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Research Paper

Design and Analysis of Solar Photovoltaic System for Power Generation in Crid Office

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Abstract
In today's society, information dissemination is profoundly influenced by social media technology. This study investigates the impact of social network structures on information diffusion in Nigeria, focusing on the information behaviour of undergraduate students in selected universities in Nigeria. Five research objectives guide this study, which employs a descriptive survey research design. The population includes undergraduate students. Using Israel's (2003) sample size model with a 5% precision level and a 95% confidence level, a sample size of 385 was determined. Simple random sampling was utilized to select the participants. A self-designed questionnaire, divided into five sections, was validated using a content-related approach and tested for reliability with a Cronbach's alpha coefficient of 0.679. Data analysis was conducted using IBM SPSS version 21.0, with frequency counts and percentage tables employed to present the research objectives. The study found that Facebook is the most preferred social media platform among undergraduate students, with high social media usage primarily for connecting with friends and academic activities. A significant relationship was observed between the purpose of social media use and the information behaviour of students. Based on these findings, it is recommended that university management integrate social media applications into their learning and teaching systems to maximize the benefits of social media.
Keywords*: Electricity, Solar Panel, Solar Energy, Office Appliances*

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I. Introduction

It is impossible for Nigeria to meet the ever-increasing demand for electricity because the country's electrical supply is both grossly inadequate and unpredictable, despite the fact that Nigeria possesses huge energy resources. Because of the current circumstances, people, organisations, and government institutions, particularly those that are associated with higher education, have been compelled to investigate alternative power options, mostly through the utilisation of a variety of generators. Even though these generators are successful, they require a significant amount of capital investment. Furthermore, they lead to greater operational expenses and environmental deterioration, which is a serious concern on a global scale.On a global basis, there has been a gradual shift towards the adoption of renewable energy sources, which are inherently sustainable and beneficial to the environment. Of all these possibilities, solar energy stands out as particularly noteworthy since it is readily available and holds a great deal of promise.

Commercially available since the 1970s, photovoltaic (PV) technology converts energy from solar radiation directly into electricity using semiconductor materials. It has no mechanical moving parts and lasts for decades while requiring only minimal periodic maintenance. Applications range from small-scale projects for individual groups of lighting fixtures and water pumps, to larger-scale projects for whole building power supplies, to community-scale solar gardens that service hundreds of consumers, to utility-scale photovoltaic power plants that provide electricity to thousands of end-users.Advantages of site-based photovoltaic systems are that they can be located directly at the point of power consumption, offset the full retail electricity rate of the facility, and match the peak demand loads of the end user. They are modular and can be installed on any unobstructed roof or ground space(a typical example is shown in Figure 1). Community solar and utility-scale installations provide a clean energy source for thousands of consumers who may wish to lower their carbon footprint but have project sites that are not ideal for solar installations. Photovoltaic technology often qualifies for more financial incentives than other renewable energy technologies.

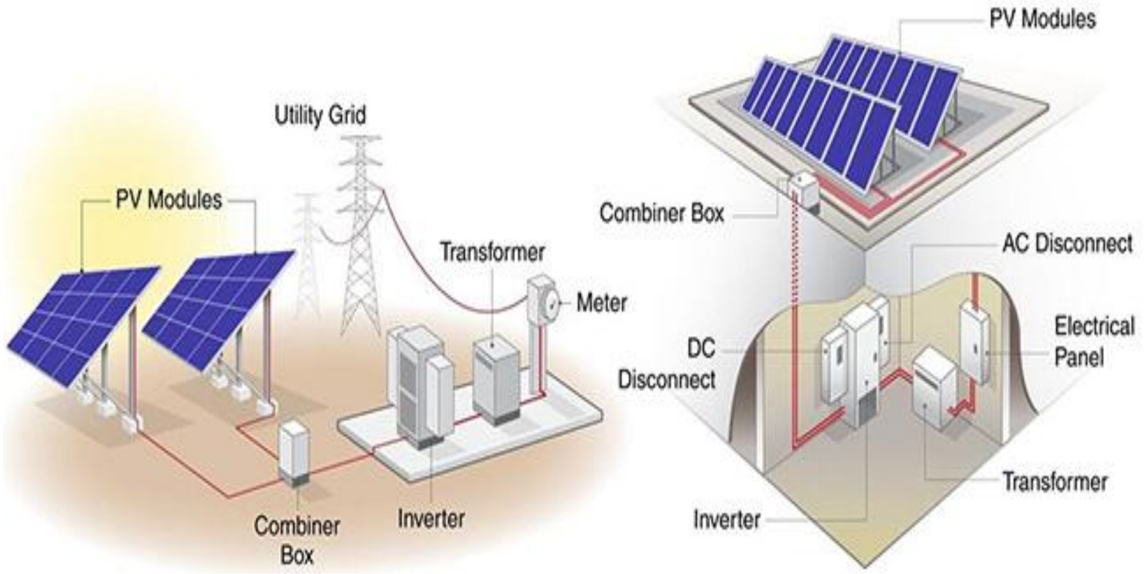

Figure 1:Example of a grid-connected photovoltaic systems, utility-scale (left) and commercial roof-top (right)
Source: U.S. Department of Energy, EERE

It has been stated by Bolaji and Adu (2007) that solar energy is the primary source of power for a variety of different types of renewable energy. According to Dike, Chineke, Nwofor, and Okoro (2011), it is an ideal replacement since it is abundant, infinite, trustworthy, financially practical, environmentally friendly, extendable, modular, and widely applicable. Each of these characteristics makes it an ideal substitute. According to the International Energy Agency (2015), solar energy has the potential to make a significant contribution to the reduction of carbon emissions in the global economy. This is in addition to the enhancement of energy efficiency and the implementation of charges on greenhouse gas emitters. The country of Nigeria has a significant potential for the implementation of solar energy, mostly as a result of the high annual sunlight levels that it receives. It has been estimated by Augustine and Nnabuchi (2010) that the average daily solar radiation can reach up to 20 MJ/m2, and that the duration of sunshine in a year is approximately 3,000 hours. Based on the information provided by Olayinka (2011), the values may differ based on the time of year and the area. Because of this, the potential annual energy output of the country is significantly more than the annual production of crude oil that the country produces (Osuji, 2003). According to Nnaji and Unachukwu (2010), Nigeria, which receives a significant amount of sunlight, possesses the potential to generate a significant amount of energy using solar power.

Photovoltaic (PV) systems, which make use of semiconductor materials, have the potential to generate energy from sunlight without the requirement of a particularly powerful light source. Solar panels are able to generate power even when there is cloud cover because they are able to capture the sunlight that becomes reflected off of the clouds. The fact that they are so versatile makes them suitable for a wide variety of applications, such as providing electricity to remote cottages, telecommunications installations, water pumping systems, street lighting, and emergency call boxes. Solar modules, batteries, charge controllers, and appliances are the four basic components that make up the photovoltaic (PV) system and its components. Because of its ease of use, versatility, and low maintenance requirements, photovoltaic (PV) systems are an excellent choice for developing countries.Numerous researchers, including Beshada, Bux, and Waldenmaier (2006),

Bolaji and Adu (2007), and Oni and Bolaji (2011), have explored and developed photovoltaic power systems for low to medium power applications. These systems have been used to generate electricity. The purpose of this project was to locate an alternative energy source that may serve as a replacement for the unreliable supply of energy provided by the government utility. Developing a solar photovoltaic system that would generate power for office use at Auchi Polytechnic, which is located in Edo State, Nigeria, was the means by which this objective was accomplished. In order to demonstrate that solar power has the potential to successfully ameliorate power shortfalls in Nigerian institutions, the system was created, put into operation, and analysed to determine its effectiveness of effectiveness.

II. System Overview

2.1 Photovoltaic systems are made up of several major components including:

i. PV Modules, and
ii. Balance of System (BOS) Components
iii. Module Mounting Systems
iv. Wiring, Combiner Boxes, DC Disconnects, AC Disconnects
v. Inverters (and Transformers for larger systems)
vi. Electrical Distribution Panels
vii. Batteries

➢ Modules

Photovoltaic (PV) modules are the most recognizable components of a PV system, comprising individual wafer cells arranged in a rectangular pattern, wired together, and encased in a rigid frame. Each module features positive and negative connector cables on the backside, allowing adjacent modules to be joined together. These modules come in various types and sizes to match installation space, environmental conditions, electrical requirements, and budget constraints. Residential and commercial modules typically measure about 40" by 66", while utility-scale modules can be up to 52" wide and 97" long.Modules vary by PV technology, cell wiring, and encasement characteristics. Some modules perform better in low-light conditions, while others generate more power in high-intensity sunlight. All modules produce direct current (DC) electricity, which can be converted to alternating current (AC) via an inverter. Modules are rated based on performance under standard test conditions (STC), with data labels on the back providing this information. Most modules have a 25-year warranty, guaranteeing at least 85% of rated power production over this period.

➢ **Balance of System (BOS)**

The "Balance of System" (BOS) encompasses all PV system components excluding the modules, such as mounting systems, wiring, combiner boxes, switches, inverters, meters, and batteries. Common mounting systems, or "racking," secure PV modules in place and must withstand wind loads, especially in hurricane-prone areas.Modules are connected in series or parallel to form "strings," which are then combined into an array. Combiner boxes merge the electrical cables from multiple strings into a single cable for the inverter, providing over-current protection and reducing system wiring.

➢ **Inverters**

Inverter convert DC electricity from the array into AC for local use, micro-grids, or the utility grid, with conversion efficiencies typically above 98%. Inverters synchronize the photovoltaic power with the utility power frequency and include anti-islanding features to protect utility workers during grid repairs. The NEC 690.12 Rapid Shutdown of PV Systems on Buildings code requires modules to be equipped with devices to reduce power output within seconds during emergencies, ensuring firefighter safety.There are two primary inverter types: string inverters, which handle multiple module outputs, and micro-inverters, dedicated to individual modules. String inverters range from 1.5 kW to 500 kW, offering cost-effective capacity and extended warranties up to 25 years. Micro-inverters, ranging from 175 watts to 380 watts, are ideal for small projects with shading issues, offering detailed module-level performance monitoring.BOS also includes electrical panels and equipment necessary for system operation, such as disconnect switches, fuses, breakers, and transformers for higher voltage interconnections. Photovoltaic systems with battery storage use charge controllers to manage voltage from the array and to the batteries, ensuring longevity through specific charging stages.

Real-time monitoring software is integral to PV systems, tracking power production, conducting economic analyses, running diagnostics, and managing electricity distribution based on user priorities.

2.2 **How Does A Photovoltaic Cell Work**

PV cells generate electricity through the photovoltaic effect, where sunlight interacts with cell materials to release electrons, creating electrical flow(see Figure 2). Manufactured from semiconductor materials, PV cells conduct electricity under certain conditions. When photons from sunlight hit the cells, they elevate electrons to higher energy levels, allowing movement and generating electricity.The cells are wired together to form modules, which are connected to create strings and arrays, accumulating electron movement to produce overall electrical output. This process leverages the abundant solar energy available in regions like Nigeria, offering a sustainable solution to energy needs (Bolaji &Adu, 2007; Dike et al., 2011).

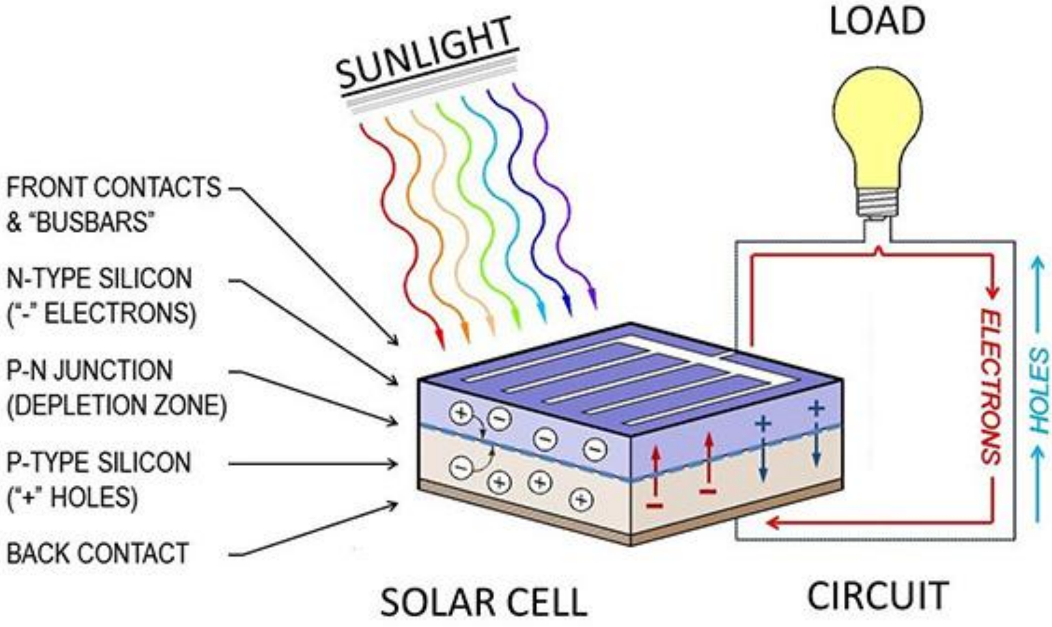

Figure 2: **The phenomenon of the photovoltaic effect arises from the interaction between sunlight and semi-conductors, resulting in the elevation of electrons into the conduction zone. This allows them to freely flow as electricity in an external circuit.**
Image: Ronald Fergle

III. Methodology

3.1 Materials

The materials used for constructing the solar power system included:

- 350-watt solar panel
- 100 Ah rechargeable battery
- 15 Ah charge controller
- Voltmeter
- 10 meters of 1.5 mm copper wire
- DC standing fan
- DC fluorescent bulbs
- Switches
- Mounting frame

3.2 Design of the Solar Power System

Load Estimation

The total energy requirement for the system was calculated using the formula:
Total connected load to PV panel system=No. of units×Rating\text{Total connected load to PV panel system} = \text{No. of units} \times
\text{Rating}Total connected load to PV panel system=No. of units×RatingTotal watt-hours rating of the system=Total connected load (watts)×Operating hours\text{Total watt-hours rating of the system} = \text{Total connected load (watts)} \times \text{Operating hours}Total watt-hours rating of the system=Total connected load (watts)×Operating hours

Appliance	Power rating (W)	No. of Units	Total load (W)	Time in use (h)	Energy (Wh)
Fluorescent bulb	60	1	60	6	360
Standing fan	50	1	50	5	250
Total			**110**		**610**

3.3 PV Module Rating

The peak power rating (kWp) of a solar panel describes the energy output under Standard Test Conditions (STC). For an 80 Wp panel:
Actual power output of a PV panel=Peak power rating×Operating factor=80×0.75=60 watts\text{Actual power output of a PV panel} = \text{Peak power rating} \times \text{Operating factor} = 80 \times 0.75 = 60 \text{

watts}Actual power output of a PV panel=Peak power rating×Operating factor=80×0.75=60 wattsEnergy produ ced by one 80 Wp panel in a day=Actual power output×8 hours/day=48.6×8=388.8 watt-hours\text{Energy produced by one 80 Wp panel in a day} = \text{Actual power output} \times 8 \text{ hours/day} = 48.6 \times 8 = 388.8 \text{ watt-hours}Energy produced by one 80 Wp panel in a day=Actual power output×8 hours/day=48.6×8=388.8 watt-hours

3.4 Estimation of Number of Solar Panels

The daily energy load consumption is 610 Wh. With 8 hours of usable sunlight: Required output power from the solar panel=6108=76.25 watts\text{Required output power from the solar panel} = \frac{610}{8} = 76.25 \text{ watts}Required output power from the solar panel=8610=76.25 watts An 80-watt solar panel was chosen to provide a safety margin.

3.5 Rechargeable Battery

Battery capacity was calculated as: Capacity (Ah)=Total Watt-Hours per day used by appliancesMaximum panel voltage (V)=6106.12=99.67 Ah\text{Capacity (Ah)} = \frac{\text{Total Watt-Hours per day used by appliances}}{\text{Maximum panel voltage (V)}} = \frac{610}{6.12} = 99.67 \text{ Ah}Capacity (Ah)=Maximum panel voltage (V)Total Watt-Hours per day used by appliances=6.12610=99.67 Ah A 100 Ah lead-acid battery was selected.

3.6 Charge Controller

Charge controllers prevent battery overcharging and excessive discharging. For an 80-watt panel: Charge controller current=Panel's wattage ratingPanel's voltage rating=8012=6.67 Amps\text{Charge controller current} = \frac{\text{Panel's wattage rating}}{\text{Panel's voltage rating}} = \frac{80}{12} = 6.67 \text{ Amps}Charge controller current=Panel's voltage ratingPanel's wattage rating=1280=6.67 Amps A 15 Amps charge controller was used for safety.

3.7 Wiring System

The system used 1.5 mm copper wires, considering the current expected to flow through them.

3.8 Installation of the System

The 80-watt solar system was installed on the office building's rooftop at Auchi Polytechnic, Edo State, Nigeria, facing north for optimal sunlight exposure. The panel, battery, and charge controller were connected in series, and appliances were connected to the battery via a switch.

IV. Results and Discussion

The solar power system powered appliances in the office, with the battery supplying power during low sunlight periods. The system's performance was satisfactory, maintaining uninterrupted power supply during office hours.

Tables

Table 1: Total Energy Requirement of the System

Appliance	Power rating (W)	No. of Units	Total load (W)	Time in use (h)	Energy (Wh)
Fluorescent bulb	60	1	60	6	360
Standing fan	50	1	50	5	250
Total			**110**		**610**

The methodology described ensured the optimal design, installation, and performance assessment of the PV system, highlighting its viability in addressing energy needs in Nigerian institutions.

V. Conclusion

This study successfully designed and implemented a solar photovoltaic power system to provide an alternative to the unreliable government utility power supply at the CRID office, Auchi Polytechnic, Edo State. The system, designed to power lighting and office appliances with a total load of 110 W, included photovoltaic modules, a mounting frame, a battery, a charge controller, and a wiring system. The system was tested on-site, demonstrating satisfactory performance with power generation lasting approximately 12 hours daily, aligning with office hours. The voltage output ranged from 12.28 to 12.38 V, with peak power output occurring between 10 AM and 4 PM, corresponding to periods of high solar radiation.The successful implementation and testing of this solar power system underscore its potential to enhance the reliability of power supply in institutional settings. The ability to maintain uninterrupted power during critical office hours highlights its viability as a sustainable solution to address the prevalent power supply challenges in Nigeria. Future research could explore scaling the system for larger applications, integrating advanced energy storage solutions to extend power availability beyond daylight hours, and optimizing cost-efficiency to enhance accessibility and system performance.The findings from this research contribute to the broader discourse on renewable energy applications in developing regions, particularly emphasizing the role of solar power in promoting energy security, reducing operational costs, and mitigating environmental impacts. Leveraging Nigeria's abundant solar resources, institutions can achieve greater energy independence and operational efficiency, setting a benchmark for similar renewable energy initiatives across sun-rich regions globally.

References

[1]. Augustine, C., & Nnabuchi, M. N. (2010). Analysis of some meteorological data for some selected cities in the Eastern and Southern Zone of Nigeria. African Journal of Environmental Science and Technology, 4(2), 92–99.

[2]. Beshada, E., Bux, M., & Waldenmaier, T. (2006). Design optimization of a photovoltaic powered grain mill. Agricultural Engineering International: CIGR Journal, 8, 1-15.

[3]. Bolaji, B. O., & Adu, M. R. (2007). Design analysis of photovoltaic pumping system for rural application in Nigeria. ASSET Series B, 6, 120-130.

[4]. Dike, V. N., Chineke, T. C., Nwofor, O. K., & Okoro, U. K. (2011). Evaluation of horizontal surface solar radiation in southern Nigeria. Journal of Renewable and Sustainable Energy, 3(2). https://doi.org/10.1063/1.3558871

[5]. International Energy Agency. (2015). Energy and climate change. World Energy Outlook Special Report: Executive Summary, Paris, France.

[6]. Nnaji, M., & Unachukwu, G. O. (2010). Energy efficiency and the Nigerian economy: The need for an integrated approach. Journal of Solar Energy, 21, 179-181.

[7]. Olayinka, S. (2011). Estimation of global and diffuse solar radiations for selected cities in Nigeria. International Journal of Energy and Environmental Engineering, 2(3), 13–33.

[8]. Oni, J. O., & Bolaji, B. O. (2011). Development of a universal DC power supply using solar photovoltaic, utility and battery power sources. Journal of Energy in Southern Africa, 22(1), 12-17.

[9]. Osuji, R. U. (2003). An evaluation of the institutional framework for Renewable Energy Education in Nigeria. Nigerian Journal of Solar Energy, 14, 25-35.