International Journal of Advances in Engineering and Management (IJAEM)
Volume 7, Issue 11 Nov. 2025, pp: 54-59 www.ijaem.net ISSN: 2395-5252

Design and Simulation of a Solar-Based Automatic Security Lighting System

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Date of Submission: 25-10-2025 Date of Acceptance: 05-11-2025

ABSTRACT
The design and simulation of a solar-based automatic security lighting system is presented this paper. The design features an energy efficient self-operated security lighting system that has the ability to alter its light intensity based on certain conditions. The system is designed around a Light Dependent Resistor (LDR) which provides automatic switch on and switch off of the system at dusk and dawn respectively; passive infrared sensor that detects motion within the range of 10m and other control logic are also included. The system is to be powered by Li-ion battery which charges from energy supplied by the solar panel. The lighting system turns on at night and off in the morning. It glows dim most of the time in order to conserve the battery energy but glows in its full strength for a stipulated amount of time on detecting a movement within its coverage distance. The design was tested under Matlab Simulink environment and was found to perform optimally.
Keywords— Light Dependent Resistor (LDR), Passive Infrared (PIR) sensor, Li-ion battery and solar panel

I. INTRODUCTION

Lack of adequate illumination of roads, residential premises, office premises and the likes is one of the major factors that lead to road accident during night driving, encourage theft, and hinder nightlife and thus have negative effect on the economy of developing countries. In a developing country like Nigeria, major urban roads rely on diesel powered generating sets to power street lights. This approach is not cost effective given the cost of diesel fuel and the corrupt practices of some public workers in the country. At times the generating set may need maintenance which may take up to two days to get it back to work again. The people would be kept in darkness for the period of repair. In most rural areas of the country, the facility is completely lacking owing to the initial cost of installation.

This paper presents an automatic solar-powered security lighting system that can replace the traditional diesel-powered street lights. The new system will draw energy from the Sun during the daytime to charge up its internal battery bank. At dusk, the system senses darkness and switches ON the LED lights. The design will feature two arrays of LEDs and will only turn ON one of the arrays. The remaining array of LED will be turned ON in addition for brighter luminance when the motion detector of the system senses movement within its coverage distance of 10m. The light stays in this last mode for a given period of time and then reverts back to the former mode of dim luminance. In off-grid scheme, energy efficiency is the main design constrains [1]; thus, the division of the lighting into two modes, namely the dim and bright modes will bring about efficient energy utilization.

This lighting system is self-operating, maintenance free and can be deployed to power streets, village squares, premises and the likes. It is green; it does not emit toxic gases into the environment; it is free from noise pollution [2]. [3] Pointed out that such night illuminations will reduce night accidents and crime and in addition create attractive surroundings. This design incorporates an automatic switching system to eliminate the need for a human operator. It is not bulky as Li-ion batteries will be used during implementation stage of this design. It is a stand-alone photo voltaic (PV) scheme. PV systems are commonly applied in stand-alone lighting schemes [1].

In this paper, the design and simulation of a solar-based automatic security lighting system is presented. This lighting system model convert sunlight energy into a dc power input for battery charging at daytime and draws energy from the battery at night to light up the LEDs. The light has a dim phase and a bright phase in which one array and two arrays of LEDs are lit up respectively. The design was simulated under SIMULINK environment and was found to perform optimally.

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II. LITERATURE REVIEW

The authors in [1] designed a novel smart solar-powered outdoor lighting system with light emitting diode (LED). The developed system would be able to monitor the energy status of the battery continuously and, equally, controls the illumination level of the LED light in order to satisfy the lighting requirement that is to keep the light "on" the longest time possible. To enhance the natural surveillance and feeling of safety in sustainable buildings and cities, the use of reliable solar energy-driven lighting system, with maximum time when the light is "on" was developed. The new smart control developed eliminates the over discharge of the system battery and, thus, ensures a longer lifetime of the system battery.

A system that will provide automatic control and fault detection of street lamps was developed in [4]. The lighting system developed targets automatic operation and send information about the street lamp fault to the control room. This eliminates errors which occur due to manual operation. The system checks the weather condition through LDR sensor to know when to ON or OFF the street light. The light condition is also used to check the lamp glowing status through LDR sensor. If light glows then the sensor sends the value to street light system through the Wi-Fi module. The PIR sensor is also used in the work to measure the motion of vehicle or any other object. Whenever there is vehicles cross within the range of the sensor the light glows bright otherwise the light will glow dim.

In [5], the authors designed a smart security lighting system named the Connected Security Lighting System (CSLS), to reduce the pedestrians' fear of crime in smart cities. The CSLS increases the brightness of security lighting by turning on additional lights to relax pedestrians' psychological fear of crime because of the increased sense of surveillance. These may also deter potential offenders. The CSLS employs various sensors and information communication technologies that are widely used in interior and outdoor smart lighting applications. It also uses a beacon device and smart phone application to effectively detect pedestrians while infrared sensors in the CSLS are activated to detect any pedestrians approaching from the opposite direction after the beacon device is initiated. The authors developed a prototype system to demonstrate the feasibility of this security lighting system in smart cities and equally described the method of controlling the CSLS.

In [6], the authors try to design a low-cost automated security lighting control system. They used ATMEGA8 Microcontroller to control the developed system functionality. The Global System for Mobile Communication (GSM) network was used to send an authenticated signal to the equipment by the user's cellular phone. The design permits a user to perform lighting switching operation from a remote location via GSM technology and its Short Message Services (SMS) functionality. The developed system utilizes a microcontroller rather than the conventional Personal Computer. The signal consists of information to be performed by the equipment that is switching the light Off/On. The microcontroller controls the different relays and triggers the required appliance on the reception of SMS message from the user's phone.

III. BLOCK DIAGRAM DESIGN

Figure 1 gives the architectural illustration of the proposed system. It shows the various elements and functional blocks of the system. The security light system draws sunlight energy during the daylight via its solar panel to charge up its battery bank. Light dependent resistor (LDR) detects the presence of daylight [7] and at night it senses darkness and switches ON one array of the security light's LED. If the IR sensor senses a moving object, it triggers the control logic to switch ON one additional LED array thus increasing the illumination level of the surroundings. It stays in this mode for a short period of time and then reverts back to its former mode. By this arrangement the battery stored energy is utilized properly. At dawn, the LDR senses the daylight and switches OFF the lighting system; the solar panel resumes the battery charging process and the cycle continues.

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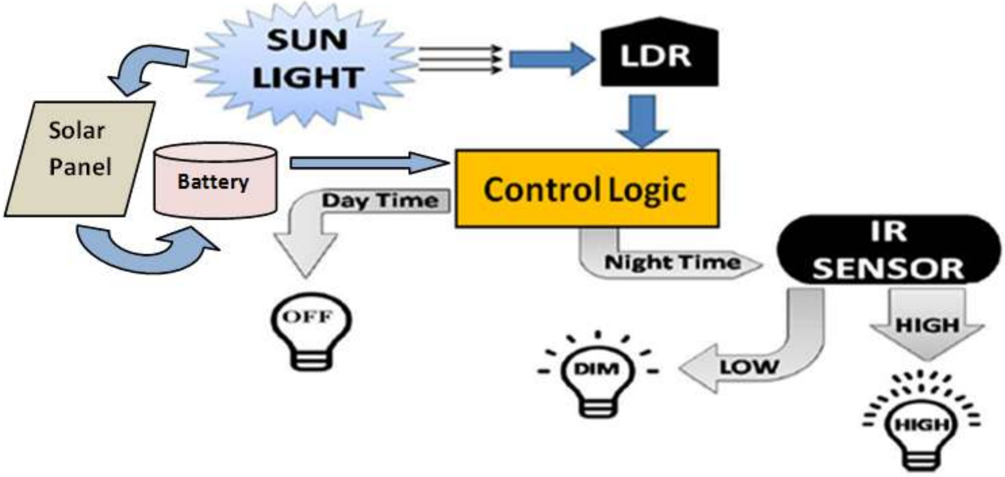

Fig.1: Architectural block diagram of the security light system

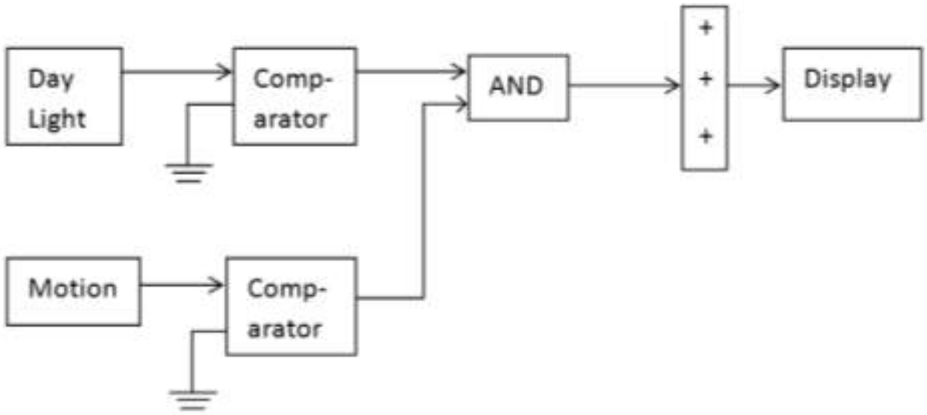

Fig. 2: Security light system proposed simulation block diagram

The simulation of security light system can be simply summarized using the simplified block diagram of figure 2. This gives an idea of the direction to go. The proposed simulation blocks are day light, comparators, motion, AND, OR and a display.

System Pseudo Code

The pseudo code of the control logic for the system is as follows:
Set Threshold
IF Light >=Threshold & Motion >=Threshold
Output = OFF
IF Light < Threshold & Motion >=Threshold
Output = ON
If Light < Threshold & Motion < Threshold
Output = NORMAL

With the pseudo codes, one is able to draw the flow chart for the security light system as shown in figure 3.

System Flowchart

The system under design can be depicted using system flow chart as shown in figure 3. This gives the behavior of the system.

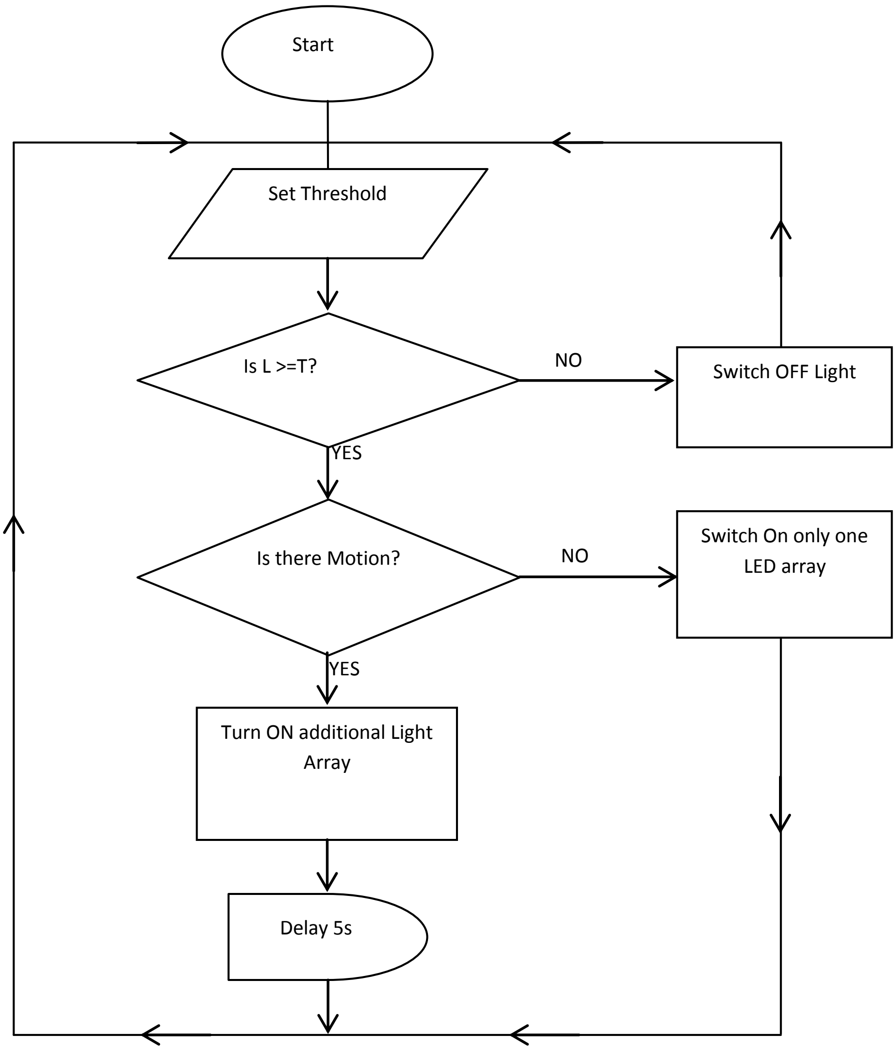

Fig. 3: Control logic flow chart for the proposed security lighting system

From the flowchart, it can be seen that, the system sets a threshold, and moves on to compare the threshold with day light (L). If the comparison was NO, the system goes back to start again. If day light is greater than or equal to threshold (T), then the system moves on to the next decision level. This time, it checks to see if there is a moving object. If the result is NO, then it switches ON only one light-emitting diode (LED) array. Should the result be YES then the control logic goes on to switch ON one additional LED array for greater illumination.

IV. SYSTEM SIMULATION

A model was developed for the proposed automatic security lighting system as seen in figure 4 and was tested. The results showed that given the condition of daylight, a dc voltage of 0V was displayed depicting no light condition, 2.5V was read off given night condition without a moving object and finally 5V for both night and moving object condition. This proved that the simulated scenario worked very well. The snap shots of the Simulink models (detailed and abridged) are shown in figures 4 and 5.

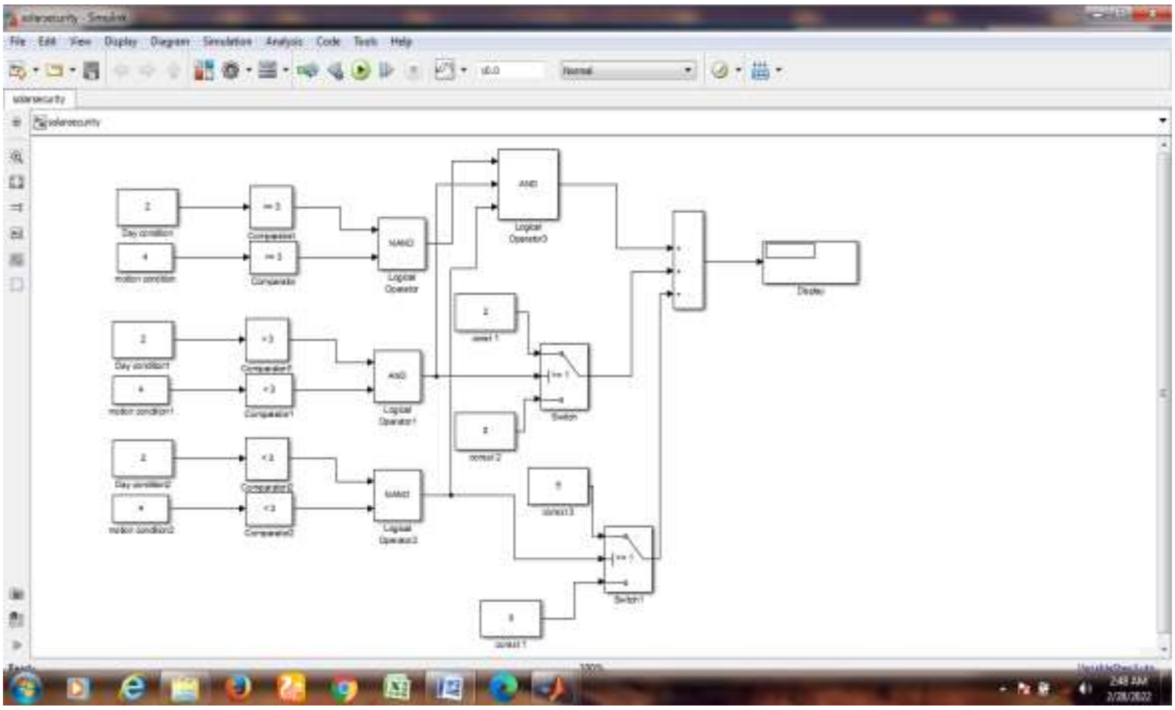

Fig. 4: A screen shot of the automatic security light system

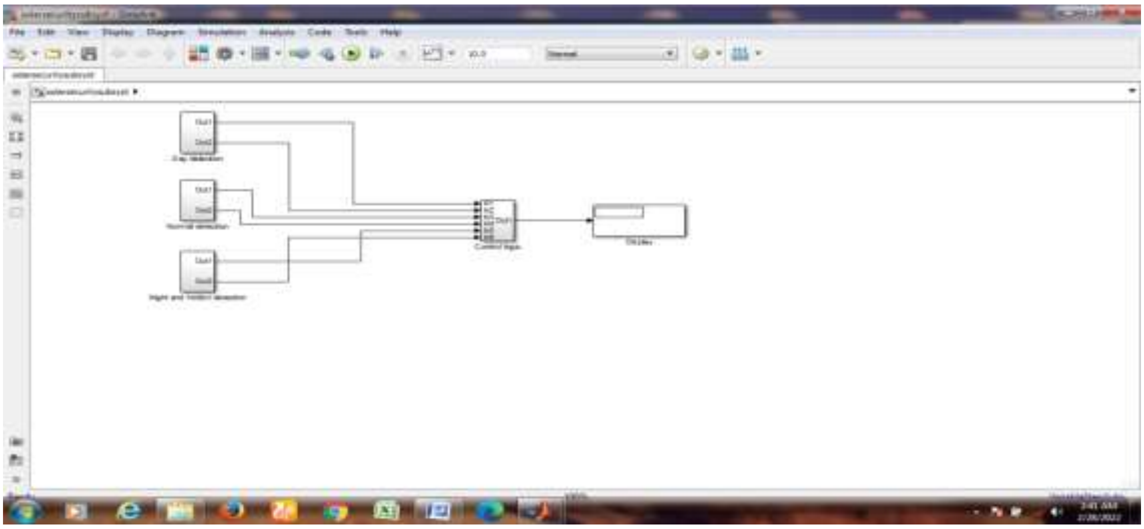

Fig. 5: A screen shot of the automatic security light system with all the blocks embedded in one block

V. CONCLUSION

The design and simulation of a solar-based automatic security lighting system has been presented in this seminal paper. This is energy efficient, self-operated security lighting system that has gets sunlight energy via its solar panel to charge a Li-ion battery during the day and automatically switches ON at night with dim light intensity in order to reduce energy usage. On sensing a moving object within the range of 10m, the security light gives brighter glow so that the moving object can be seen clearly. It stays in this full brightness mode for a short period of time and reverts back to the dim light condition. At dusk, the light is automatically switched OFF thus completely eliminating the need for a manual operator. The design was down using pseudo codes, block diagrams, and flowchart to capture the expected behavior of the proposed system. The design was finally modeled in a Matlab Simulink environment and was found to perform optimally.

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