OPTIMIZATION OF DC - DC BOOST CONVERTER USING FUZZY LOGIC CONTROLLER

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Special dedication to

my beloved parents, family, supervisor, lectures, friends and personal who have encouraged, guide and inspired me throughout my journey of education.

Thanks for all the support

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Bismillahirrahmanirrahim

"*In the name of Allah, the most gracious and the most merciful*"

Alhamdulillah to Allah, because of His bless, I can finished my final semester project with good health and cheerful until the last day.

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ABSTRACT

DC-DC converters are electronic devices used to change DC electrical power efficiently from one voltage level to another. Operation of the switching devices causes the inherently nonlinear characteristic of the DC-DC converters including one known as the Boost converter. Consequently, this converter requires a controller with a high degree of dynamic response. Proportional-Integral- Differential (PID) controllers have been usually applied to the converters because of their simplicity.

However, the main drawback of PID controller is unable to adapt and approach the best performance when applied to nonlinear system. It will sufer from dynamic response, produces overshoot, longer rise time and settling time which in turn will influenced the output voltage regulation of the Boost converter. Therefore, the implementation of practical Fuzzy Logic controller that will deal to the issue must be investigated. Fuzzy logic controller using voltage output as feedback for significantly improving the dynamic performance of boost dc-dc converter by using MATLAB@Simulink software. The design and calculation of the components especially for the inductor has been done to ensure the converter operates in continuous conduction mode. The evaluation of the output has been carried out and compared by software simulation using MATLAB software between the open loop and closed loop circuit between fuzzy logic control (FLC) and PID control. The simulation results are shown that voltage output is able to be control in steady state condition for DC-DC boost converter by using this methodology. Scope of this project limited only one types that is Triangle membership function for fuzzy logic control.

ABSTRAKT

Penukar DC-DC adalah litar elektronik kuasa yang menukarkan satu aras voltan DC kepada satu aras voltan DC yang lain. Penukar Boost digunakan untuk meningkatkan voltan masukan untuk memenuhi syarat yang dikehendaki oleh sesuatu operasi. Operasi peranti pensuisan yang tak linear memerlukan pengawal Proportional-IntegralDifferential (PID).

Walau bagaimanapun, kelemahan utama pengawal PID tidak dapat menyesuaikan diri dan mendekati prestasi terbaik apabila merujuk kepada sistem tak linear seterusnya akan mempengaruhi peraturan voltan keluaran penukar Boost. Oleh itu, pelaksanaan pengawal Fuzzy Logik diperkenalkan bagi meningkatkan prestasi dinamik dengan menggunakan MATLAB @ Simulink perisian. Reka bentuk dan pengiraan komponen terutama bagi induktor telah dilakukan untuk memastikan penukar beroperasi dalam mod konduksi berterusan.

Penilaian output telah dijalankan dan dibandingkan dengan perisian simulasi menggunakan perisian MATLAB antara litar gelung terbuka dan gelung tertutup.

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LIST OF SYMBOLS AND ABBREVIATIONS

µe- degree of membership function of error

∆e- degree of membership function of delta of error

u- degree of membership function of voltage ouput

∨ - maximum operator

O - output of COG

∧ - minimum operator

B - Bisector of Area

C - Capacitor

CCM - Continuous Conduction Mode

che - Change of Error

COG - Centroid of Gravity

D - Duty Cycle

DC - Direct Current

DCM - Discontinuous Conduction Mode

e - Error

FLC - Fuzzy Logic Controller

Fs - Frequency Switching

Triangular - Gaussian Membership Function

KD - Derivative gain

KI - Integral gain

KP - Proportional gain

L - Inductor

MF - Membership Function

MOM - Mean of Maximum

MOSFET - Metal–Oxide–Semiconductor Field-Effect Transistor

NB - Negative Big

NS - Negative Small

PB - Positive Big

PID - Proportional Integral Derivative

PS - Positive Small

PWM - Pulse Width Modulation

R - Resistor

S - Switch

VC -Voltage (Calculation)

Vo -Output Voltage

s -K_{th} - switching cycle Input Voltage

V_{ref}- Reference output

ZE – Zero

CHAPTER 1

INTRODUCTION

1.1 Project overview

DC to DC step-up power converter, or more popularly known as the Boost converter, is widely used in power electronics systems. Its application is widespread and wide ranging-Boost power supply can be found in the tiniest cell phone (mill watt) to the high power train propulsion system (hundreds of kilowatts). One of the main requirements of the converter is the robustness of its controller.

A good controller should perform the following tasks: (1) able to regulate output voltage when the input voltage and reference is changed (2) able to stabilize the system for any input disturbances and load changes. The performance of the controller is normally characterized by its response to a step input reference, i.e. transient percentage of overshoot, settling time and steady state error.

Due to its nonlinear and time-invariant nature, the design of high performance controller for the Boost converter presents a challenging task. Traditionally, classical methods such as frequency response and root locus/pole placement techniques are employed. Examples of classical controllers are the Proportional Integral Derivative (PID)[1], Deadbeat controllers [2] and sliding mode controllers [3].

These controllers are known as "model based", relying heavily on mathematical model of the converter for accurate control action. An equivalent circuit-averaging model is derived to determine the converter's variables within a switching period. Based on the averaged model, a suitable small-signal model is obtained by performing small signal perturbation and linearization around a specific (nominal) operating point. For a Boost converter, it is known that the poles and a right-half plane zero are dependent on the load resistance, R [4]. Since classical controllers are designed to operate at one nominal operating point (i.e. fixed duty cycle, D), they are unable to respond satisfactorily to a large operating point variation (i.e. large change in D). Similarly, it could not cope with large load disturbance (large change in R).

Moreover, classical controllers are sensitive to the changes in system parameters, resulting in unpredictable control performance when subjected to changes in temperature, aging, operating point etc. To alleviate the dependency on the mathematical model, “non-model based” controllers have been proposed. Among the most popular is the Fuzzy Logic Controller (FLC). In essence, FLC is a linguistic-based controller that tries to solve problems by means of systematic rule inferences. It does not require precise mathematical model, very robust and has excellent immunity to external disturbances [5]. Although promising, FLC requires substantial computational power due to complex decision making processes, namely fuzzification, rule base storage, inference mechanism and defuzzification operations. To obtain optimized performance, FLC require a much longer time because for most cases, the design is done heuristically [6],[7].

In this project, MATLAB/Simulink is used as a platform in designing the fuzzy logic controller. MATLAB/Simulink simulation model is built to study the dynamic behavior of dc to dc converter and performance of proposed controller.

1.2 Problem statement

DC-DC converter consists of power semiconductor devices which are operated as electronic switches. Operation of the switching devices causes the inherently nonlinear characteristic of the DC-DC converters including one known as the Boost converter. Consequently, this converter requires a controller with a high degree of dynamic response. Proportional-Integral- Differential (PID) controllers have been usually applied to the converters because of their simplicity. However, the main drawback of PID controller is unable to adapt and approach the best performance when applied to nonlinear system. It will suffer from dynamic response, produces overshoot, longer rise time and settling time which in turn will influenced the output voltage regulation of the Boost converter.

In general, PID controller produces long rise time when the overshoot in output voltage decreases.(W.M.Utomo, April 2011). Therefore, the implementation of practical Fuzzy Logic controller that will deal to the issue must be investigated.

The Fuzzy control is a practical alternative for a variety of challenging control applications because Fuzzy logic control is nonlinear and adaptive in nature that gives it a robust performance under parameter variation and load disturbances. Fuzzy controllers are more robust than PID controllers because they can cover wider range of operating conditions than PID, and can also operate with noise and disturbance of different natures. Developing the fuzzy controller is cheaper than developing a model based or other controllers for the same purpose.

Fuzzy logic is suited to low-cost implementations and systems of fuzzy can be easily upgraded by adding new rules to improve performance or add new features.

1.3 Project objective

The objectives of this project are;

i) To model and analysis a DC-DC Boost converter without controller (open loop) and simulate using MATLAB Simulink.

ii) To design Proportional-Integral-Derivative (PID) Controllers to control the switching of DC-DC Boost converter.

iii) To design fuzzy logic controller (FLC) to control the switching of DC-DC Boost converter

iv) To analyze the voltage output for DC-DC Boost converter between open loop and closed loop for PID controller and fuzzy logic controller.

1.4 Project scope

The scopes of this project are to simulate the proposed method of optimization of DC-DC boost converter using Triangle fuzzy logic controller with MATLAB Simulink software. Analyses of the converter will be done for continuous current mode (CCM) only. The scope of proposed fuzzy logic controller is limited Triangle as a proposed controller. The analysis only covered the output voltage based on reading on overshoot ratio, rise time, peak time and settling time.

1.5 Project report layout

This project report is organized as follows;

i) Chapter 1 briefs the overall background of the study. A quick glimpse of study touched in first sub-topic. The heart of study such as problem statement, project objective, project scope and project report layout is present well through this chapter.

ii) Chapter 2 covers the literature review of previous case study of types of DC/DC converters and based on fuzzy logic controller background and development. Besides, also Proportional-Integral-Derivative (PID) Controllers, general information about Boost Converter and theoretical revision on fuzzy logic control system also described in this chapter.

iii) Chapter 3 presents the methodology used to design open loop Boost Converter and closed loop for fuzzy logic controller and Proportional-Integral-Derivative (PID) controllers. All the components that have been used in designing of fuzzy logic controller are described well in this chapter.

iv) Chapter 4 reports and discuss on the results obtained based on the problem statements as mentioned in the first chapter. The simulation results from open loop, PID controller and the proposed of fuzzy logic controller will be analyzed with helps from set of figures and tables.

v) Chapter 5 will go through about the conclusion and recommendation for future study. References cited and supporting appendices are given at the end of this project report.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Since fuzzy logic controller can mimic human behavior, many researchers applied fuzzy logic controller to control voltage output. A thorough literature overview was done on the usage of fuzzy logic controller as applied DC-DC Boost Converter.

Ismail, N.F.N. Musirin, I. ; Baharom, R. ; Johari, D (2010) proposed a fuzzy logic controller using voltage output as feedback for significantly improving the dynamic performance of boost dc-dc converter by using MATLAB@Simulink software. The simulation results are shown that voltage output with fuzzy logic controller with 0% overshoot shows the better performance compared to the open loop circuit (without fuzzy logic controller) whereby it has 80% overshoot.

Md. Shamim-Ul-Alam, Muhammad Quamruzzaman and K. M. Rahman (2010) proposed design of a sliding mode controller based on fuzzy logic for a dc-dc 7 boost converter. Sliding mode controller ensures robustness against all variations and fuzzy logic helps to reduce chattering phenomenon introduced by sliding controller, thereby increasing efficiency and reducing error, voltage and current ripples.

The proposed system is simulated using MATLAB/SIMULINK. This model is tested against variation of input and reference voltages and found to perform better than conventional sliding mode controller.

Ahmed Rubaai, Mohamed F. Chouikha (2004) proposed controllers for DCDC converters Simulation results have been obtained using appropriate scaling factors associated with the input variables of the fuzzy controller. Simulation results show the ease of applying fuzzy control to dc/dc converters, as an interesting alternative to conventional techniques.

Based on those related work, the researchers make a great efforts to propose the good to overcome the DC-DC Converter problems. Their applications of each method differ, thus the further investigation of this controller is needed.

2.2 DC / DC Converters

The DC/DC converter is a device for converting the DC voltage to step-up or step-down depending on the load voltage required. If the requirement of voltage is step-up then it is necessary to use a boost converter. It the requirement of voltage is step-down, and then it necessary to use a buck converter. Sometimes, both step-up and step-down is required to cover the load, but at different times then it is necessary to use a buck-boost converter. Therefore, different types of DC/DC converters are used for different voltage levels in load. Generally DC/DC converters are divided into two types [9].

1- Non isolated DC-DC converter

2- Isolated DC-DC converter

2.2.1 Non Isolated DC-DC Converters

2.2.1.1 Buck converter

Figure 2.1 shows the basic circuit configuration used in the buck converter. There are only four main components namely switching power MOSFET Q1, flywheel diode D1, inductor L and output filter capacitor C1. In this circuit the transistor that is switched ON will put voltage V_{in} on one end of the inductor. This voltage causes the current of the inductor to rise. When the transistor is switched OFF, the current continue to flow through the inductor. At the same time, it flows through the diode. Initially it is assumed that the current flowing through the inductor does not reach zero; thus the voltage will only go across the conducting diode during the full OFF time. The average voltage depends on the average ON time of the transistor on the condition that the current of the inductor is continuous.

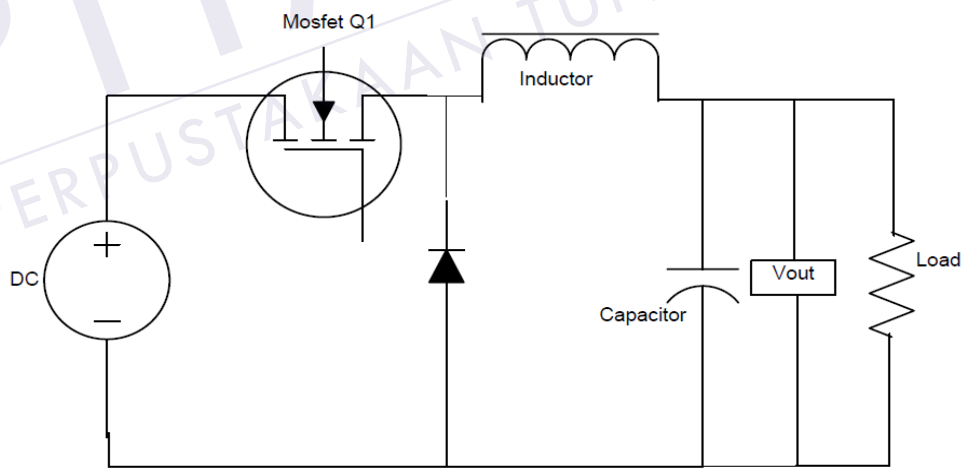

Figure 2.1: The Basic Circuit Configuration of the Buck Converter

2.2.1.2 Boost Converter

A boost converter or a step up converter is a non-isolated converter. It the most commonly used DC/DC converter, especially used in UPS and PV. This is because battery charge requires high DC voltage to be fully charged. Figure 2.2 shows the basic boost converter. The theory of a boost converter is not complicated as other converters rather. It is simple and straight forward. If the switch, S is ON, the current flows only through the inductor, which has stored energy. When the switch, S is OFF, the energy in the conductor is translated to a capacitor, which usually has a large capacity to store a bigger amount of energy. Finally, this energy converts to load with a high DC voltage.

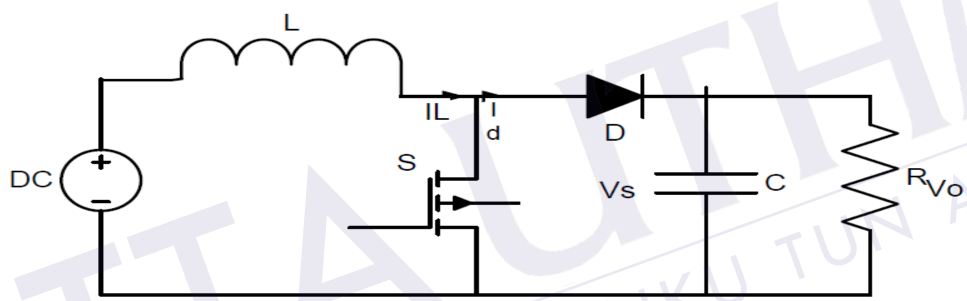

Figure 2.2: Basic Circuit of Boost Converter

2.2.1.3 Buck-Boost Converter

The main components in a buck-boost converter are the same as in the buck and boost converter types, but they are configured in a different way. Figure 2.3 in buck-boost converter, a step-up or step-down voltage can change the value of duty cycle. Nevertheless, in a similar process, once the switch is ON, the inductor begins charging and, the converter is stored with energy. However, once the switch is OFF, the circuit changes into inductor and capacitor simultaneously hence all the stored energy in the inductor is converted to capacitor. One thing that controls the voltage is the duty cycle. If the duty cycle is big, voltage is high in the load. On the other hand, when the duty cycle is small, voltage in the load is low.

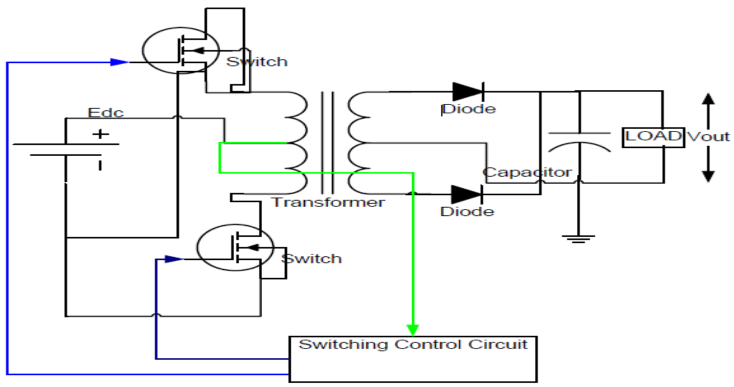

Figure 2.3: Basic Circuit of Buck-Boost Converter

2.2.1.4 Cuk Converter

All the three converters buck, boost and buck-boost converters, transfer energy between input and outputs through the inductor. The analysis is based on voltage balance across the inductor. The Cuk converter in Figure 2.4 uses capacitive energy transfer. This analysis is based on current balance of the capacitor.

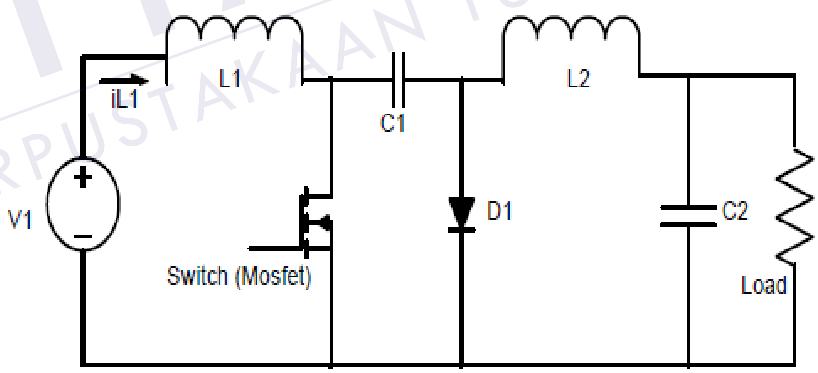

Figure 2.4: Basic Circuit of Cuk Converter

However, the buck-boost converter such as the Cuk converter can step the voltage up or down, depending on duty cycle. The main difference between the two buck-boost and Cuk converters is that, the series of inductors at both input and output record much lower current ripple in both circuits.

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