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Development of Solar Powered LED Street Lighting with Auto Intensity Control

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Abstract: Solar is a non-conventional source of energy, and by using a charge controller, electricity can be captured by solar panels and stored in batteries. There are times where the streetlight is not turned on and off in a suitable time. The streetlights are ON even during daytime and sometimes the streetlights will not be turned ON at night. This kind of situation directly will be increasing the street lighting cost. The purpose of the solar streetlight study is to develop a system that does not consume an enormous amount of electricity, maintaining optimum use with minimum energy loss. The function of a charge controller is to control the battery charging process. This stored energy is used throughout the night to illuminate the streetlight. Solar streetlights are designed to read the inputs from sensors and analyze them for desired output, based on Arduino Uno microcontroller as the controller. Two sensors used in this study are light-dependent resistor (LDR) sensor and infra-red (IR) sensor. At dusk, streetlights can turn ON and automatically switch OFF at dawn, do not emit light when there is no motion, and emit light when it senses a movement of either the vehicle or people walking by. As the system in this study comes with a different situation, which is the streetlight will turn ON only if there is a vehicle or human passing through it, the electrical wastage and cost while operating the streetlight can be reduced. Based on the result, the streetlight at 5 ft of height produced 0.39 lux and 2.63 lux measured at actual and prototype, respectively with voltage 1:1. In this study, it shows that almost 85.00 % differences of lux at a voltage ratio of 1:1 has been obtained.

Keywords: Solar Panel, Charge Controller, Arduino Uno, LDR Sensor, IR Sensor

1. Introduction

Electrical energy has been used throughout the earth. For example, appliances, power devices and transportation methods used in everyday life are used. Electrical energy must be emitted from energy sources, such as power plants, to allow an entity to absorb the power it requires to operate in order to make things work. Most of the energy sources have been generated from non-renewable energy such

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as fossil fuels like coal, oils and gas. It takes millions of years for fossil fuels to form as they are formed by plant and animal remains of dead cells. Nuclear energy is often known as non-renewable energy since the Earth's crust has a small supply of uranium [1]. All this non-renewable energy will take thousands of years to form naturally and cannot be replaced as fast as they are being consumed. Besides, there are many sources came from renewable energy such as wind energy and solar energy. In order to stave off the worst effects of rising temperatures, renewable energy typically tops the list of improvements the planet can produce. This is because carbon dioxide and other greenhouse gases that lead to global warming have not been released by renewable energy sources such as solar and wind. Solar power is usable energy generated from the sun in the form of electric or thermal energy. In some ways, solar energy is captured either directly using photovoltaic (PV), indirectly using concentrated solar power or by a mixture [2]. In addition, sunlight is one of the main natural resources in Malaysia, 70.00 % of the year because of its hot weather [3]. This energy is stored in a rechargeable battery and supplied to the LED strip when illumination is required.

Nowadays with growing population and energy demand, the renewable option has been taken as an energy source. Providing street lighting is one of the most parts of infrastructure either in a city or rural areas [4]. The cost of the street lighting can be reduced by applying the energy-efficient technologies and design mechanism. In controlling the streetlight system, there are various control strategies and methods to ensure that it uses less energy and is less costly in terms of money and usage.

Streetlights are important, but costly, so the system needs to be optimized in a way that is economical and conserves energy effectively [5]. The development of solar-powered LED street lighting with auto intensity control is studied. Nowadays, during the day, the streetlight still switched ON and a major waste of energy occurs. Wastage will also occur at midnight, which will light up at full intensity, as there is not much car and traffic. To overcome this problem, an auto intensity streetlight system using solar energy controlled by Arduino proposes to become a better solution for a solar streetlight. in order to reduce the electrical wastage and cost while operating the streetlight.

2. Literature Review

2.1 Solar panel

The solar panel is a combination of multiple solar cells to convert sunlight to produce electricity [6]. Commonly solar cells made from a semiconducting material such as silicon wafer. There are three types of solar panel which is monocrystalline, polycrystalline or also known as multi-crystalline, and thin film. These solar panels vary in material, performance has its advantages and disadvantages. The suitable type of solar panel selected depend on installation method or desired system characteristics such as performance. The performance of the solar panel can be rated according to their maximum DC power output (Watt) under standard test condition (STC) [7]. In terms of technology and price, crystalline-based solar panels are commonly used because of their maturity. Although poly-crystalline solar panels are cheaper than mono-crystalline solar panels, in Streetlight applications, mono-crystalline panels are preferred because they are smaller than poly-crystalline because of their higher performance, making the construction of the pole simpler and cheaper. The monocrystalline solar panel has a higher efficiency compared to a polycrystalline and thin film. Monocrystalline efficiency is 15.00 %, polycrystalline efficiency is 14.00 % and thin-film efficiency is 10.36 % [8].

2.2 Battery

To store the electricity generated by the solar panel, batteries are used. The battery and/or load will be supplied with electricity produced by the solar panels during the day. These batteries can provide stable energy to the load when the load demand is greater than the energy received from the solar panels [9]. There are three types of batteries which are Nickel-Cadmium (Ni-Cad) battery, Lead-Acid (LA) battery, and Lithium-Ion (LI) or Lithium-Polymer (LP) battery [9]. Due to its maturity in technology and low costs, the Lead-Acid battery is the most widely used in solar-powered systems. They can only be used to prolong their lifetime with a low depth of discharge (DOD). Its DOD ranges from 20.00 % to 50.00 %. There are two types of Lead-Acid batteries, which is flooded and valve-regulated lead-acid (VRLA) batteries that are free batteries for maintenance.

2.3 Charge controller

To control the charging of the batteries, charge controllers are used. The charge regulator or charge controller is the device to protect the battery from over or under charged by the solar panel [10]. It also functions as regulator for voltage coming from solar panel. Both types have same function but have different principle. Pulse-width modulation (PWM) controller effect the sensitive load because of noise created by frequency while maximum power point tracking (MPPT) controller can use with larger voltage solar panel (such as with 20 V solar panel, it can charge a 12 V battery bank) [11]. Besides, PWM controller is less cost compared to MPPT controller.

2.4 Method on using LED in solar powered streetlight

References from [12] and [13] shows the significant use of LEDs as a component of the lighting for solar powered street light. This is due to the emergence of new LED driver technology in which on-par or better than conventional high-intensity discharge (HID) or high-pressure sodium light (HPS) lamps can perform more efficient LED modules. In [14] and [15], it discusses the design of solar powered streetlights using conventional method. In the design, there is no "intelligent" system being used or an approach optimization method. The only energy-efficient element is the use of LED lamps that, compared to conventional HID or HPS lamps, have a low power load.

2.5 Related work

N. Yashaswini, et al in implementation of automatic street light control by detecting vehicle movement [16]. This project is planned to monitor the movement of vehicles on roadways so that only a block of road lights in front of it can be switched on and the trailing lights can be turned off to conserve electricity. For cars, each of the lights on the expressway remain ON throughout the night. Usage of the microcontroller to monitor the LED. The hardware model consists of fourteen streetlamp light-emitting diodes and eight photodiode or infrared diode sets used as sensors, variable resistors and switch-functioning transistors. On the side of the street, the infrared diodes are set and photodiodes are positioned on the opposite side of the street, directly confronting IR diodes.

For the automatic street lighting system for energy efficiency based on low cost microcontroller [2] by the R. Husin, they use an automated street lighting system based on a low-cost, energy-efficient controller to monitor the LED. Because of its features and benefits, the LED is seen as the promising alternative to the current street lighting scheme. There are three sensors used in this project, including vector and non-vector type sensors that are dark or light sensor, LDR sensor and laser sensor.

A. Shariqueanees et al in their paper for solar powered LED street light with auto intensity control [17]. Based on this design project, solar panel from the photovoltaic cells are used for charging the batteries. Solar panels from photovoltaic cells are used to charge the batteries, based on this design project. The photovoltaic can convert the energy of sunlight into electrical energy. In the rechargeable battery, the electrical energy will be stored. Then the solar panel used the different reflectors to obtain more thermal energy from the sun. A case study is also done in this project to show benefits of solar led streetlight compare to traditional streetlight. Other components used in this project is rechargeable battery, voltage divider circuit, Arduino and LDR.

In the design of the solar powered auto intensity control of street light with SMS feedback system [18], V. Chauhan and J. Singh Sadhak use global system for mobile communications (GSM) communication system. In order to power the lamp, this project uses solar panel systems. The GSM communication system enables streetlight monitoring by using a current sensor and a voltage sensor with a voltage divider circuit. The GSM is an automated system designed to increase streetlight accuracy and efficiency. The microcontroller will then process the streetlight relevant information when the fault occurs. This microcontroller will send the data to the server through way of a GSM communication device.

J. Santosh et al in their paper of auto intensity control of solar street light using Arduino [4], they use Arduino Uno as a microcontroller. There are a variety of components used in this project, such as solar power, LEDs and street lighting sensors. The PWM controls the appropriate strength of the LED used. In this project, because of the single output that goes high when the movement is detected, PIR sensors are used to detect the infrared radiation of the human body.

A. Bhoir et al in their paper of solar based auto intensity control street light using Arduino [5]. This project objective is to create a system which is saving for energy. Therefore, this project also makes a system to senses the brightness of the environment and then adjust the intensity as per the same. Manual control of streetlights nowadays taking a lot of time and significant waste of energy is done at morning because it could not be turned OFF together at once. Solar panel, Arduino, LED, battery, LDR sensor, IR sensor, solar module and stems for connecting the panels used in this project.

3. Methodology

A block diagram as shown in Figure 1 is used to represent the system layout and structure that is involved in this study. Based on Figure 1, the power supply represented by a 6 V 4.5 Ah sealed lead acid rechargeable battery is used as a supply to activate the Arduino Uno microcontroller and 4 channel 5 V relay module. Arduino Uno Rev3 is used as a controller to interface the hardware component and software. The intensity of light at various time slots is controlled by this controller. The IR sensor consists of an infrared-transmitter, an infrared-receiver, and a distance adjustment potentiometer. This sensor senses the movement of the vehicle on the road to provide the controller with input throughout the night. The LDR sensor module is used to detect the darkness of the ambient level of light or to measure the intensity of light. The resistance is very high during the night, but the resistance can decrease significantly during the daytime, depending on the strength of the sun. The 4 channel 5 V relay module used to interface with microcontroller of Arduino Uno Rev3 and act as a switch either ON or OFF the LED strip.

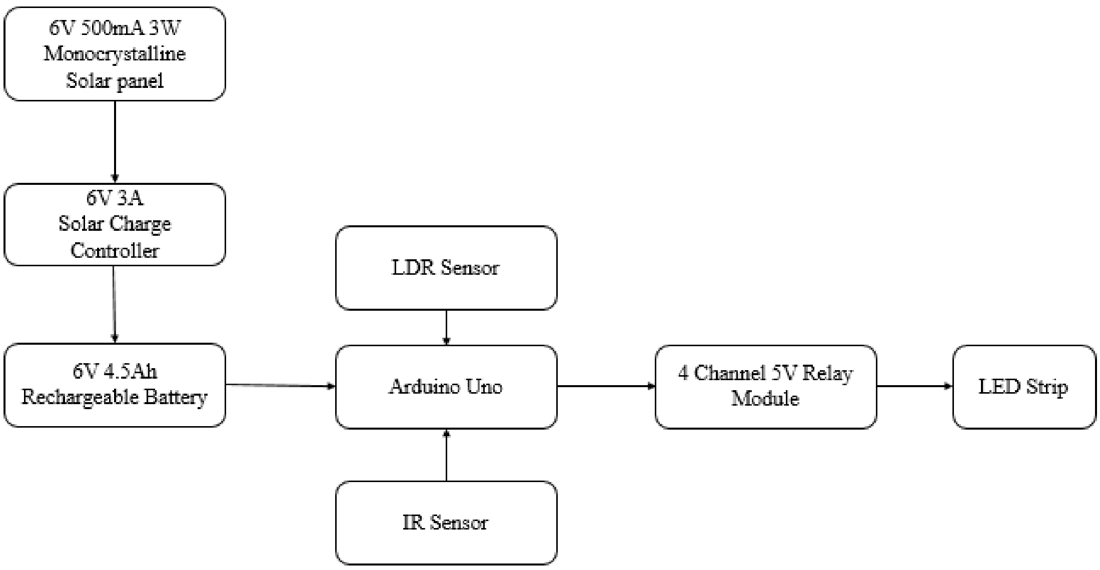


Figure 1: Block diagram of the solar powered LED street lighting with auto intensity control

When 6 V 500 mA (3 W) solar panel expose to sunlight, the generated electricity control by PWM charge controller to charge the battery. The charge controller automatically manages the working of solar panel, 6 V 4.5 Ah sealed lead acid rechargeable battery and connected load in the solar system. The rechargeable battery is a unit for energy storage that can be recharged after discharge. During the day, this battery stores the energy from the solar panel and this power is used during the night. In this study, the solar panel transforms solar energy into electrical energy that is used to power the system or to charge a battery. The output used to emit visible light when it is activated is the LED strip.

3.1 Flow chart

The flow chart in Figure 2 shows the operation of LDR sensor. Based on Figure 2, when LDR sensor detect dark, the LED strip 1 turn ON until LDR sensor detect the presence of light of vehicle, the relay activated and turn OFF the LED strip 1. The LED strip 1 turn ON back when the LDR sensor detect dark and did not detect the presence of light. The flow chart in Figure 3 shows the operation of IR sensor.

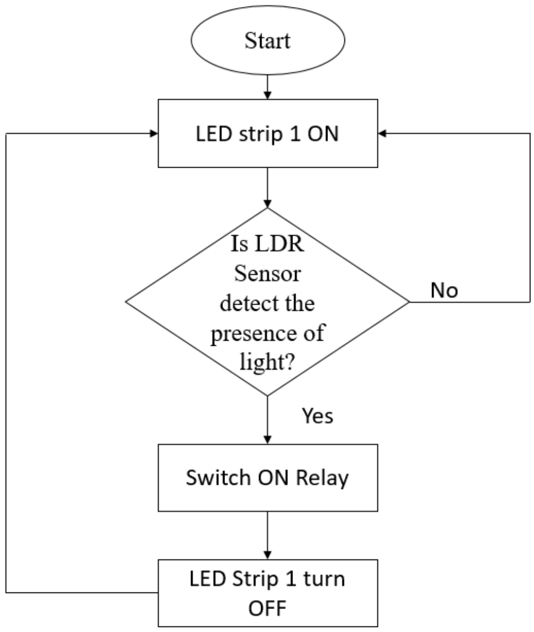


Figure 2: Flowchart of LDR sensor

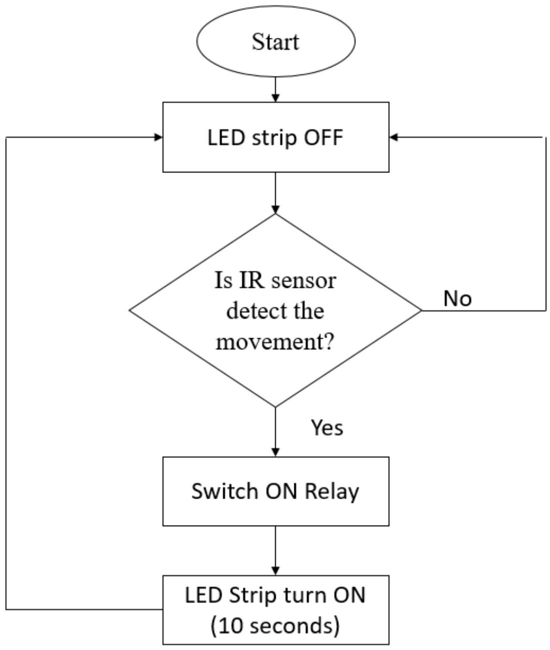


Figure 3: Flowchart of IR sensor

Based on Figure 3, when IR sensor detect the movement, the relay activated and turn ON the LED strip. When the IR sensor does not detect the movement, the relay cannot be activated and the LED strip did not light up**.** The flow chart in Figure 4 shows the operation of overall project. Based on Figure 4, solar panel and rechargeable battery are connected to the solar charge controller to charge the battery. The power in a rechargeable battery used to activate the Arduino Uno microcontroller and 4 channel 5 V relay module. When LDR sensor detects the presence of light, the relay activated and LED strip turn ON. Then, when IR sensor detects the movement, the relay activated and LED strip turn ON. When the LDR and IR sensor did not detect the presence of light and movement, the sensor keeps waiting for the sensor to activate.

Figure 4 shows the circuit diagram of solar powered LED street lighting with auto intensity control. It works in accordance with the varying sunlight. Whenever there is sufficient sunlight in surroundings, LDR exhibits high resistance and acts as an insulator, while in darkness this LDR behaves as low resistance path and allows the flows of electricity, this LDR's operates with the help of IR sensors, these sensors are activated under low illumination conditions and these are controlled by an ATMega328P micro controller, every basic electronic circuit operate under regulated 5 V DC. When any object comes in the range of IR sensors, as IR LED emits the radiations and reflected to IR photodiode by the object. Hence, object is detected.

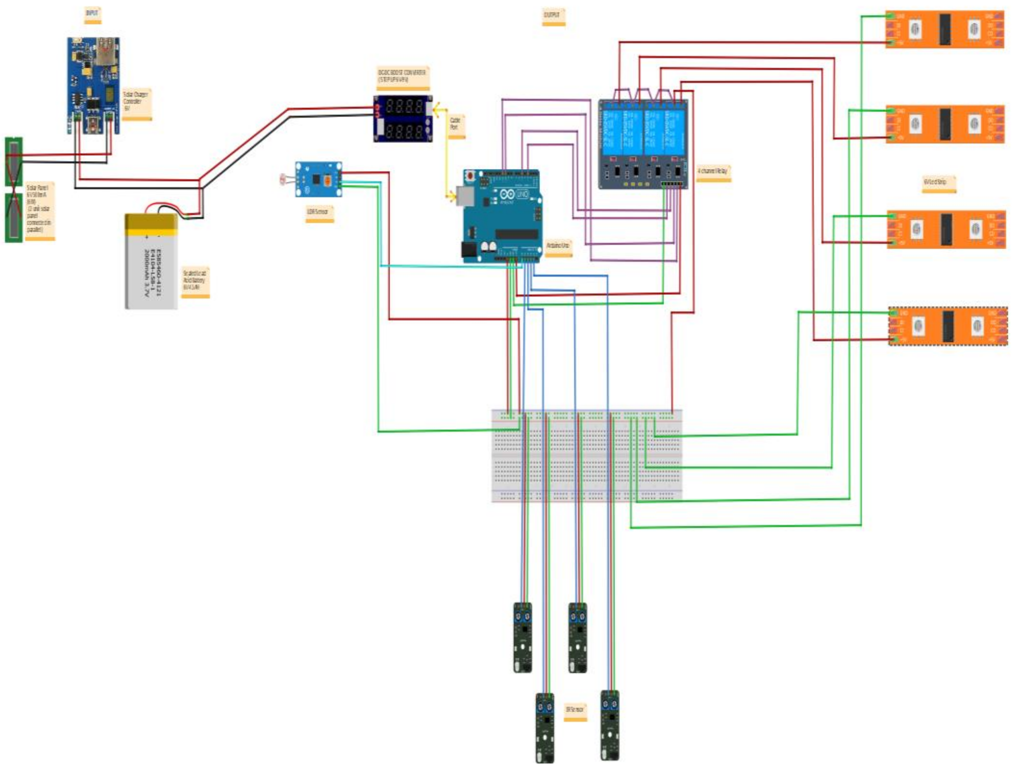
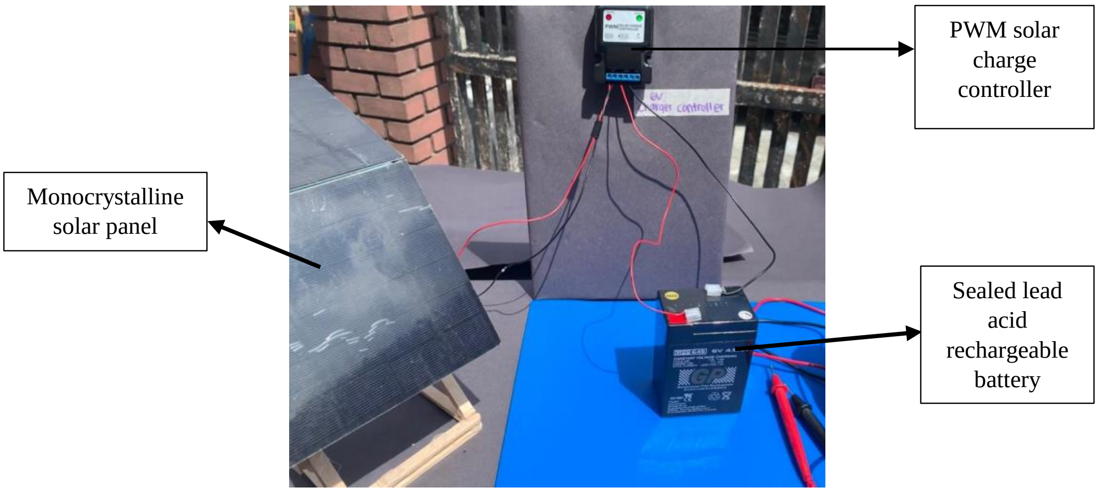


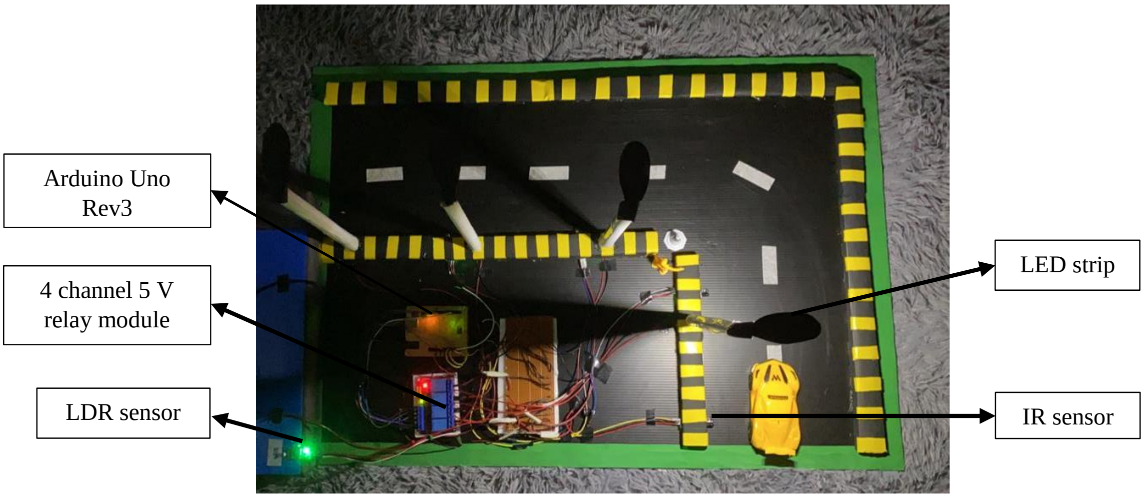
Figure 4: Circuit diagram of solar powered LED street lighting with auto intensity control

4. Results and Discussion

Based on Figure 5 (a), a testing for solar panel power generation to charge a rechargeable battery during sunny condition has been conducted. Figure 5 (b) shows the output of the LED strip to produce the streetlight which consists of Arduino Uno microcontroller, and 4 channel 5 V relay module, LDR sensor, IR sensor and LED strip.



(a)



(b)

Figure 5: Hardware prototype of the (a) input and (b) output part

4.1 Output voltage generated by solar panel

The testing for solar panel power generation to charge a rechargeable battery was conducted at Kolej Kediaman Pagoh, UTHM during sunny conditions. The 6 V 500 mA 3 W solar panel, 6 V 4.5 Ah rechargeable battery and 6 V 3 A charger controller was selected while running this experiment for charging the battery. The data reading has been taken once in half an hour using a multimeter. The result in Table 1 shows the voltage that has been charged on rechargeable battery within a stated time. As shown in Figure 8, the absorbed voltage generated by the 6 V solar panel to the 6 V rechargeable battery increased between 11.00 am until 3.30 pm.

Table 1: Continuous outcomes using 6 V 500 mA 3 W solar panel

Time	Voltage (V)
11.00 am	1.34
11.30 am	1.52
12.00 am	2.37
12.30 am	3.56
1.00 pm	3.89
1.30 pm	4.52

2.00 pm	4.78
2.30 pm	5.65
3.00 pm	5.89
3.30 pm	6.28

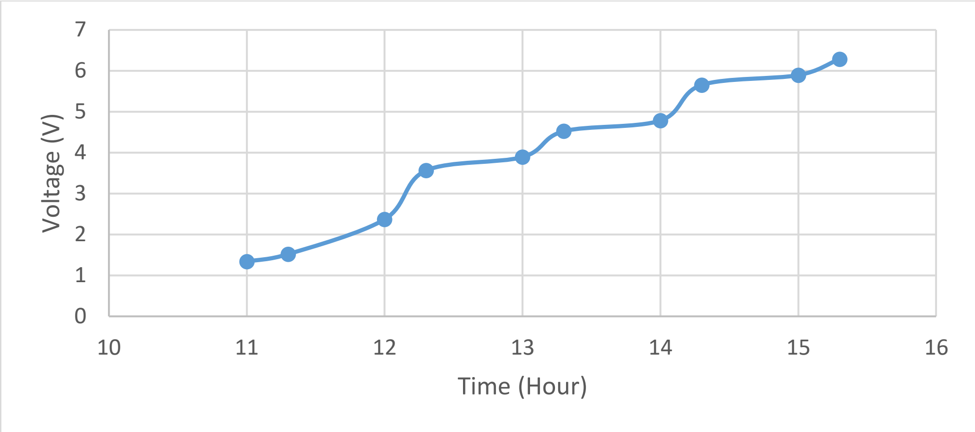


Figure 6: Solar panel generate power to charge a rechargeable battery

4.2 The streetlight data

The testing for the actual street lighting system was conducted at Jalan Pagoh road. The brightness value (lux) of the lamp of actual and prototype streetlight has been observed to compare the results. The lux meter was selected while running this experiment for streetlight. The data reading has been taken for 4 poles with a different height which is 4 and 5 ft from the lowest point of streetlight up to the main point of the streetlight lamp. The results in Table 2 show the lux value for 4 poles with two different heights at the actual streetlight. Table 2 shows the data reading of the actual streetlight at the road. The data proved that when the distance of lux measurement which is lux meter is nearest to the main point of street lamp, the value of lux will increase. While, the lux value decreases when the lux meter far from the main point of street lamp. As referred to Table 2, it can be concluded that, at 4 ft from the lowest point of streetlamp, the value of lux at 4 ft lower than 5 ft height which is between 41 to 46 lux for 4 ft and between 44-49 lux for 5 ft.

Table 2: The brightness (lux) of actual streetlight

Pole	Height (ft)	
	4	5
	Brightness (lux)	
1	41	44
2	44	48
3	44	48
4	46	49

The data in Table 3 shows the lux value for 4 poles with two different heights at the prototype streetlight. Table 3 shows the data reading of the prototype streetlight. The data pattern is the same with the actual streetlight data. The value of lux at 5 ft height is bigger than 4 ft height as it is nearest towards the street lamp. If compared with two previous data taken for actual and prototype streetlight, the bar graph in Figure 7 shows the lux value at height 4 ft while Figure 8 shows the lux value at height 5 ft for both actual and prototype condition.

Table 3: The brightness (lux) of prototype streetlight

Pole	Height (ft)	
	4	5
	Brightness (lux)	
1	10	17
2	8	15
3	9	16
4	8	15

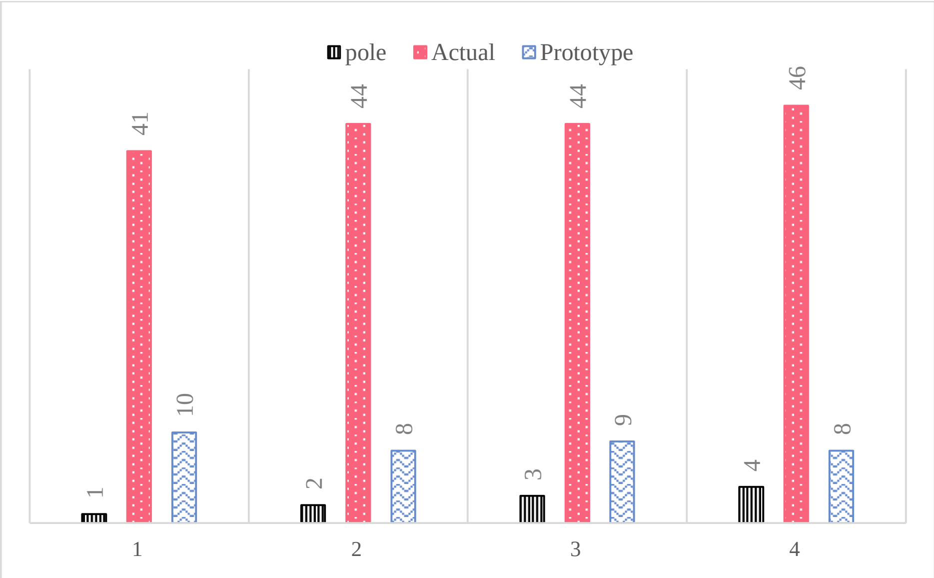


Figure 7: Lux value at a height of 4 ft of actual and prototype streetlight

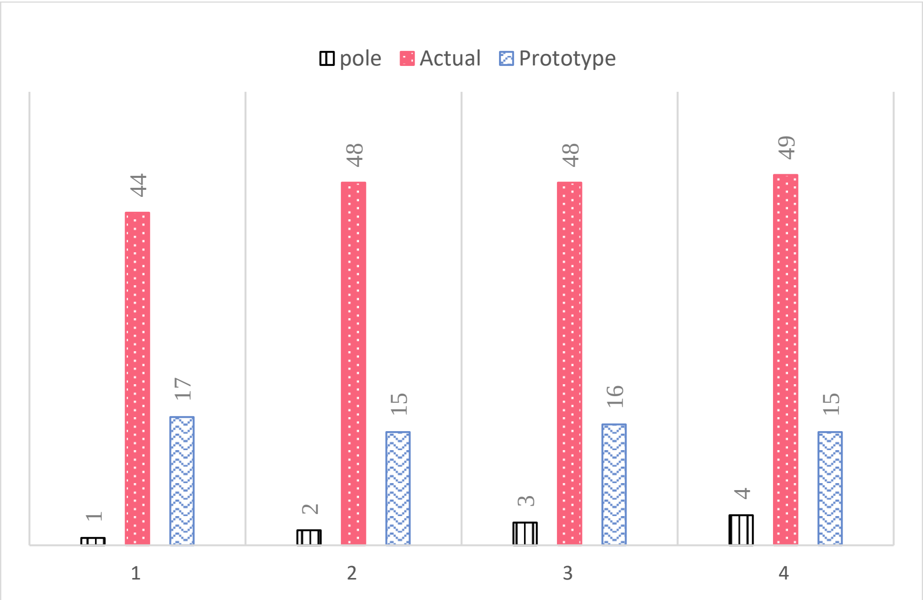


Figure 8: Lux value at a height of 5 ft of actual and prototype streetlight

Based on Figure 7 and Figure 8, the lux value at 4 and 5 ft height for the actual condition is higher than the lux value at 4 and 5 ft for prototype streetlight. The most common streetlight (actual) operating voltage was 120 Volts while for this project, 6 Volts streetlight was used. Table 4 shows the ratio for actual and prototype streetlight. Figure 9 illustrates the comparison between the average brightness at four poles (refer to Table 4) in actual and prototype streetlight for both heights which is 4 and 5 ft with a voltage ratio 1:1. Based on Figure 9, the brightness, lux value produced for prototype streetlight is higher than actual streetlight for 1 V. The 1 V of actual streetlight produced 0.36 lux while prototype streetlight produced 1.46 lux for 1 V. It shows that even though the voltage is low, but it can produce high lux value which is the streetlight turn on bright. In this case, it had been proved that the usage of electrical for streetlight prototypes was reduced.

Table 4: Ratio for actual and prototype streetlight

Ratio (Volts)		Actual (lux)	Prototype (lux)
120 : 6	4 ft	43.75	8.75
	5 ft	47.25	15.75
1 : 1	4 ft	0.36	1.46
	5 ft	0.39	2.63

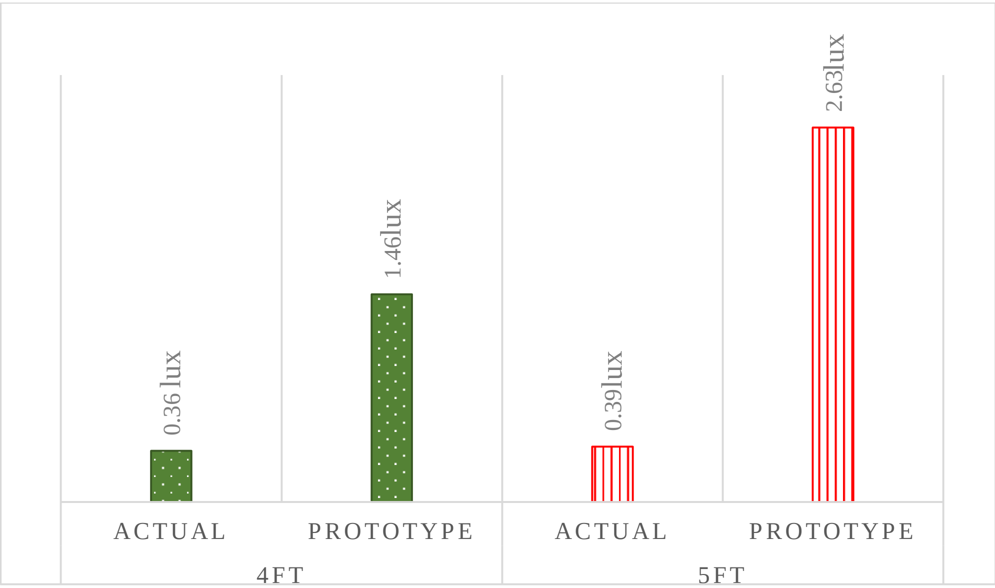


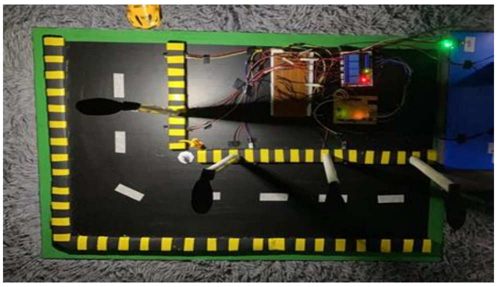
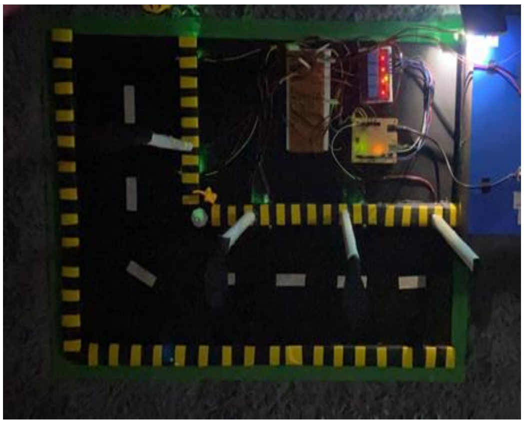
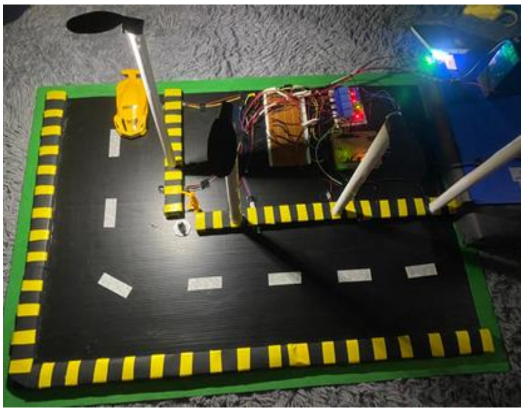
Figure 9: Average brightness at 4 and 5 ft of streetlight with ratio 1:1

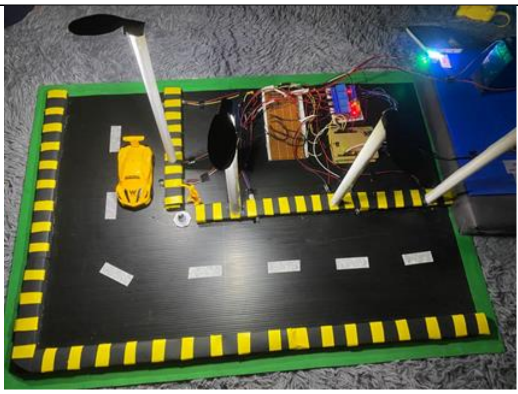
4.3 Picture overall project

Table 5 shows the flow process of LED street lighting in different condition. The first condition shows the LDR sensor detected dark, LED strip 1 remains turned ON (for safety purpose) until the LDR sensor detects the presence of the light of any vehicle. The second condition shows the condition when the LDR sensor detects the presence of the light of the vehicle, the LED strip 1 turns from ON to OFF. In this stage, all LED strips are in OFF condition and IR sensor ready to activate. The LED strip turns ON after any vehicle attaches to the IR sensor. The third condition shows when IR sensor 1 detects movement from the vehicle, LED strip 1 turns ON for 10 seconds. The fourth condition shows when

IR sensor 2 detects movement from the vehicle, LED strip 2 turns ON for 10 seconds. The fifth condition shows when IR sensor 3 detects movement from the vehicle, LED strip 3 turns ON for 10 seconds. The sixth condition shows when IR sensor 4 detects movement from the vehicle, LED strip 4 turns ON for 10 seconds. When all the LDR sensor does not detect presence of light of any vehicle at night, LED strip 1 turns ON (as first condition).

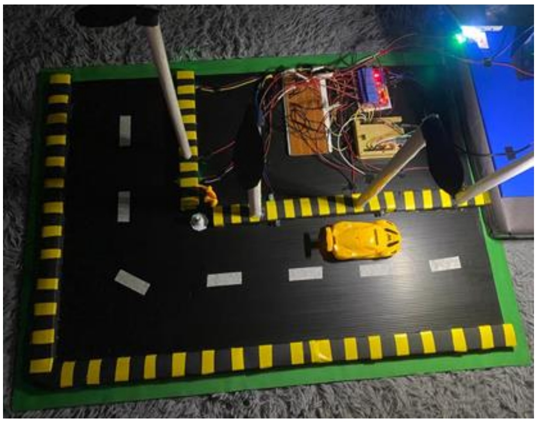
Table 5: Flow process of the LED streetlight

Condition	Results
1. LED strip 1 turn ON when LDR sensor detect dark	
2. LDR sensor detect the presence of light	
3. LED strip 1 turn ON	
4. LED strip 2 turn ON	



5. LED strip 3 turn ON

6. LED strip 4 turn ON



5. Conclusion

The development of solar-powered LED street lighting with auto intensity control using Arduino IDE, Proteus and Fritzing apps successfully produced. The street lighting hardware had been completed by using a strip-board. Based on the development process, the first objective is achieved which is to develop an auto intensity street light system using solar energy controlled by Arduino. These designs are sufficient to make a solar street lighting practical for portable usage since they can be placed wherever the user needs. The second objective is to propose a better solution for a solar street light. In order to reduce the electrical wastage and cost while operating the streetlight. As the system comes with a different situation, which is that the street light will turn ON only if there is a vehicle passing through it, the electrical wastage can be reduced. This system is a cost-effective, practical and safest way to save energy. Solar energy is one of the important and major renewable sources of energy. It can solve the problems that the world is facing today, saving energy and also disposal of incandescent lamps very efficiently.

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