Development of a Smart Solar-Powered LED Street Lighting System for Greener Community

Warlito M. Galita

College of Industrial Technology, Bulacan State University, Malolos, Philippines
Email: chloky_23@yahoo.com

Received 18 February 2015; accepted 5 March 2015; published 10 March 2015

Abstract

The major objective of the study was to design and develop a Smart Solar-Powered LED Street Lighting System for a Greener Community. The project is different from conventional street lighting systems not only in the sense that it uses solar energy, but more importantly, it is also a stand alone device that provides for an efficient energy management program that ensures effective maintenance and reduced energy wastage due to malfunctioning lighting controls. In addition, it is much cheaper to fabricate and maintain as compared with its commercially available counterparts. One important feature of the project is that it automatically controls the brightness of the LED lamp depending on a particular time of day, especially in cases where full level illumination is not needed, thus reducing power consumption. It automatically activates and deactivates lighting depending on the hours whereby daylight is sensed, thus ensuring a continuous cycle of charging and discharging the storage battery for maximum efficiency. All of these functions are possible since the project uses a controller, allowing for variable settings of time activation as well as brightness level, depending on the preference of the end-users. The project functioned according to expectations, being a cheaper and environment-friendly alternative as compared with its commercially available counterparts. It also provided a cost-effective approach to managing street lighting systems in a wide variety of applications.

Keywords

Solar, Street Lighting, Smart, LED, Green Community

Subject Areas: Electric Engineering

1. Introduction

At this point in mankind's existence, most of the energy households consume is gathered from the numerous

How to cite this paper: Galita, W.M. (2015) Development of a Smart Solar-Powered LED Street Lighting System for Greener Community. *Open Access Library Journal*, **2**: e1291. http://dx.doi.org/10.4236/oalib.1101291

power plants driven by fossil fuels. However, these fossil fuels are nearing their extinction and becoming more and more expensive to source. Not only is it an expensive resource, but it also contributes negatively to the environment. Gases emitted by these power plants cause such a harmful effect on our environment and because of this, the world is now facing a much bigger problem that is global warming.

Due the impending scarcity of many valuable resources as well as its harmful effects on the environment, people are now starting to consider other sources of energy. Although there have been many studies on the viability of wind or water energy as an easy transportable energy solution, solar energy has now become the major alternative since it is the easiest to collect energy. By using solar energy, the earth's non-renewable sources of energy can be preserved, thus helping the environment. Because of this, solar energy is also termed as a green fuel since it does not cause pollution or harm the environment in any way. Hence, this results in a win-win solution in opting for solar energy to cut down the consumption of the conventional electricity while simultaneously helping to make the earth a better place to live in.

Solar energy can be used in various different ways, making it very versatile. It can be used for both domestic and the industrial purposes. Many products that are being used today are solar batteries, solar cookers, calculators, etc. Although the applications for solar energy applications are endless, the major goal of this study is to design and develop an intelligent street lighting system. Interest in solar lighting systems, particularly street lighting, is rising because of the possibility to install them in remote areas such as rural areas in less developed countries [1]. However, the street lighting system that will be developed is not the usual halogen or incandescent lamps being utilized today, but the light emitting diode (LED) type. The introduction of LED has created a superb new range lighting systems that are environment-friendly, easy to install and maintain and offers tremendous light output. This is a big deviation from the usual street lighting systems that utilize conventional electricity supplied by local power utilities.

In addition, the proposed street lighting system does not require complicated and entrenched wiring systems unlike those presently being utilized today. The project at hand can be easily installed and moved and delivers free renewable energy which is stored in a battery ready to be used when darkness falls. It also addresses the need of people to be conscious about the ecological impact of the different kinds of lighting systems being developed to cater the intelligent needs and the demands of the end-users.

The study aims to underscore the importance of tapping vast renewable energy sources to address various energy issues confronting the global environmental landscape. This burning desire of the researcher leads to the realization of the major objective of the study, which is to design and develop a Smart Solar-Powered LED Street Lighting System for a Greener Community.

The Research Problem

The major objective of this undertaking is to design and develop a Smart Solar-Powered LED Street Lighting System for a Greener Community. Specifically, the study aims to answer the following:

1. Determine an appropriate lighting system and solar panel suitable for the needs of the project.
2. Design an appropriate control circuit for managing the operation of the system.
3. Design a suitable casing/enclosure for the circuit.
4. Determine the acceptability of the device based on the following criteria, namely:
   4.1. Functionality;
   4.2. Reliability;
   4.3. Usability;
   4.4. Maintainability;
   4.5. Portability;
   4.6. Workability; and
   4.7. Safety.

2. Methodology

The framework that guided this study is depicted in the form of paradigm. This study followed the input, process and output (IPO) model (**Figure 1**).

The INPUTS of the study consist of concepts and ideas, related literature and studies, tools and equipment used in the construction of the project and expenses incurred in the fabrication of the project. The PROCESS of

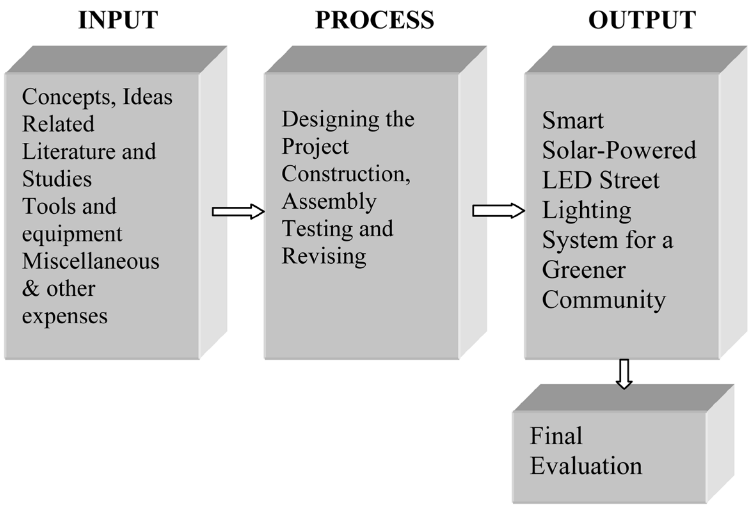

Figure 1. Conceptual model.

the study consists of designing the project, acquisition of needed materials, construction and assembly, testing and revising in case of some technical problems and revisions. The OUTPUT of the study is the finished and functional Smart Solar-Powered LED Street Lighting System for a Greener Community. Upon the completion of the project, it was subjected to various tests before submitting it for final evaluation regarding its acceptability and performance.

Several literature reviews and informal surveys were done to see what type of solar street lighting systems were already in existence as well as the cost of putting up such systems. Various configurations were examined in different types of environments and settings. It was found that intelligent solar-powered LED street lighting systems were the ideal set-up in communities especially in these times where environmental considerations are put at a premium [2].

According to Davis [2], the 4.4 million streetlights in the US ten largest metropolitan statistical areas use an estimated 3 billion kWh of electricity annually, producing the equivalent of 2.3 million metric tons of carbon dioxide. If only a 50 percent reduction in power used could be achieved, this will amount to a savings of 1.5 billion kWh or 1.1 million metric tons of carbon emissions. It is for this reason that an intelligent outdoor lighting system can help local communities do their part in meeting this global challenge. Intelligent lighting systems utilize the latest technologies to optimize the light intensity according to the situation by dimming the lamp. All lamps can be communicated with, so their condition can be assessed remotely and, if necessary, the lamp can be controlled remotely. The key benefits are: 1) reduced energy costs; 2) reduced greenhouse gas emissions; 3) reduced maintenance costs; 4) higher community satisfaction; 5) fast payback; and 6) information.

A work plan was laid out to design and execute the fabrication of the project at hand. It included a system analysis of what type of LED lamp was to be used, the type of battery, whether maintenance-free of deep cycle battery and the solar panel to be selected, in terms of maximal efficiency for minimal area, low foot print realization in terms of whether mono-crystalline and poly-crystalline technologies will be utilized. Various designs of the pole to be used, in terms of solidity of material (resistance to corrosion, weight and atmospheric conditions such as humidity and moisture), its effective height as well as the type of battery casing to be used for the project were put forward. After a careful system analysis of each component specification was done, additional considerations with regards to the availability and cost of each of the needed parts were also considered.

The design goals for this project were efficiency, simplicity, reliability and the availability of parts in the research locale. Hence, after undertaking the system analysis on the project components, the following components were used for the project. A medium type poly-crystalline solar panel (100 W) rated with a charging current of 5.78 A and charging voltage of 17.3 volts was used in conjunction with a deep cycle 3SM solar battery. Deep cycle batteries are designed with thicker plates and with overall less surface area. These batteries give up just as much power for their rated size, but do it over a much longer period of time. It is in this vein that deep cycle batteries are best suited for solar electric systems [3].

It is very important to match the solar panel's current rating capacity to the battery's amp-hour rating. A simple LED lamp controller (50 watts) was used to control the charging system as well as the automatic dimming and shut-off of the lamp during operation. This controller charge controls the battery by day to a user-selected voltage and then at night, turns on the light until the battery discharges to a user defined voltage. The controller not only controls solar energy storage to the battery, but it also manages the power consumption to the LED streetlight [4].

In addition to the pole used, a battery casing enclosure was designed to secure the battery in place and a tilting mechanism for the solar panel was included in the design for adjustment of angle of the panel. The mounting bracket of the LED lamp was also designed to be movable for flexibility of height adjustment. Shown in **Figure 2** is the finished prototype of the project.

In terms of costs, the project only incurred a total fabrication expense of Php 28, 207.50. As compared with its commercially available counterparts, it is substantially lower since the cheapest solar streetlight in the market nowadays is Php 60,000 and above.

About forty-five (45) working days were consumed in the preparation and fabrication of the project. Upon completion of the project, it was subjected to a dry run of two (2) weeks continuous operation inside the school premises. Time-lapse cameras were installed to observe the automatic turn on and shut off times of the lamp. The charging times and cycles of the solar battery were also observed during this period. An audio-video presentation was also prepared as a documentation procedure of the actual demonstration of the operation of the project. It included the actual assembly procedure as well as 2-week dry run operation of the project captured in time-lapse form. After continuously testing the project on a varied number of parameters, an objective evaluation was undertaken by the researcher to test the acceptability and performance of the project in terms of the predetermined criteria set forth in the conceptualization of the study. A 5-point Likert scale was used to quantify responses of the evaluators, with 5 being the highest and 1 being the lowest.

Scale	Verbal Interpretation
4.21 - 5.00	Highly Acceptable
3.41 - 4.20	Acceptable
2.61 - 3.40	Moderately Acceptable
1.81 - 2.60	Unacceptable
1.00 - 1.80	Highly Unacceptable

Figure 2. Pictures of the project.

A panel of experts in the field of Electrical and Electronics Technology/Engineering were chosen to evaluate the project. A discussion of the salient features of the project was given as well as an actual demonstration using the video presentation prepared by the researcher. The experts were composed of forty-six (46) experts, who were a mixture of educators in HEIs and professionals employed in different companies in the area of Bulacan.

3. Results and Discussion

The primary objective of the study is to develop a Smart Solar-Powered LED Street Lighting System for a Greener Community and evaluate it in terms of acceptability and performance. A discussion of each of these criteria follow:

3.1. Functionality

Table 1 shows the evaluation results of the project in terms of its functionality. As shown in the tabular results all statements regarding the projects suitability, accurateness, interoperability, compliance and security were rated "Highly Acceptable, with mean ratings ranging from 4.4 to 4.6.

The average mean rating of 4.5, interpreted as "Highly Acceptable", shows that the project was rated favorably by the respondents in terms of its functionality.

3.2. Reliability

Table 2 shows the evaluation results of the project in terms of its reliability. All statements regarding the projects reliability were rated favorably, as evidenced by the average mean rating of 4.5, interpreted as "Highly Acceptable".

3.3. Usability

In terms of its usability, **Table 3** shows that the evaluators rated the statements favorably, as evidenced by the average mean rating of 4.52 interpreted as "Highly Acceptable".

Table 1. Mean and descriptive ratings for the projects' functionality.

CRITERIA Functionality	MEAN	INTERPRETATION
Suitability. Functions are appropriate to specification.	4.6	Highly Acceptable
Accuracy. Function specified performed according to specifications.	4.5	Highly Acceptable
Interoperability. The prototype can be interfaced with other components or systems.	4.4	Highly Acceptable
Compliance. Adherence to industry standards for similar hardware components.	4.5	Highly Acceptable
Security. Provision for security requirements.	4.5	Highly Acceptable
Average Mean	**4.5**	**Highly Acceptable**

Table 2. Mean and descriptive ratings for the projects' reliability.

CRITERIA Reliability	MEAN	INTERPRETATION
Maturity. Absence of failure.	4.3	Highly Acceptable
Fault tolerance. Ability to withstand and recover from component failure.	4.4	Highly Acceptable
Recoverability. Ability to bring back a failed system to full operation.	4.7	Highly Acceptable
Average Mean	**4.5**	**Highly Acceptable**

Table 3. Mean and descriptive ratings for the projects' usability.

CRITERIA Usability	MEAN	INTERPRETATION
Understandability. Ease of which the systems' functions can be understood.	4.5	Highly Acceptable
Learnability. Learning effort for different users, *i.e.*, novice, expert, etc.	4.5	Highly Acceptable
Operability. Ability of the prototype to be easily operated by a given user in a given environment.	4.5	Highly Acceptable
Provision for comfort and convenience.	4.6	Highly Acceptable
Average Mean	**4.52**	**Highly Acceptable**

3.4. Maintainability

Based on the results of the evaluation, the projects' maintainability was rated "Highly Acceptable" as evidenced by the average mean rating of 4.4 (**Table 4**).

3.5. Portability

In terms of its portability, **Table 5** shows that the evaluators rated the statements favorably, as evidenced by the average mean rating of 4.4 interpreted as "Highly Acceptable".

3.6. Workability

Table 6 shows the evaluation results of the project in terms of its workability. All statements regarding the projects workability were rated favorably, as evidenced by the average mean rating of 4.56, interpreted as "Highly Acceptable".

3.7. Safety

In terms of its safety criterion, **Table 7** shows that the evaluators rated the statements favorably, as evidenced by the average mean rating of 4.43 interpreted as "Highly Acceptable".

3.8. Summary Findings

As reflected in **Table 8**, all evaluation criteria set forth at the outset of the study were given favorable ratings of "Very Acceptable" by the panel of evaluators in terms of 1) functionality; 2) reliability; 3) usability; 4) maintainability; 5) portability; 6) workability and 7) safety (**Table 8**).

In addition, it was determined that it was the appropriate design that integrated the most practical and adaptable design for both domestic and even industrial applications. Finally, the project also functioned according to expectations, in being a cheaper alternative as compared with its commercially available counterparts. It is in this line that intelligent or smart street lighting technology has now matured, providing a cost-effective approach to managing street lighting systems in various communities.

4. Recommendations

In light of the significant findings derived from the development of this project, the following are the recommendations:

1. The Smart Solar-Powered LED Street Lighting System for a Greener Community is very affordable and as such, can be mass-produced to address the energy concerns of communities as well as the global warming concerns;

2. The projects' solar panel should be equipped with a sensor ball circuit to automatically follow the position of the sun;

Table 4. Mean and descriptive ratings for the projects' maintainability.

CRITERIA Maintainability	MEAN	INTERPRETATION
Analyzability. Ability to identify the root cause of failure within the prototype.	4.4	Highly Acceptable
Stability. Characterizes the sensitivity of the prototype to adjust to changes within the system.	4.4	Highly Acceptable
Testability. Characterizes the effort needed to verify (test) a system change.	4.4	Highly Acceptable
Can hardware be serviced, maintained and upgraded locally?	4.4	Highly Acceptable
Average Mean	**4.4**	**Highly Acceptable**

Table 5. Mean and descriptive ratings for the projects' portability.

CRITERIA Portability	MEAN	INTERPRETATION
Adaptability. Ability of the system to change to new specifications or operating environment.	4.5	Highly Acceptable
Installability. Are different options available for installation? Can hardware be installed and maintained by local utility personnel?	4.4	Highly Acceptable
Replaceability. Ease of exchanging a given prototype component within a specified environment.	4.3	Highly Acceptable
Appropriateness of size and weight suitability.	4.4	Highly Acceptable
Average Mean	**4.4**	**Highly Acceptable**

Table 6. Mean and descriptive ratings for the projects' workability.

CRITERIA Workability	MEAN	INTERPRETATION
Availability of Materials. Consideration must be given to whether a line of equipment and/or spare parts is still available or discontinued.	4.5	Highly Acceptable
Availability of technical expertise.	4.4	Highly Acceptable
Availability of tools and machines. Provisions for diagnostic tools and procedures.	4.8	Highly Acceptable
Average Mean	**4.56**	**Highly Acceptable**

Table 7. Mean and descriptive ratings for the projects' safety.

CRITERIA Safety	MEAN	INTERPRETATION
Absence of toxic or hazardous materials.	4.6	Highly Acceptable
Absence of sharp edges.	4.3	Highly Acceptable
Provision against harmful or dangerous events/objects.	4.4	Highly Acceptable
Average Mean	**4.43**	**Highly Acceptable**

Table 8. Summary of responses.

Criteria	Mean	INTERPRETATION
1. Functionality	4.50	Highly Acceptable
2. Reliability	4.50	Highly Acceptable
3. Usability	4.52	Highly Acceptable
4. Maintainability	4.40	Very Acceptable
5. Portability	4.40	Very Acceptable
6. Workability	4.56	Highly Acceptable
7. Safety	4.43	Very Acceptable
Overall mean	**4.47**	**Very Acceptable**

3. Further studies should be done to expand the functions and capabilities of the project so as to further add additional features to the existing prototype.

References

[1] Silvestro, R. (2010) Solar Street Lighting Application with ZXLD1374. http://www.diodes.com/_files/products_appnote_pdfs/AN74_ZXLD1374_for_solar_street_lighting.pdf

[2] Fiona, D. (2009) Intelligent Street Lighting. Jennic Ltd. www.jennic.com

[3] http://www.wsetech.com/battery.php

[4] http://www.st.com/web/en/resource/technical/document/application_note/CD00227569.pdf