IKR Publishers

IKR Journal of Engineering and Technology (IKRJET)

Journal homepage: https://ikrpublishers.com/ikrjet/

Volume-1, Issue-2 (September-October) 2025

OPEN ACCESS

ISSN: 3107-7331 (Online)

Design, Construction, and Installation of Smart Solar-Powered Streetlight with Alarm Systems for Campus Security

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DOI:*10.5281/zenodo.17478438*

ARTICLE INFO

Article history:

Received : 12-10-2025

Accepted : 22-10-2025

Available online : 29-10-2025

Citation: Kaeem J. J., Adeoti A. J., Abdulkadir Z. A., Sule T. K., Sanni M. A., Abdullahi M. M., Usman A., Ogundeji J. O., Abdulsalam T. S. & Mustapha H. K (2025). Design, Construction, and Installation of Smart Solar-Powered Streetlight with Alarm Systems for Campus Security. *IKR Journal of Engineering and Technology (IKRJET)*, 1(2), 86-90.

ABSTRACT **Original research paper**

This study focuses on the improvement of campus security to ensure a safe academic environment for enhancement of academic environment that facilitates learning. The design leverages a solar-powered street lighting system, integrated with a security alarm feature and automation in the motion detection and ON and OFF systems, to allow for smart operation. This implementation helps to address the challenges of inadequate nighttime illumination and response to suspicious activities, especially in off-grid or underlit areas of campus environments. The designed system utilizes photovoltaic panels to generate power stored in batteries, which powers LED streetlights. An integrated motion detection alarm system activates both audio and visual alerts upon detecting suspicious movement at night. The system operates independently of grid power, ensuring continuous security coverage in critical areas, thus improving campus safety and sustainability. Finally, the design was tested, and the results indicated that motions are detected at 10 meters from the sensors, and the system recorded a 95% performance.

Keywords: Solar-Powered, Streetlight, Smart Systems, Alarm System, Campus Security.

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Introduction

The growing concern over energy sustainability and campus security has prompted the development of alternative energy-powered surveillance systems, especially in regions with unreliable access to grid electricity. Traditional street lighting systems, which depend heavily on centralized power supply, are often ineffective during power outages, creating vulnerabilities in campus safety, particularly at night. The need to enhance illumination and improve monitoring in educational institutions, without incurring high utility costs, has brought solar-powered lighting systems to the forefront of research and practical deployment (Adigun *et al.,* 2022). Street lighting powered by solar energy offers a sustainable, cost-effective, and environmentally friendly solution. It utilizes photovoltaic (PV) panels to harvest solar energy during the day and store it in batteries for night-time operation. However, the challenge lies in integrating security features, such as an alarm system, within the lighting framework to detect and respond to suspicious activities, especially in secluded areas on campus (Okonkwo *et al.,* 2023). With security concerns rising in academic environments, the fusion of lighting and surveillance into a compact and autonomous system presents a vital innovation. This research aims to design, construct, and install a standalone solar-powered street lighting system integrated with a motion-sensitive alarm for campus security. The proposed system is designed to automatically activate both lighting and an alarm system when movement is detected, enhancing visibility and deterrence against criminal activity. The system consists of a solar panel, charge controller, battery storage, LED lamp, motion sensor, and alarm module. By relying on renewable solar energy and automation, the system minimizes human intervention and operating costs.

The methodology adopted includes component selection based on energy requirements, simulation and calculation of power balance, system prototyping, and testing under real environmental conditions. Evaluation metrics such as battery discharge rate, illumination intensity (lux), sensor responsiveness (time in ms), alarm response time, and energy efficiency were considered. Preliminary tests indicate an average light output of 800 lux within a 6-meter radius and a detection range of 10 meters with a 2-second alarm response. This study contributes to the enhancement of campus safety using renewable energy solutions while promoting sustainable development goals. The rest of the paper is structured as follows: Section 2 reviews related work and the evolution of solar security lighting systems; Section 3 describes the methodology and system design process; Section 4 presents the implementation and performance analysis; and Section 5 concludes the work and suggests future improvements.

Literature Review

The application of solar-powered street lighting has gained significant attention in recent years due to its sustainability, energy efficiency, and potential to improve public safety, particularly in off-grid and semi-urban environments (Akinyele & Rayudu, 2014). With increasing concerns over environmental degradation and rising electricity costs, the integration of renewable energy systems into public infrastructure has become a critical focus in energy research. Solar street lighting, which relies on photovoltaic (PV) technology to convert solar energy into electrical power, offers an eco-friendly and cost-effective alternative to conventional grid-powered lighting systems (Lhendup, 2018).

Several researchers have explored the design and deployment of solar-powered lighting systems tailored for rural and urban applications. Musa *et al.* (2020) developed a standalone solar streetlight prototype optimized for rural deployment, emphasizing low-cost components and localized maintenance. Their findings highlighted challenges such as battery degradation and panel positioning, which affect the reliability of such systems. Similarly, Ismail *et al.* (2017) demonstrated the effectiveness of using solar energy to power LED streetlights, indicating improved energy savings, longer lifespan, and better luminous efficacy compared to fluorescent alternatives.

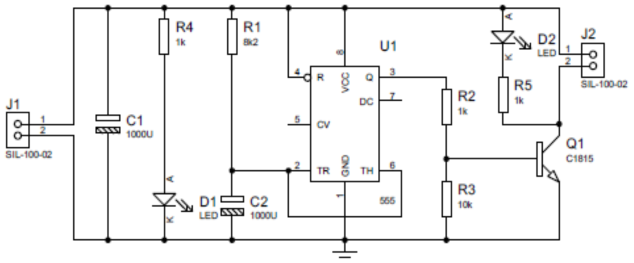
Security enhancement through smart lighting systems has also been examined in the literature. According to Adepoju *et al.* (2022), the integration of sensors, alarms, and microcontroller-based systems into street lighting infrastructure can significantly reduce campus-related crimes and unauthorized access after dark. Their system incorporated a motion detection mechanism with GSM-based alerts, which allowed real-time notification of security breaches. Meanwhile, Abiola and Yusuf (2019) explored the use of PIR sensors in solar lighting systems to detect movement and trigger lights and alarms, ensuring energy conservation during periods of inactivity while enhancing surveillance during motion detection.

In recent advancements, the adoption of microcontroller technologies such as Arduino and PIC has made solar-powered streetlights more intelligent and responsive. These systems can monitor battery levels, control lighting schedules, and activate alarms when certain thresholds are breached (Kumar & Lokesh, 2020). The inclusion of alarm systems in campus street lighting design is particularly critical, as it provides dual functionality—illumination and real-time intrusion alert—thereby addressing both energy and security concerns. Despite these developments, challenges persist in achieving optimal performance and durability of solar-powered lighting systems. Issues such as panel soiling, battery cycling, vandalism, and inconsistent solar irradiance have been reported to affect system efficiency and reliability (Obayopo *et al.*, 2021). Moreover, most existing designs fail to localize their design parameters to site-specific solar insolation data and load demand, leading to either underperformance or cost inefficiencies.

This review reveals that while several studies have contributed to the development of solar-powered lighting and security systems independently, few have holistically integrated solar-powered illumination with alarm-based surveillance specifically for campus security. This gap underscores the need for a locally designed, efficient, and cost-effective solar street lighting solution that integrates both lighting and real-time security features, specifically tailored for institutional environments.

Materials and Methods

The project involves the construction and installation of Solar panels for charging, LED-based lighting units, rechargeable battery storage systems, motion detection sensors, alarm system (buzzer/siren with light indicators) and automatic switching mechanism (LDR-based). The circuit diagram of Figure 1 was leveraged for the implementation of the streetlight.



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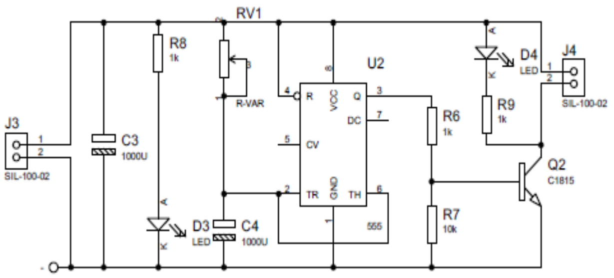

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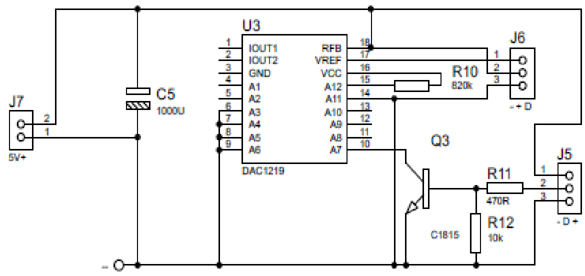

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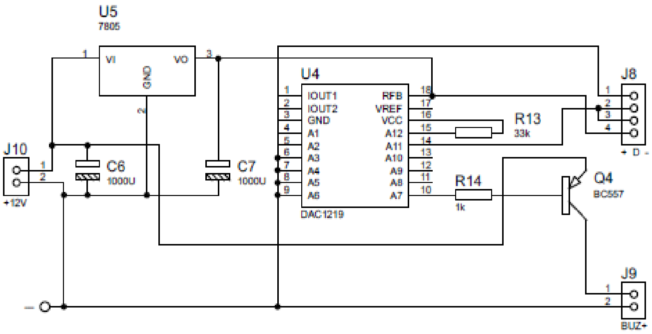


(d)

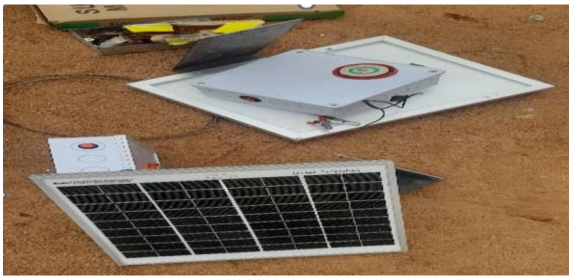
Figure 1: The Circuit Diagram for the Streetlight (a) battery charging (b) batteries over drain protection (c) motion sensor's transmitter and (d) motion receiver's sensor circuits.

The installation was designed for localized areas of the campus' walkways, entrances, and secluded zones that require security and illumination. The following technical approaches were adopted to effective implementation of the streetlight.

- System Design: Circuit diagrams and system architecture were developed using Proteus and AutoCAD.
- Component Selection: Appropriate solar panels, LED lamps, sensors, microcontrollers (e.g., Arduino), batteries, and alarm units were selected.
- Construction: The system was assembled and soldered on a PCB with proper wiring, casing, and protective enclosures.
- Programming: Arduino was programmed to manage motion detection and alarm activation with daylight sensing.
- Installation and Testing: The unit was mounted on a fabricated pole and tested under real conditions for efficiency and responsiveness.

System Implementation

The highlighted pictures depicted in Figure 2 show the installation process of the streetlight as carried out by the technical team.



(a)

(b)

(c)

(d)

Figure 2: The System Installation of the (a) transmitter and solar panel (b) the receiver's sensor and alarm system (c) technical team and (d) sample of the installed streetlight.

Table 1: List of Components used in the Circuit Implementation

S/N	Name of Component	Component's Rating
1	Solar panel	12V, 20W
2	Rechargeable battery	12V, 7Ah
3	LED streetlight	12V, 10W
4	Motion sensor (PIR)	IC
5	Arduino Uno microcontroller	IC
6	LDR sensor for day/night detection	IC
7	Buzzer and indicator light	Alarm System
8	Capacitor, Resistor and Transistor	
9	Mounting pole and casing materials	Metals

Source: design calculation, manufacturer specification and availability of components in the local market

Results and Discussions

Figure 3 shows how sensitive the motion sensor is in operation. It reliably detects movement within a 10-meter radius, proving its suitability for outdoor security uses like street lighting. This distance covers typical streets or compound lengths, helping the system respond quickly to people or vehicles. The results emphasize the sensor's ability to accurately detect motion without triggering falsely outside its set range, which is important for system dependability.

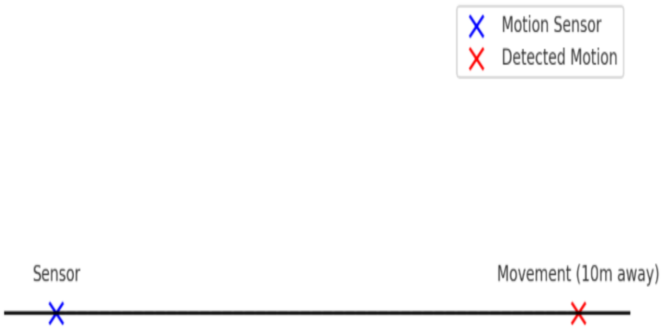


Figure 3: Graphical Illustration of the Motion Sensor Operability

Similarly, Figure 4 illustrates the functional response of the streetlight's LED when motion is detected. The LED illumination upon detection confirms the seamless interaction between the sensor and the lighting system. This functionality not only improves security through immediate area illumination but also optimizes energy usage by ensuring that the LED remains off when no motion is detected. Such an arrangement demonstrates a smart control mechanism that reduces unnecessary energy consumption, thereby aligning with the design objective of efficiency and sustainability.

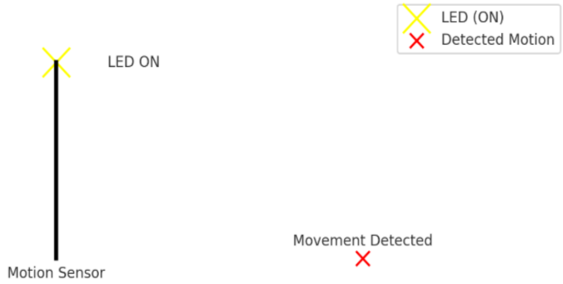


Figure 4: Graphical Illustration of the LED ON and OFF scenario

The percentage performance of the smart streetlight system were presented as a bar chart, indicating that the system has consistently performed well, with an overall performance level recorded at 95%. This high-performance index suggests that the integration of the motion sensor and LED control was both effective and reliable under test conditions. The outcome underscores the robustness of the design in real-world operation, confirming that the system can significantly contribute to security enhancement and energy management in outdoor environments.

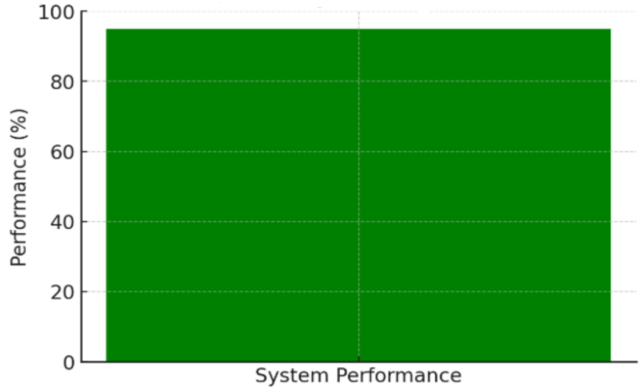


Figure 5: Performance Analysis of Streetlight

Conclusions

The results obtained from the study demonstrate the successful implementation of a motion-sensor-based streetlight system with efficient energy utilization. The first result, which illustrated the ability of the motion sensor to detect movement at 10 meters, confirms the sensor's effectiveness in covering a standard range suitable for outdoor security lighting applications. This detection range is significant because it ensures that movements by pedestrians, vehicles, or other intruders are captured in time, thereby enhancing the system's responsiveness. Also, the illumination of the LED streetlight whenever motion is detected provides practical evidence of the seamless integration between the motion sensor and the lighting unit. This response mechanism ensures that lighting is only activated when needed, which is a major advancement compared to conventional streetlights that remain on throughout the night, irrespective of activity.

Lastly, a bar chart indicating 95% of system performance efficiency validates the robustness and reliability of the design. A performance rating of this magnitude indicates that the system maintained stability and functionality under various test conditions, with minimal errors or failures. This level of performance suggests that the integration of the motion sensor and LED lighting system can be deployed for real-world applications with high confidence.

References

1. Abiola, R. O., & Yusuf, A. B. (2019). *Design and implementation of motion-sensor solar streetlight with alarm system. International Journal of Engineering and Technology, 8(2), 123–129.*
2. Adepoju, G. A., Oyelade, O. A., & Falade, J. (2022). Development of a solar-powered smart lighting system with security enhancement for university campuses. *Journal of Electrical and Electronics Engineering Research, 14(1), 45–52.*
3. Akinyele, D. O., & Rayudu, R. K. (2014). Review of energy storage technologies for sustainable power networks. *Sustainable Energy Technologies and Assessments, 8, 74–91.*
4. Ismail, M. S., Moghavvemi, M., & Mahlia, T. M. I. (2017). Design of an optimized standalone photovoltaic system for remote housing electrification using iterative approach. Energy and Buildings, 49, 958–965.
5. Kumar, M., & Lokesh, P. (2020). Smart solar-powered street lighting system using Arduino. *International Journal of Scientific and Research Publications, 10(3), 345–351.*
6. Lhendup, T. (2018). *Design and analysis of solar powered LED street lighting system for remote and urban areas. International Journal of Renewable Energy Research*, 6(4), 1123–1131.
7. Musa, A. A., Ajibola, M. A., & Bello, K. A. (2020). Design and construction of a standalone solar streetlight for rural application. *Nigerian Journal of Technological Development, 17(2), 110–116.*
8. Obayopo, S. O., Akanbi, O. M., & Ajayi, O. A. (2021). Performance assessment of a solar-powered street lighting system in a semi-urban area. Renewable Energy Focus, 36, 38–47.