Solar light emitting diode (LED) street lighting with automatic vehicle detection system

by

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LIST OF ABBREVIATIONS

LDR	Light Dependent Resistors
LED	Light Emitting Diode
DC	Direct Current
MOSFET	Metal Oxide Semiconductor Field Effect Transistor
PCB	Printed Circuit Board
CCM	Continuous Conduction Modes
EEPROM	Electrically Erasable Programmable Read-Only Memory
PWM	Pulse Width Modulation
IC	Integrated Circuit

Sistem Lampu Jalan Solar Diod Pemancar Cahaya (LED) dengan Sistem Pengesan Kenderaan Automatik

Abstrak

Thesis ini adalah berkenaan dengan pembangunan dan pembinaan sistem lampu jalan solar diod pemancar cahaya (LED) dengan pengesan kenderaan automatik. Lampu jalan solar yang ada pada masa kini, beroperasi berasaskan kepada sistem pemasa ataupun sistem pengesan cahaya yang mana ianya akan menyalakan lampu sepanjang malam walaupun tiada kenderaan yang melaluinya. Untuk mengatasi masalah ini, satu sistem yang dapat mengesan kenderaan pada waktu malam dengan menggunakan perintang peka cahaya (LDR) dan pengawal mikro dibangunkan. Pengawal mikro akan mengawal sistem operasi secara keseluruhannya, termasuklah proses mengecas dan menyahcas bateri dan juga penyalaan lampu LED. Projek ini terdiri daripada pembinaan penukar rangsangan arus terus ke arus terus (AT ke AT), pengesan kegelapan dan kenderaan dan juga pengawal lampu LED. Penukar rangsangan dibangunkan untuk mengatasi masalah yang disebabkan oleh nilai voltan keluaran yang rendah daripada panel solar berbanding dengan nilai voltan yang sesuai untuk mengecas bateri. Hasil daripada ujikaji yang dijalankan, voltan keluaran yang didapati dari penukar rangsangan ini adalah sebanyak 14.5 volt. Kehadiran kenderaan dan kegelapan dikesan melalui pengesan kenderaan dan kegelapan. Ujian dijalankan untuk menentukan jarak kenderaan yang dapat dikesan oleh pengesan tersebut. Semasa ujian menggunakan lampu rendah, jarak kenderaan yang dapat dikesan oleh pengesan adalah sejauh 80 meter. Manakala bagi ujian menggunakan lampu tinggi, jarak kenderaan yang dapat dikesan adalah sejauh 170 meter. Untuk menyalakan lampu LED tersebut, satu sistem peranti AT dibangunkan. Ianya akan mengawal bekalan elektrik daripada bateri kepada lampu LED. Keseluruhan litar bagi sistem ini dibangunkan diatas papan litar bercetak (PCB). Berdasarkan kepada keputusan ujikaji, sistem ini didapati dapat mengecas bateri dari 20% hinggga ke 100% dalam masa sehari. Bateri yang dipilih dapat membekalkan tenaga yang diperlukan oleh beban untuk tempoh masa 10 jam. Pengesan kenderaan dapat mengesan kehadiran kenderaan diatas jalan. Sementara pengesan kegelapan dapat membezakan diantara keadaan siang atau malam.

Solar Light Emitting Diode (LED) Street Lighting with Automatic Vehicle Detection System

Abstract

This thesis is about a development and fabrication of solar light emitting diode (LED) street lighting with an automatic vehicle detection system. Present available solar street lightings are operated based on the timer or light sensor which continuously turns on during night time even though the street is empty i.e. without any vehicle passing through it. To overcome this problem a system that was able to detect a vehicle at night using light dependent resistor (LDR) and microcontroller was designed. The microcontroller controlled the whole operation of the system, including the charging and discharging of the battery and the illumination of the LED lamp. The project comprises of the development of the DC to DC boost converter, dark and vehicle detection sensor and LED lamp driver. The boost converter system was designed to overcome the problem due to the lower output voltage from the solar panel compare to the optimum level of batteries charging voltage. From the experiment the output voltage from this DC to DC boost converter was 14.5 volts which is the optimum charging voltage. The vehicle and weather condition was detected by the vehicle and dark sensors. The test determined the distance of the incoming vehicle that the sensor can detect. During low beam testing the sensor managed to detect a vehicle at 80m away from it. For the high beam the vehicle detected by the sensor at 170m from it. In order to turn on the LED lamp, a DC relay system was developed. This relay controlled the electrical supply from batteries to the LED lamp. The complete circuit for this system was developed on the printed circuit board (PCB). The experimental results show that the system can charge the battery from 20% to 100% within a day. The battery chose was adequate to supply enough power to the load for 10 hours. The incoming vehicle on the street can be detected by vehicle sensor. While the dark sensor can distinguish between day and night condition.

CHAPTER 1

INTRODUCTION

1.1 Introduction

This chapter describes about the project's introduction. It consists of overview of the project, the project aim, objectives and scopes of the project.

1.2 Project Overview

The most common method in controlling the street lighting operation nowadays is using a timer or light dependent resistors (LDR) sensor. One of the problems using this kind of system is that the lamps stay on all night long or during cloudy days even when there is no vehicle on the street.

In this project the solar Light Emitting Diode (LED) street lighting illuminate when vehicle approaches the street, which are triggered by two LDR sensors. This system was installed on the street at the remote area, which is less vehicle passing through it during night time. This system is not only a green technology (minimum pollution plus no conventional power input), but it can also be located anywhere regardless of any electrical availability. With this system it can prolong the lifetime of the battery due to the charging and discharging cycle of the batteries are lesser compared to the conventional solar street lighting. Thus it lower the maintenance cost of the street lighting.

1.3 Project Aim

The aim of this project is to developed and fabricated the solar light emitting diode (LED) street lighting, automatic vehicle detection system and battery charging circuit. DC to DC Boost converter is designed to charge the 12V lead acid battery. To control the switching cycle for the circuit, the microcontroller (dsPIC30F4013) is used. The lighting circuit is controlled by a microcontroller, photocell sensors and a 12V DC relay. The microcontroller determined the dark or bright conditions and also the presence of vehicles by detecting the signals from the photocell sensors. In order to illuminate the street lighting there are two conditions need to be fulfilled. The area must be dark and there is a vehicle approaching the street. After that the microcontroller triggered the 12V relay to switch on the street lamp.

1.4 Objective

The general objective of this project was developed solar light emitting diode (LED) street lighting with an automatic vehicle detection system. The specific objectives to achieve the above referred goals are as follows:

1. **To develop the DC to DC converter circuit:** This objective was to design DC to DC boost converter that can convert the output voltage of solar panel to the optimum value of battery charging voltage. To ensure that the solar panel can charge 12V lead acid battery using.
2. **To develop a dark and vehicle detection sensor:** The dark sensor must be able to differentiate between daylight and night. While the vehicle detection sensor must be able to detect the approaching vehicle on the street during night time.
3. **To develop an LED lighting driver circuit:** The circuit should be able to control the switching of the LED lighting operation. The control systems carried out by the microcontroller (dsPIC30F4013).

1.5 Scope of Project

Designed and fabricated 30W solar street lighting system using a 12V, 75W solar panel that automatically turn on the street lighting when a vehicle passing through it at night. This concept is expected to reduce the charge-discharge cycle of the battery in which it can extend the battery life time, which means the maintenance costs of the street lighting decreased.

1.6 Thesis Layout

This dissertation is divided into five chapters. Chapter one explain a brief description of the project, that is overview of the project, project aims, the objectives and scopes of the project. Chapter two describes a useful review of previously publish research documents which are related to this project. Chapter three provides the details of the research methodology used in this project. Chapter four shows the result and analysis of the experiments conducted. Finally in chapter five, the conclusion of this project is derived.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter describes some important research papers available in the literature for an automatic solar street lighting. Most of the approaches in the literature using a concept of switching the lamps during night time and switch it off during day time. Some of them also use timer to control the switching of the lamps.

2.2 Solar energy

Photovoltaic energy is the conversion of sunlight into electricity. A photovoltaic cell, commonly called a solar cell or PV, is the technology used to convert solar energy directly into electrical power. It is not the heat required form the sun but the amount of irradiation available (Eskom, 2013).

Sunlight is composed of photons, or particles of solar energy. These photons contain various amounts of energy corresponding to the different wavelengths of the solar spectrum. When photons strike a photovoltaic cell, they may be reflected, pass right through, or be absorbed. Only the absorbed photons provide energy to generate electricity. When enough sunlight energy is absorbed by the material that is a semiconductor, electrons are come out from the material's atoms. Special treatment of the material surface during manufacturing makes the front surface of the cell more receptive to free electrons, so the electrons naturally migrate to the surface. When the electrons leave their position, holes are formed. When many electrons, each carrying a negative charge, travel toward the front surface of the cell, the resulting imbalance of charge between the cell's front and back surfaces creates a voltage potential like the negative and positive terminals of a battery. When the two surfaces are connected through an external load, electricity flows. Photovoltaic cells, like batteries, generate direct current (DC) which is generally used for small loads like electronic equipment.

Advantages of photovoltaic systems are:

i) Conversion from sunlight to electricity is direct, so that bulky mechanical generator systems are unnecessary.

ii) PV arrays can be installed quickly and in any size required or allowed.

iii) The environmental impact is minimal, requiring no water for system cooling and generating no by-products.

2.3 Battery charger

A battery charger is a device used to put energy into a secondary cell or rechargeable battery by forcing an electric current through it. The charge current depends upon the technology and capacity of the battery being charged. For example, the current that should be applied to recharge a 12 V car battery was very different from the current for a mobile phone battery. A simple charger works by connecting a constant DC power source to the battery being charged. The simple charger does not modify its output based on time or the charge on the battery. This simplicity means that a simple charger is inexpensive, but there is a tradeoff in quality. Typically, a simple charger takes longer to charge a battery to prevent severe over-charging. Even so, a battery left in a simple charger for too long weakened or destroyed due to over-charging. These chargers can supply either a constant voltage or a constant current to the battery.

2.4 Street Lighting

The most common type of lamp used in the street lighting nowadays was using a high intensity discharge lamps, often High Pressure Sodium (HPS) type. These lamps currently provide the highest lumens per watt, 110 Im/W. However, the colour of light that HPS lamps emit is not the most conducive for night lighting. White light has been shown to be the most beneficial in terms of obstacle perception, security and driver's reaction times (Whitaker, 2007). The recent emergence of ultra-bright, white, high-power LEDs brings the onset of a new approach to street lighting. The key characteristics of these high power LEDs are excellent reliability, instant turn on, dimmability, high operating hours (approximately 50000) and good colour rendering. Their efficiency is typically 90 Im/W (D. R. Nuttall, 2008).

Many street lights today operate with the use of solar sensors which activate the light when it gets dark. Some are also solar powered, allowing them to operate on standalone poles without the need for an energy source. Some cities may use timers for their street lights, primarily in the case of older systems which have not been upgraded.

An automatic control circuit of LED street lamp was designed by Wang Yongqing (2009). This street lamp has three working modes which are light control, delay quenching and delay plus low power. However, one problem has been detected whereby all of these modes can only illuminate the lamps during the night and will turn off during daylight. Apart from that, it has no vehicle detection mode to turn on and turn off the lamp during the nigh time.

Jing-hua Sun (2010) has designed a multi-sensor system which applies the infrared and sound sensors in order to collect and recognize the signal of a human body, and using the lighting-control method which enables them to controls the switching timing of lamp. The output power and lighting luminance can be adjusts dynamically. However they just detected the sound and human presence only without detecting the vehicle.

Miomir Kostic (2009) was recommended the use of dimming systems for street lighting because of during late night and early morning hours the number of vehicle is greatly reduced. The electrical energy can be save with the use of dimming systems and will represent a financially justified investment. However with this method the power still need to be supply to the lamp. With the used of vehicle detection system where the lamp will be off if there is no vehicle passing through the street, thus the discharging of the solar batteries will stop.

Mokhtar Ali (2011) has proposed a low cost high efficiency standalone solar street LED light system. This system comes with a single microcontroller for the power management of the system. It has a better bulb lifetime and also lesser in power consumption. Apart from that, the feasibility cost is only 30% as compared to the other regular systems.

2.5 DC to DC Converter

DC to DC converters are power electronic circuits that convert a dc voltage to a different dc voltage level, often providing a regulated output. There are three basic types of dc-dc converter circuits, termed as buck, boost and buck-boost. In all of these circuits, a power device is used as a switch.

No doubt, converter is one of the most important components in the solar conversion. Peter Hazucha (2005) stated that the boost is a popular non-isolated power stage topology, sometimes called a step-up power stage. Most of the power supply designers have chosen the boost power stage because the required output is always higher than the input voltage.

A boost converter is then proposed by (Pui-Weng Chan, 2010). The boost converter is able to produce a constant output voltage of 24 V from a variable voltage of solar panel with highest efficiency of 95%. Using PIC16F877 microcontroller, this converter is able to perform the voltage feedback control technique successfully.

Reemmer (2007) stated that a boost converter is part of a subset of DC-DC converters called switch-mode converters. The circuits belonging to this class, including buck, flyback, buck-boost, and push-pull converters are very similar. They generally perform the conversion by applying a DC voltage across an inductor or transformer for a period of time (usually in the 100 kHz to 5 MHz range) which causes current to flow through it and store energy magnetically, then switching this voltage off and causing the stored energy to be transferred to the voltage output in a controlled manner. The output voltage is regulated by adjusting the ratio of on/off time. As this subset does not use resistive components to dissipate extra power, the efficiencies are seen in the 80-95% range.

2.6 Microcontroller System

A microcontroller is a compact microcomputer designed to govern the operation of embedded systems in motor vehicles, robots, office machines, complex medical devices, mobile radio transceivers, vending machines, home appliances, and various other devices. A typical microcontroller includes a processor, memory, and peripherals.

The use of a microprocessor controller in controlling a Maximum Power Point Tracking (MPPT) for the photovoltaic lighting system can greatly improve the charging and discharging cycle of the batteries and this is further proven by Peng Fang (2011), Shi-cheng Zheng (2011) and Jose Antonio Barros Viera (2010).

Mikihito Matsui (2007) has developed a power converter module that charges a battery using solar power. All control functions in an MPPT are implemented in digital algorithm and a HITACHI H8 microprocessor is used for the control.

2.7 Vehicle Detection

Vehicle detection is a fundamental component of an automatic street lighting operation. The popular technique used to detect the vehicle on the street is using a digital camera.

A vehicle detection is simulated by Jungdong Jin (2011) using a rectified image and a disparity image based on dedicated hardware architecture.

Hussain (2012) has proposed an algorithm based on image processing using vertically positioned camera for vehicle detection and classification according to their size. In his project, the photocell sensor is used as the vehicle detection sensor. The success rate for their project was 85%.

Sonnadara (2010) has carried out study to count vehicles during night time using digital camera. From the result obtained by them, the accuracy was 88 to 90 percent.

2.8 Summary

Due to the very low power consumption and also longer lifespan of the bulb, makes the LED lamp is the best choice for the street solar lighting system. Since the output voltage from solar panel is not in favour with the charging voltage of the battery, the voltage converter need to be used in order to ensure that the voltage supply to charge the battery is optimum. There are few types of DC to DC voltage converters i.e buck converter, boost converter and buck-boost converter. The selection of which types of converter is depend on the requirement of the system. The use of microcontroller system can simplify and improved the system performance due to the capabilities of the microcontroller to process and analysed the data. The sensor plays a big part of any system, the sensor send a signal to the microcontroller and was analysed before any appropriate actions was taken. So the developments of sensor need to be done properly.

CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter briefly discusses many aspects of designed and development of solar light emitting diode (LED) street lighting with automatic vehicle detection system. It covered both hardware and software development. The implementation of hardware includes the DC to DC converter, dark and vehicle detection and LED driver. While the software implementation included the PWM control, sensor detection and LED driver control that controlled by dsPIC30F4013 microcontroller using C programming language. The overview process of the development of this system is shown in Figure 3.1.

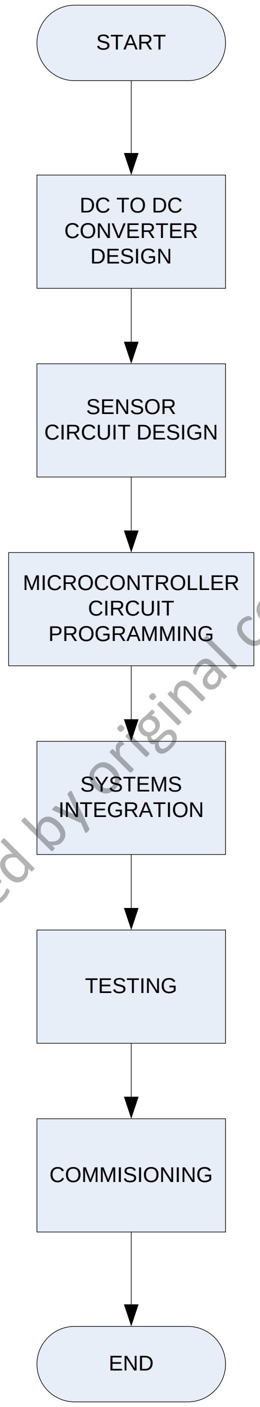

Figure 3.1: Overview process of solar light emitting diode (led) street lighting with an automatic vehicle detection system development

3.2 Hardware Design

The hardware of this system consists of solar panel, DC to DC converter, microcontroller, vehicle detection sensor, dark sensor, battery, LED driver and LED lamp. There are four components that are designed for this project. They are DC to DC converter, sensors, microcontroller system and LED lighting driver. The block diagram of the system is shown in Figure 3.2. The system is supplied from 12V, 75W solar panel. Where the open circuit voltage is 15V and Short circuit current is 6A. The system was connected to the 12 volts, 35 watts LED lighting.

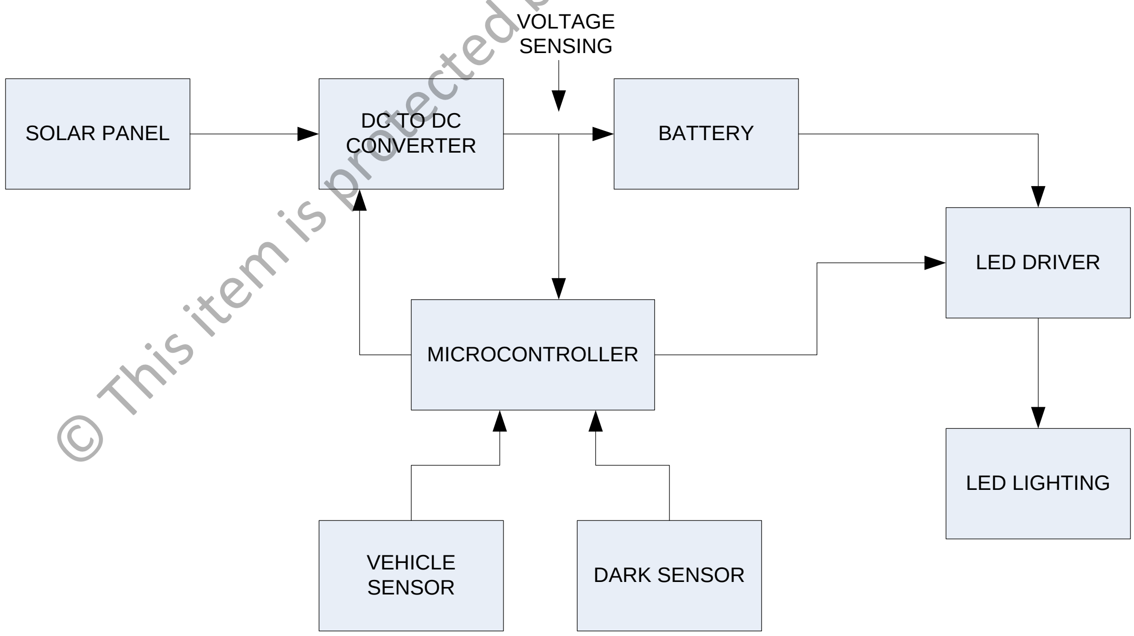

Figure 3.2: Block Diagram of an Automatic Solar Street Lighting