Design of Controller for Boost Converter to RegulateVoltage Output

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LIST OF ABBREVIATIONS

C	Capacitor
CCM	Continuous Conduction Mode
D	Duty Cycle
DC	Direct Current
DCM	Discontinuous Conduction Mode
HBLED	High Brightness Light Emitting Diode
IEEE	Institute of Electrical and Electronics Engineers
L	Inductor
LED	Light Emitting Diode
PID	Proportional Integral Deviation
PV	Photo-Voltaic
PWM	Pulse Width Modulation
R	Inductor
RC	Resistor Capacitor
SMPS	Switching Mode Power Supplies
T	Time
THD	Total Harmonic Distortion
V	Volt
Vcap	Voltage Capacitor
Vout	Voltage Output

Rekabentuk Pengawal Kepada Penukar Arus Naik Untuk Mengawal Voltan Keluaran

ABSTRAK

Kapasitor boleh digunakan sebagai sumber penyimpanan tenaga untuk membekalkan kuasa kecil dengan menggantikan bateri. Kelebihan menggunakan kapasitor adalah masa pengecasan lebih cepat daripada mengecas bateri. Tetapi kekurangannya adalah voltan kapasitor tidak tetap apabila disambungkan dengan beban. Oleh itu, projek disertasi telah dilakukan untuk merekabentuk pengawal menggunakan penukar arus naik untuk mengawal output voltan kapasitor. Penukar arus naik digunakan untuk mengawal tahap voltan keluaran. Penukar arus naik dibina bersama suis kuasa MOSFET. Untuk menghasilkan pemodulatan lebar denyut untuk MOSFET, PIC16F877 digunakan untuk menghasilkan PWM pada frekuensi pensuisan tertentu. Voltan keluaran akan ditingkatkan daripada voltan masukan dan gunakan untuk mengendalikan beban. Dalam projek ini, litar lengkap direka dengan menggunakan perisian Matlab Simulink dengan parameter komponen dari nilai tertentu. Parameter reka bentuk didalam simulasi dan dilaksanakan ke dalam perkakasan litar lengkap dan diuji untuk mendapatkan hasilnya. Terdapat dua eksperimen yang dijalankan. Yang pertama adalah mengukur voltan keluaran ketika pengawal disambungkan kepada atau tidak disambungkan dan kedua pengawal litar disambungkan kepada beban. Dari eksperimen, voltan keluaran kapasitor untuk rangkaian tanpa rangsangan penukar mempunyai hasil yang mengikuti voltan masukan

dan kesan beban. Rangkaian dengan penukar arus naik dapat mengekalkan pada 24V untuk setiap voltan masukan dan juga apabila bersambung dengan pelbagai beban.

Design of Controller For Boost Converter to Regulate Voltage Output

ABSTRACT

Capacitor can be used as an energy storage element to supply small power in replacing a battery. The advantage of using capacitor is the charging time is much faster than charging a battery. But the disadvantage is that the capacitor voltage value is not constant to supply a load. From that, a dissertation project has been conducted to design a controller using boost converter to regulate the capacitor voltage output. The boost converter used to control the voltage level. The boost converter circuit is constructed with power switch MOSFET. To generate pulse width modulation (PWM) to the MOSFET, a PIC16F877 used to drive PWM at specific switching frequency. The output voltage will step up from input voltage and use to operate the load. In this project, the complete circuit is designed using Matlab Simulink software with a specific value of parameter components. The design parameter is simulated and implemented into hardware and tested to get the result. There are two experiment has been handled. The first is the measurement of voltage output capacitor when connecting with or without controller and second is the controller design is connected to a load. From the experiment, the output voltage capacitor for circuit without boost converter has the result proportionally to the voltage input and the effect of the load. The circuit with boost converter is maintained at 24V for every voltage input and also connected to various load.

CHAPTER 1

INTRODUCTION

1.1 Project Background

Energy storage is one of the storage elements that can be used in power system application and also in power electronic devices. The development of this energy storage make it most of important role in electrical system and has been used even in high voltage application. It can be used in various purpose based on the suitable of the energy want to be used. Capacitor and inductance are among of the components that have the ability to store electrical energy (Hailian, X., L. Angquist, 2006).

Capacitor is a device that consists of a two conductor separate by an insulator. Capacitor can possesses a specific amount of capacitance which is the capability of to store electrical energy. This ability of a capacitor to store electrical energy depends on the electrostatic field between the plates and the distortion of the orbits of the electrons in the dielectric material. But in eventually, capacitor energy will gradually drops during discharging through connecting to a load. It can't maintain the energy storage while it will discharge slowly depend on the size load (O.Bishop, 2006)(Earl D. Gates, 2006).

For this problem, a controller will be designed that will maintain the voltage output from the capacitor across the load for a specified period of time depending on the energy capacity of the capacitor used and size of the load. The controller will operate as a boost controller and feedback system to regulate the capacitor voltage output. This will maintain the voltage output for a period of time depending on the load used.

1.2 Problem statement

The advantage of a capacitor is it can store electrical energy. This characteristic make this capacitor can be used as the battery. Basically the size of storage energy of the capacitor voltage will depend on the size of the capacitance. But the energy store in capacitor can't keep for a long time because it will gradually drops during discharging time. It will discharge the energy store when a load is connected. This will make the capacitor voltage will drain the energy stored.

1.3 Objectives

The main objectives of this research project are:

- To design a circuit of a capacitor voltage controller that can maintain constant voltage output depending of the load condition
- To observe the duty cycle for the system and the size of capacitance that will be used to maintain voltage output when a load connected in specific time
- To design a feedback system that will operate with the controller to maintain voltage output in feedback situation.

1.4 Project Scopes

This research will be limited to the following scopes:

- Designing a controller to maintain voltage output to be constant when connected to a particularly load with appropriate size of capacitance
- Develop microcontroller system to be handling feedback system for this controller

1.5 Thesis Outline

This thesis report is have five chapters which conclude the overall of the project. In chapter one, is about the introduction of the project. It explains briefly about project background, problem statement of project, objectives of the project and scopes of the project.

Chapter two for literature reviews. It discuss more on the theory about this project such as boost converter, regulating capacitor voltage output and other method has been done based on this project.

In chapter three, it will cover the methodology of this project, such the construct the circuit using Matlab simulation, construct hardware and measurement process including change the capacitor value as the variable for this project.

Chapter four will explain and discuss about all the result obtained of the project. An analysis about the result for measurement and simulation has been show in this chapter. A graph also will show the comparison between the voltage capacitor by without using boost converter and with using boost converter.

In chapter five it provides the conclusion that has been made by this project. In this chapter, future recommendations also discuss for implement in this project.

CHAPTER 2

LITERATURE REVIEW

2.1 Overview

In recent years from a decade ago, many of electrical operations used DC to DC converter as switched mode power supplies (SMPS). In SMPS must contain two semiconductor switches, a diode and a transistor with at least one energy storage element such as inductor or capacitor. There a various of DC-DC converter used as to step up or step down an unregulated DC input voltages such as buck, boost, buck boost Choke and full bridge converters. One of it is boost converter to step up DC voltages as the output voltage are greater that it input DC voltage.

To produce the operations of SMPS in high efficiency, the switch in SMPS must turn on and off quickly and can have less losses based on the operation circuit. (Masri & Chan, 2010)(Brown, 1990)

2.2 History

Switching systems such as SMPS are challenged to design since it model depends on applications and how this switch is opened or closed. Starting in 1950s, the SMPS commercial semiconductor represented the milestone of this dc-dc converter such as boost converter. Based on the situation, in early 1960, the main DC-DC converters were developed mostly when this semiconductor switches were available. Most of the applications used this converter to operate well to the electrical equipment.

R.D Middlebrook from Caltech in 1977 published the models for DC-DC converters that mostly used in market today. Basically in his model, he averaged the circuit configuration for each switch state in a technique called state-space average modeling. Based on his publisher models, it led to insightful design equations which help the SMPS growth. From this situation, most of the manufacturer doing research and development to build new SMPS to fulfill the request from industrial manufacturer(Carl Nelson, 1986).

2.3 Capacitor as Energy Storage

The ability of a capacitor to store electrical energy depends on electrostatic field between the plates and the distortion of the orbits of the electrons in the dielectric material. When a capacitor connected to a DC electrical source, electron accumulated on the plate that is connected to the negative supply terminal (negative charge) and deficiency of electrons on the other plate will have positive charge. When the capacitor is charge, all currents stop and the capacitor voltage is equal to the voltage of the voltage source (O.Bishop, 2006)(Earl D. Gates, 2006).

Based on the studies by Wong.K in journal IEEE, an observation of the sizing capacitance affected the capability of storage electrical energy to the size output current used. The voltage store are depended on the size of capacitance. For a large output current, a small capacitance cannot store enough energy for it. The suitable capacitance size is needed for suitable operation applications. Large capacitance can maintain the capacitor voltage for a period of time depending on the load. This topic discussed about the application of capacitor as an energy storage where already been discussed and proposed (Wong, 2004).

2.4 Step Up Switch Mode Power Supply: Ideal Boost Converter

Boost converter is one of the SMPS also known as step-up converter. Basically this converter converts an unregulated DC voltage to regulated or variable DC voltage (chopper). The ideal basic boost converter is it must have power semiconductor switch, inductor, diode, capacitors and pulse width modulator (PWM) controller. From this components also, it can cover up to produce buck converter but arrangement is different due to the different output level produce.

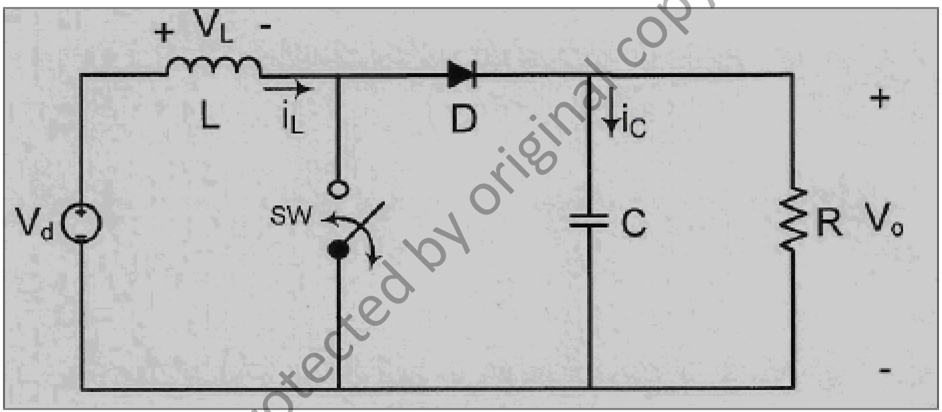

Figure 2.1 : Boost Converter Diagram (M.Rubaee, 2008)

There are several assumptions to be made to analyze the ideal circuit:

1. When the switch (SW) on, the voltage drop across the diode is zero and the current through is zero.
2. The diode has zero voltage drops in conducting state and zero current in reverse bias mode
3. The time delay in switching on and off the switch and the diode are negligible.
4. The inductor, L and capacitor, C are lossless.

5. The response in the circuit is periodic. The value of inductor current at the starting and ending of a switching is the same. The net increase in inductor current over a cycle is zero.
6. The switch is made On and Off at a fixed frequency and let the period corresponding to the switching frequency be time, T. Given that the duty cycle is D, the switch is on for a period equal to DT, and the switch is off for a time interval equal to (1-D)T.
7. The inductor current is continuous and is greater than zero
8. The capacitor is relatively large. The RC time constant is so large, that the changes in capacitor voltage when the switch is On or Off can be neglected for calculating the change in inductor current and the average output voltage. The average output voltage is assumed to remain steady.
9. The source voltage remains constant.

Essentially, control mechanism for boost converter is turning power semiconductor on and off. When the switch is closed, the current through the inductor increases and the energy stored in the inductor builds up. When the switch is open, the inductor is discharging its energy make the current continue to flow via diode, capacitor, resistor and lastly back to the source.

When energy stored in inductor is discharge, its polarity changes such that it adds to the input voltage. Thus, the voltage across the inductor and the input voltage are in series and together charge the output capacitor to a voltage higher than the input voltage. It can be seen that inductor acts like a pump, receiving energy when the switch is closed and transferring it to the RC network when the switch is open. The switching device of boost converter must turn on and off quickly from PWM signal and have very low losses(M.Rubaee, 2008).

2.5 Boost Regulator Using Capacitor

The proposed of boost regulator used to boost up the capacitor voltage output. The electrical energy in capacitor will drop when connecting to the load. This made the energy storage will drop fast. Boost converter will control the voltage output when current flow in the circuit (Cheng, 2004).

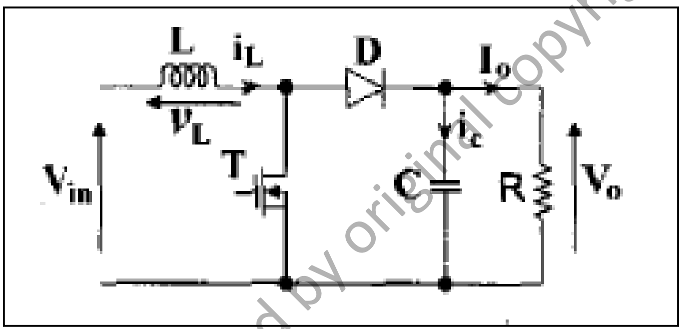

Figure 2.2: Circuit of Boost Converter (Cheng, 2004)

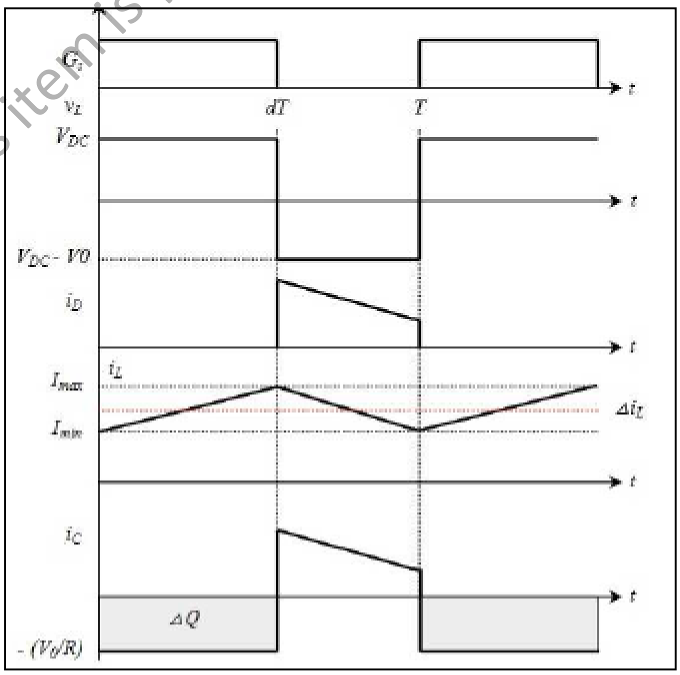

Figure 2.3: Waveform Operation of Boost Converter (Cheng, 2004)