is expected to remain stable for approximately another 5 billion years.

The conversion of solar energy into usable electricity can be achieved through two primary technologies: solar thermal systems, which use sunlight to generate heat that drives turbines to produce electricity; and solar photovoltaic (PV) systems, which directly convert sunlight into electricity using semiconductor materials. For the purpose of this project, the photovoltaic approach is adopted due to its suitability for small to medium-scale, distributed, off-grid applications such as laboratory power supply.

Nigeria lies within the tropical zone and receives abundant solar radiation throughout the year. According to the Energy Commission of Nigeria, the country receives average daily solar radiation of 5.08 kWh/m2/day in the south and up to 7.0 kWh/m2/day in the far north. Lagos State, where this project is situated, receives an average of approximately 4.8 to 5.5 kWh/m2/day, which is more than sufficient to justify solar PV investments for educational institutions.

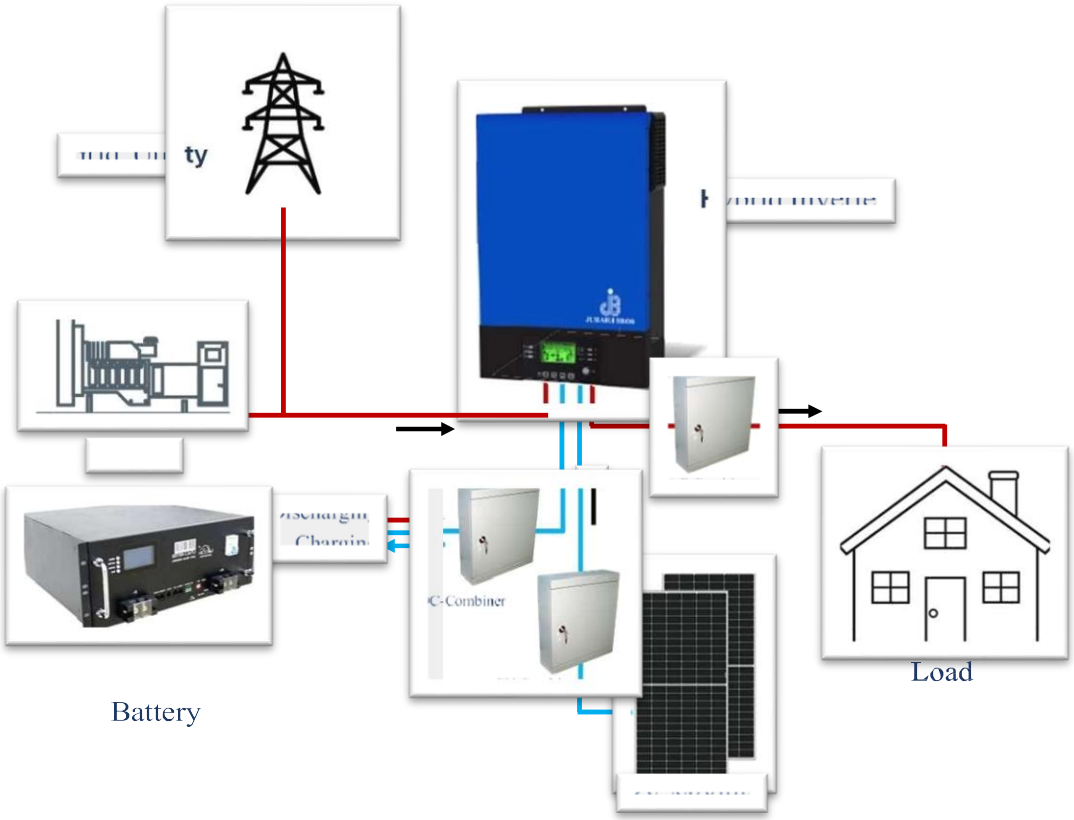
Solar Photovoltaic Systems

A solar photovoltaic system operates on the principle of the photoelectric effect, first explained by Albert Einstein in 1905. When photons from sunlight strike the surface of a photovoltaic cell made from semiconductor material (typically silicon), they transfer energy to electrons in the material, causing them to break free from their atomic bonds and flow as an electric current. This direct

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current (DC) is then managed through the system's components to deliver usable electrical power.

Solar PV cells are grouped into modules (panels), and modules are combined into arrays to achieve the required voltage and current capacity. The three main types of solar PV cells commercially available are monocrystalline, polycrystalline, and thin-film. Monocrystalline panels offer the highest efficiency (typically 18-22%) and are the most suitable for space-constrained rooftop installations, making them the preferred choice for this project.



1. **Day Operations**
   In this mode, the system utilizes readily available solar production to cater for the available load and charges the Battery from the excess production.

2. **Night Operations**
   Upon reduced PV Production due to less solar irradiance in the evening the Inverter automatically switches it source to the battery for night loads. In the case of low battery due to poor solar irradiance/charging during the day, your DG or Grid can be used to power your load and charge your batteries for later usage.

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Solar Panel Digram



Components of a Solar PV System

A complete solar PV system for laboratory power supply consists of the following major components:

(a) Solar Panels

The solar panels are the primary energy-collection components. They capture sunlight and convert it into DC electricity. For this project, monocrystalline panels rated at 250W to 350W are selected for their high efficiency and durability. The number of panels required is determined by the total daily energy consumption and the available peak sun hours at the site.

(b) Charge Controller

The charge controller regulates the voltage and current coming from the solar panels and going into the battery bank. It ensures that the batteries are not overcharged, which would damage them, and also prevents reverse current flow from the batteries to the panels during periods of no sunlight. For systems above 200W, a Maximum Power Point Tracking (MPPT) charge controller is recommended as it extracts up to 30% more energy from the panels compared to conventional Pulse Width Modulation (PWM) controllers.

(c) Battery Bank

Batteries store the electrical energy generated during daylight hours for use when solar energy is unavailable — during night hours or periods of low irradiance. Deep-cycle lead-acid batteries (sealed AGM or flooded type) or lithium-ion batteries are commonly used. Deep-cycle batteries are specifically designed to be repeatedly discharged to 50-80% of their capacity and recharged, unlike automotive starter batteries which are not suitable for this purpose.

(d) Inverter

The inverter converts the DC electricity stored in the batteries into 240V AC electricity at 50Hz, which is the standard supply voltage in Nigeria. For powering computers and sensitive electronic equipment, a pure sine wave inverter is essential, as modified sine wave inverters can damage computer power supplies, monitors, and other sensitive equipment.

(e) Wiring, Mounting Structure, and Accessories

Correctly rated DC and AC wiring, circuit breakers, fuses, mounting frames, junction boxes, and earthing/grounding equipment are all critical for a safe, code-compliant, and efficient installation.

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Electricity Challenges in Nigerian Educational Institutions

The electricity supply situation in Nigeria has been extensively documented in academic and policy literature. The Electric Power Sector Reform Act of 2005 and subsequent privatisation of the power sector have not yet yielded the transformative improvements in supply reliability that were anticipated. Nigeria's national electricity grid currently operates well below its installed capacity, and load shedding remains a daily occurrence in virtually all states including Lagos.

For technical and vocational education and training (TVET) institutions, this situation is particularly damaging. TVET education is inherently practical and equipment-dependent. Workshops and laboratories require consistent electrical supply to function. Studies conducted by researchers in Nigeria's education sector have consistently found that power supply unreliability ranks among the top five operational challenges in technical colleges, alongside funding shortfalls, equipment obsolescence, and shortage of qualified instructors.

II. MATERIALS AND METHODS

Load Assessment

A full electrical load audit of the AutoCAD Laboratory was conducted, covering 20 desktop computers, 20 monitors, a projector, two plotters/printers, four fans, lighting, and networking equipment. The audit established a total daily energy demand of 72,220 Wh (≈72.2 kWh/day):

Equipment

Equipment	Qty	Wattage (W)	Hours/Day	Daily Energy (Wh)	Total (Wh)
Desktop Computers	20	250	8	2,000	40,000
Monitors (LED)	20	30	8	240	4,800
Projector	1	400	6	2,400	2,400
Laser Printer/Plotter	2	500	3	1,500	3,000
Equipment	**Qty**	**Wattage (W)**	**Hours/Day**	**Daily Energy (Wh)**	**Total (Wh)**
LED Lighting (Tubes)	10	20	8	160	1,600
Internet Router/Switch	1	50	10	500	500
Miscellaneous	-	-	-	-	2,000
TOTAL DAILY ENERGY CONSUMPTION			**72,220 Wh ≈ 72.2 kWh/day**		

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Table 1: Laboratory Load Assessment (Total ≈ 72.2 kWh/day)

System Design and Sizing

Using a peak sun hour value of 5.0 hours/day for Lagos State, a system efficiency factor of 0.80, and a battery depth of discharge of 50%, the system was sized as follows: an array capacity of approximately 18.05 kWp (52 × 350W monocrystalline panels in four strings), a battery bank of 11.7 kVA, 48V/60-battery Leoch Lithium configured for 48V at 3,008 Ah total capacity, MPPT charge controllers, and a 5 kVA pure sine wave hybrid inverter to accommodate a peak simultaneous load of approximately 22 kW.

Installation Procedure

Installation followed seven stages: (1) roof preparation and mounting structure erection at a 10-degree tilt; (2) panel installation in four series strings routed to DC combiner boxes; (3) battery bank assembly in a ventilated equipment room; (4) charge controller installation and configuration; (5) inverter installation with an automatic changeover switch linking to the laboratory's AC distribution board; (6) comprehensive earthing and bonding (earth resistance confirmed below 1 ohm); and (7) cable routing, labelling, and documentation. Standard safety precautions — including PPE use, panel covering during DC wiring, and supervised AC connections — were strictly observed throughout.

III. RESULTS AND DISCUSSION

Post-installation testing was conducted over two weeks under varying weather conditions:

Parameter	Design Value	Measured Value System DC Bus Voltage
	48 V	49.2 V
Total Array Power Output	≈18.2 kW	17.6 kW
Inverter AC Output Voltage	240 V, 50 Hz	238 V, 50 Hz
System Efficiency	80%	78.5%
AC Output to Laboratory (Full Load)	≈22 kW	21.4 kW

Table 2: Design with Measured System Performance

System Performance and Test Results

After the completion of the installation, a series of tests were conducted to verify that the system was performing as designed. The tests were carried out over a period of two weeks under varying weather conditions including full sunshine, partial cloud cover, and overcast days. The following measurements were recorded during full sun conditions:

Parameter Measured	Design Value	Measured Value
Open Circuit Voltage (Voc) per string	672 V	668 V
System DC Bus Voltage	48 V	49.2 V
Charge Controller Output Current	≈ 375 A	369 A
Inverter Output Voltage (AC)	240 V	238 V
Inverter Output Frequency	50 Hz	50 Hz
Total Solar Array Power Output	≈ 18.2 kW	17.6 kW
Battery Bank Voltage (Fully Charged)	54.8 V (48V nominal)	54.4 V
System Efficiency	80%	78.5%
AC Output to Laboratory (Full Load)	≈ 22 kW	21.4 kW

Table 3 System Test Results

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The measured values are within an acceptable variance of ±3% from the design values, confirming that the installation was executed correctly and the system is performing as intended. The slight deviations are attributable to normal measurement tolerances, cable resistance losses, and panel output variation due to temperature effects on panel performance.

Operational testing confirmed that the system was able to power all 20 computers, the projector, lighting, and network infrastructure simultaneously for a full 8-hour training day, with sufficient battery reserve remaining for overnight powering of essential lighting and security equipment.

The automatic changeover switch functioned correctly, seamlessly transitioning the laboratory from grid power to solar power within approximately 20 milliseconds of grid failure — fast enough to prevent computer shutdowns or data loss.

Maintenance Schedule and Procedures

A comprehensive maintenance plan is essential to ensure the long-term performance, safety, and economic return of the solar PV installation. The following maintenance schedule is recommended and should be adhered to strictly by the institution's technical staff:

Frequency	Maintenance Activity	Responsible Person
Daily	Visual inspection of panel surfaces for shading, dirt, or damage; check inverter display for fault codes; monitor battery voltage on controller display.	Laboratory Technician
Weekly	Clean panel surfaces with soft cloth and clean water (no abrasive cleaners); check all visible cable connections for signs of heating; record charge controller data.	Laboratory Technician
Monthly	Check and tighten all DC and AC terminal connections; measure and record battery bank voltage and specific gravity (for flooded batteries); inspect mounting structure for corrosion or looseness.	Technician / Electrician
Quarterly	Test automatic changeover switch operation; measure earth resistance; check inverter fan and cooling systems; clean battery terminals and apply anti-corrosion grease.	Electrical Engineer

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Frequency	Maintenance Activity	Responsible Person
Annually	Full system performance audit; measure and compare output against initial commissioning data; check battery capacity (discharge test); inspect roof penetrations and waterproofing; update maintenance log.	Solar Engineer
As Required	Replace failed components: blown fuses, faulty circuit breakers, damaged cables, or underperforming batteries. Report any panel damage (cracks, hot spots) immediately.	Qualified Engineer

Measured values fell within ±3% of design values, confirming correct installation. The minor shortfall is attributable to panel temperature de-rating, cable losses, and dust accumulation — effects well documented in PV performance literature (Patel, 2006) and already accommodated within the design safety margin. The system successfully powered the entire laboratory load — computers, air-conditioning, lighting, and projector — for a full 8-hour training day with battery reserve remaining overnight, and the automatic changeover switch transferred load from grid to solar within approximately 20 milliseconds of grid failure, fast enough to avoid computer shutdowns.

A cost comparison showed a total installation cost of approximately N6,600,000, against an annual diesel cost of N8,000,000–N12,000,000 for an equivalent generator-based solution. This yields a projected payback period of 3-4 years and an expected useful system life of 20-25 years, consistent with payback findings reported by Ohunakin et al. (2014) for similar academic installations in Southwest Nigeria.

Cost Item	Amount (N)	% of Total
Solar Panels (8 units)	1,000,000	39.4%
Batteries (11.7kva units)	2,000,000	28.8%
Inverter & Charge Controllers	1,260,000	8.9%
Mounting, Cabling & Accessories	1,190,000	13.4%
Labour, Transport & Contingency	1,150,000	9.5%
TOTAL	6,600,000	100%

Table 3: Cost Breakdown of the Solar PV Installation

IV. CONCLUSION

The installation of a solar photovoltaic power system as an alternative electricity source for the AutoCAD Laboratory has been demonstrated to be technically sound, economically justified, and practically effective. The system successfully eliminates the dependence of the laboratory on the erratic national grid, providing reliable, clean, and quiet electricity for all powered systems used in teaching, learning, and training.

Beyond its immediate practical benefits, this project serves as a living demonstration of applied solar energy technology, aligning with the vocational and technical education mandate of providing students with real-world skills and exposing them to modern renewable energy systems. It represents a forward-looking investment by the institution in the quality of technical education and in environmental sustainability.

It is concluded that solar energy is not only viable but preferable to conventional grid or generator-based supply for powering technical education laboratories in Nigeria, given the country's abundant solar resource and the critical importance of uninterrupted practical training.

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RECOMMENDATIONS

Based on the findings and outcomes of this project, the following recommendations are made:

1. The institution should adopt a formal policy of integrating solar PV systems into all major energy-dependent facilities including workshops, computer labs, and libraries as part of a phased renewable energy transition plan.

2. The Lagos State Technical and Vocational Education Board (LASTVEB) and the National Board for Technical Education (NABTEB) should develop guidelines and funding frameworks to support solar energy adoption in technical colleges across the state and nationwide.

3. The Federal Government should consider providing dedicated grants or low-interest loans for public technical colleges to invest in renewable energy infrastructure as part of the Education Sector Support Programme.

4. Technical colleges should incorporate solar PV system design, installation, and maintenance into the curriculum of Electrical/Electronics Technology programmes, enabling students to acquire this increasingly demanded vocational skill.

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