UNIVERSITI TEKNIKAL MALAYSIA MELAKA

Development of Controller for Boost Converter

This report is submitted in accordance with the requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor Degree of Engineering Technology
(Electronic Industry) (Hons)

By

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2015

DECLARATION

I hereby, declared this report entitled "Development of Controller for Boost Converter" is the results of my own research except as cited in references.

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APPROVAL

This report is submitted to the Faculty of Engineering Technology of UTeM as a partial fulfillment of the requirements for the degree of Bachelor of Engineering Technology (Electronic Industry) (Hons.). The member of the supervisory is as follow:

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(CIK SITI HALMA BINTI JOHARI)

ABSTRAK

Peningkatan kos sara hidup pada masa sekarang telah membebankan pengguna dalam meneruskan kehidupan seharian. Pada masa yang sama, sektor industri turut terkesan dengan masalah ini. Penggunaan elektrik oleh alatan elektrik bervoltan tinggi menyebabkan mereka terpaksa membayar lebih untuk kos penggunaan elektrik. Penggunaan sumber yang boleh diperbaharui diperkenalkan dalam menangani masalah kekurangan sumber yang tidak boleh diperbaharui. Sumber yang boleh diperbaharui seperti tenaga solar adalah sumber yang biasa digunakan dan sesuai untuk digunakan. Negara membangun telah lama menggunakan sumber tenaga solar untuk menjana tenaga. Keluaran voltan yang tidak stabil yang dihasilkan daripada panel solar menyebabkan tidak sesuai digunakan untuk alatan elektrik dan jumlah voltan yang dihasilkan oleh panel solar terlalu sedikit untuk menjana alatan elektrik berkuasa tinggi. Jadi, penghasilan pengawal untuk penukar naik dicadangkan untuk menangani masalah tersebut. Dengan memperoleh voltan masukan 12 volt(V) dari panel solar, ia akan menghasilkan voltan keluaran 24 V. Litar pengawal yang digunakan ialah mikropengawal PIC untuk mengawal kestabilan voltan keluaran dan kitaran bersih dalam menghasilkan nilai voltan keluaran yang tetap. Pemandu pintu MOSFET dan IGBT digunakan untuk memberi isyarat denyut untuk operasi suis oleh MOSFET.

ABSTRACT

Increasing daily cost life nowdays had burden peoples in continuing their life. At the same time, industry sector also struck with this problem. Electricity usage for high voltage electrical appliances that consume more energy makes them to pay more of electricity cost. Renewable energy usage had also emphasized to overcome the lack of non-renewable energy day by day. Renewable energy such as solar energy that get from sun is the common renewable energy and reliable to use. Develop countries had been used this renewable energy in generate electricity for a long time. The unstable output voltage from solar panel makes it not suitable for electrical appliances usage and amount of voltage produced from solar energy is too small to generate high voltage electrical appliances. So, development of controller for boost converter is proposed to overcome this problem. By getting input 12 V from solar panel, it will produce 24 V constant output voltages for electrical appliances usage. The controller circuit that used is PIC microcontroller that will control the stability of output voltage and duty cycle to get the constant value. Insulated gate bipolar transistor (IGBT) and metal oxide semiconductor field effect transistor (MOSFET) gate driver is used to giving the pulse signal for MOSFET for its switching operation.

DEDICATION

To my beloved parents and special thanks to my supervisor

ACKNOWLEDGEMENT

I would like to thank to all individuals that involve directly or indirect in developing controller for boost converter project. Thank to my supervisor that was help in giving guidance how to make this project and report successfully done. Not forget also to my parents that always giving morale support in continuing my study.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS, SYMBOLS AND NOMENCLATURE

$\frac{\Delta Vout}{\Delta V}$ - Output ripple voltage

ADC – Analog Digital Converter

CCM – Continuous Conduction Mode

C_{min} – Capacitance minimum value

D – Duty Cycle

DCM – Discontinuous Conduction Mode

F – Farad (Capacitor unit)

f_s - Switching Frequency

H – Henry (Inductor unit)

IGBT – Insulated Gate Bipolar Transistor

L_{min} – Inductance minimum value

MOSFET – Metal Oxide Semiconductor Field Effect Transistor

P – Power (Watt)

PCB – Printed Circuit Board

PIC – Programmable Integrated Circuit

PSIM – Power Simulation

PWM – Pulse Width Modulation

R_L – Resistor Load

RMS – Root Means Square

V_{in} – Voltage Input

V_{out} – Voltage Output

$V_{out\ max}$ – Maximum voltage output

$V_{out\ min}$ – Minimum voltage input

V_s – Voltage Source

ΔiL – Change of Inductor current

ΔV – Change of Voltage

CHAPTER 1

INTRODUCTION

1.1 Background Project

Boost converter is also known as chopper. It converts unregulated DC voltage to regulated DC output voltage. It is called a boost converter because the output voltage is larger than the input voltage. For boost converter development, the requirement of input supply is 12 V and the required output voltage is 24 V. The input voltage 12 V is taken from the solar panel that connected to the input of the boost converter. Besides, the state feedback controller also develops to the boost converter.

Power Simulator (PSIM), MULTISIM and PROTEUS simulation software are used to support the development of boost converter and state feedback of converter. Programmable Integrated Circuit (PIC) 18F4550 microcontroller is used to generate a pulse width modulation (PWM) to the boost converter. Program code of PWM typed in PIC C Compiler and then the program code is burned into the PIC Microcontroller. But for this project, the input voltage supply that used is direct current (DC) supply of adapter as replacement input supply from solar panel. Once the hardware development is done, the required result which is 24 V DC output voltages can be observed by connecting to the DC motor.

1.2 Problem Statement

Increasing live cost nowadays bring more expenses in daily life. Usage of electrical appliances in house and a lot of machines in industries consume more electricity. Operational cost will increase as the increasing of electricity consumption. Sometimes, the generated electricity has not stable output voltage. This will cause the electrical appliances and machine in industries cannot be operating very well. To overcome this problem, boost converter project is executed. Only small amount of input DC power supply is needed and it steps up the output voltage so that the high voltage electrical appliances or machine can be operated.

1.3 Project Objective

1. To develop a Boost converter with an output value of 24 VDC.
2. To create a suitable controller for Boost converter.
3. To analyze the performance of the controller that applied to the DC Motor.

1.4 Project Scope

This boost converter is work in Continuous Conduction Mode (CCM) which is the inductor current, I_L flow continuously and never falls to zero. The output voltage must be 24 VDC and the output current is ± 4.2 A. The required power rating of the boost converter is 1W. The output voltage has stabilized to value 24 V after 0.06 second which is settling time once the input supply is applied. The switching frequency that supplied to IGBT Gate Driver is 20 kHz from the PIC 18F4550. The duty cycle is 50% of PWM for IGBT switching control so that the output voltage is 24V.

1.5 Project Significant

Development of controller for boost converter is one of the new features that had developed to the conventional boost converter. From unregulated input voltage, 12 V getting from solar panel, the boost converter can step up the output voltage but the stability of the output voltage cannot be achieved. The existence of the controller circuit, it can be stabilize the output voltage beside it can control and maintain the desired output voltage. The result can be obtained by connecting to the 24 V DC motor that drive an electric scooter and bicycle motors.

CHAPTER 2

LITERATURE REVIEW

This chapter discussed details of development of controller for boost converter. Previous works done by other researchers are also explained.

2.1 Previous researches

Modelling of DC-DC boost converter using logic controller for solar energy system application presented by (Haripriya, T, Rao, 2013) , in their research paper, the boost converter is modeled by using mathematical approach and simulate using Simulink in MATLAB. In this paper also, the boost converter is develop to overcome environmental issue which is pollution problem and renewable energy problem. The solar energy is used as input supply for the DC-DC boost converter that the solar energy is captured by using photovoltaic cells. This paper only modelling the boost converter and real of boost converter is not developed.

Development of controller of boost converter proposed a something new for human daily life. This boost converter project is friendly to user that is can be used for electrical home appliance and also it can be used in industry. By giving small input supply voltage, this boost converter circuit can drive electrical appliances that require higher voltage. Differ from the previous research, this boost converter not only modeled, but it can be developing to become hardware.

2.2 DC-DC Boost converter

The dc-dc boost converters are used to convert the unregulated dc input to a controlled dc output at a desired voltage level. They generally perform the conversion by applying a dc voltage across an inductor or transformer for a period of time 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. (Kumar, Indira, Nadu, & Nadu, 2014) DC-DC converters are operated under continuous conduction mode (CCM) or discontinuous conduction mode (DCM). As the name implies, the output voltage of boost converter is higher than the input voltage. The input and output power of DC-DC converters are same for ideal case. The DC-DC boost converters operate under two cases, switch ON (SW closed) and switch OFF (SW opened) (Mohammed, 2011). Figure 2.1 shows the basic circuit of boost converter.

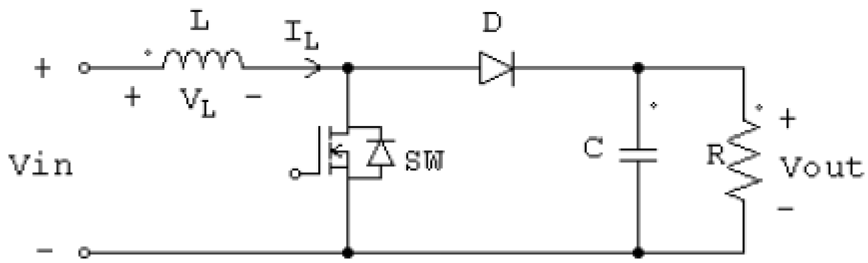

Figure 2.1: Basic circuit of Boost Converter (Masri & Chan, 2012)

2.3 Analysis of DC-DC Boost converter

Boost converter circuit has an element that act as switch that turn ON and OFF periodically. This switching process is to ensure that the inductor that connected parallel with this switch can store and release energy when the boost converter circuit is ON or OFF mode so that the desired output voltage is achieved.

Initially, when the switch is closed, the current flow through inductor (L) and the energy is stored in inductor at this time. During the switch is opened, the stored current in the inductor then flow through load resistor (R_L) and capacitor. The output voltage then produces across the load resistor (R_L) and capacitor. During switch closed, the current from input supply flow through inductor and it storing energy. However, at the same time, the energy stored in the capacitor during switch opened is discharged across load resistor (Mohammed, 2011). The diode (D) is reverse biased in switch opened and it blocks the reverse flow of current from load to source (Mohammed, 2011). That why the load current and voltage is continuously produced. The voltage output is controlled by the duty cycle of the switch. Pulse is needed for controlling the switching process of the switch of DC- DC boost converter. Pulse width modulation (PWM) is general technique to generate the triggering pulse to control the switch process (Mohammed, 2011).

2.3.1 Analysis for switch Closed

This analysis is done when the switch is turn ON means that the voltages supply is flow through to inductor and the switch only. The other components that consist in the boost converter do not receive any voltage or current because of the diode become reverse biased. When the switch is closed, the diode is reversing biased (W.D. Hart, 2011). The Equation (1) of Kirchhoff’s voltage law that consist voltage source, inductor and closed switch is

$$V_L = V_S = L\frac{di_L}{dt} \text{ or } \frac{di_L}{dt} = \frac{V_s}{L} \qquad (1)$$

The rate of change of current is constant, so that the current increases linearly when the switch is closed. The change in inductor current is derived as in Equation (2).

$$\frac{\Delta iL}{\Delta t} = \frac{\Delta iL}{DT} = \frac{Vs}{L} \qquad (2)$$

The rate of current change when switch closed is in Equation (3).

$$(\Delta iL)\ close = \frac{Vs\ DT}{L} \qquad (3)$$

Figure 2.2 refer the condition of boost converter when the switch is closed.

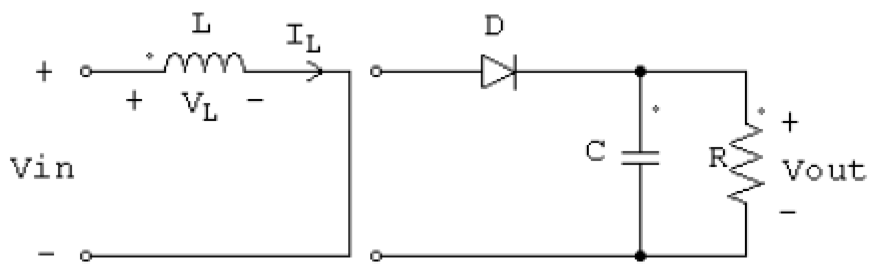

Figure 2.2: Condition of Boost converter when switch closed (Masri & Chan, 2012)

2.3.2 Analysis for switch open

This condition is analyzed when the switch is open means that the switch is turn OFF. When the switch is opened, the inductor current cannot change instantaneously, so diode become forward-biased to provide a path for inductor current (W.D. Hart, 2011). Assume the output voltage is constant; the voltage across inductor is in Equation (4).

$$V_L = V_s\text{-}V_{out} = L\ \frac{diL}{dt} \qquad (4)$$

$$\frac{diL}{dt} = \frac{Vs\text{-}V_{out}}{L} \qquad (5)$$

The rate of change of inductor current is constant and current must change linearly while the switch is open. The rate of change inductor current when switch open is in Equation (7).

$$\frac{\Delta iL}{\Delta t} = \frac{\Delta iL}{(1\text{-}D)T} = \frac{Vs\text{-}V_{out}}{L} \tag{6}$$

$$(\Delta iL)open = \frac{(Vs\text{-}Vout)(1\text{-}D)T}{L} \tag{7}$$

Figure 2.3 indicate the situation of boost converter circuit when switch is opened.

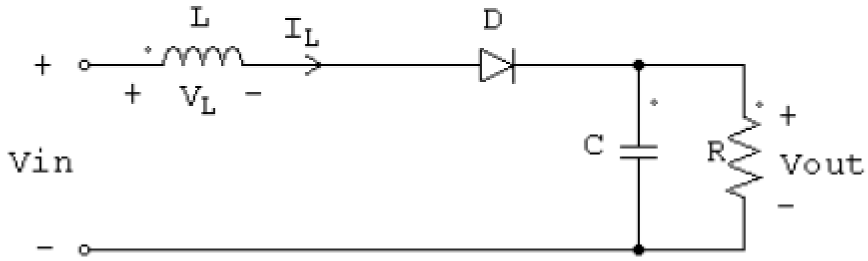

Figure 2.3: Condition of Boost converter switch is opened (Masri & Chan, 2012)

2.3.2 General analysis of boost converter condition

For steady- state operation, the net change in inductor current must be zero, by combining both equation of rate of change inductor current when closed and opened, the derive equation as Equation (8) (W.D. Hart, 2011).

$$(\Delta iL)close \text{ -}(\Delta iL)open = 0 \tag{8}$$

$$\frac{Vs\ DT}{L} + \frac{(Vs\ \text{-}Vout)(1\text{-}D)T}{L} = 0 \tag{9}$$

From the Equation (9), the output voltage can be calculated as in Equation (10)

$$V_{out} = \frac{Vs}{1\ \text{-}\ D} \tag{10}$$