AUTOMATED SOLAR-POWERED LAMP POSTS

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Abstract

The Automated Solar Powered Lampposts is a project design that collects solar energy from the sun and converts it into electrical energy. This was built to save energy and put it to use for the safety of students of the Baliuag University during night time specifically along Baliuag University fence near gate two. This design project used monocrystalline solar panel as its main component. Monocrystalline Solar Panel collects the solar energy from the sun, the collected energy is stored in a lead acid battery. Using a power inverter, the output of the solar panel was converted from DC to AC. The converted energy was used to power up seven (7) 11-watt LED lamp. A night sensor (LDR) was used to control the LED lamp for its automation and to lessen the human interventions. A switch was paralleled to manually turn off the system in case the sensor was triggered accidentally even day time. This study focused on the utilization of renewable and eco-friendly source of energy. This project was conceptualized in accordance with the advocacies of having clean environment. The use of solar energy is just growing; hence the researchers attempted to contribute and helped to promote the potential that solar energy can do. This project can help to promote the use of renewable energies and can help to have a better world.

Keywords: monocrystalline solar panel, power inverter, renewable energy, solar energy, battery, LED, AC, DC.

Climate change is now affecting every country on every continent. It is disrupting national economies and affecting lives, costing people, destroying communities and countries greatly today and, even more tomorrow.

People are experiencing the significant impacts of climate change, which include changing weather patterns, rising sea level, and more extreme weather events. The greenhouse gas emissions from human activities are driving climate change which continue to be felt with the global temperature to continue to rise. They are now at their highest levels in history. Without action, the world's average surface temperature is projected to rise over the 21st century and is likely to surpass 3 degrees Celsius this century—with some areas of the world expected to warm even more. The poorest and most vulnerable people are being affected the most. (http://www.un.org/sustainable development/climate-change-2/, January 9, 2017)

As the population increases, the necessity for energy to produce electricity, run vehicles, operate plants and other structures also increases. Most of the electric power generated in the world comes from the burning of fossil fuels to generate a consistent supply of energy. These energy sources are conventional, meaning they are fixed in nature and non-renewable. During the combustion of fossil fuel, carbon dioxide and other greenhouse gases were released to the atmosphere. If this process happened continually and in a faster rate, more gases will be trapped to the atmosphere, resulting to global warming and eventually to climate change. (Power blackouts and alternative energy solutions for Tanzania, http://www. business-times.co.tz, January 9, 2017)

In the Philippines, the effect of climate change can be exemplified through the strongest and largest typhoon in history, the super typhoon "Yolanda". This typhoon has caused many infrastructures, establishments, houses and tourist spots to be destroyed and it has also caused thousands of casualties. With this, people must do some actions in order to prevent the devastating effects of climate change mainly due to the huge amount of greenhouse gasses that are being locked on into the atmosphere.

As the fears of climate change increase, the demands for devices that generate electricity that are environmentally friendly will steadily increase. The need to develop clean energy-producing systems that can perform as reliably as fossil fuel

plants must be implemented throughout the world in order to decrease the effects man has on the planet. Alternative energy is a term used for an energy source that is an alternative to using fossil fuels. Generally, it indicates energies that are non-traditional and have low environmental impact.

The quest for an environmentally-friendly, renewable source of energy has caused a spike in interest in this research study. In the Philippines, there are many non-conventional sources of energy — hydroelectric, geothermal, wind, biogas and solar. The researchers has focused on the use of solar energy as an alternative source of energy.

The most abundant fuel source in the realm of renewable energy is the sun. This form of energy collection is viable in regions of the world where the sun is plentiful, like the Philippines, and can be used in remote regions, schools or on houses to supplement the rising cost of electricity from a power grid. Solar panel produces electricity through individual photovoltaic cells connected in series. To convert the sun's energy, the cells capture photons to create freed electrons that flow across the cells to produce usable current.

Considering the great advantage of using solar energy, schools and universities will benefit the most. Baliuag University is a well-known school and one of the many institutions that support the advocacies of maintaining a clean environment. It has the so called Green Building, a state of the arts facility that promotes the use of power saver LED lighting.

Baliuag University has students who have classes until night, and some of them bring motorcycle which is being parked in front of gate two of the university. With these concepts, a solar -powered lamppost can be useful to maintain security of the university and its students. The Automated Solar-Powered Lampposts will provide additional lighting for a number of hours in the said area and will help secure all the students and their motorcycle against criminals who are active when the place is dark. The lampposts will ensure the safety of the students while waiting for their service or parents to fetch them and while walking in the area.

Problem Statement

The general problem of this study is: how to illuminate the sidewalk and motorcycle parking area at gate two of the university using solar energy?

Specifically, it sought to answer the following questions:

1. What system design is needed to properly harvest the solar energy?
2. What device can be used to convert energy from the sun into electricity?
3. What circuit design will be able to store the electricity produced by the solar panel?
4. What lighting infrastructure is suitable for the parking area and sidewalk?

Methods

Conceptual Framework

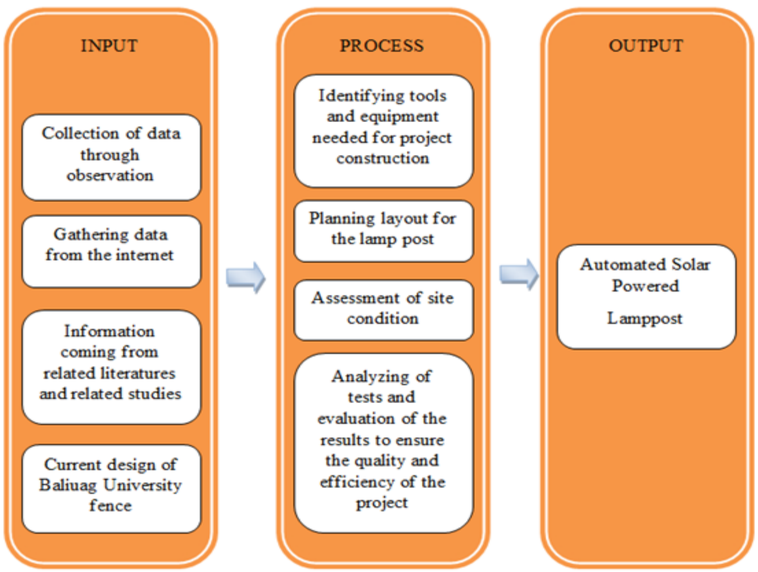

Figure 1. The IPO Model of the Automated Solar-Powered Lamp Post

The study utilized the research paradigm presented in Figure 1 in designing the Automated Solar-Powered Lampposts for fence of gate two of Baliuag University. The inputs needed for the proposed study were generated from collection of data through observation, gathering data from the internet, information coming from related literatures and related studies and current design of Baliuag University fence.

The procedures include identifying tools and equipment needed for project construction, plan layout for the lamp post, assessment of site condition, analyzing of test and evaluation of the results to ensure the quality and efficiency of the project. This represents the development of the proposed study, the Automated Solar-Powered Lamp Post.

This project showed the methods and procedures in converting solar energy to electrical energy to be stored in the battery that would operate the lamp post. The procedure must yield less error to gather good results during the experiment. This part determines the design and the devices that were used in the study to achieve the desired output.

- **Literature Review Method.** The researchers carefully searched for related projects from the internet to gather information. Data gathered from the related projects gave ideas to the researchers in developing this study.
- **Experimental method.** This study used an experi-mental design because the researchers studied about what would happen when the variables are manipulated and controlled. This study also includes an experiment if the solar energy can charge the battery, how long it can fully charge the battery and if it can power up the load.

Project Description

This project study was designed to convert solar energy to electricity and store it to power up a lamp post. A solar panel was placed on the roof deck of the bookstore in the Baliuag University where the sunlight is abundant during daytime. The output of the solar panel would be stored in a battery. A night sensor would control the lighting of the lamp post to limit its use and conserve the energy generated by the solar panel.

One of the concerns why the researchers came up with this project is to conserve energy and promote the use of alternative energy. It also provided additional lighting facility that would secure safety of students during night time.

Project Development

- **Identifying needed equipment and tools for the design.** The purpose of this phase is to identify the needed devices for the proposed project. The tools and equipment needed for this study were carefully searched in order to achieve its desired output.
- **Identifying the design.** In this phase the needed design of the study is identified in order to achieve its desired output.
- **Prototyping.** In order to examine this study, a prototype is needed to test the device and evaluate its output.
- **Testing the device.** The purpose of this phase is to identify if the device is properly working.

Block Diagram

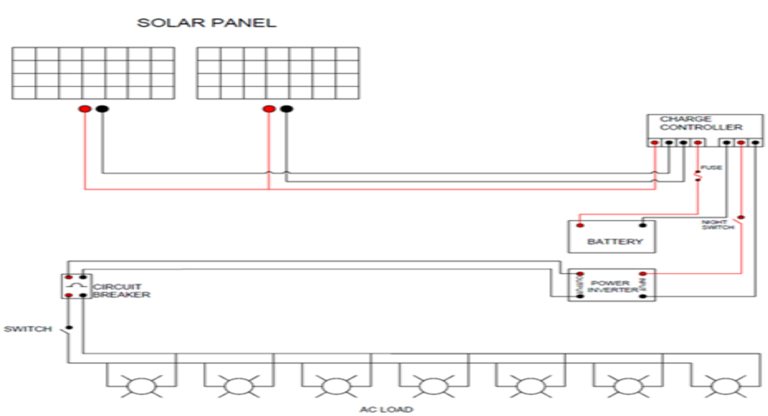

Figure 2. Block diagram of the Automated Solar Powered Lamp posts system.

Figure 2 illustrates the block diagram of Automated Solar Powered Lampposts. Photovoltaic cells capture sunlight and convert it into d-c supply. Monocrystalline type, made from single crystal of ultra-pure silicon, was used because of its high efficiency. This type performs better under low light than polycrystalline.

The d-c supply is regulated by a charge controller before being stored in a battery. Fuse was connected in series with the battery for protection. A charge controller prevented overcharging and may protect against overvoltage, which reduce battery performance or lifespan.

LDR was connected in series with the power inverter, for automatic illumination. The power inverter shifts the d-c supply coming from the battery to a-c. Circuit breaker was used for the purpose of over current protection and it served as the main switch of the lamp post. LED bulb was used as a load; it was energy efficient, long lifespan and it consumed less power than incandescent bulb.

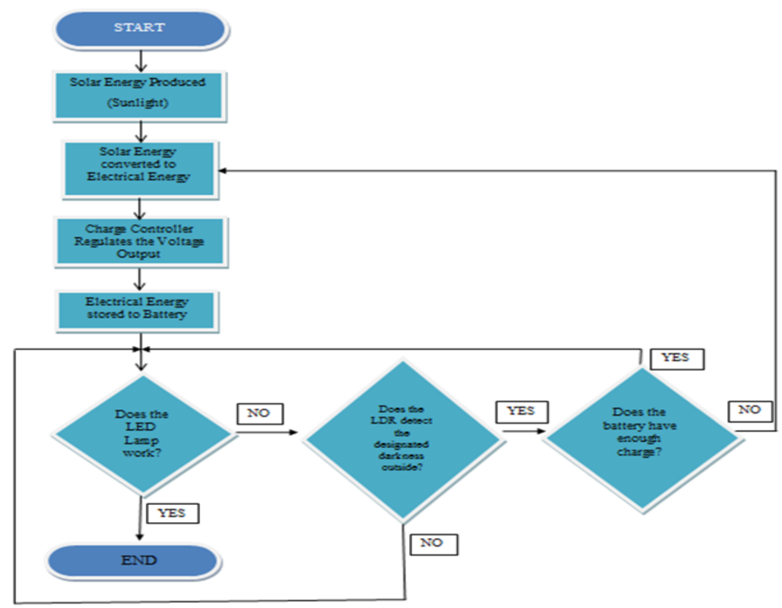

Figure 3. The flow chart of the Solar-Powered Lamp Post

Figure 3 shows the systematic flow of the Solar Powered Lamppost. Solar energy is converted to electrical energy. The output voltage produced is regulated by the charge controller before it is stored in the battery. When the LDR sensed darkness and the battery had sufficient charge, the LED lamp would work and light up.

Hardware Specification

The following items are the devices and equipment used in the construction of the system.

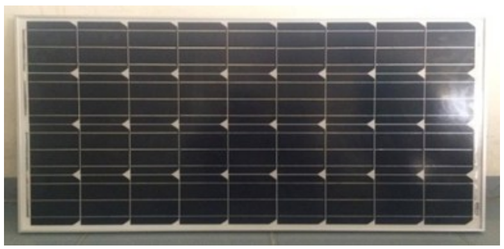

Figure 4. Solar Panel

Type	:	Monocrystalline
Peak Power	:	100 W
Max Voltage	:	18.0 V
Max Current	:	5.56 A
Lifespan	:	25 years

Figure 4 shows the monocrystalline solar panel used in the project with its peak power and maximum voltage and current specified.

Figure 5. Charge Controller

Input	:	12 V/24 V
Amps	:	20 A

Figure 5 illustrates the charge controller to regulate the input current from the solar panel.

Figure 6. Lead Acid Battery

Power Output	:	12 V
Capacity	:	100 AH
Rating whr	:	1200
Lifespan	:	5 years

Figure 6 shows the type of battery used which is the lead acid with the capacity of 100 Ah and a maximum lifespan of 5 years.

Figure 7. Power Inverter

Output wave form	:	Pure Sine Wave
Rated Power	:	800 W
Output Voltage	:	220-250 VAC
Output Frequency	:	(50/60 HZ)

Figure 7 illustrates the power inverter used in the study. It specifies that the rated power capacity is about 800 W with an output voltage of 220 V minimum.

Figure 8. Circuit Breaker

Amperage	:	20 A
Voltage	:	220-240 V
Type	:	miniature circuit breaker "MCB"

Figure 8 shows the circuit breaker that helped protects the whole system against the damage of overloading.

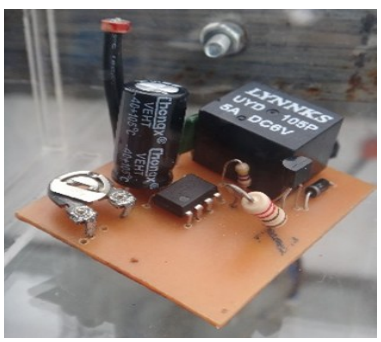

Figure 9. Night Switch

Voltage	:	12 VDC
Power Capacity	:	120 W

Figure 9 illustrates an automatic switch called the night switch. The maximum power capacity is about 120W with an output voltage of 12 Vdc.

Figure 10. LED Bulb

Rated Voltage	:	220 V AC
Power	:	11 W

Figure 10 shows the light bulb used in illuminating the area. Light – emitting diode type was chosen for the efficiency and economical factor it introduces.

Figure 11. Wire

Size	:	$2mm^2$
Type	:	THHN / THWN
Ampacity	:	20 A

A standard 2 mm^2 diameter of THHN/THWN copper wire was utilized to control the switching of the lamp posts.

Figure 12. Electrical Conduit

Type	:	PVC
Length	:	10 FT
Diameter	:	1/2”

Figure 12 illustrates the electrical conduit to hide and protect the cable wires used in the project study.

Figure 13. Junction box

Junction box was also used for the copper cables used in the system, as shown in Figure 13.

Figure 14. Light Fixture

A type of light fixture, as shown in Figure 14, was chosen to meet the requirement of the design of the fence.

Cost Efficiency Analysis:

Total Electricity Bill in 25 years:

kWh = (77) (12 hours) (30 days)
= 27.72 kWh
Price / kW = P 8
Bill/month = (27.72 kW) (P11) +(P5)
= P 309.92
Bill in 25 years = (P 309.92) (300 months)
= P 92,976.00

(Note: Inflation rate is excluded in this computation.)

Total cost of System in 25 years:

Initial cost of Solar Module (battery, solar panel, charge controller, power inverter and night switch)
Initial Cost = P 32, 287.77

Additional Cost for battery replacement every 5 year until 25^{th} year:
Additional Cost = (P 8,500) (4)
= P 34,000.00

Salvage value at 20% of battery initial cost at the end of every five-year periods until 25th year:

Total Salvage Value	= (P 8,500) (0.20) (4)
	= P 6,800.00
Total Cost	= P 32,287.77 + P 34,000.00 - P 6,800.00
	= P 59,487.77
Total Saving in 25 years:	= P 92,976.00 – P 59,487.77
	= P 33,488.23

Results and Discussion

Figure 15. Mounted Solar Panel

Solar Panels were placed on a rack, mounted at the wall of the roof deck of BU Bookstore.

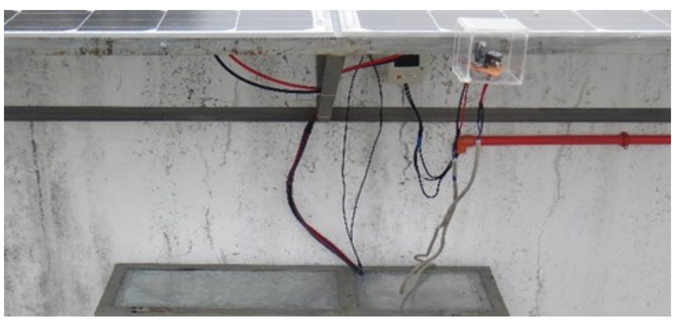

Figure 16. Installed automatic switch (night sensor)

Night Sensor and Circuit Breaker were installed at the roof top of bookstore.

Figure 17. Enclosure

Battery, Charge Controller and Power Inverter enclosure were installed at the roof top of bookstore.

Figure 18. Installed Lamp posts

Solar-Powered Lampposts installed at the fence near gate two of Baliuag University campus are shown in Figure 18.

Figure 19. The system used at night.

Solar-Powered Lampposts during its operation is shown in Figure 19.

System Set-up

Listed below are the procedures for the actual set-up of the device which the researchers did for this project study:

1. Install the solar module to the designated area.
2. Connect the wires of the solar panel and battery to the charge controller.
3. Connect the night switch before the power inverter.
4. Then the circuit breaker
5. Connect the load in the system.
6. Check the wiring of the device.

Testing Procedure

In testing the voltage and current output of solar panels, the following procedures were undertaken:

1. Set-up the system by connecting the charge controller between the solar panel and battery. The charge controller will determine if there's any output coming from the solar panel. (See charge controller's configuration on page 42)
2. Connect a voltmeter in parallel to the line connecting the solar panel and battery. Record the voltage output displayed in voltmeter.

3. Connect an ammeter in series to the line connecting the solar panel and battery. Record the current output displayed in ammeter.

Testing Results

Battery Charging

The researchers conducted the experiments on the charging time of the battery using one solar panel. The results of the test are contained in Table 1.

Table 1. Charging Results of the Test Conducted on the Battery using Solar Panel

Date	Time	Weather	Voltage output (in Volts)	Current output (in Amperes)
October 9	8:00-10:30	Cloudy	17.2	1.34
	1:00-3:00	Rainy	14.5	1.25
	5:00-5:30	Rainy	7.2	0.62
October 10	8:00-10:30	Cloudy	13.6	1.10
	1:00-2:00	Rainy	9.6	0.89
	5:00-5:30	Cloudy	6.4	0.68
October 11	8:00-10:30	Sunny	18.52	1.49
	1:00-3:00	Sunny	19.56	1.63
October 12	8:00-10:30	Cloudy	16.45	1.28
	1:00-3:00	Rainy	14.5	1.25
	5:00-5:30	Rainy	7.2	0.62
October 13	8:00-10:30	Cloudy	16.45	1.28
	1:00-2:00	Cloudy	17.19	1.34
	5:00-5:30	Rainy	7.68	0.74

The test was conducted on three types of weather and each had different outputs.

- The charging output was at its peak when it is sunny.
- Less output has occurred when it is cloudy and least when it is raining where minimum voltage occurred.
- The panel produced no output during night time.

The project used two 100W monocrystalline solar panels connected in parallel to charge the 100Ah battery. The parallel connection increased the current that flows to the battery from the solar panels.

Battery Efficiency Analysis

Table 2. Analysis of the Loads Used on Seven Lampposts

Load	Wattage	Quantity	Power	Current (I=P/V)
LED Bulb	11	7	77	0.35

Table 2 showed that the total power required for the system is 77 W and the current required for the system is about .35 A. The battery could supply 1000 W of power and 10 A of current for 10 hours at 12 VDC.

Therefore, the battery could supply power for all the loads for more than 7.5 days (182 hrs.) without recharging (battery fully charged). With the battery charging at daytime, 8 hours of charging, the loads would not be out of supply.

Night Sensor Testing

Table 3. Testing of the LED Lights with Night Sensor

Date	Weather	Time triggered	
October 24-25, 2017	Normal	5:45 P.M.	6:05 A.M
October 25-26, 2017	Normal	5:40 P.M.	6:04 A.M
October 26-27, 2017	Normal	5:30 P.M.	6:10 A.M

Table 3 shows the testing results of the triggering time the night sensor switch-on the lamps during night and switch-off the lamps in the morning. The test was conducted from October 24-27, 2017 to know the efficiency of the night sensor used.

Summary

The Solar Powered Lampposts was designed to provide illumination specifically along Baliuag University fence near gate two. Frame was fabricated in order to provide sufficient support for the solar panels. Galvanized metal storage provided weather proofing features to ensure that the equipment is safe from exposure to sun and rain. Night sensor was installed on the system to provide automatic switching which lessen human interventions.

By conducting multiple testing, the researchers found a solution for unexpected operation of the lampposts. A switch was provided for the lamp posts to turn off when the night switch is triggered during daytime.

An AC supplied night switch sensor is not applicable for all types of power inverter. After testing several power inverters, a specific type of inverter was found suitable for the system which is Aeolus power inverter. Instead of buying a brand -new Aeolus power inverter which is expensive, the researchers decided to use a DC supplied night switch sensor to achieve the automation of the system.

The 100 Ah battery was enough to supply power to seven (7) LED bulbs for one night of operation. The total cost of the whole solar-powered system is Php 32,287.77. This may vary depending on the market value and availability of equipment.

Conclusion

Installation and testing were performed at Baliuag University bookstore and fence near gate 2. Most of the equipment were installed at the university bookstore except for the seven (7) LED lamp and its housing which are mounted on top of the posts. The objective of providing sufficient illumination for the Baliuag University fence was achieved by the system. In addition to this the design of the lamp post installed was suitable for the aesthetic of the fence as approved by the university architect, physical plant head officer and representatives coming from the administration. The solar panels were able to provide enough charge for the battery to store during daytime charging and supply it to the system for night time operation. The charging duration to fill the maximum charge capacity of the battery varies depending on the weather.

The factors that the researchers encountered during the construction of the Solar Powered Lampposts helped them in determining and making the proper structural design of the system enabling them to cope up with the equipment's limitations which were identified during testing.

Recommendation

Based on the conclusions of the study, the researchers hereby recommended the following for the enhancement of the project:

1. To install additional storage battery in order to prolong the lifespan of the battery, increase the duration of lamp post operation and carry additional loads.
2. To install additional solar panels if another load like outlets is to be installed in the future.
3. To install Solar Tracking system to the solar panel in order to maintain energy collection at its peak level.
4. To install an AC night sensor that is suitable for all types of power inverters.
5. To acquire lightning arresters placed near the solar panels to protect the panels from being stroked by lightning.
6. To use a switch or design another circuit diagram that would enable the transfer of power supply from battery to main power supply in case of failure in stand-alone system.
7. To increase the wattage of solar panels for faster charging in case of expansion in the battery storage capacity.

8. To transfer the battery, charge controller and power inverter into a much safer place.

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