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DESIGN, IMPLEMENTATION, AND INSTALLATION OF SOLAR POWER ENERGY FOR BLOCK OF OFFICES: A CASE STUDY OF COMPUTER SCIENCE DEPARTMENT

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ABSTRACT

The persistent challenges of unreliable grid electricity and the environmental impacts of diesel generator reliance in Nigeria's academic institutions necessitate the exploration of sustainable energy solutions. This study focuses on the design, implementation, and installation of a solar-powered system to provide reliable energy to five lecturers' offices within the Computer Science Department at the Federal University of Petroleum Resources, Effurun. The system integrates twelve high-efficiency 450W monocrystalline solar panels, a 10kVA hybrid inverter with a built-in Maximum Power Point Tracking (MPPT) charge controller, and four 220Ah 12V tubular batteries connected in series. The methodology adopted an Agile, iterative approach to adapt to evolving load requirements, ensuring uninterrupted power for a minimum of five hours daily. The total hourly energy demand of 2.39 kWh was successfully met by the system's 5.4 kW peak generation capacity. Performance evaluations revealed that the system operates at 85-90% efficiency on sunny days, yielding 8-10 kWh/day. On cloudy and rainy days, output drops significantly, but the 10.56 kWh battery bank provides sufficient supplementary power to maintain uninterrupted office operations. The results demonstrate that the solar-powered system effectively mitigates energy reliability issues, reduces long-term operational costs, and minimizes environmental pollution compared to diesel alternatives. This study underscores the technical feasibility and ecological significance of renewable energy adoption in institutional settings.

Keywords: Solar Energy; Photovoltaic System; Hybrid Inverter; Renewable Energy; Grid Electricity; Energy Storage

1 INTRODUCTION

In an age where environmental sustainability is paramount and energy costs continue to rise, the integration of renewable energy solutions has become imperative. Among these, solar power stands out as an abundant, inexhaustible source of clean energy [1]. In Nigeria, a country grappling with the instability of its power grid system characterized by frequent outages and unreliable supply, the need for alternative energy sources is critical [2]. The erratic nature of grid electricity supplied by distribution companies poses significant challenges to academic institutions, disrupting learning environments, research endeavors, and administrative operations.

Currently, the university relies on electricity supplied by the Benin Electricity Distribution Company (BEDC) as its primary source, supplemented by diesel generators [3]. While diesel generators provide crucial backup power, their usage is accompanied by high operational costs due to fluctuating fuel prices, rigorous maintenance requirements, and substantial noise and environmental pollution [4]. The reliance on such systems severely impacts the productivity of academic staff and contributes to the institution's carbon footprint. Consequently, there is an urgent need to explore sustainable, environmentally friendly alternatives such as solar photovoltaic (PV) systems [5].

Solar energy systems present numerous benefits, including the reduction of greenhouse gas emissions, low ongoing operational costs, and energy independence [6]. Recent studies highlight that hybridizing solar power with grid electricity and robust storage solutions markedly improves the efficiency and reliability of energy delivery in institutional settings [7]. Furthermore, advancements in solar cell technology, particularly monocrystalline panels, have demonstrated superior efficiency and durability in tropical climates similar to Nigeria [8].

The primary aim of this project is to design, implement, and install a solar power system for five lecturers' offices within the Computer Science Department. The study evaluates the energy consumption of office equipment, designs a customized 10kVA solar hybrid system to ensure a minimum of five hours of daily power, and assesses its performance across various weather conditions. By harnessing abundant regional sunlight, this project seeks to create a resilient energy infrastructure, mitigating the inadequacies of the current power grid and establishing a model for sustainable campus energy management.

2 MATERIAL AND METHODS

2.1 Site Assessment and Energy Demand Calculation

The project focuses on five lecturer offices, each equipped with standard academic appliances including desktop computers, laptops, printers, ceiling fans, and LED lighting. An initial site assessment was conducted to evaluate the electrical infrastructure and calculate the combined hourly energy demand. The total estimated load for the five offices operating simultaneously for five hours a day was calculated to be 2.39 kWh/hour, resulting in a minimum daily energy requirement of 11.95 kWh.

2.2 System Components and Architecture

To meet and exceed the calculated load, the system architecture integrated three core components: solar panels, a hybrid inverter, and battery storage.

Solar Panels: Twelve monocrystalline solar panels, each rated at 450W, were selected due to their high efficiency (17-22%) and superior performance in high-temperature environments [8]. The total generation capacity of the array is 5.4 kW. The panels were mounted on the roof at a fixed 15° tilt angle to optimize sunlight capture.

Hybrid Inverter: A 10kVA hybrid inverter was chosen to manage power distribution. This inverter capacity (capable of handling up to 8 kW of real power) provides a substantial buffer over the 2.39 kW/h demand, ensuring scalability. It includes a built-in Maximum Power Point Tracking (MPPT) charge controller, which continuously adjusts the operational voltage to maximize solar energy harvest [9]. The inverter features an Automatic Transfer Switch (ATS) for seamless transitioning between solar, battery, and BEDC grid power.

Battery Storage: The energy storage unit comprises four 220Ah, 12V tubular deep-cycle batteries. These were connected in series to create a 48V system with a total capacity of 10.56 kWh. A 48V configuration was utilized to reduce current flow, minimize energy losses during transmission, and improve overall system efficiency [10].

2.3 Agile Implementation Methodology

The installation adopted an Agile methodology, characterized by iterative sprints to allow for flexibility and continuous feedback. The phases included:

3 RESULTS AND DISCUSSION

3.1 System Configuration and Electrical Output

The twelve 450W solar panels were connected in a 3-series, 4-parallel (3S4P) configuration. Connecting three panels in series increased the system voltage to approximately 111V-126V, which is highly efficient for transmission to the 10kVA inverter. The four parallel strings subsequently increased the overall amperage, allowing the 48V battery bank to charge rapidly and effectively. Under optimal conditions, this configuration successfully delivered the theoretical peak output of 5.4 kW per hour, which is more than double the offices' combined hourly demand of 2.39 kW/h.

3.2 Performance Evaluation Across Weather Variations

The system was subjected to performance testing under varying environmental conditions to assess its reliability and energy output.

Sunny Days: On clear, sunny days, the system operated at 85-90% efficiency. Energy generation averaged between 8 to 10 kWh/day. Peak generation occurred around 12:00 PM, producing 1.1 kW at 103V. The surplus energy fully charged the 10.56 kWh battery bank, pushing the battery voltage to a stable 54.2V, ensuring ample reserve power for evening hours.

Cloudy Days: Cloud cover resulted in a 50-60% reduction in solar irradiance capture. Daily energy output dropped to 3 to 5 kWh/day, with peak daytime production falling to 355-375W. During these periods, the system automatically supplemented the reduced solar yield by discharging 3-4 kWh from the battery bank, effectively bridging the supply gap without relying on the BEDC grid or diesel generators.

Rainy Days: Dense cloud cover and rain severely limited photovoltaic generation. The system operated at 10-20% efficiency, yielding only 1 to 2 kWh/day. Early morning outputs were as low as 7W at 80V. Under these extreme conditions, the system relied heavily on the tubular batteries, discharging 6-7 kWh to sustain office operations. The battery voltage dropped to 48-50V but successfully maintained the required load until grid power was available to assist.

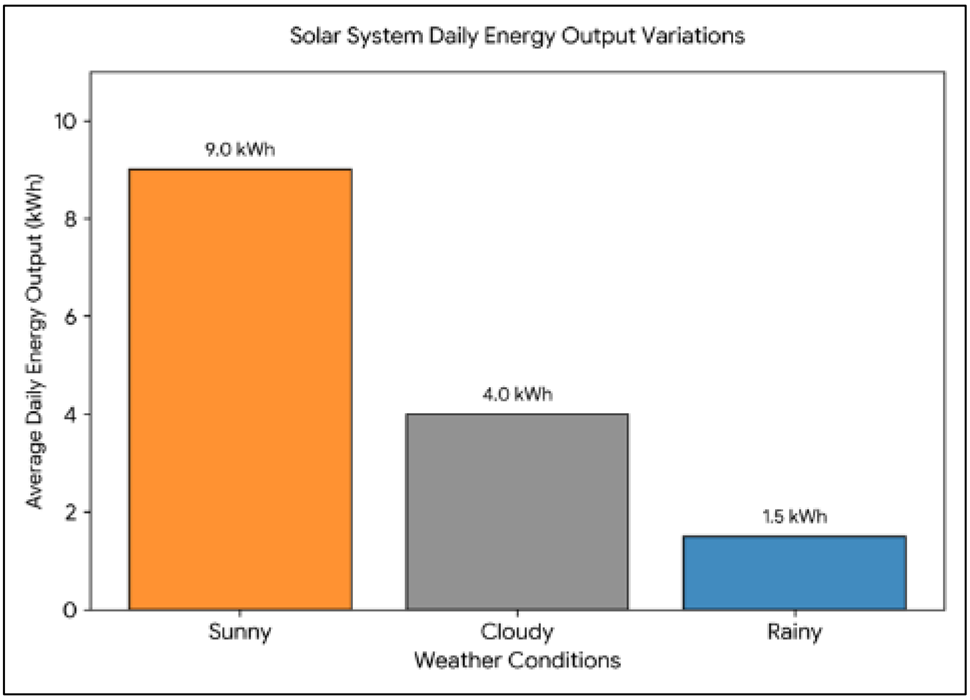

Figure 1: Average daily energy output (kWh) of the solar power system across different weather conditions.

Load Testing and System StabilityPost-installation load testing was conducted by simultaneously powering all computers, printers, fans, and lighting across the five offices. The total drawn load remained below 30% of the 10kVA inverter's maximum capacity. This low utilization threshold ensures that the inverter does not overheat, thereby prolonging the lifespan of the system components and providing massive headroom for future scalability. The Automatic Transfer Switch (ATS) functioned seamlessly, swapping between solar, battery, and grid inputs with zero latency, preventing computer reboots or equipment failure.

4 CONCLUSION

The successful design and implementation of this 10kVA solar-powered system conclusively addresses the critical energy challenges faced by academic staff in the Computer Science Department. By transitioning away from an unreliable power grid and heavily polluting diesel generators, the institution has established a sustainable, cost-effective, and highly reliable power infrastructure. The integration of high-efficiency monocrystalline panels with a robust 48V battery storage bank ensures that the system comfortably meets the 11.95 kWh daily energy demand, providing uninterrupted electricity across diverse weather conditions. Ultimately, this project stands as a pragmatic model demonstrating how targeted renewable energy adoption can foster a conducive academic working environment, reduce long-term operational expenditures, and significantly lower institutional carbon footprints.

RECOMMENDATIONS

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

- Routine Maintenance: Establish a strict biannual maintenance schedule focused on cleaning the solar panels and inspecting the deep-cycle batteries and inverter connections to preserve the 85-90% peak efficiency rate.
- System Expansion: Leverage the 10kVA inverter's unused capacity to scale the system, integrating additional administrative offices or adjacent laboratories without requiring a complete hardware overhaul.
- Advanced Storage Adoption: For future iterations, the institution should consider upgrading from tubular lead-acid batteries to lithium-ion storage solutions to achieve greater depth of discharge (DoD) and prolonged lifespans.
- Smart Monitoring: Incorporate IoT-based smart energy management systems to provide real-time, remote analytics on energy consumption and pinpoint operational inefficiencies.

STATEMENTS ON COMPLIANCE WITH ETHICAL STANDARDS

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Statement of ethical approval

The research was conducted in compliance with the academic and ethical guidelines of the College of Science, Federal University of Petroleum Resources, Effurun.

Declaration of competing interest

The author declares no known competing financial interests or personal relationships that could have appeared to influence this work.

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