INTEGRATION OF LED AND IOT FOR SMART STREET LIGHTING SYSTEM

ANGELA TEO WEE CHIA

BACHELOR OF ELECTRICAL ENGINEERING WITH HONOURS
UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2021

INTEGRATION OF LED AND IOT FOR SMART STREET LIGHTING SYSTEM

ANGELA TEO WEE CHIA

A report submitted
in partial fulfillment of the requirements for the degree of
Bachelor of Electrical Engineering with Honours

Faculty of Electrical Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2021

DECLARATION

I declare that this thesis entitled “INTEGRATION OF LED AND IOT FOR SMART STREET LIGHTING SYSTEM” is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature :

Name : ANGELA TEO WEE CHIA

Date : 05/07/2021

APPROVAL

I hereby declare that I have checked this report entitled "Integration of LED and IoT for Smart Street Lighting System" and in my opinion, this thesis it complies the partial fulfillment for awarding the award of the degree of Bachelor of Electrical Engineering with Honours

Signature :

Supervisor Name : Dr. Azziddin Bin Mohamad Razali

Date : 7/7/2021

DEDICATIONS

To my beloved mother and father

ACKNOWLEDGEMENTS

This final year project provides me a chance to further understand the theory that I have studied throughout my four years of study in Electrical Engineering and the method to apply that knowledge for developing a functional project in real life.

Firstly, I would like to express my sincere appreciation to my final year project supervisor, Dr. Azziddin Bin Mohamad Razali for providing guidance and supervision during the progress of preparing my final year project. He is patient in answering the question I asked and suggesting solutions based on his experiences and knowledge. Without his encouragement and support, this project would not be the same as presented here.

I would like to thank my fellow friends for giving me support during the preparation for this project. They gave me a lot of advice and suggestions when I faced the problem in the progress to complete this project. I also would like to express my gratitude to my beloved family for their supports in many ways that helped me throughout my academic years.

Lastly, I would like to thank all people who contributed to my project directly or indirectly.

ABSTRACT

The goal of this final year project is to produce an LED Driver using IoT technology for a smart street lighting system. The AC-DC Rectifier, Power Factor Correction (PFC), and DC-DC Buck Converter are included in this LED Driver. This entire device will convert AC into desired DC level which is ideal for the LED streetlight to light up. The rectifier will be designed to transform AC into DC supply. This system consists of Power Factor Correction (PFC) to obtain a better power factor and improved harmonic distortion. Based on the parameters of the LED Driver module in Appendix A, the desired DC output voltage range is 65-100V. The open-loop and closed-loop buck converter will be simulated by using MATLAB Simulink. The PI controller is designed and implemented into the closed-loop buck converter. Arduino is used as a PI controller to control the duty cycle and inject signal to the MOSFET. The main purpose is to achieve a constant output voltage based on the reference voltage. Simulation and hardware work are both going to be completed. MATLAB Simulink will be used to design and develop the LED Driver.

ABSTRAK

Matlamat projek akhir tahun ini adalah untuk membina sesuatu Pemacu LED yang menggunakan teknologi IoT untuk sistem lampu jalan pintar. Pemancu LED ini mengandungi Penerus AC-DC, Pembetulan Faktor Kuasa (PFC) dan penukar buck DC-DC. Keseluruhan sistem ini akan menukar AC ke tahap DC yang diingini dan sesuai untuk lampu jalan LED. Penyearah akan dirancang untuk mengubah AC kepada bekalan DC. Sistem ini terdiri daripada Pembetulan Faktor Kuasa (PFC) untuk memperolehi faktor kuasa yang lebih baik dan penyelewengan harmonic yang lebih baik. Berdasarkan parameter bagi modul Pemacu LED di Lampiran A, julat voltan keluaran DC yang diinginkan adalah 65-100V. Penukar buck bagi gelung terbuka dan tertutup akan disimulasikan dengan menggunakan MATLAB Simulink. Pengawal PI dirancang dan dilaksanakan ke dalam penukar buck secara gelung tertutup. Arduino digunakan sebagai pengawal PI untuk mengawal kitaran tugas dan menyuntikkan isyarat ke MOSFET. Tujuan utama adalah untuk mencapai voltan keluaran tetap berdasarkan voltan rujukan. Kerja-kerja simulasi dan perkakasan akan dijalankan. MATLAB Simulink akan digunakan untuk merancang dan mengembangkan Pemacu LED.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS AND ABBREVIATIONS

AC	-	Alternating Current
CCM	-	Continuous Current Mode
CFL	-	Compact Fluorescent Light
DC	-	Direct Current
DCM	-	Discontinuous Current Mode
ESL	-	Equivalent Series Inductance
ESR	-	Equivalent Series Resistance
IDE	-	Integrated Development Environment
IoT	-	Internet of Thing
KVL	-	Kirchhoff's Voltage Law
LDR	-	Light Dependent Resistor
LED	-	Light Emitting Diode
LoRa	-	Long Range
LoRaWan	-	Long Range Wide Area Network
LPWAN	-	Low Power Wide Area Network
MOSFET	-	Metal Oxide Semiconductor Field Effect Transistor
PFC	-	Power Factor Correction
PIR	-	Passive Infrared Sensor
PWM	-	Pulse Width Modulation
RF	-	Radio Frequency
THD	-	Total Harmonic Distortion

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

The first chapter in this report will discuss the project background, problem statements, scope, objectives, and report outlines. Report outlines included the summary for every chapter in this report.

1.1 Project Background

The usage of Internet of Things (IoT) Technology is getting common in this era with advanced technology. This technology can be used to control and monitor the operation of a certain process by sending the signal or instruction to the controller. It makes our life becomes easier and reduces the manpower for the operation.

In power electronics, there are four types of converters which are DC-DC converter (DC-DC chopper), AC-AC converter (AC-AC chopper), AC-DC converter (AC-DC rectifier), and DC-AC converter (DC-AC inverter). In this project, there are two types of converters are being used which are DC-DC converter and AC-DC converter (Rectifier).

In DC-DC converter, it can be classified into three types: Buck Converter, Boost Converter, and Buck-Boost Converter. The main function is to convert the input DC voltage to regulated output DC voltage. The voltage of DC output can be higher or lower than the input voltage. Buck converter is selected for this project to step down the voltage value which is suitable for LEDs.

1.2 Problem Statement

Street Lighting is important in our daily life, especially during nighttime and rainy day. It is used to light up the surrounding area when the brightness is low. There is a lot of problem with the existing street lighting system in our country. Firstly, the most significant problem is high expenses and high-power consumption of conventional streetlight systems. Even though conventional lamp has a lower initial cost, but it consumes higher power to be lighted up while comparing to LEDs. Higher power consumption causes higher expenses on electricity billing.

Next, the second problem is a large amount of manpower for maintenance is required. It is hard for a technician to know the exact location of the streetlight that needed to be repaired or replaced. This process also takes a lot of time to identify which streetlight is having the problem.

The last problem is the lifespan of a conventional lamp. LEDs have a longer lifespan compared to conventional lamps. Normally the lifespan of an LED streetlight is about 10 to 15 years. To make it easier, the comparison of CFL bulbs, Incandescent Lamp, and LED bulbs is explaining the truth whereby the average lifespan of CFLs is about 8000 hours and Incandescent Lamp is about 1200 hours but the average lifespan of LEDs is about 25000 hours. LEDs will be the better choice for long-term usage.

1.3 Objectives

The objectives of this project are:

i. To design a DC-DC Buck converter suitable for lighting up the LEDs by using MATLAB Simulink

ii. To design an AC-DC Rectifier with Power Factor Correction for converting AC to DC voltage with improved power factor and harmonic distortion

iii. To simulate the designed circuit for Rectifier and Buck Converter by using MATLAB Simulink

1.4 Scope

This project is focusing on the design of the AC-DC Rectifier with Power Factor Correction (PFC) and the DC-DC Buck Converter for the Smart Street Lighting

System. The AC-DC Rectifier is used to convert the AC input voltage into DC output voltage. Boost Power Factor Correction is connected to the rectifier to improve the power factor and harmonic distortion. Next. the DC-DC Buck Converter can provide a suitable output DC voltage with the range of 65V – 100V for LED street lighting. The parameters are designed based on the Constant Current LED Driver that is shown in Appendix 1. The main function of a buck converter is to step down the higher DC voltage to a desired and lower DC voltage. In this case, it is required to step down from 240V to the range of 65-100V. The simulation of the circuit is designed and conducted by using MATLAB Simulink.

1.5 Report Outlines

Five chapters will be discussed in this report. Those chapters are stated as follows:

Chapter 1 is about the introduction of this project on the AC-DC Rectifier with PFC and DC-DC Buck Converter for Smart Street Lighting System. This chapter includes the project background, problem statement, objectives, and scope of the project.

Chapter 2 consists of the Literature Review on the theory and working principles about the AC-DC Rectifier, Power Factor Correction (PFC), and DC-DC Buck Converter.

Chapter 3 describes the methodology used to design the simulation circuit by using MATLAB. It includes the parameters used for the components in AC-DC Rectifier without and with Power Factor Correction (PFC) and the calculation for the parameter used in the DC-DC Buck Converter for Open Loop and Closed Loop.

Chapter 4 is about the simulation result for this project based on the design of MATLAB Simulink.

Chapter 5 provides the conclusion and recommendation of this project with advanced functions in the future.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter explained the components involved and the theories of the concept applied in this project. For example, the working principle of LED driver and the benefit of using Light Emitting Diode (LED) Street Light. A concept such as DC-DC Buck Converter, AC-DC Rectifier, and Power Factor Correction (PFC) will also be discussed in this chapter.

2.2 Light Emitting Diode (LED)

Light Emitting Diode (LED) is a semiconductor device that emits light when an electrical current is passed through it. LED Street light is an integrated light that uses LED as its light source. The advantages of using LED light are high efficiency, low power consumption, longer lifespan, longer operating time, and environmentally friendly compared to a conventional light. The estimated lifespan of a LED streetlight is usually 10 to 15 years. The operating time for an LED lamp is approximately 50000 hours with 70-80% lumen maintenance [1]. LEDs have also higher luminous efficacy than conventional light which means it is capable to convert more electricity into visible light. Table 2-1 presents the comparison of several types of lamps [2].

Table 2- 1 The comparison of several types of lamps

Type of Light	Lifespan (Hours)	Luminous Efficacy (lm/W)	Colour Temperature
Mercury Vapor Light	12000 – 24000	13 – 48	4000K
Metal Halide Light	10000 – 15000	60-100	3000K – 4300K
High Pressure Sodium Light	12000 – 24000	45 – 130	2000K
Low Pressure Sodium Light	10000 – 18000	80 – 180	1800K

Fluorescent Light	10000 – 20000	60 – 100	2700K – 6200K
Compact Fluorescent Light	12000 – 20000	50 – 72	2700K – 6200K
Induction Light	60000 – 100000	70 – 90	2700K – 6500K
LED Light	50000 – 100000	70 – 150	3200K – 6400K

2.3 LED Driver

LED Driver is a device that is used to control the regulated power supply to the LEDs. This is a significant item to an LED circuit [3]. System failure will happen if the operation of the LED circuit without the LED driver. LEDs require a reliable power supply for their operation. LED Drivers can be also known as a device converting alternating current (AC) to direct current (DC). They ensure the power supply is consistent and not interrupted by the changes in the temperature and electrical conductivity of the LEDs. This can prevent the problem of overheating, flicking, color changes, and degraded performance. There is some LED Driver that capable to control the brightness of the LED light systems and change the displayed colors by the LEDs.

There are two kinds of LED drivers that exist: Constant Current and Constant Voltage. Constant Current LED Driver has a designated range of output voltages and a specified output current (mA). Constant Voltage LED Driver is built for a single DC output voltage. Usually, the output voltages are 12VDC or 24VDC [4].

2.4 DC-DC Buck Converter

Buck Converter is known as a power electronics device that transforms a higher voltage source into a lower regulated voltage [5]. Buck converter circuit contains a switching device, diode, capacitor, inductor, resistor, and voltage source. The buck converter circuit diagram is displayed in Figure 2-1. The power switches in the converter can be switched on or off by using the pulse width generator (PWM).

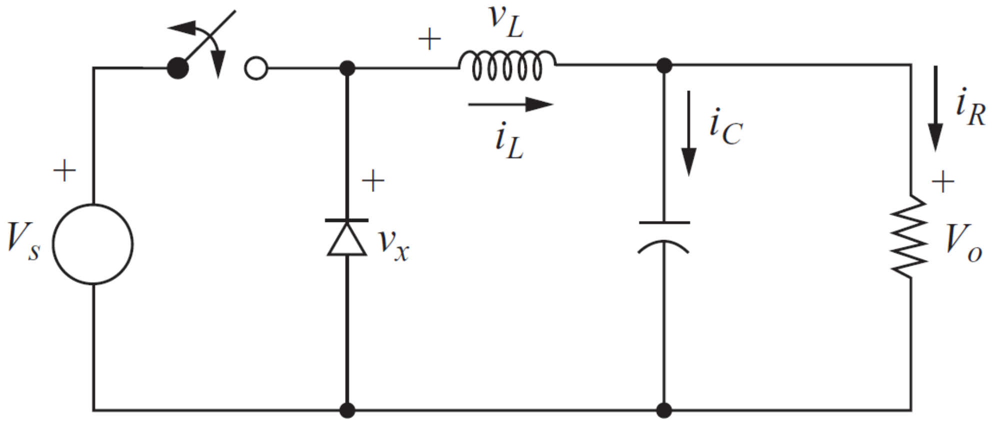

Figure 2-1 The buck converter circuit diagram

2.4.1 Operating Principle of Buck Converter

This converter has two kinds of conduction modes which are either continuous current mode (CCM) or discontinuous current mode (DCM). The current of the inductor will often be positive and remain continuous throughout the switching time and never drops to zero in CCM operation. For DCM, the current of the inductor will not flow continuously and remains zero in the switching time for some time [5].

2.4.2 Operation of Buck Converter when the Switch is on

During the switch is closed in the circuit, the diode will be in the reverse-biased state. The inductor current will flow to the capacitor and resistance. Due to the reverse-biased state of the diode, it will not pass through the diode. Based on Kirchhoff's Voltage Law (KVL), the formula to show the voltage across the inductor is:

$$V_L = V_s - V_o = L\frac{di_L}{dt}$$

After rearranging the equation,

$$\frac{di_L}{dt} = \frac{V_s - V_o}{L}$$

By computing the equation above,

$$\frac{di_L}{dt} = \frac{\Delta i_L}{\Delta t} = \frac{\Delta i_L}{DT} = \frac{V_s - V_o}{L}$$

Thus,

$$\Delta i_{L(closed)} = \left(\frac{V_s - V_o}{L}\right) DT$$

Figure 2.2 presents the circuit of the Buck Converter when the switch is closed.

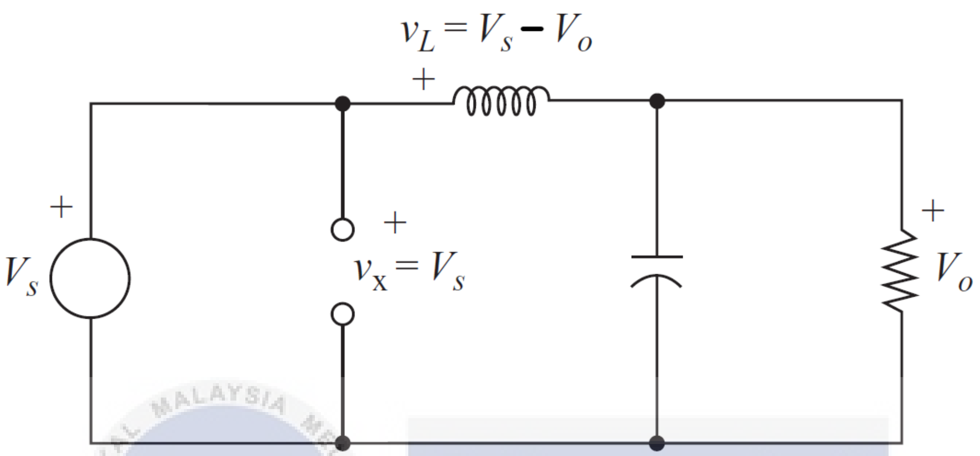

Figure 2-2 The circuit diagram of Buck Converter (Switch is closed)

2.4.3 Operation of Buck Converter when the Switch is off

During the switch is open, the diode will be in a forward-biased state, and it will carry the current of the inductor. Based on Kirchhoff's Voltage Law (KVL), the voltage across the inductor is:

$$V_L = -V_o = L\frac{di_L}{dt}$$

After rearranging the equation,

$$\frac{di_L}{dt} = \frac{-V_o}{L}$$

By computing the equation above,

$$\frac{di_L}{dt} = \frac{\Delta i_L}{\Delta t} = \frac{\Delta i_L}{(1-D)T} = \frac{-V_o}{L}$$

Thus,

$$\Delta i_{L(open)} = \left(\frac{-V_o}{L}\right)(1-D)T$$