APPROVAL

I hereby declare that I have read through this report entitle " Analysis of Asynchronous and Synchronous Buck Converter for Battery Charging" and found that it has comply the partial fulfillment for awarding the degree of Bachelor of Electrical Engineering (Power Electronic and Drive).

Signature : …….

Supervisor's Name : …….

Date : …….

ANALYSIS OF ASYNCHRONOUS AND SYNCHRONOUS BUCK CONVERTER FOR BATTERY CHARGING

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A report submitted in partial fulfillment of the requirements for the degree of Bachelor of Electrical Engineering (Power Electronic and Drive)

Faculty of Electrical Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

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DECLARATION

I declare that this report entitle "Analysis of Asynchronous and Synchronous Buck Converter for Battery Charging" is the result of my own research except as cited in the references. The report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : …….

Name : ……

Date : ……

DEDICATION

To my beloved mother and father

ACKNOWLEDGEMENTS

First and foremost I would like to express my thanks to God because of His love and strength that He given to me to finish the project analysis and writing the report. I do thank for His blessings to my daily life, good health, healthy mind and good ideas. I would also like to take this opportunity to express my sincere acknowledgement to my supervisor Miss Siti Azura Binti Ahmad Tarusan for her essential supervision, support and encouragement towards the completion of this thesis.

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ABSTRACT

Power electronic device is widely used in industry as equipment to protect others device and saving the consumption of energy. To develop the electric vehicle (EV) and uninterruptible power system (UPS), power electronic research is done. Buck converter circuit is the one of power electronics circuit that used to step down the output voltage. In buck converter circuit, it has two topologies that used to operate which are asynchronous and synchronous. These two topologies have their own construction of circuit and circuit efficiency. However to make sure the circuit in stable system, the feedback circuit is develop in order to regulate the output voltage. Main objective of this project is to design, simulate, analyse and compare the Asynchronous and Synchronous buck converter efficiency. In addition, to study the voltage mode control of these different topologies. This project consists of two parts which are analysis at power stage of buck converter and design the circuit of voltage mode control for each circuit. At power stage circuit, the efficiency of these two circuits is compared. To validate the result, the step of experiments is repeat again by using others duty cycle value. Thus the suitable value for parameters that used in type III compensator is finding in order to design the voltage mode control circuit. Then, the result of comparison of these circuits is compared. In a nutshell, this project proved the Synchronous topologies is more efficient compared to Asynchronous if the circuit is operate at half and above the value of duty cycle.

ABSTRAK

Perkakas elektronik kuasa digunakan secara meluas di dalam industri sebagai peralatan untuk perlindungan peralatan lain dan menjimatkan penggunaan tenaga. Untuk membangunkan bidang kereta elektrik dan sistem kuasa yang tidak terganggu, penyelidikan dalam bidang elektronik kuasa dibuat. Litar penukar Buck ialah merupakan salah satu litar elektronik kuasa yang digunakan untuk menurunkan nilai voltan keluaran. Dalam litar penukar buck, ia mempunyai dua topologi yang digunakan untuk beroperasi iaitu asynchronous dan synchronous. Dua topologi ini mempunyai binaan litar dan kecekapan tersendiri. Bagaimanapun, untuk memastikan litar dalam sistem yang stabil, litar maklum-balas dibuat untuk mengawal voltan keluaran. Objektif utama projek ini ialah untuk reka, simulasi, analisis dan banding kecekapan penukar buck Asynchronous dan Synchronous. Selain itu, untuk belajar mod kawalan voltan bagi topologi yang berbeza ini. Projek ini mempunyai dua bahagian iaitu analisis pada bahagian kuasa penukar buck dan cipta litar kawalan mod voltan bagi setiap litar. Pada bahagian litar kuasa, kecekapan bagi dua litar ini dibandingkan. Untuk mengesahkan keputusan, langkah eksperimen diulangi lagi dengan menggunakan nilai kitaran tugas yang lain. Seterusnya, nilai parameter yang digunakan dalam pemampas jenis III dicari untuk membuat litar kawalan mod voltan. Seterusnya, keputusan perbandingan bagi dua litar ini dibandingkan. Kesimpulannya, projek ini membuktikan topologi Synchronous lebih cekap berbanding dengan Asynchronous jika litar beroperasi dengan nilai kitaran tugas separuh dan ke atas.

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CHAPTER 1

INTRODUCTION

1.0 Introduction

This chapter describes the project background, problem statement, objectives and scope of project. For this background of project it describes the types of dc-dc converter, the types of topologies that used in buck converter circuit and the type of switching mode control that used which is voltage mode control.

1.1 Project Background

There are many types of switch mode of power converter used in field of power electronic circuit such as switch mode of dc-dc converters. In categories of dc-dc converters, they are divided in some of types such as buck converter, boost converter, buck-boost converter and ćuk converter etc. The main objective and scope of this proposal are to analyse and study buck converter. Every types of dc-dc converter has the method to control the switching. There are some of types of switching control normally used in circuit of dc-dc converter such as voltage mode control, current mode control, hysteretic

mode control in switch mode power supplies (SMPS), sliding mode control and many more. Each method has some advantages and disadvantages in terms of efficiency of power circuit, noise and cost there need to produce the circuit.

1.2 Project Motivation

Nowadays, application of power electronics device is one important thing in daily life as equipment to protect the devices from damages and as a device to saving the power consumption. The non – isolated converter which is DC – DC converter is one of the power electronics field. There are many applications of DC – DC converter such as application in the development of electric vehicle (EV), uninterruptible power system (UPS), energy conversion, battery charger and many more. In general, application of DC – DC converter is a device that used to control performance of load by control the frequency, voltage and current in the circuit. Besides that, it also as an equipment to regulated the output voltage value.

1.3 Problem Statement

There are many types of switching controller to generate switching signal for DC-DC converter. The examples types of switching controller are voltage mode control, current mode control, hysteretic mode control in switch mode power supplies (SMPS) and sliding mode control. Voltage mode control is the first switching regulator design where it has single voltage feedback in circuit. The operation for circuit of voltage mode control is a pulse width modulation performed by comparing a constant ramp waveform and the signal of voltage error. Voltage mode control has low efficiency compared to current mode control because it causes ringing and instability if it is not compensated. The type of compensator circuit used in voltage mode control circuit is compensator type III. However,

the circuit for voltage mode control is simplest compared to the circuit of current mode control. Meanwhile, method of current mode control has two loops in the circuit which they are inner loop and outer loop. Inner loop for loop of current control and outer loop for voltage mode control. In inner loop of current mode control circuit, it consists of output filter inductor, so current mode control will eliminate the pole of inductor and second order characteristic. There are two types of buck converter circuit which are asynchronous buck converter and synchronous buck converter. In circuit of asynchronous buck converter, it used single switching device and one diode to complete the operation of cycle which are ON and OFF condition. While Synchronous buck converter used two switching devices in the circuit to operate and complete the ON and OFF cycle condition. Based on these two types of buck converter circuit, each circuit has their own characteristics advantages and disadvantages. Besides that, the different topologies of buck converter also have their efficiency value which is asynchronous and synchronous has different value in terms of efficiency circuit at power stage circuit. The value of duty cycle also can effect to the value of output voltage of the buck converter circuit. In general, the efficiency of synchronous is better than the asynchronous buck converter topology. In comparison of their output voltage ripple, the output voltage ripple value produces in synchronous is less than the asynchronous buck converter. So, it make the efficiency of synchronous is better than asynchronous. However, the buck converter circuit whether asynchronous or synchronous topologies not stable if it circuit has not circuit of mode control which is feedback circuit to regulate the output voltage value. To make sure these two topologies of buck converter operate in stable condition, it circuit must connected to the mode control circuit whether voltage mode control, current mode control and so on.

1.4 Objectives

Project objectives are:

i. To study and simulate of voltage mode control of Asynchronous and Synchronous buck converter using Matlab and Pspice software.

ii. To compare the performance of power stage circuit between Asynchronous and Synchronous buck converter in term of their efficiency.

1.5 Scope

The scopes for this project are:

i. In this project, the type of converter that will be use is asynchronous and synchronous buck converter (DC – DC converter) which is the input voltage is 30V and the output voltage is 15V. Analysis of efficiency circuit will be done at this power stage and the values of duty cycle that will be used are 0.3, 0.5 and 0.7.

ii. The mode control that used for this project is voltage mode control and the type of compensator used in this project is type III compensator.

iii. This project consists of simulation and do not cover hardware part, simulation at the power stage circuit of asynchronous and synchronous buck converter using Matlab software. Matlab software also used to get bode diagram graph to determine the stability condition in order to get the suitable value for compensator that will used for this project. Pspice software is used to simulate complete circuit of buck converter whether asynchronous or synchronous connected to the voltage mode control circuit.

CHAPTER 2

THEORIES AND LITERATURE REVIEWS

2.0 Introduction

This chapter describes the basic theories related to the buck converter circuit and the type of mode control that will be used in this project which is voltage mode control. This chapter also consists of theories about type III compensator.

2.1 Power Converter – DC-DC Converter

Power converter is power electronic circuit that converts one type of electrical energy to another form. Several types of power electronic circuit converter in electrical engineering are AC-DC converter, DC-AC converter, AC-AC converter and DC-DC converter. In power electronic circuit, converter is the intermediate device between source and load [1]. The function of DC-DC converter is same as transformer function where to convert one level of voltage value or current value to another level either step up or step down voltage value. Normally power converter circuit have options to control the output voltage. In linear voltage regulators circuit, it controls by using transistor. Disadvantages

of this circuit are creates voltage drop at transistor and decrease the efficiency of circuit. Figure 2.1 shows the basic circuit of linear voltage regulator.

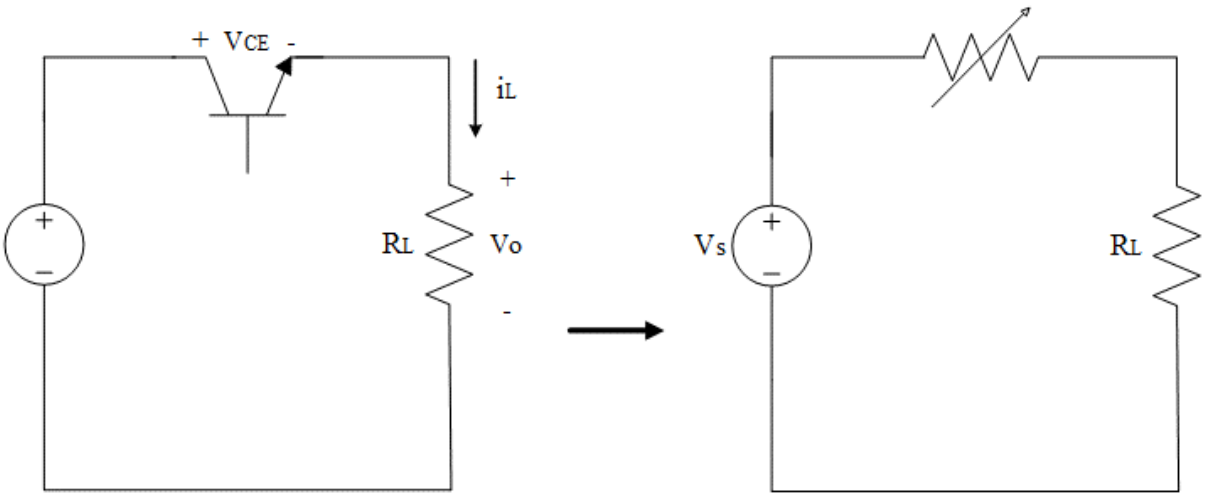
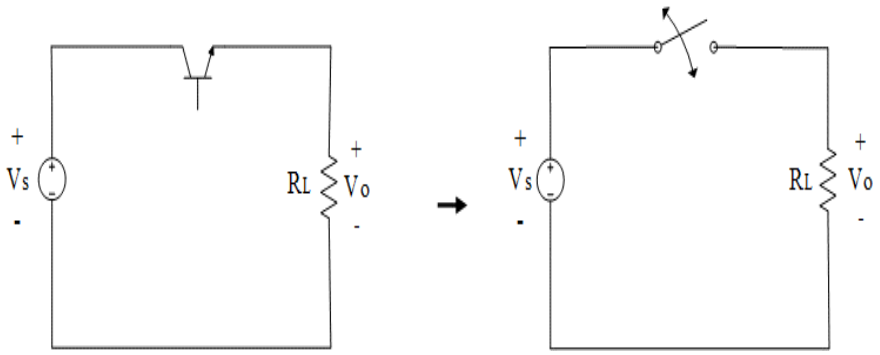
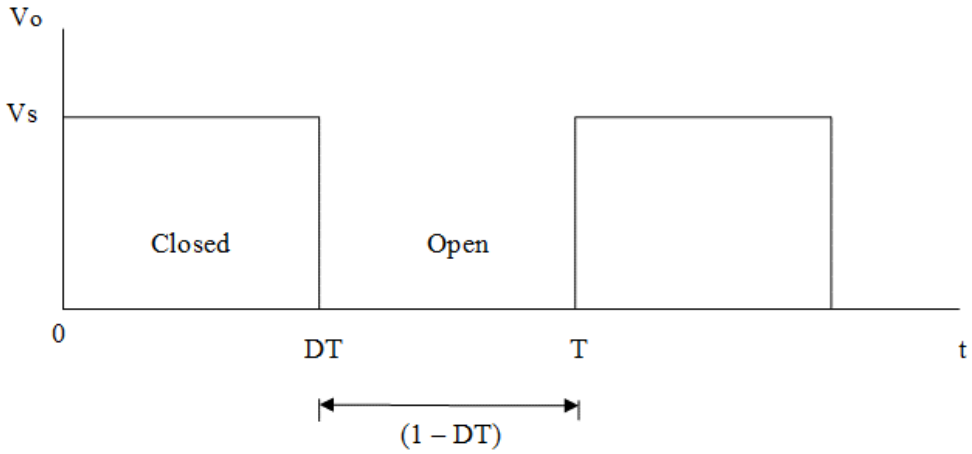


Figure 2.1: Basic circuit of linear voltage regulator.

However, in power converter circuit, it also has the device to control the circuit such as BJT and MOSFET. Controller of the circuit or switching is the main component to operate the power converter. A basic switching converter is better than linear voltage regulator because it can increase the efficiency of the circuit. In switching converter circuit, transistor operates either fully on or off condition; by the way transistors do not absorb any power because there is no voltage drop at the transistor. Figure 2.2 shows a basic switching converter circuit.



(a) (b)



(c)

Figure 2.2: (a) A basic dc-dc switching converter; (b) Switching equivalent circuit; (c) Output voltage waveform.

In DC-DC converter circuit, it is divided some of parts such as input, switches, filter and output part [2]. For input part, it has only dc voltage supply. In switching part, it consists of device to control the switching such as BJT and MOSFET. For part of filter it consists of inductor and capacitor as filtering devices which is low pass filter. For output part it has resistor as a load. Figure 2.3 shows the block diagram of DC-DC converter [2].

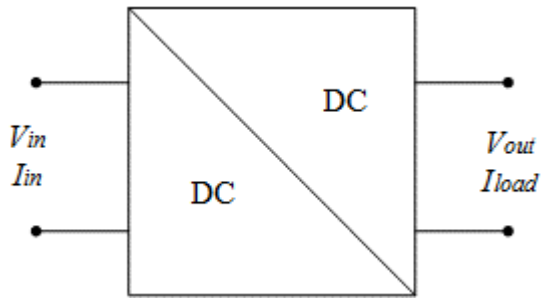


Figure 2.3: Block diagram of DC-DC converter.