A MODIFIED PID CONTROLLER FOR DC-DC BOOST CONVERTER

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A report submitted in partial fulfillment of the requirements for the degree of electrical engineering (Control, Instrumentation & Automation)

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APPROVAL

I hereby declare that I have read through this report entitled "A MODIFIED PID CONTROLLER FOR DC-DC BOOST CONVERTER" and found that it has complied the partial fulfillment for awarding the degree of Bachelor of Electrical Engineering (Control, Instrumentation & Automation).

Signature : ....

Name : Dr. Azrita Binti Alias

Date : 19/6/2017

DECLARATION

I declare that this report entitles "A MODIFIED PID CONTROLLER FOR DC-DC BOOST CONVERTER" is the result of my own research except as cited in the reference. The report has not been accepted for any degree and is not concurrently submitted in the candidature of any other degree.

Signature : ....

Name : AHMED ABBAS ALI

Date : 19/6/2017

DEDICATION

To my beloved Mother, Father, Family and Friends

ABSTRACT

Recently, the advancement in power electronic is increasingly growing. Power electronic circuit is a circuit that uses to converter the source energy from one form to another. The utilization of power electronic in nowadays application contributes significantly to produce well-functioning and less complex designed. DC-DC converters are an essential part of power electronic which focus on changing the DC voltage input level whether to higher or lower level. Boost converter is one of DC-DC converters, it's also known as a step-up output voltage. It can be applied to replace the transformer due to more flexible, able to produce a higher output voltage at high efficiency, as well as the building of boost converter is simple and easy to be analyzed, offered at a low price and less noise.

This project aims to design a DC-DC boost converter that will be driven with utilizing Pulse Width Modulation (PWM) where the DC level compared with carrier signal. In addition, Proportional-Integral-derivative (PID) controllers have usually been applied to the DC-DC boost converter due to its simplicity of design. However, this implementation of this control method cause suffers on the dynamic response of boost converter output voltage. Thus, the motive of this project is to modify this PID controller to improve its performance and generate the desired output voltage.

ABSTRAK

Kemajuan dalam kuasa elektronik semakin pesat berkembang. Litar kuasa elektronik adalah litar yang digunakan untuk menukar tenaga sumber dari satu bentuk ke bentuk yang lain. Penggunaan kuasa elektronik pada masa kini menyumbang kepada pengunaan sistem yg ringkas secara optimum. Penukar DC-DC adalah bahagian yang penting bagi kuasa elektronik yang memberi fokus kepada perubahan tahap input voltan DC sama ada tahap yang lebih tinggi atau lebih rendah. Pengubah boost adalah salah satu daripada penukar DC-DC, ia juga dikenali sebagai voltan langkah keluaran. Ia boleh digunakan untuk menggantikan pengubah kerana lebih fleksibel, mampu menghasilkan voltan yang lebih tinggi dan keluaran pada kecekapan tinggi, serta pembinaan rangsangan pengubah adalah mudah dan mudah untuk dianalisis, ditawarkan pada harga yang rendah dan kurang bertindak kepada ganguan luar.

Projek ini dilaksanakan bertujuan untuk mereka bentuk penukar DC-DC rangsangan yang akan dipandu dengan menggunakan pulse lebar modulasi (PWM) di mana tahap DC dibandingkan dengan isyarat pembawa. Di samping itu, pengawal, 'Proportional-Integral-Derivative (PID)' biasanya telah digunakan untuk penukar DC-DC rangsangan kerana kesederhanaan reka bentuk. Walaubagaimanapun, pelaksanaan kaedah kawalan ini menyebabkan masalah pada sambutan dinamik rangsangan penukar voltan output. Oleh itu, tujuan utama projek ini adalah untuk mengubah pengawal PID untuk meningkatkan prestasi dan menjana keluarga voltan yang dikehendaki.

ACKNOWLEDGEMENTS

Firstly, I am grateful that Dr. Azrita Binti Alias is my supervisor for my Final Year Project. Her guidance throughout the period of the final year project is very appreciated. Her patience, motivation, and knowledge guide me to the right track of conducting this project. Her guidance and corrections on writing the thesis have helped me a lot in term of writing a good and qualified technical report. Also, I would like to thank my panels En. Tarmizi Bin Ahmad Izzuddin and Prof. Madya. Dr. Chong Shin Horng.

Secondly, I am thankful to my friends for their enormous assistance and discussion with me throughout this Final Year Project. Through discussion we were able to exchange and share ideas with us, so I gained a lot of meaningful knowledge about my project.

Lastly, I am very thankful to my beloved father, mother and family who give me the courage and confidence throughout the whole research of my Final Year Project. I keep receiving all the support from them to do my best in achieving the success whole university life.

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CHAPTER 1

INTRODUCTION

1.1 Introduction

DC-DC converters are advice that converts an input voltage to lower or higher output voltage. It is a sort of electric power converter. DC-DC converters are used in traditional application such as solar photovoltaic (PVs) system, electric vehicle, DC motor drives, DC power supplies and telecommunication. DC-DC converters use to increase or decrease the output voltage from the lower input voltage. There is three general application of DC-DC converter, the converters are known as boost, buck, and buck-boost converters. Figures 1.1 and 1.2 show the diagram of PVs system and the configuration of DC-DC boost converter, respectively. The proposed of designing DC-DC Boost Converter is to maximize the unregulated DC voltage that is generated by the solar panel to a higher output voltage that required by batteries.

Figure 1.1: The diagram of PVs system

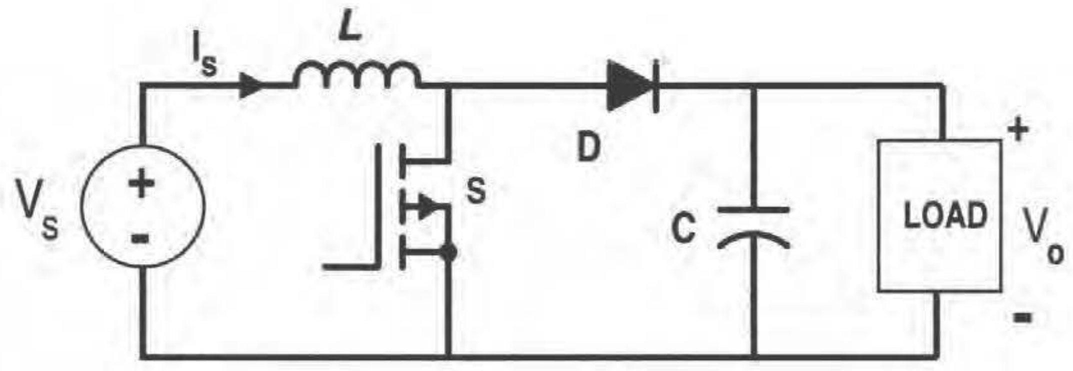

Figure 1.2: DC-DC boost converter

1.2 Motivation

This final year project is based on the title "Modified PID for dc-dc boost converter". Boost converter is also known as a step-down converter where it produces an output voltage that is lower than the input voltage. Modified PID is being design based on the reference from the classical PID. The benefit of modified PID is it helps to ensure a better output response and a more desired output based on the requirement. This DC-DC boost converter is designed specially to boost low voltages. Therefore, it is useful in boosting low solar panel (12V) to higher voltage so that 36Vdc can be generated. At this time, the efficiency is also high and it is cost effective. It is also a transformerless topology. In order to achieve a stable output voltage at the output terminal, a modified PID is added into the design to produce a better output response for the system. This design helps the global by producing a high output voltage based on the demand for usage such as the solar panel by using this design is better than using a transformer which produces lots of heat and energy that will be loss to the surrounding and produces lots noise. This design is more convenient to be used in global and the cost of this design is affordable if compare to use of the transformer.

1.3 Problem Statement

A suitable design of DC-DC boost converter can step-up the voltage from its input supply to its output load. DC-DC converter contains of power semiconductor devices which are operated as electronic switches. The process of the switching devices causes the DC-DC boost converter to be nonlinear characteristic.

A conventional PID control system not able to produces a desired output voltage based on the requirement. Therefore, to improve the system, a modified PID is required instead of classical PID to produce a better output as desired and to enhance the system. DC-DC boost converter and the switching PWM are simulated using MATLAB.

1.4 Objectives

The objectives of this project are:

I. To design a PWM switching manner of DC-DC boost converter.
II. To propose a modified PID as a feedback control system to address issues of step-changes in reference and load for DC-DC boost converter.
III. To compare the system's responses between the conventional cascaded PID and the proposed modified PID controller.

1.5 Scope

The scopes of this project are list below:

i Simulate the DC-DC boost converter that has a specification of V_i=12 and V_o=36.
ii Apply a mathematical Model of DC-DC boost converter.
iii Modeling and simulating the PWM switching manner of DC-DC boost converter.
iv Simulate and design PID controller, and modified PID controller MATLAB/SIMULINK.
v Compare the results of conventional PID and modified PID controllers.

1.6 Report outline

This report contains five chapters. The first chapter explains about introduction which includes the motivation, objectives, and scope of this project. Theory and literature review on DC-DC converters are discussed in chapter 2. In Chapter 3, the methodology of this project is described in detail. Chapter 4 consists of all results obtained. Lastly, Chapter 5 covers the conclusion of the project.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Nowadays, the advancement in power electronic is increasingly growing. Numerous researchers have given a great effort in order to design and develop new and sophisticated power electronic devices that can be utilized in various applications. Power electronics circuits used to convert electric power from one source to anther through converter devices. The circuit of power electronic function consist of a semiconductor as switches, so that, adjusting or operating monitoring a (voltage or current). Power electronics applications domains from high-powered tools, be it dc power transmission, cordless screwdrivers, power supplies for a variety of applications, laptop, hybrid automobiles, and mobile charger[1].

2.2 DC-DC Converter

A DC-DC converter is a circuit that utilized to converts an input DC voltage and generates an output DC voltage. Usually, the output generated is higher or lower compared to the input voltage. Furthermore, DC to DC converters is utilized to provide noise isolation. Figure 2.1 shows the symbol of DC-DC converter. There are three familiar types of DC to DC converter, be it buck, boost and buck-boost converter, they are utilized to step-up or step-down the output voltage [2].

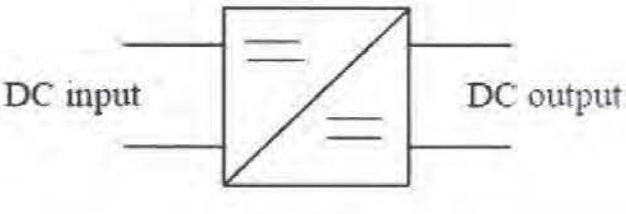

Figure 2.1: Symbol of DC-DC converter

2.2.1 DC-DC Buck Converter

step-down also known as a buck converter is power converter that usually utilized to reduce the output DC voltage to the desired value which will suit a corresponding application. the buck converter is a common non-isolated power stage topology. The buck converters can convert a voltage input 7volts into a lower adjusted output voltage classically to 0.4volts. the main component of Stepdown converters circuit is a diode, a switch, at least one inductor and capacitor. those basic components are able to transfer small packets of energy. Buck converters in most situations propose higher efficiency. The power switch connected in series with power supply, while the diode is connected in parallel. The buck converter can work in different methods; discontinuous and continuous mode. Figure 2.2 shows the circuit of buck converter [3].

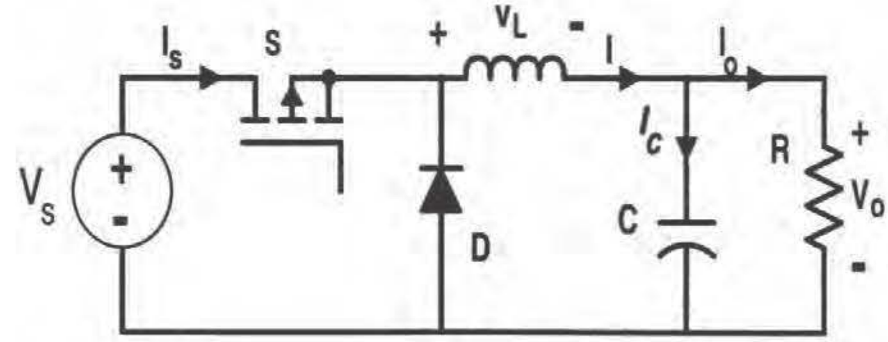

figure 2.2: The circuit of buck converter

2.2.2 DC-DC Boost Converter

Boost converter or voltage step-up converter is the converter that uses to step-up the voltage of DC supply to meet the required voltage demanded by selected application. Its powerful device which can easily increase 12V DC in Photovoltaic (input voltage source) to 30-36V required by the battery charger. The boost is a common non-isolated power stage topology, the main component of step-up converters circuit is a diode, a switch, at least one inductor and a capacitor, the basic construction of this components is quite simple, boost converter uses inductor and diode in series with DC supply while a power switch connected parallel. Figure 2.3 shows the diagram of boost converter [4].

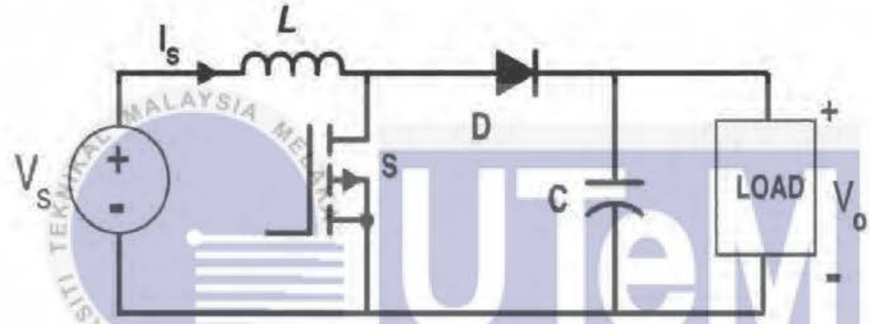

Figure 2.3: The block diagram of boost converter

2.2.3 DC-DC Buck-Boost Converter

Step-up/down also known as a buck-boost converter is power converter that usually applied to step-up or step down the output voltage, it is a sort of DC to DC converters that combine two functions of boost and buck converters in one circuit. Figure 2.4 shows a block diagram of the buck-boost converter, the construction of buck-boost converter circuit is that the power switch (IGBT) connected in series with power supply voltage and the inductor connected in parallel, while the capacitor connected in parallel to the load. [5].

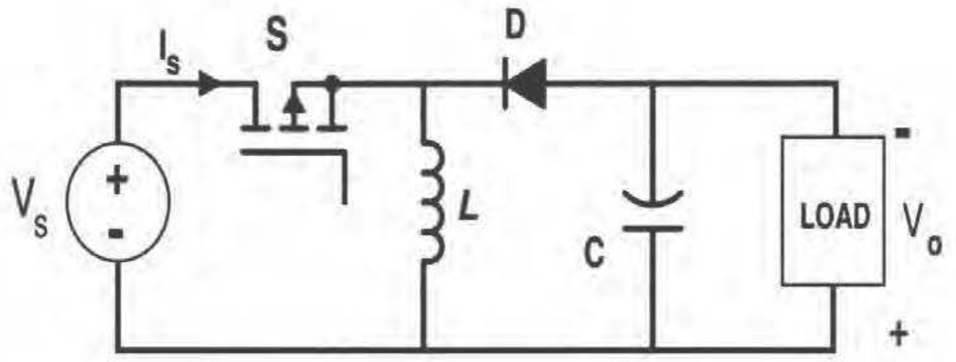

Figure 2.4: The block diagram of the buck-boost converter

2.3 Pulse Width Modulation DC-DC Converters

Pulse Width Modulation (PWM) is a technique which converts an analog signal into digital signal. Pulse Width Modulation (PWM) signals have been widely employed in power electronic applications, there are many uses for PWM include Telecommunications, DC motors, RC devices, Audio/video effects, Voltage regulation and LED (increase and decrease the brightness). The idea of high (1) and low (0) that PWM signally produces is the remarkable approach of controlling semiconductors switches. DC-DC converters are power converter which converts a DC sources from one voltage level to anther lever (higher or lesser) simply by changing the duty cycle of the power switching in the converter circuit [6]. Figure 2.5 shows Pulse Width Modulation (PWM) generation.

A duty cycle can be expressed as the percentage of one period in which a signal is active. A period is a time it takes for the signal to complete an ON and OFF cycle. A duty cycle expressed as:

$$D = \frac{T}{P} \times 100\%$$

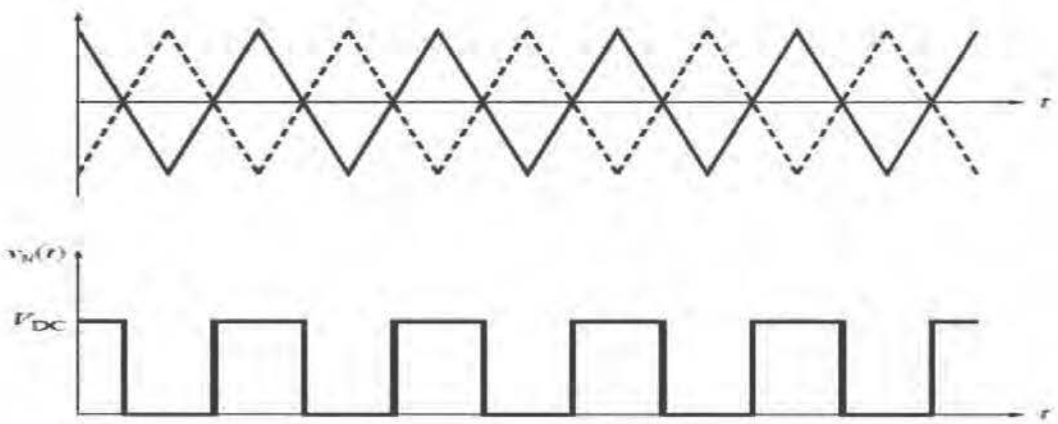

Figure 2.5: Pulse Width Modulation (PWM) generation

2.4 Feedback controller

Feedback controller can be defined as a target assigned to one or several state-variable such is output. A circuitry monitors the output voltage deviations with respect to the input voltage and output currents. If the output voltage deviates from its target, an error is created and fed-back to the power stage for action. The action is a change in the control variable: duty cycle (VM), peak current (CM) or the switching frequency. Such a control system is necessary if it is desired to change the output voltage set point, or if the system conditions change (e.g. input voltage source changes, load changes, etc). The most popular feedback controller used in DC-DC converter is the frequency response. The main function of feedback controller is to compensate the converter shortcomings[7].

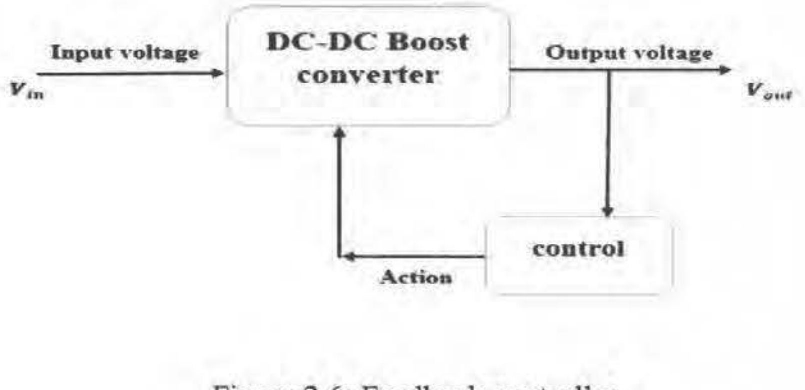

Figure 2.6: Feedback controller

2.5 PID Controller

PID controller is the one of the most common close-loop controller often utilized in industry. PID controller utilize a three main performance types P (proportional) for an overall control action, I (integral) to reduces steady-state errors and D (derivative) is seldom used on it' s own in control systems it utilized to improves transient response. PID control is one of the oldest and classical controllers used for the boost converter. due to the various advantage of PID, it is widely used for industrial applications in the power electronic field. It uses one of the controllers including P, PD, PI, and PID. The PID utilized to develop the overshoot, transient response, and steady state error. The PID combining proportional, integral, and derivative together to get a stable output. It provides excellent control behavior of boost converter by obtaining the gain value of P, I and D. Figure 2.7 shows the circuit of PID controller[8].

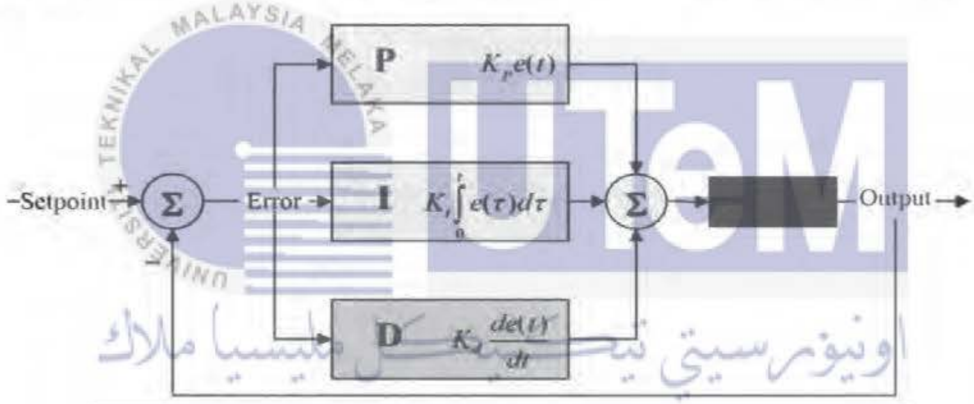

Figure 2.7: PID Controller

2.6 Tuning of loop

As one knows the controlled process input can be unstable when the PID controller parameters such as the proportional gain, integral gain, derivative gain when they are not chosen correctly. Tuning a controller is just the adjustment of the control parameter to an optimum value to obtain the desired control response. Generally, the stability of the output response is required but at the same time the process must no oscillate for other combination of process condition and set point. There are different methods for tuning PID loops such as the Ziegler-Nichols, tune by feel, software tools and also the Cohen-coon method. All these methods have their own advantages and also its disadvantages as done by previous researches[9]. Table 2.1 shows the effect of parameters.

Table 2.1: The effects of increasing the parameters

Parameters	Rise time	Overshoot	Settling time	Steady-state error
Proportional gain	low	high	Small change	low
Integral gain	low	high	high	Eliminate
Derivative gain	Small change	low	low	None

2.7 Ziegler-Nichols method

Ziegler-Nichols method, introduced by John G. Ziegler and Nathaniel B. Nichols. As in Ziegler-Nichols tuning method, the I and D gains are first set to zero. The "P" gain is increased until it reaches the "critical gain" Kc at which the output of the loop starts to oscillate as shown in figure 2.8 [10]. Kc and the oscillation period Pc are used to set the gains as shown in the table below.

Table 2.2: Ziegler-Nichols Method

Control type	K_p	K_i	K_d
P	0.5Kc	-	-
PI	0.45Kc	1.2Kp/Pc	-
PID	0.6Kc	2Kp/Pc	KpPc/8

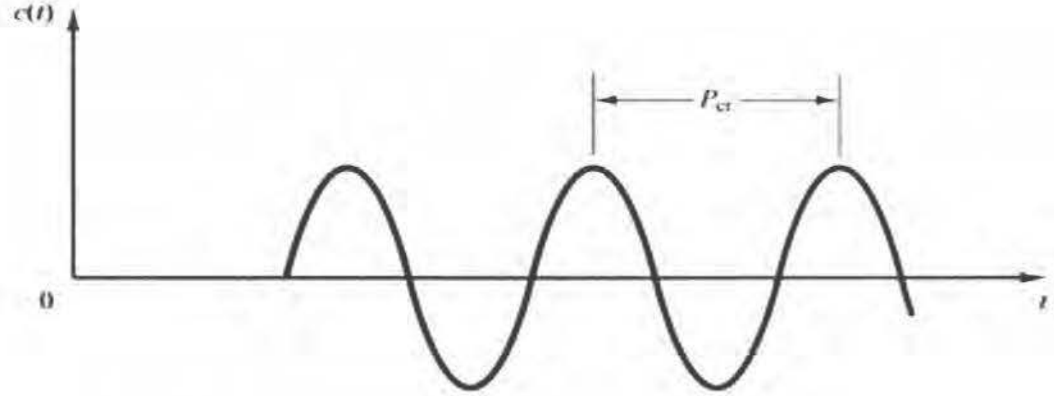

Figure 2.8: Sustained oscillation with period P_c

2.8 Modified PID Controller

The position of integral action has remained unchanged on a forward path which affects the difference of reference signal and the feedback signal. Though, derivative and proportional actions have changed on a feedback path to affect only the output signal. The purpose is to force the system's output to follow a given bounded reference value.

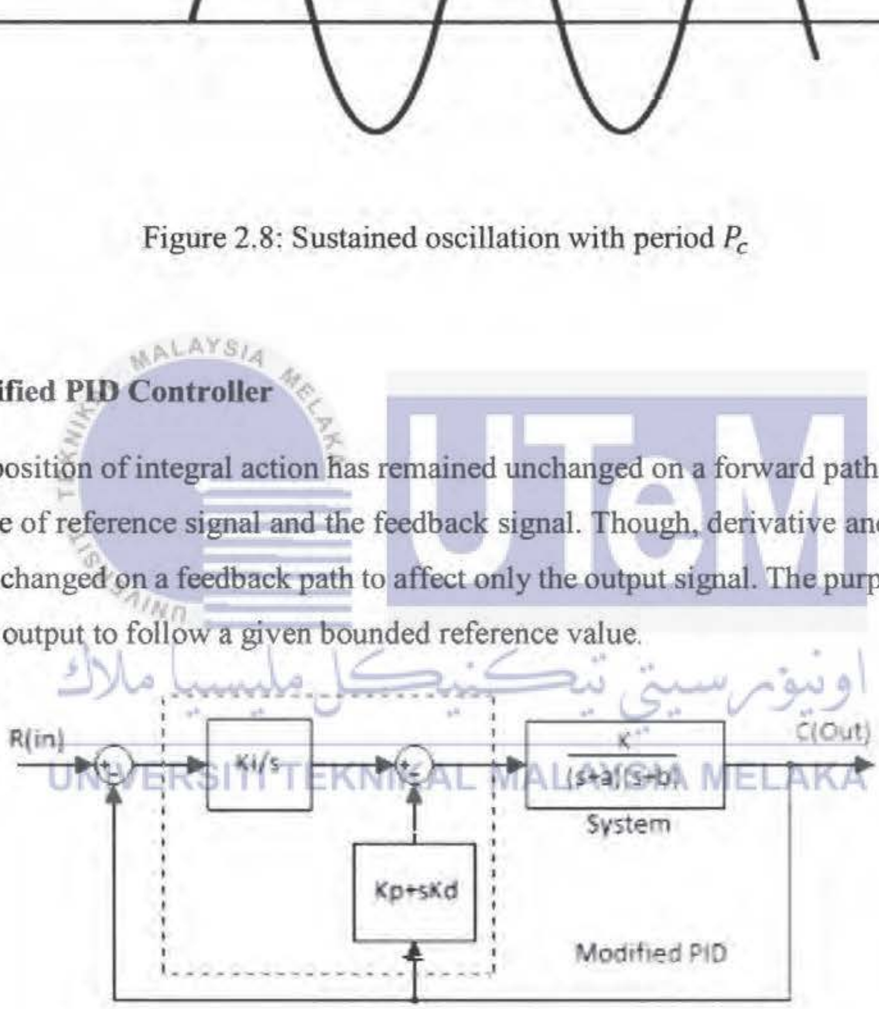

Figure 2.9: Modified PID controller

The modified PID controller can be expressed as follow:

$$G_C(S) = \frac{K_{i-SK_P-S^2K_d}}{S}$$

It is hard to adjust the system response due to two zeros in the system with conventional PID controller. The effect of two zeros occurs as higher overshoot. The response by adding proportional and derivative blocks of PID on feedback path instead of on forward path. Therefore, a better solution of system response is achieved in modified PID in comparison with conventional PID [11].

2.9 Previous related works

Nowadays, DC-DC converters have received a great attention by researchers and industry to utilize them in the power electronic due to their dramatic expansion of renewable energy sources, advantage features and their ability to produce a simple and good functionality design. The boost converter is a particular one of the DC-DC converters which could be utilized to rise-up the small input DC to higher output DC voltage. in order to get maximum performance and stability of designed system, various type of controller have been used.

In [12], a Fractional Order PID designed to drive boost converter. The controller can't derive a suitable start-up response. small overshoot and a good settling time are the main characteristics for a suitable start-up response. Numerous nonlinear controller techniques like H_∞ control, fuzzy control, μ analysis and synthesis control could be applied, PID controllers fit to ruling industrial controllers. Normally the techniques to develop the traditional PID controllers involved the usage of fractional order controllers within non-integral and integral derivation parts. the research concludes by proposing FOPID controller for Boost converter may give a better robustness and a better dynamic response with a perfect start-up response.

While in [13], PID controller designed for solar power system used boost converter with PID control, system requirements to convert the inconstant dc output voltage of a solar power into a stable output voltage that will be sent into the connected part. Boost converter (step-up converter) is the converter that uses to rise-up the output of DC supply. therefore, a boost converter is needed to rise up the output voltage. Hence, in order to regulate the output voltage that could be done by modifying the duty cycle that will be supported by PID controller. According to the experimental results, by implementing the Ziegler-Nichols Technique, the output voltage remains constant for any variation in the input voltage.

Moreover, in[14], a new explanation to drive boost converter that shows Inverse Response because of the existence of Right Hand Side Zero, require a limit on the possible closed-loop bandwidth of the driven thus the controller gain K will be minimized. Different methods are suggested to design a PID controller such Ziegler-Nichol's (Z-N), as Internal Model Control (IMC), Synthesis and Equating Coefficient, which can be utilized to control the boost converter. The study concludes that Synthesis controller is the best controller in term of settings, very less ISE value and reducing overshoot.

Recently in[15], a new technique is proposed for optimal of modified PID and PID converter, it is important to design a converter to provide an output voltage that must qualify appropriate steady state error and transient response. The problem of adjustment of the output voltage have been an issue, in order to control the converters there are different methods are easily designed and are simple but are not effective and robust, while some others can be effective but there are too complicated to implement such as neural network control, intelligence techniques, and model predictive controller. The research concludes by combines the advantage of LT spice for simulation of converters using actual components with artificial intelligence.

2.10 Summary

To sum it up, this chapter introducing about DC-DC converter concept, also by introduce three common type of DC-DC converters, buck, boost, and buck-boost. The detail of each converter of buck, boost and buck- boost converter include the circuit construction has been discussed. The advantage of this dc-dc converter is very useful in our daily life such as in portable electronic devices such as cellular phones and laptop computers. Moreover, the control strategies utilized in these converters was discussed as well. The modified PID controller helps to produce a better output of the Dc-Dc Boost converter. Lastly, a review of previous works has been discussed.

CHAPTER 3

METHODOLOGY

3.1 Introduction

From the literature review, DC-DC converters are electronic circuits utilized to change the input DC voltage from one level to another, there is three popular type of DC-DC converters like a buck, boost, and buck-boost converters are available in the industry. Each one of them has its own ability to step-up or step-down the output voltage.

The boost DC-DC converter is chosen to be the focus of this project. The simulation design is developed in MATLAB/SIMULINK to verify the operation of DC-DC boost converter one voltage level to another.

The methodology of this project has been divided into two parts: final year project1 is about Design and analyze boost converter circuit and final year project 2 is about analyze and compare modified PID with conventional PID as shown in figure 3.1, while Figure 3.1 shows the flowchart of this project.

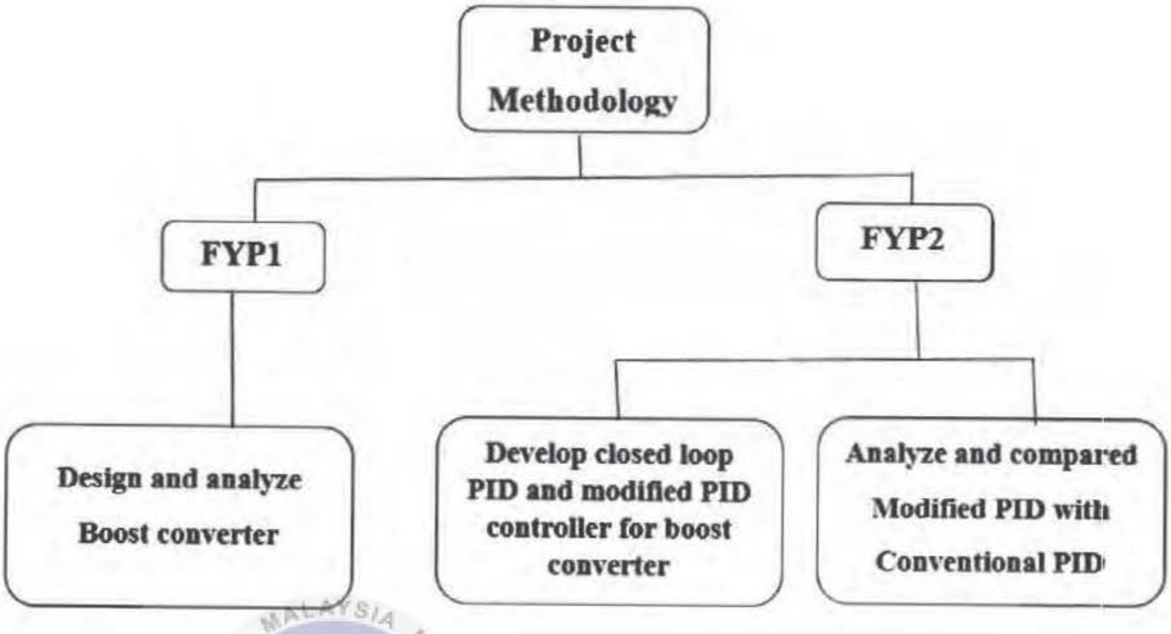

Figure 3.1: Project Methodology

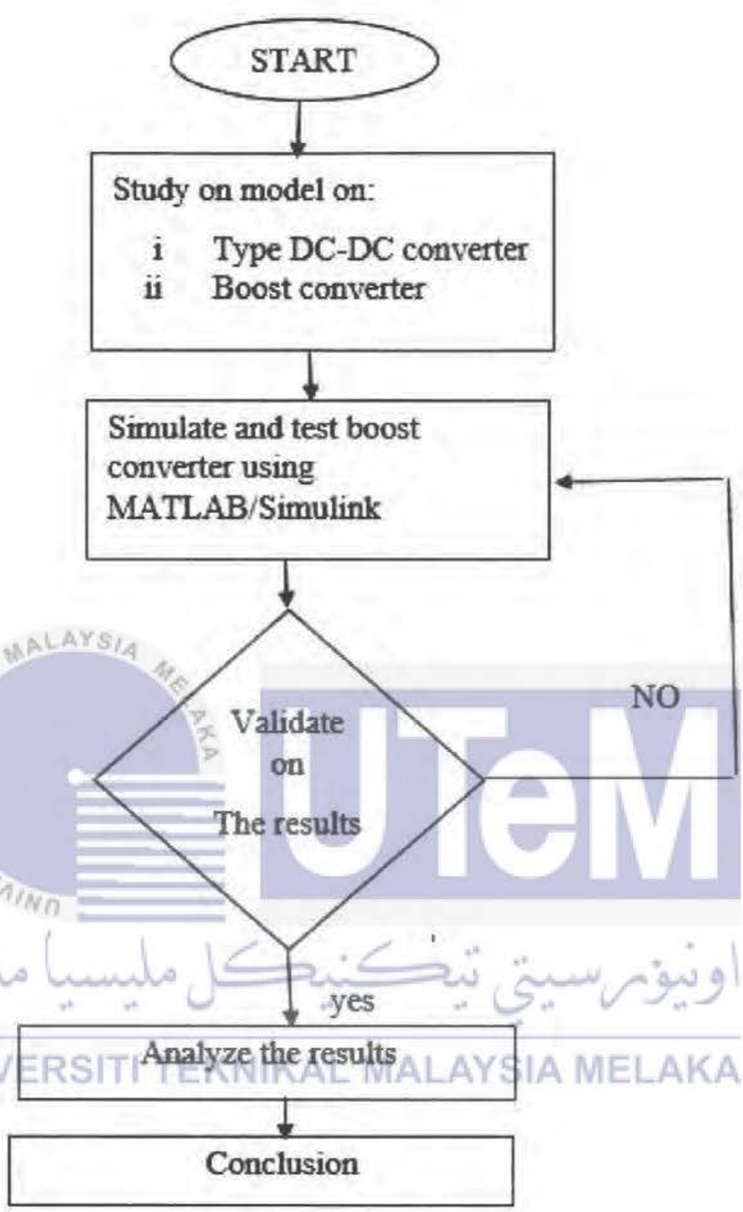

Figure 3.2: Project Flowchart

3.2 Principle operation of boost converter

A boost converter containing at least two semiconductors (a diode and a transistor) and at least one energy storage element, a capacitor, inductor, or the two in combination. the analysis relationship between inductor voltage and current assumes as:

- The capacitor very large, and the output is held constant at voltage Vo.
- The circuit is operating in steady state.
- The inductor current is always positive.
- The switching period is T, the switch is closed for time DT and open for (1-D) T.
- The components are ideal.

The main principle of the boost converter is that could be operated by periodically opening and closing an electronic switch. Figure 3.3 shows the boost converter with its open and close switches.

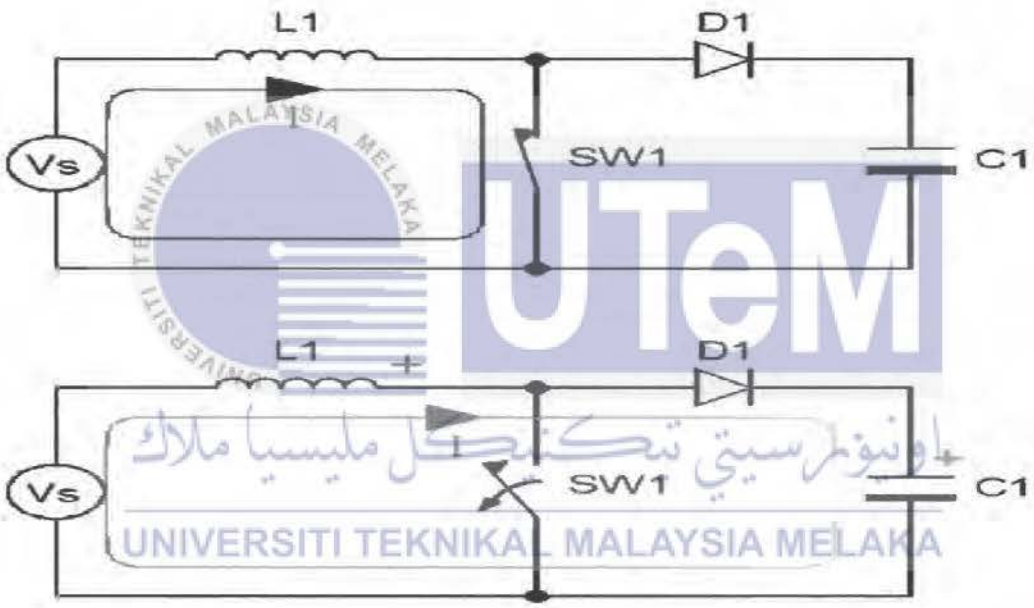

Figure 3.3: Boost converter with open and close switches

- **switch closed, diode off**

The diode basically prevents the capacitor from discharging. When the switch is closed current flow from input into inductor straight to the ground. If the switch keeps close for a very long time basically there will be a short circuit through the inductor, hence the switch is going to be close for fraction of a second. The switch going to be close long enough for some current to start flowing through the inductor, this process storing energy into inductor in the form of magnetic field. Now there is some current flowing through the inductor, therefore there is some energy stored in the inductor, the switch quickly will be open. By referring to figure 3.4 and the waveform in figure 3.5 the voltage across the inductor will be equal to the input voltage which can be express in equation 3.1

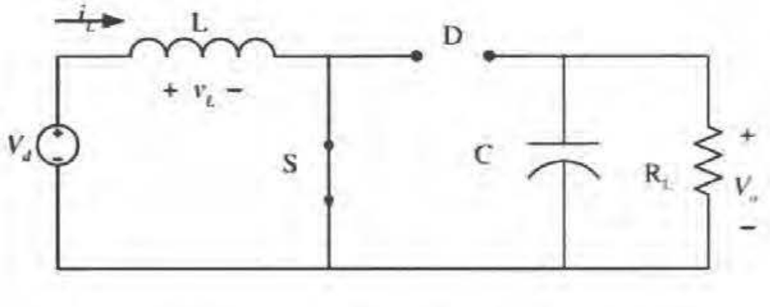

Figure 3.4: Boost converter with close switches

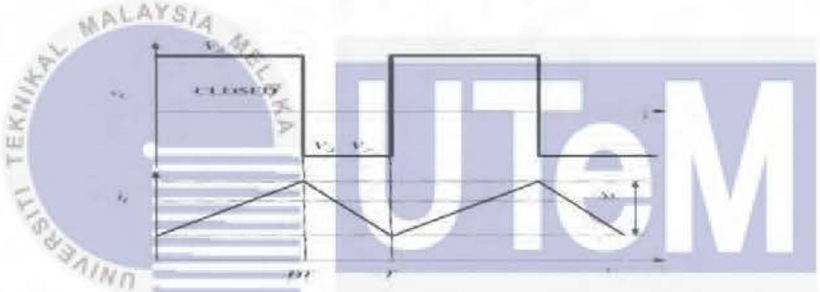

Figure 3.5: Boost converter waveform of inductor voltage and inductor current

$$V_L = V_D$$

$$V_L = V_s \quad (3.1)$$

where

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

Also, the derivative is the changes in the current with time so

$$\frac{di_L}{dt} = \frac{V_D}{L}$$

$$\frac{di_L}{dt} = \frac{\Delta i_L}{\Delta i_t} = \frac{\Delta i_L}{DT}$$

$$\frac{di_L}{dt} = \frac{V_D}{L}$$

Hence

$$(\Delta i_L)_{CLOSED} = \frac{V_D DT}{L} \tag{3.2}$$

❖ **switch open, diode on**

when the power switch is open, the current coming from the supplied will flow through the inductor, through the diode, so energy gets transferred from the inductor to the output capacitor and the voltage increases, our boost converter now has boosted the voltage. Furthermore, figure 3.6 shows boost converter when switch is open, while figure 3.7 shows the waveform of inductor voltage and inductor current

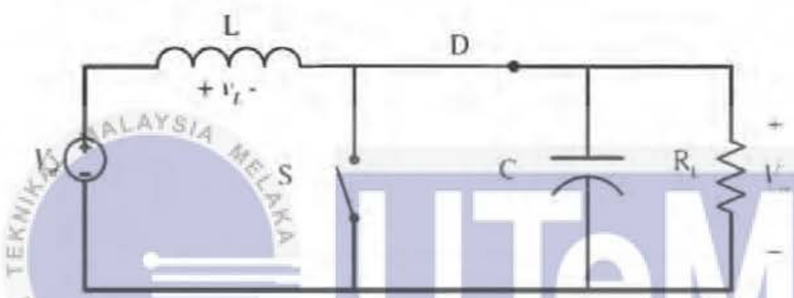

Figure 3.6: Boost converter switch open

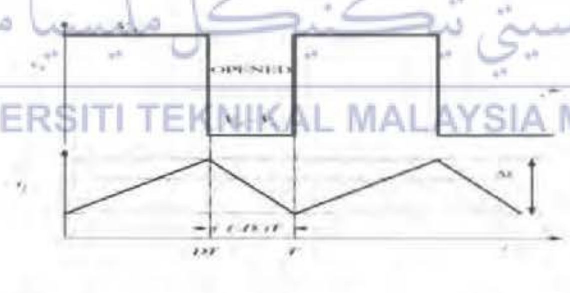

Figure 3.7: Boost converter waveform inductor voltage and inductor current

$$V_L = V_D - V_O$$

where

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

Also, the derivatives are changes in the current with time so

$$\frac{di_L}{dt} = \frac{V_D - V_O}{L}$$

$$\frac{di_L}{dt} = \frac{\Delta i_L}{\Delta i_t} = \frac{\Delta i_L}{(1-DT)}$$

$$\frac{di_L}{dt} = \frac{V_D - V_O}{L}$$

Hence

$$(\Delta i_L)_{OPENED} = \frac{(V_D - V_O)(1-D)T}{L} \tag{3.3}$$

To obtain the value of output voltage of boost converter by combine equation (3.2) and (3.3)

$$(\Delta i_L)_{OPENED} + (\Delta i_L)_{CLOSED} = 0$$

$$\frac{(V_D - V_O)(1-D)T}{L} + \frac{V_D DT}{L} = 0 \tag{3.4}$$

Rearranging equation (3.4) yield:

$$V_O = \frac{V_s}{1-D} \tag{3.5}$$

Average, Maximum and Minimum Inductor Current

Input power = output power

$$V_d I_d = \frac{V_O}{R}$$

$$V_d I_L = \frac{(\frac{V_D}{1-D})^2}{R} = \frac{{V_D}^2}{(1-D)^2 R} \tag{3.6}$$

From equation (3.6) the Average inductor current will be:

$$I_L = \frac{V_D}{(1-D)^2 R} \tag{3.7}$$

Maximum current:

$$I_{max} = I_L + \frac{\Delta i_L}{2} = \frac{V_D}{(1-D)^2 R} + \frac{V_D DT}{2L} \tag{3.8}$$

Minimum inductor current:

$$I_{min} = I_L - \frac{\Delta i_L}{2} = \frac{V_D}{(1-D)^2 R} - \frac{V_D DT}{2L} \qquad (3.9)$$

L and C values:

$$I_{min} \geq 0$$

$$L_{min} > \frac{D \times (1-D) \times V_{in}}{2f \times I_{out}} \qquad (3.10)$$

Ripple factor:

$$r = \frac{\Delta V_O}{V_O} = \frac{D}{RFC}$$

Output Voltage Ripple.

The peak-to-peak output voltage ripple can be calculated from the capacitor current waveform, shown in Figure 3.8.

Figure 3.8: The capacitor output current

$$|\Delta Q| = \left(\frac{V_O}{R}\right) DT = C\Delta V_O$$

Therefore, the ripple voltage ΔQ become

$$\Delta V_O = \frac{V_O DT}{RC} = \frac{V_O D}{RCf}$$

$$\frac{\Delta V_O}{V_O} = \frac{V_O D}{RCf} \qquad (3.11)$$

where f is the switching frequency. Alternatively, expressing capacitance in terms of output voltage ripple yield

$$C = \frac{D}{R(\frac{\Delta V_O}{V_O})f} \qquad (3.12)$$

3.3 Transfer function of boost converter

Based on the knowledge obtained in electric circuit theorem applied in order to calculate the transfer function for a boost converter, it can be calculated by referring to figure 3.3 that shown Boost converter when the switch is open.

$$V_{in} = I(Ls + R_1 + \frac{1}{Cs} + R_2)$$

$$V_{in} = \frac{I(Ls + R_1 + \frac{1}{Cs} + R_2)}{S} \qquad (3.13)$$

$$V_O = I(\frac{1}{Cs} + R_2)$$

$$I = \frac{V_O}{(\frac{1}{Cs} + R_2)}$$

$$I = \frac{V_O s}{(\frac{1}{C} + R_2 s)} \qquad (3.14)$$

From equation 3.13 and 3.14 the transfer function of boost converter will be

$$\frac{V_o}{V_i} = \frac{(\frac{1}{C} + R_2)}{(Ls^2 + (R_1 + R_2)s + \frac{1}{C})}$$

3.4 Response Characteristics

The most important transient response parameters are indicated in Figure 3.9. These parameters are defined as follows:

- Rise time, Tr. The time required for the waveform to go from 0.1 of the final value to 0.9 of the final value.
- Peak time, T_P. The time needed to reach the peak value.
- Percent overshoot, %OS is stated as a percentage of the steady-state value, refers to an output greater than its steady-state value.
- Settling time, T_S. The time required for the response to reach and within a certain range about (two presents to five present).

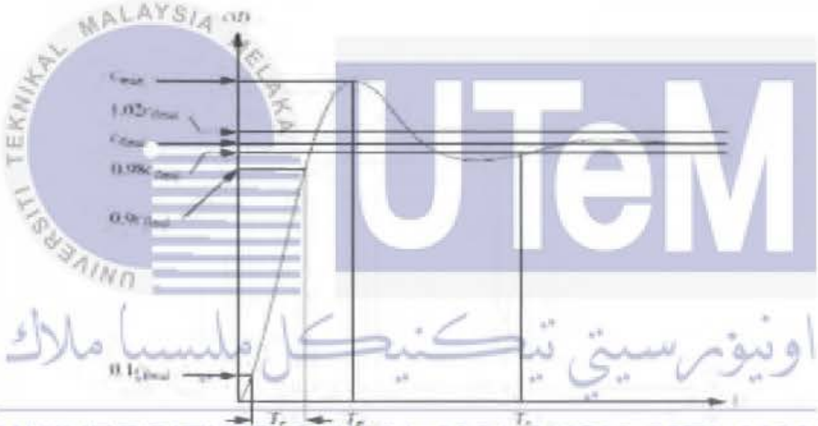

Figure 3.9: Second-order underdamped response

From Figure 3.9 the percent overshoot, %OS, is given by

$$\%OS = \frac{C_{max} - C_{Final}}{C_{Final}} \times 100 \tag{3.15}$$

Damping ratio is given by:

$$\zeta = \frac{-\ln(\frac{\%OS}{100})}{\sqrt{\pi^2 + \ln(\frac{\%OS}{100})^2}} \tag{3.16}$$

Peak time is given by:

$$T_P = \frac{\pi}{\omega_n\sqrt{1-\zeta^2}} \tag{3.17}$$

Settling time is given by:

$$T_s = \frac{4}{\zeta\omega_n} \tag{3.18}$$

3.5 Simulation development

The simulations have been done by considering the assumptions of:

- The value DC voltage source is 12 volts.
- Ideal power switch used is IGBT.
- The fundamental frequency is 20kHz.
- The main DC-DC converter used is boost converter.

3.6 Boost converter design (open loop)

Boost converter is the converter that uses to step-up the voltage of DC supply to meet the required voltage demanded by selected application. Figure 3.10 shows the design of boost converter using MATLAB software. In the boost converter circuit, a Pulse Width Modulation PWM stored in MATLAB was utilized to provide a gating signal to semiconductor IGBT.

The duty cycle of the boost converter is produced by comparing a constant duty cycle with the triangle wave, it is utilized to control the output voltage.

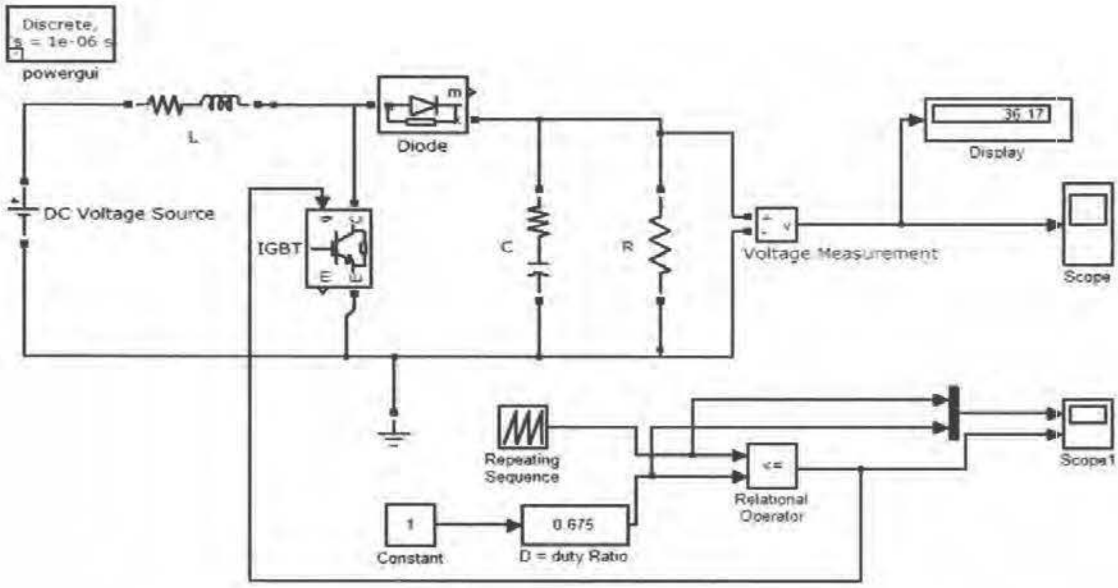

Figure 3.10: The design of boost converter using MATLAB

3.7 Boost converter design with a Fixed duty cycle

The open circuit of boost converter shown in figure 3.10 in which the duty cycle of boost converter is produced by comparing a constant duty cycle with the triangle wave. In the open loop design, the output has no relationship to produce the duty cycle, however, the duty cycle equation expresses by $D = 1 - \frac{V_i}{V_o}$. Hence the duty cycle redesigned to include the output and input voltage to produce the duty cycle. Figure 3.11 shows circuit design of boost converter with fixed duty cycle, which includes the input and output voltage as references

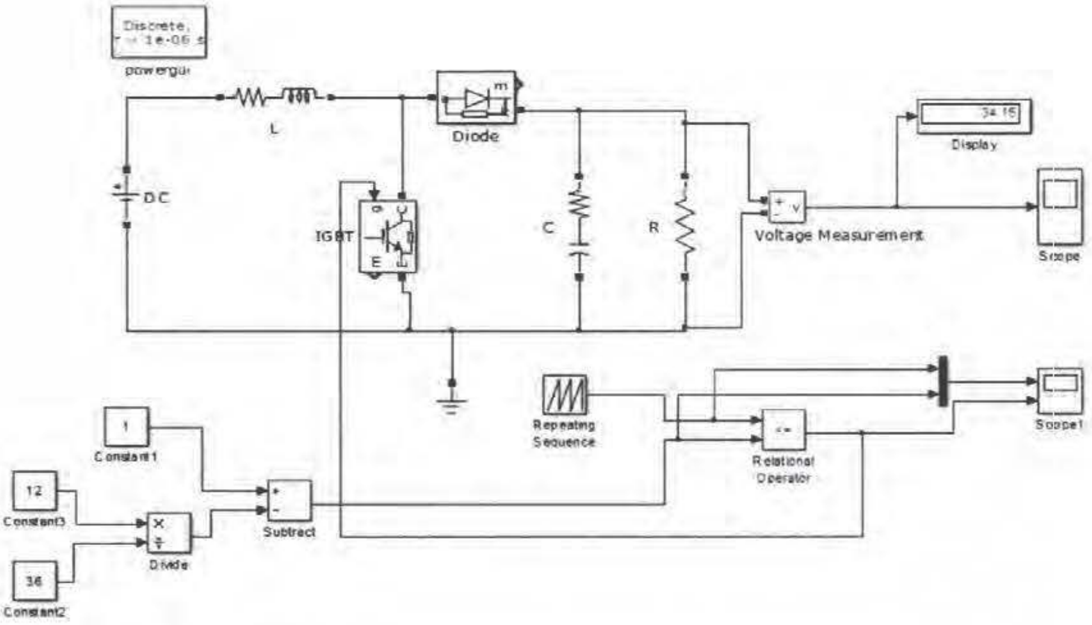

Figure 3.11: Boost converter design with fixed duty cycle

3.8 Control Mechanism of boost converter

Pulse Width Modulation PWM is a common tool for controlling power electronic. The concept of ON (1) and OFF (0) that an ideal PWM produces is a remarkable approach to controlling semiconductors switches. A boost converter implements one power semiconductor switch (IGBT) connected in parallel with DC source, the main advantage of utilizing PWM signal to trigger ON or OFF cycle of IGBT in sequence. Figure 3.12 shows the Pulse Width Modulation PWM circuit utilized to produce a gating signal to drive the IGBT.

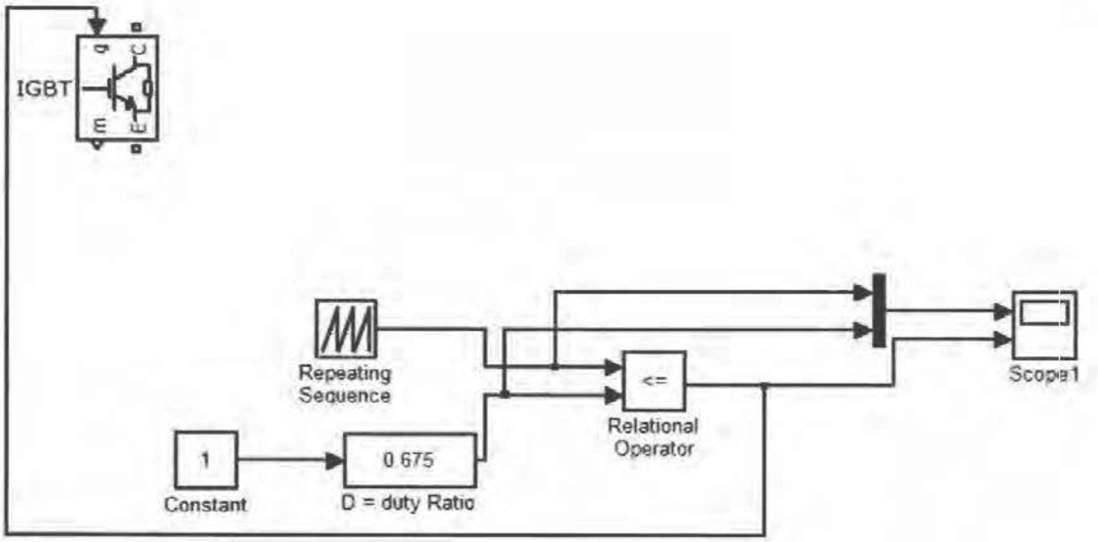

Figure 3.12: PWM circuit for boost converter

3.9 Boost converter by changing R Load Value

The aim of this project is to design a boost converter by adding different parameters and controllers to observe the changes in the output and obtain the best design circuit. In the main design of the boost converter R load is fixed in the design. In this section, additional Resistance R2 will be connected in parallel with R1 as, so the value of the load varied in order to observe the changes in the output voltage. R1 and R2 are selected to be 10ohms and 20 ohms.

The circuit design of boost converter by changing the R load value is shown in figure 3.13. A breaker is connected and set from open and then close in t secs. So, the R load will change from 10 to 6.67 ohms.

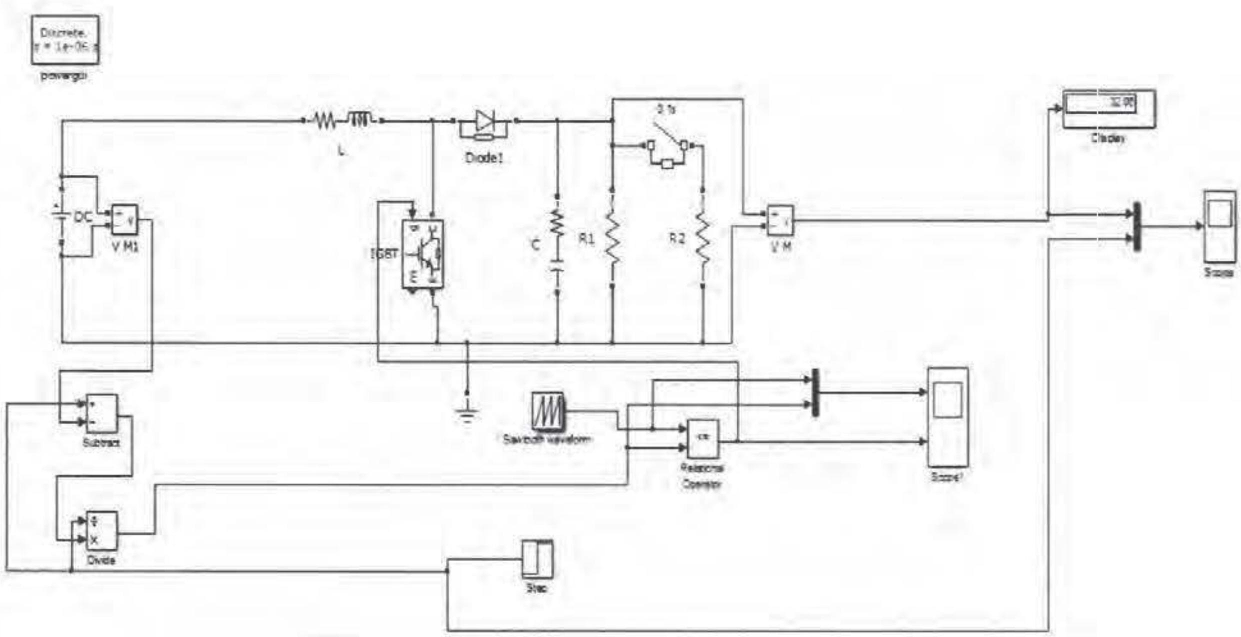

Figure 3.13: Boost converter design with additional Resistance R load

3.10 PID controller

Normally, the duty cycle for boost converter is considered in between 0.5 to 1. Selection of duty cycle depends on input voltage supply and required output voltage. When boost converter used PID controller it gives high steady state error. Using conventional Ziegler-Nichols can't give the desired output voltage. Therefore, A Modified PID controller is needed. Figure 3.14 shows PID controller of boost converter.

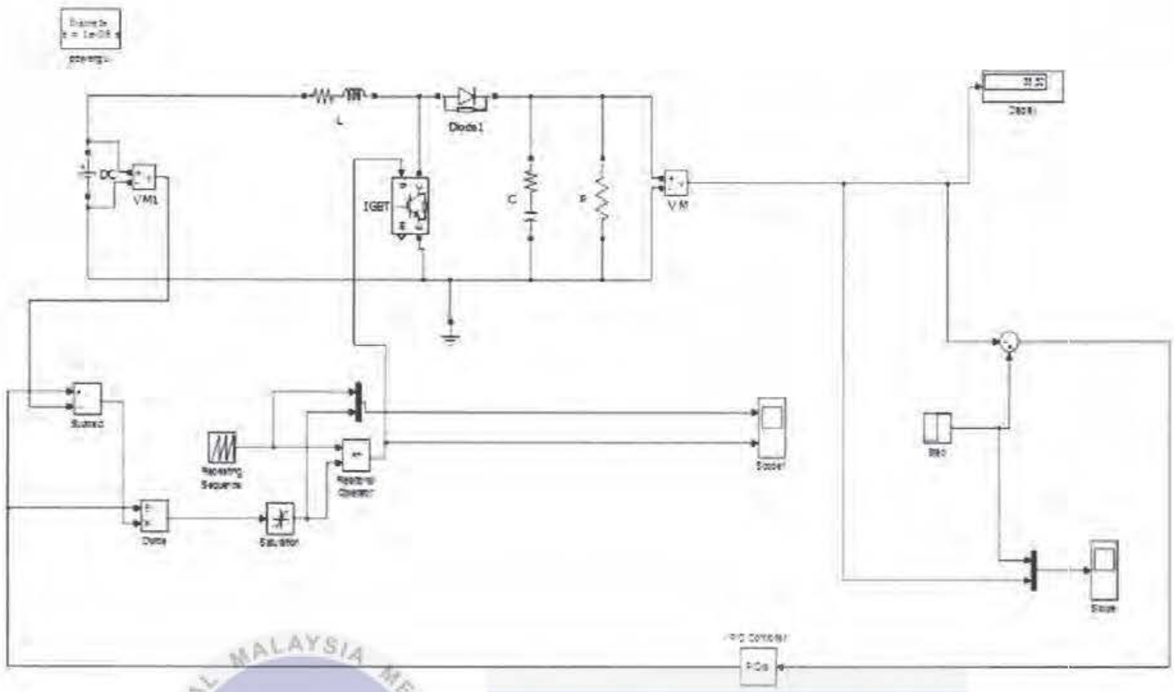

Figure 3.14: PID controller for boost converter.

3.11 Modified PID Controller

Modified PID means by ones separate the characteristics in a PID. Modified meaning by changing classical PID controller. There are many ways in modifying PID controller such as by remaining the proportional and integral action and moves the derivative action to the feedback this modification is known as PI-D controller as shown in figure 3.15 another method by remaining the proportional and derivatives action and moves an integral part to the feedback this modification is known as PD-I controller as shown in figure 3.16. One method used in this final year project is by remaining an integral part of the system and then the derivative action moves to the feedback path so that any change in reference input signal may not involve in the manipulated signal this modification is known as I-D controller as shown in figure 3.17. A modified PID controller for DC-DC boost converter using MATLAB/SIMULINK shown in the figure 3.18.

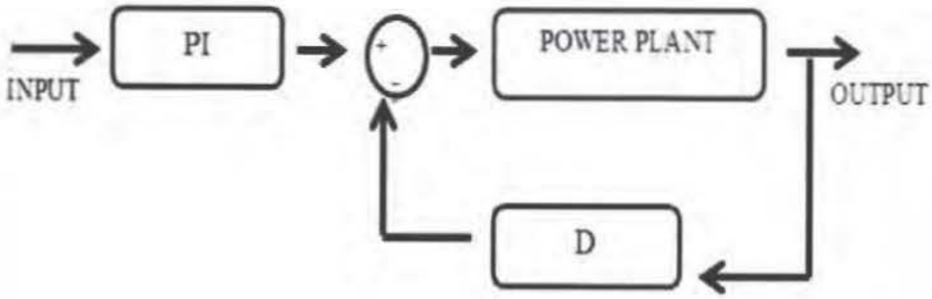

Figure 3.15: The control architecture for PI-D

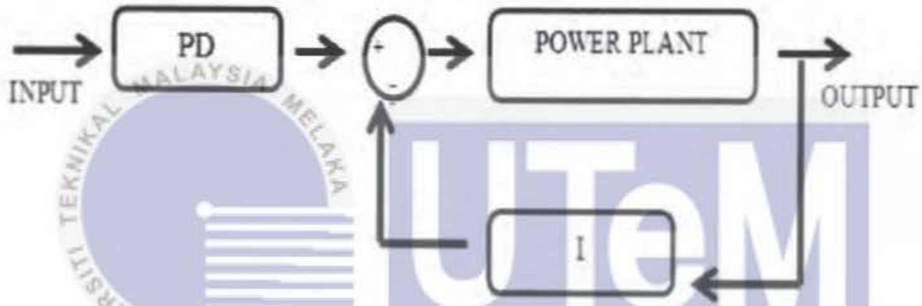

Figure 3.16: The control architecture for PD-I

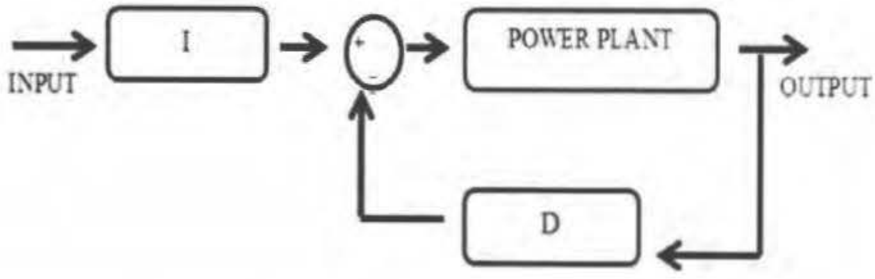

Figure 3.17: The control architecture for I-D

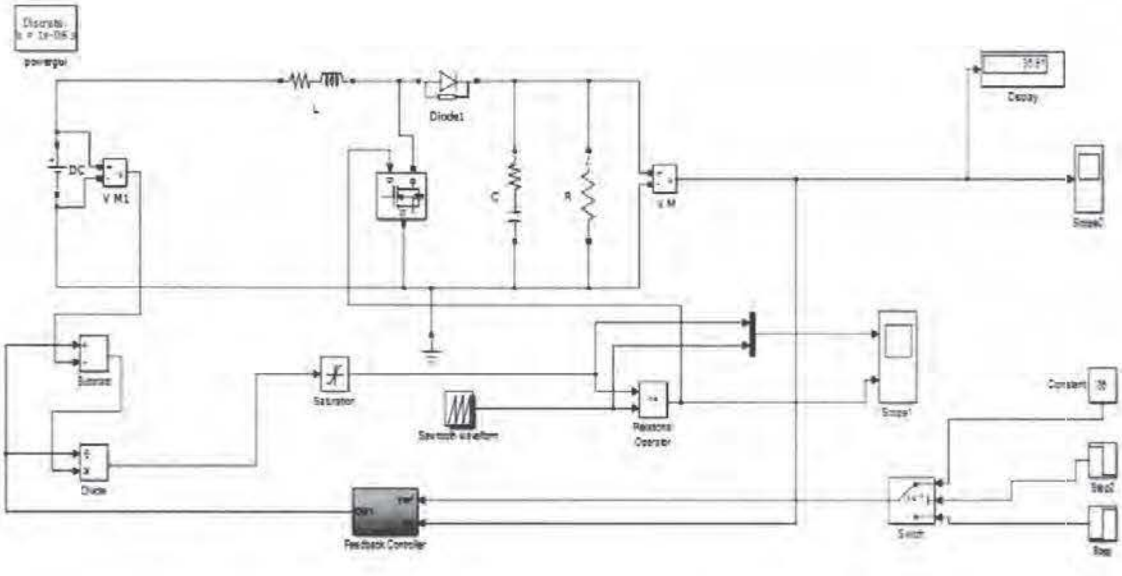

Figure 3.18: Modified PID controller of boost converter

The advantage of Modified PID is to prevent earlier peak and higher overshoot. Besides that, the proposed modified PID controller can also help to prevent negative effect as well as to ameliorate system response with a comparison to the classical type of PID.

3.12 Summary

To summarize, this chapter presents a flowchart that shows the sequence implementation of this project. Theoretical knowledge about boost converter when the circuit works in On and Off switch. the derivation equations for the inductor, capacitor, duty cycle and inductor current when the switch is an open and closed switch. the derivation equations for the transfer function of boost converter. Theoretical knowledge about different types of a modified PID controller.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

The performance of the output voltage of boost converter is analyzed using MATLAB/SIMULINK.

This chapter particularly presents the results of the simulation generated for the boost converters when subject to parameter variations. The parameters considered in the simulation are shown in table 4.1.

Table 4.1: Parameters are considered

Parameter	Value
Frequency	20KHz
input voltage	12Volts
output voltage	36Volts
Resistor	10ohm
Duty cycle	0.67
Inductance	70μH
Capacitance	100μF
Switch	IGBT

The duty cycle is calculated for value of input voltage is 12 volts and the output voltage is 36 volts by applying the equation (3.5).

$$D = 1 - \frac{12}{36} = 0.666$$

$$I_{out} = \frac{12}{10} = 1.2\ A$$

While inductor and capacitor are obtained by equation (3.10) and (3.12).

$$L_{min} > \frac{0.66(1-0.66)\times 12}{2\times 20{,}000\times 1.2} = 56.1\mu H$$

$$C = \frac{0.67}{10\times 0.03\times 20{,}000} = 100\mu F$$

Therefore, in this project, the value of the capacitor and inductor will be chosen as 70μH and 100μF to produce a suitable output voltage.

4.2 Simulation Results

The simulation results in DC-DC boost converters have been done for open loop and closed using PID and modified PID controllers to analyze its performances.

4.3 Boost Converter (Open Loop)

The boost converter is the main converter utilized for this project. Hence a detailed analysis will be presented. The comparison of the carrier with DC voltage is shown in figure 4.1. The modulated PWM gating is presented in figure 4.2.

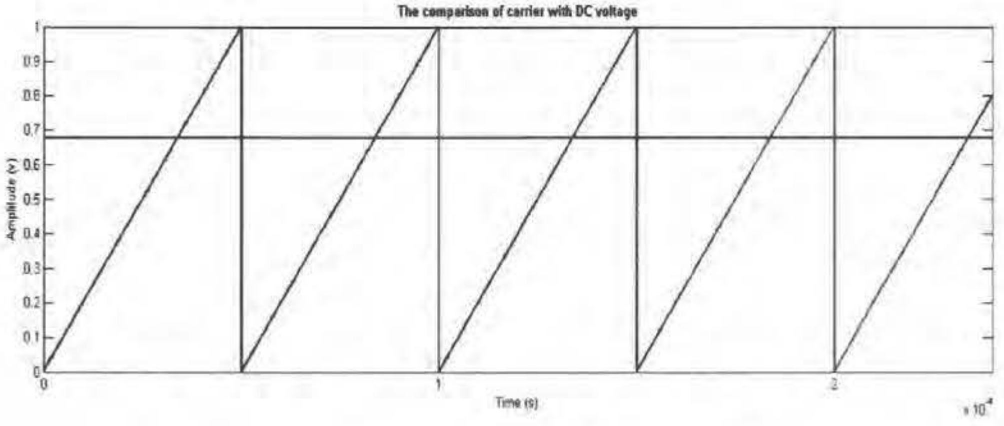

Figure 4.1: The comparison of carrier with DC voltage

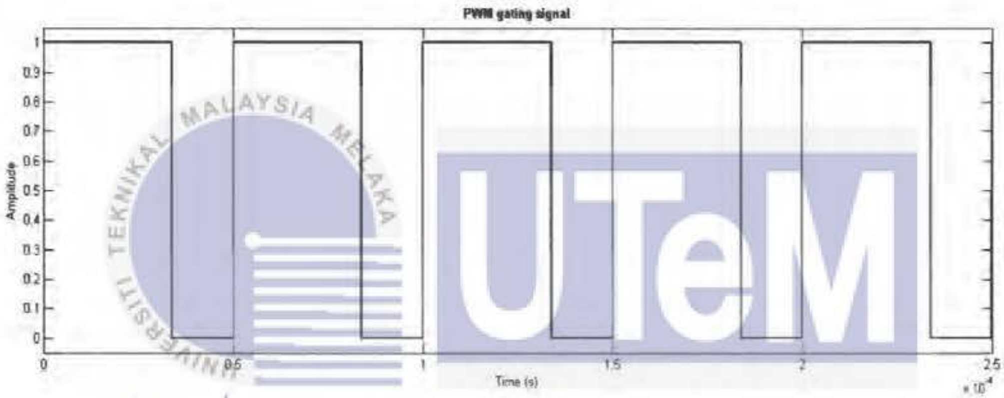

Figure 4.2: PWM gating signal

4.4 Boost Converter with Fixed Duty cycle

The boost converter model has been designed with fixed duty cycle and the output voltage is presented in figure 4.3. To calculate the overshoot, settling time and peak time that by refereeing to figure 3.9.

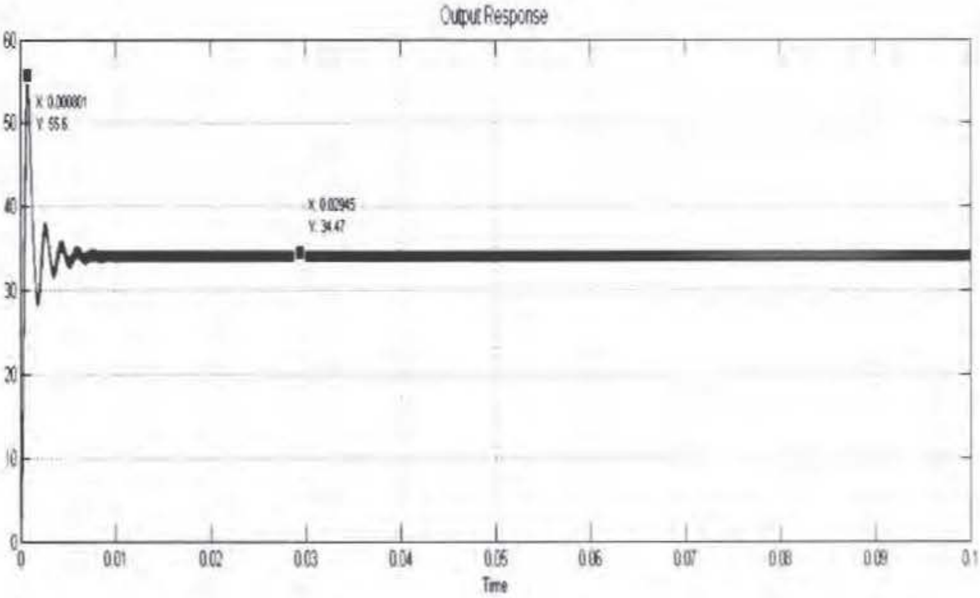

Figure 4.3: Output Response

From the graph, the time response property of boost converter of the uncompensated system is calculated as below and show in table 4.2.

Therefore, the percent overshoot $\%OS$ can be calculate using the formula below

$$\%OS = \frac{C_{max} - C_{Final}}{C_{Final}} \times 100$$

Hence

$$\%OS = \frac{55.6 - 34.47}{34.47} \times 100$$

$$\%OS = 61.3\%$$

Daming ratio ζ can be calculate by using equation (3.16)

$$\zeta = \frac{-\ln(\frac{80.66}{100})}{\sqrt{\pi^2 + \ln(\frac{80.66}{100})^2}} = 0.154$$

From the graph, the peak time will be 0.002 by using equation (3.17) to calculate ω_n

$$\omega_n = \frac{\pi}{0.002\sqrt{1-0.154^2}} = 1589.7 \text{ rad/s}$$

Therefore, to calculate settling time use equation (3.18)

$$T_s = \frac{4}{0.154 \times 1589.7} = 0.0163$$

Table 4.2: Time Response property of boost converter of uncompensated system

Response Characteristics	Uncompensated value
Overshoot	61.3%
Settling time	0.0163s
Peak time	0.002s

4.5 Analysis the results

The simulation results of the proposed boost converter design with different values duty cycle shown in Figure 4.4 and table 4.3. As observed from the simulation, the highest output voltage needs higher duty cycle whereas the lowest output voltage needs lower duty cycle.

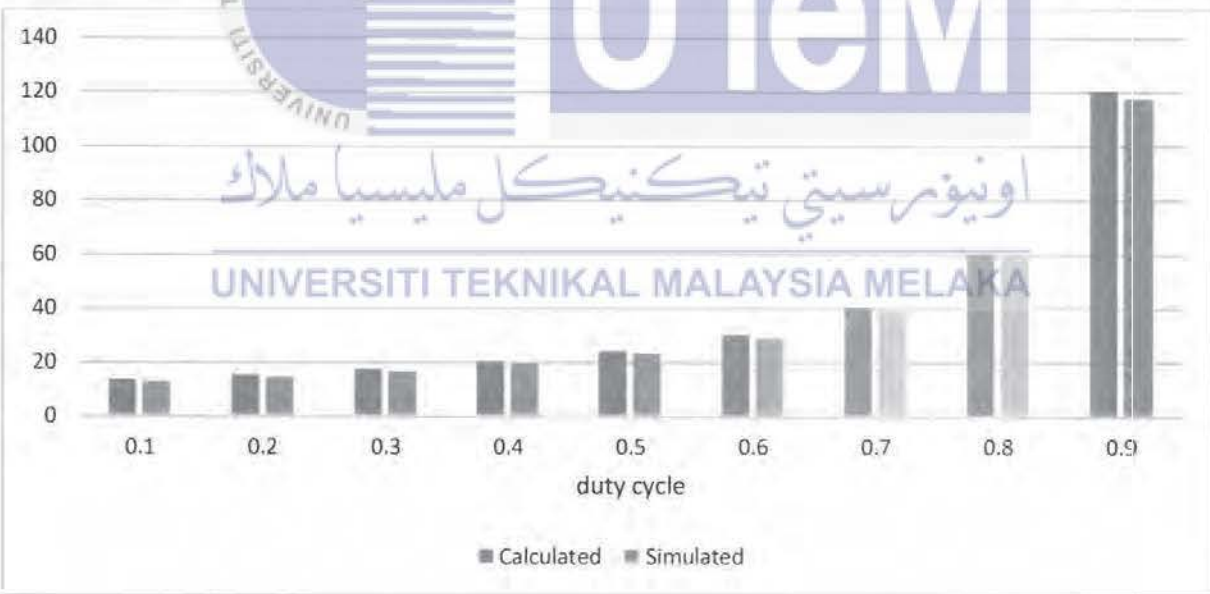

Figure 4.4: Calculated and simulated output voltage

Table 4.3: Comparison of output voltage with different duty cycles

Duty ratio	V_{in}	Calculated V_{out}	Capacitor	Inductor	Simulated V_{out}
0.1	12	13.33	0.00005	0.0000225	12.56
0.2	12	15	0.0001	0.00004	14.25
0.3	12	17.14	0.00015	0.0000525	16.35
0.4	12	20	0.0002	0.00006	19.14
0.5	12	24	0.00025	0.0000625	23.07
0.6	12	30	0.0003	0.00006	29.02
0.7	12	40	0.00035	0.0000525	39.07
0.8	12	60	0.0004	0.00004	59.49
0.9	12	120	0.00045	0.0000225	117.4

4.6 Boost converter without controller

Case 1: Reference change

There were two reference voltage have been test in order to observe the changes in the output voltage. From the table 4.4, when the reference voltage is set as 24, the overshoot is quite high, Fast settling time, the Output ripple voltage is 0.7 and steady state error is not equal to the reference voltage as shown in figure 4.4.

When the reference voltage is set as 36v, the overshoot is lower than the overshoot of $V_{ref} = 24$v, the Steady state error bigger compare to $V_{ref} = 24$v, the Output ripple voltage is 1.5 and the steady state error is not equal to the reference voltage as shown in figure 4.4.

Table 4.4: The Response characteristic of boost converter without controller

Response Characteristics	$V_{ref} = 24$v	$V_{ref} = 36$v
Overshoot	50%	10.65%
Settling time	0.015 s	0.078 s
Peak time	0.002 s	0.042 s
Output ripple voltage	0.7v	1.5v

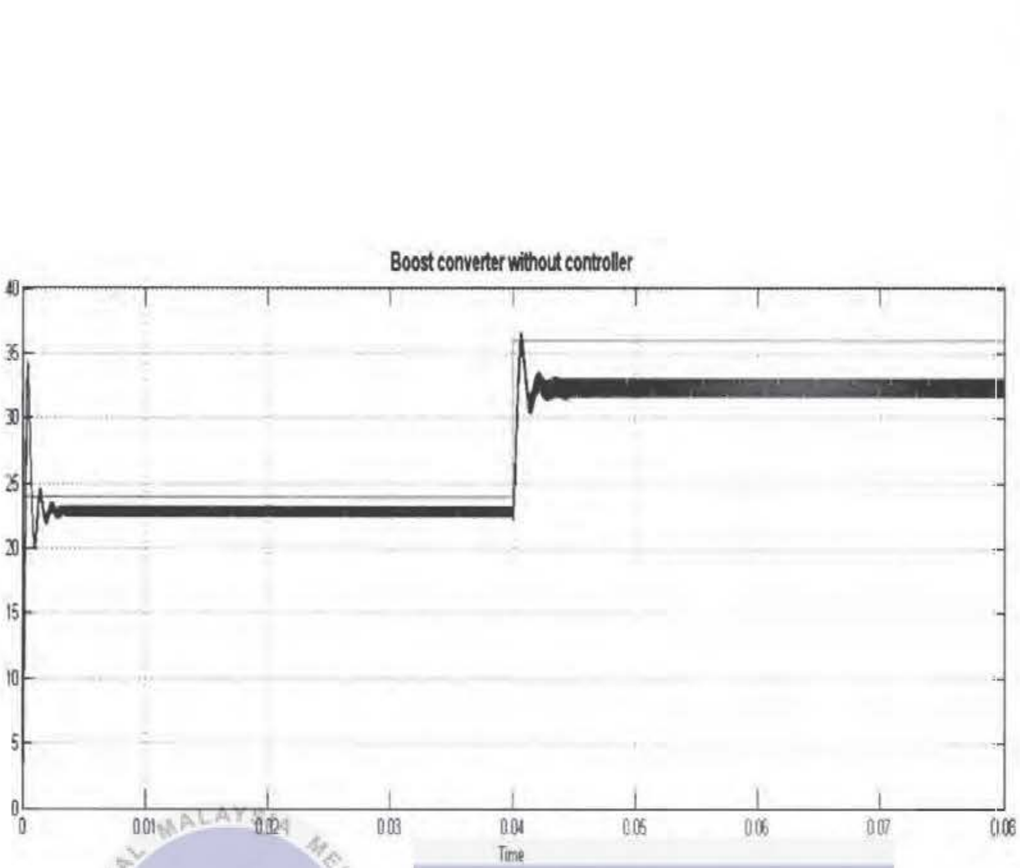

Figure 4.5: Output voltage of boost converter without controller

The conclusion, the overshoot variations from high to low, that happened due to the change in the reference voltage (24v) is quite large, started from 0 to 24, also the steady state error is greater when the reference voltage is 36v, that occurred due to the output current is high (when the voltage increase the current also increase), therefore when the current getting higher the losses will be higher too $P_{loss} = I^2R$.

Case 2: Load changes

The reference voltage set to 36v. As shown in figure 4.6 there is a drop at time 0.04s of the output voltage, that drop happened due to the switch is close. When the switch closed R1 become parallel with R2 and will produce a new resistance value R_{total}.

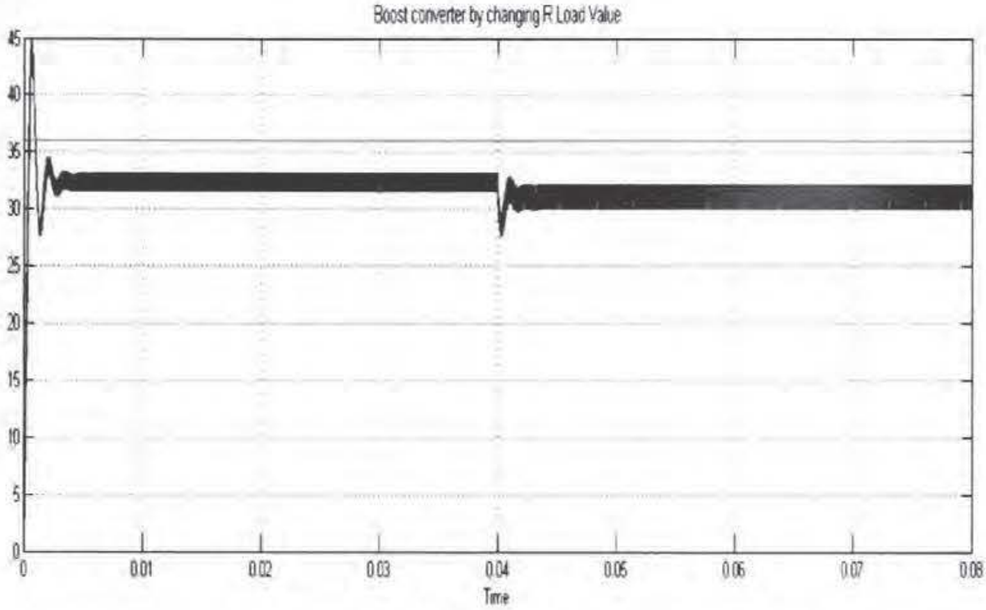

Figure 4.6: Output voltage of boost converter with additional R load

4.7 Boost Converter with Controller

4.7.1 PID Controller

Case 1: Reference change

The PID controller is fed into boost converter. The parameters generated by using root locus as shown in table 4.5 and the output voltage is presented in figure 4.7, PID controller produce output voltage with high ripple voltage. Therefore, PID controller was not able to generate the desired output voltage.

Table 4.5: PID controller parameters

Parameter	Value
K_p	6.5124
K_i	369.9974
K_d	0.0022947

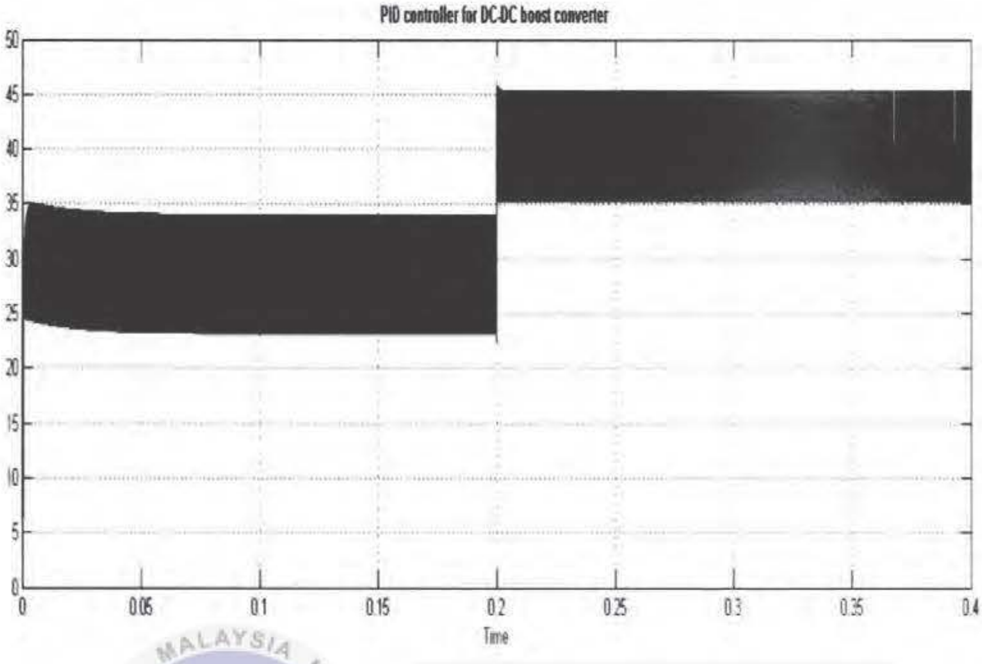

Figure 4.7: Output voltage of boost converter with PID controller

Case 2: Load change

The PID controller is fed into a boost converter with additional R load and the output voltage still has high ripple voltage but when additional R load connected at 0.05s the ripple voltage reduced a bit as shown in figure 4.8.

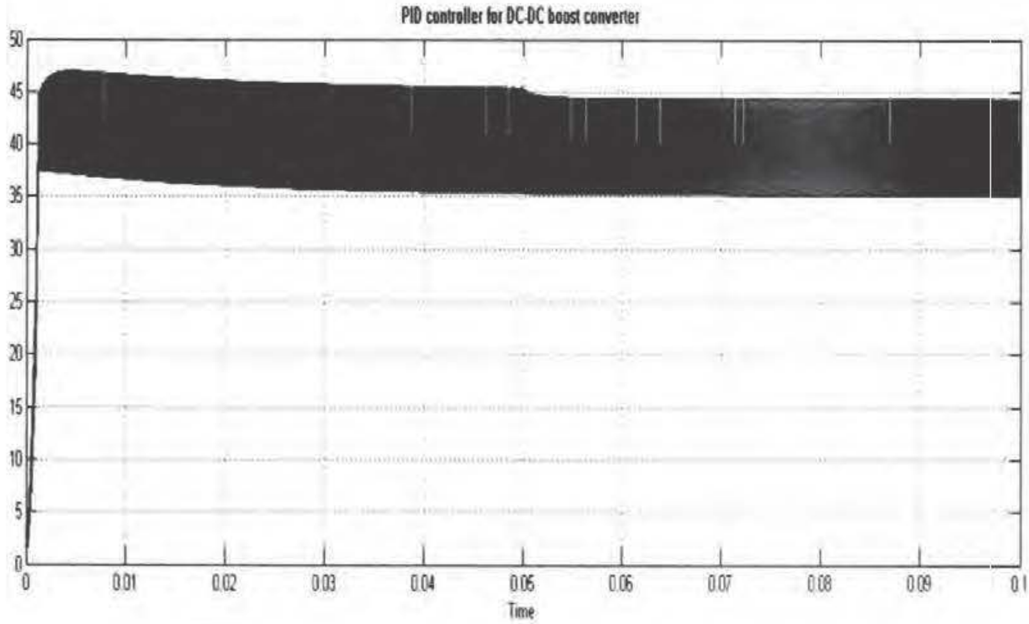

Figure 4.8: Output voltage with PID controller and additional R load

4.7.2 Modified PID controller

Case 1: Reference change

The modified PID controller is a modification from the classical PID controller. The type of Modified PID controller implement in this final year project is I-D where integrator is remains and derivative is put as a feedback. Modified PID controller is fed into the boost converter and the paramerters values are considered K_i=450 and K_d =0.02. The output voltage is presented in figure 4.9. The reference voltage is set to a different value (36, 24 and again to 36) in order to test the modified PID controller whether is able to track the reference or not. From the figure below it is clear that the controller is able to track the reference voltage.

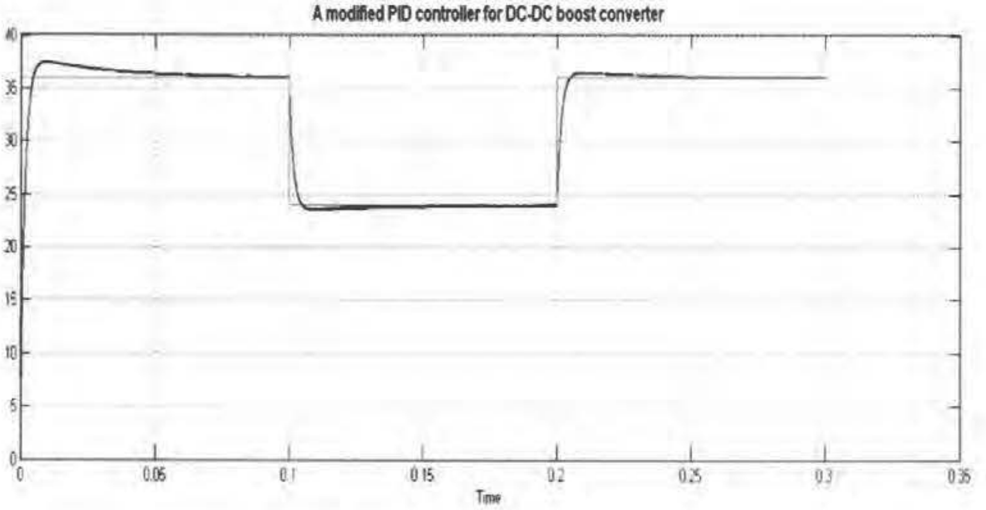

Figure 4.9: Output voltage with A Modified PID controller

Case 2: Load change

There was three resistances in parallel R1=100ohm, R2=100ohm, and R3=12.5ohm as shown in figure 5.12. The system was run at 0.3s, R1 connected while R2 and R3 disconnected. When 100ohm resistance connected to boost converter the ripple voltage is higher compared to 10ohm this because boost converter designed using 10ohm. At 0.1s, R1 and R2 become parallel while R3 disconnected the total resistance became 50ohm. When 50ohm connected to boost converter the ripple voltage is less than 100ohm resistance. However, the controller still able to follow the reference voltage as shown in Figure 4.10.

At 0.2s R1, R2 and R3 became parallel so the total resistance became 10ohm the controller able to track the reference voltage with low ripple voltage compare to 100ohm and 50ohm.

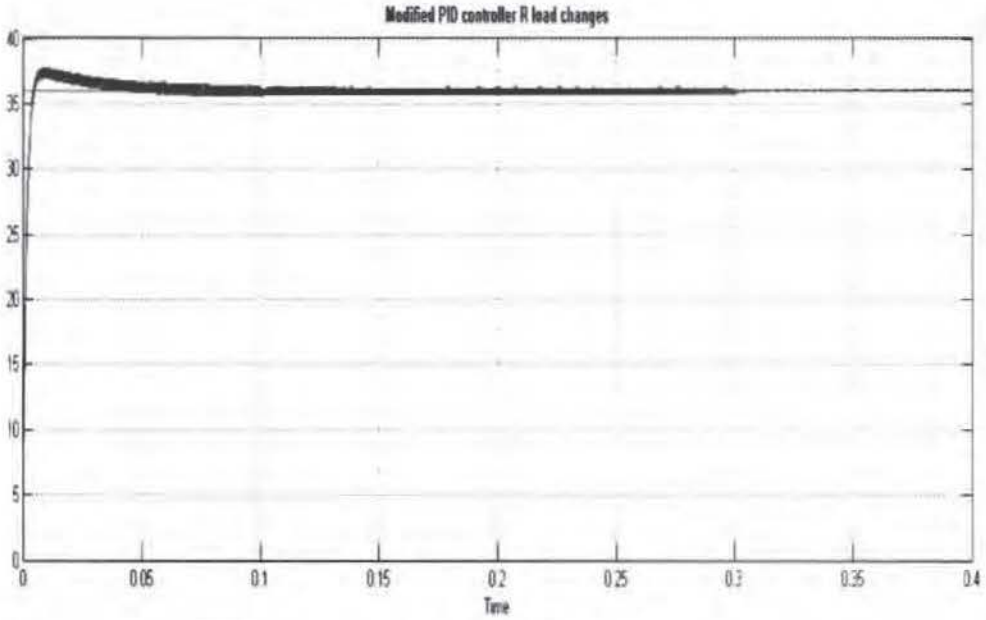

Figure 4.10: Output voltage with Modified PID controller and additional load

4.6 Summary

To summarize, this chapter the boost converter has been simulated using MATLAB and the output voltage of boost converter had been presented. Boost converter parameter variation has been discussed by comparing the result obtained from simulation with calculated value with different duty cycle values. The characteristic response output boost converter has been calculated. Boost converter has been tested without and with controller in order to observe the best output results. Modified PID controller produced the desired output voltage with low ripple voltage for the DC-DC boost converter.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

Power electronics is an interesting field for researcher's due to its significant contribution in producing small devices that can control large applications, hence it helps to build simple and flexible designs. DC-DC converters are utilized to convert the unregulated DC input to a controlled DC output voltage. There is three types of DC to DC converters for example buck, boost, and buck-boost. Each type has different principle operation such as buck converter uses to step down the output voltage, boost converter uses to step up the output voltage and buck-boost converter use to comprise both steps up and step down the output voltage.

Boost converter was the main type of this project. Boost converter circuit has been constructed using MATLAB/SIMULINK software with variation duty cycle and constant input voltage. A Dc-Dc boost converter is being used to provide a regulated output voltage of 36V from an input voltage of 12V, the boost converter is able to produce a constant output voltage of 36V from a variable of the input voltage. However, a modified PID controller is required to change the steady-state and the time response graph of the output voltage produced by the DC-Dc boost converter. A modified PID controller helps to ensure a more appropriate and to enable the desired result to be obtained. Based on the analysis being made, classical PID controller doesn't give the desired output voltage, therefore a modified PID being tested using I-D controller. Modified PID seems to be performed better by producing better output response of the output voltage compared to the classical PID controller. For future recommendation, Modified PID can be improving to a better state to produce a better result of output voltage. More practical and researches can be carries out in order to have a better design of the modified PID for the dc-dc Boost converter. Besides that, Properties of Boost converter can be improve by adding coupling inductor or other to step up the voltage more successful and involve a new control strategy such as Fuzzy controller. Greater improvement can be done if more time is provided for the project.

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APPENDICES

Figure 5.1 to figure 5.9 shows the output voltage of boost converter when the duty cycle change from 0.1 until 0.9

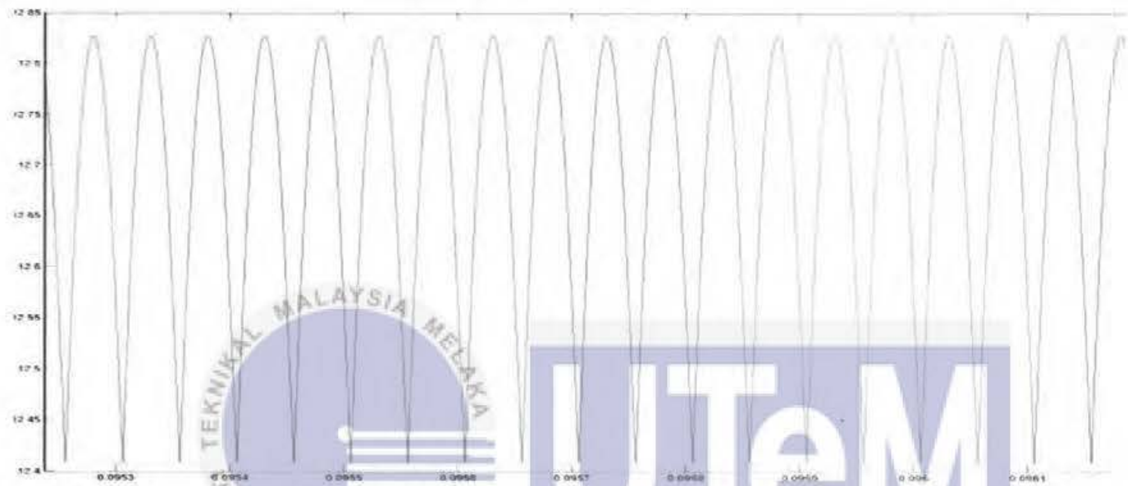

Figure 5.1: Output voltage of boost converter with 0.1 duty cycle

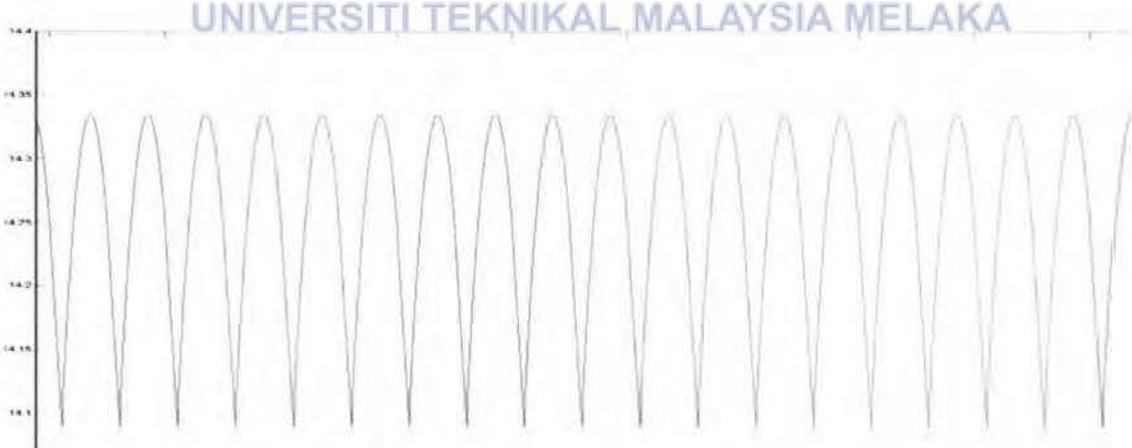

Figure 5.2: Output voltage of boost converter with 0.2 duty cycle

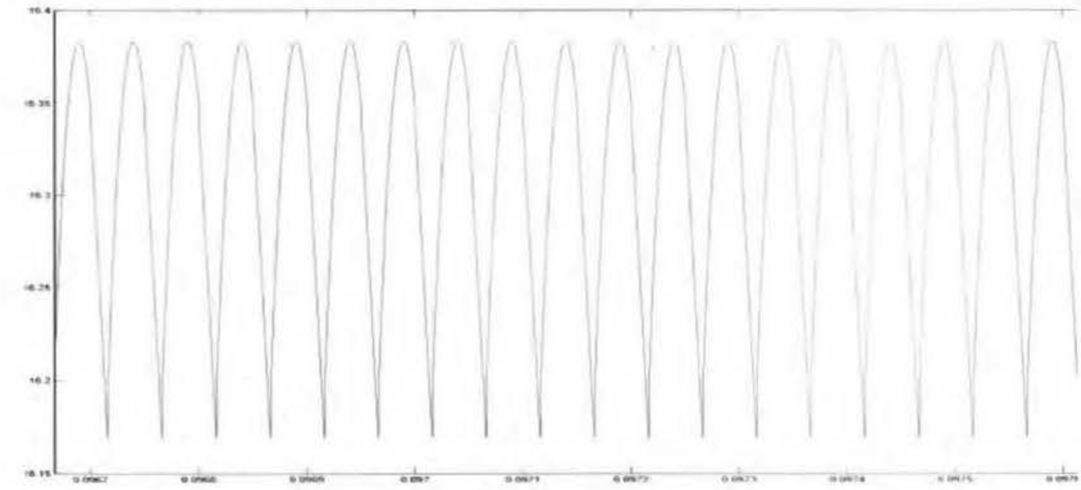

Figure 5.3: Output voltage of boost converter with 0.3 duty cycle

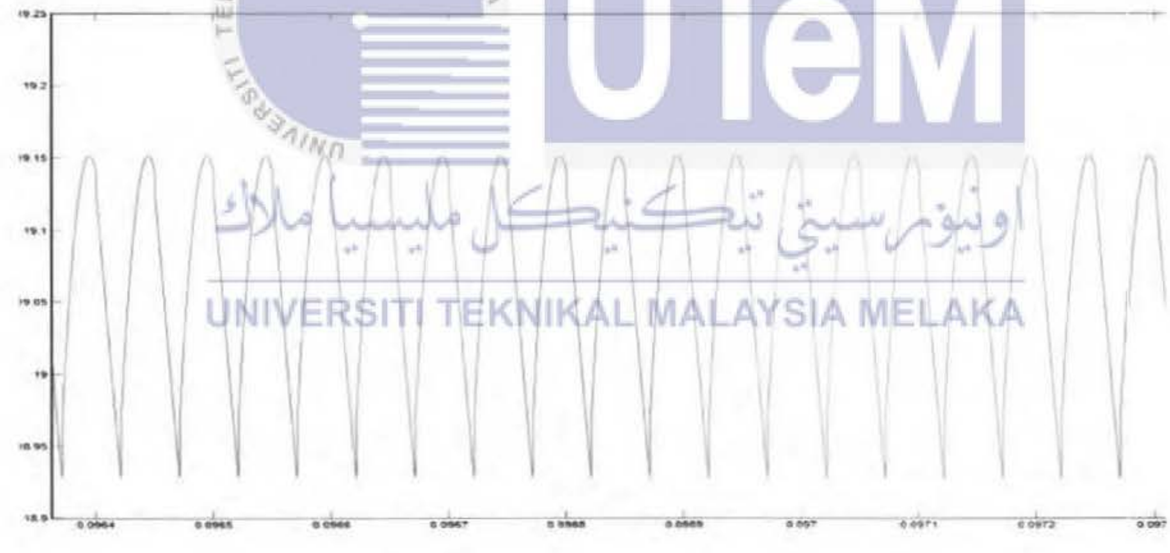

Figure 5.4: Output voltage of boost converter with 0.4 duty cycle

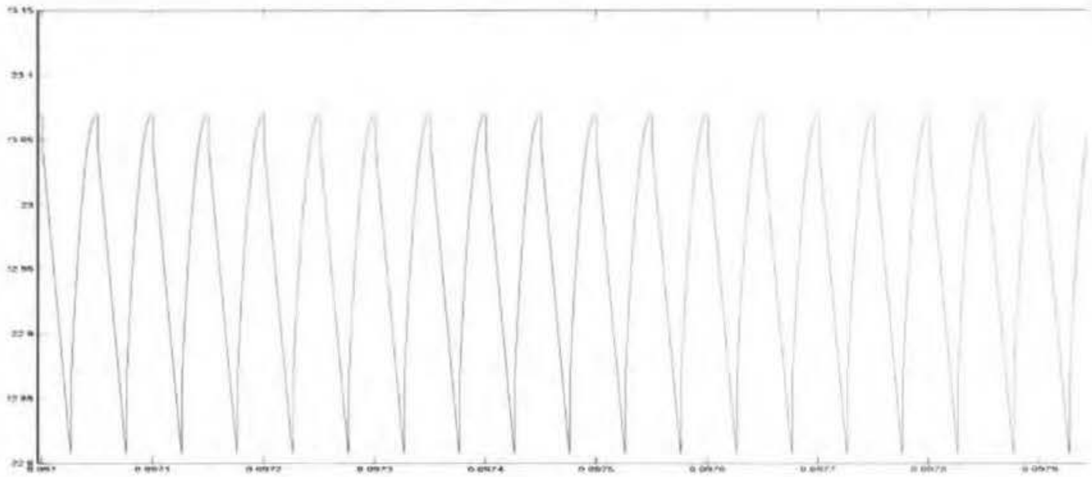

Figure 5.5: Output voltage of boost converter with 0.5 duty cycle

Figure 5.6: Output voltage of boost converter with 0.6 duty cycle

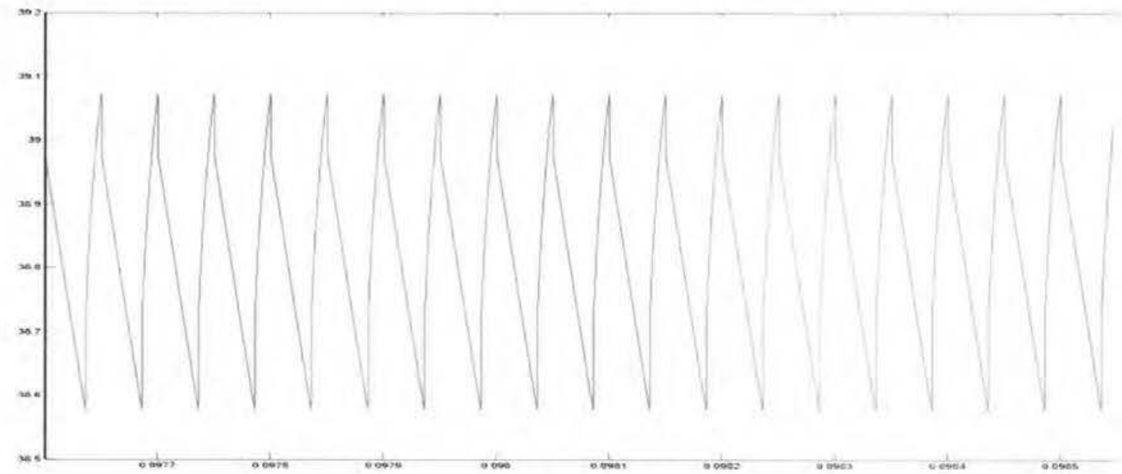

Figure 5.7: Output voltage of boost converter with 0.7 duty cycle

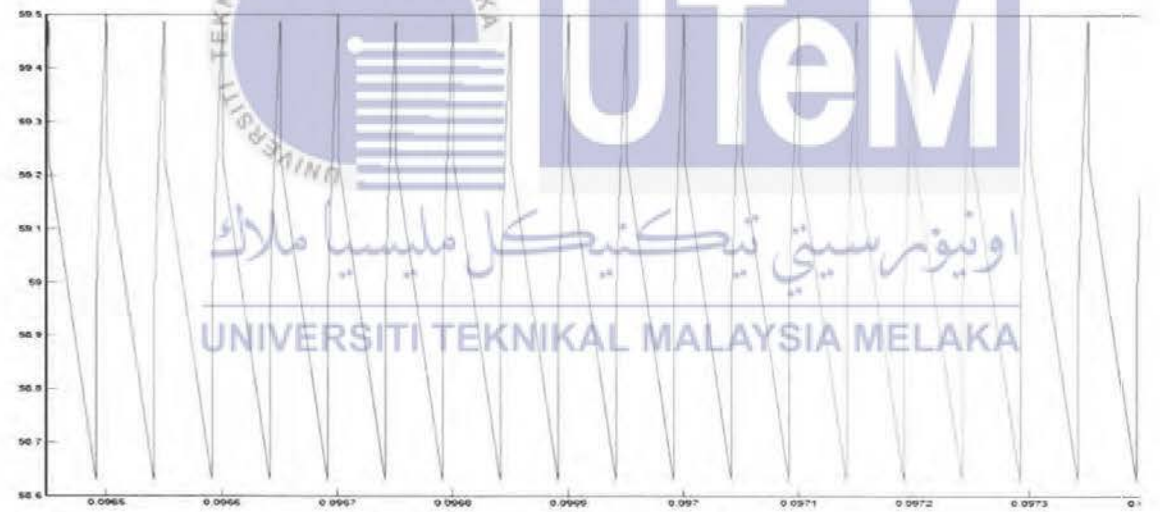

Figure 5.8: Output voltage of boost converter with 0.8 duty cycle

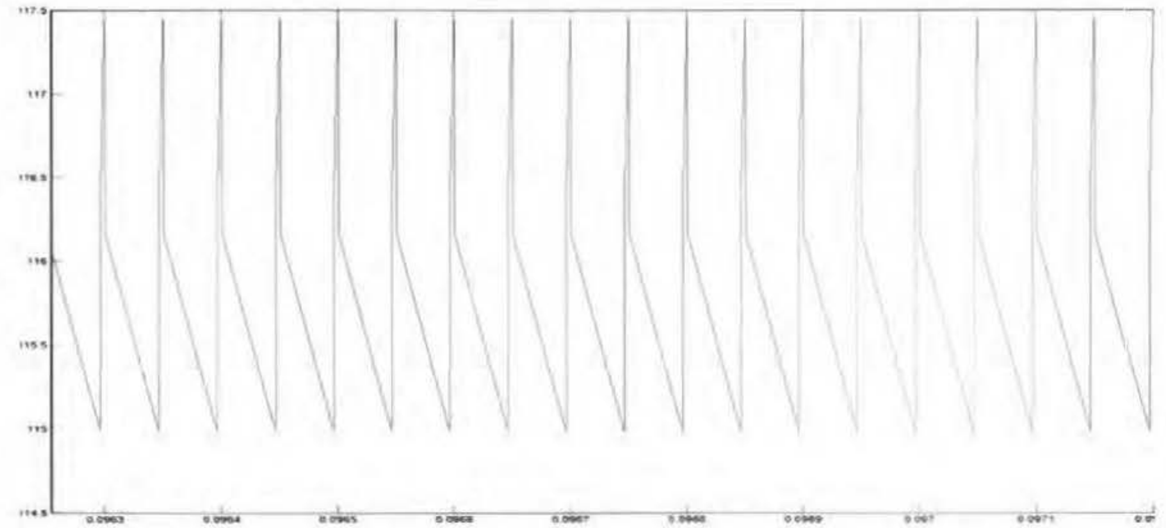

Figure 5.9: Output voltage of boost converter with 0.9 duty cycle

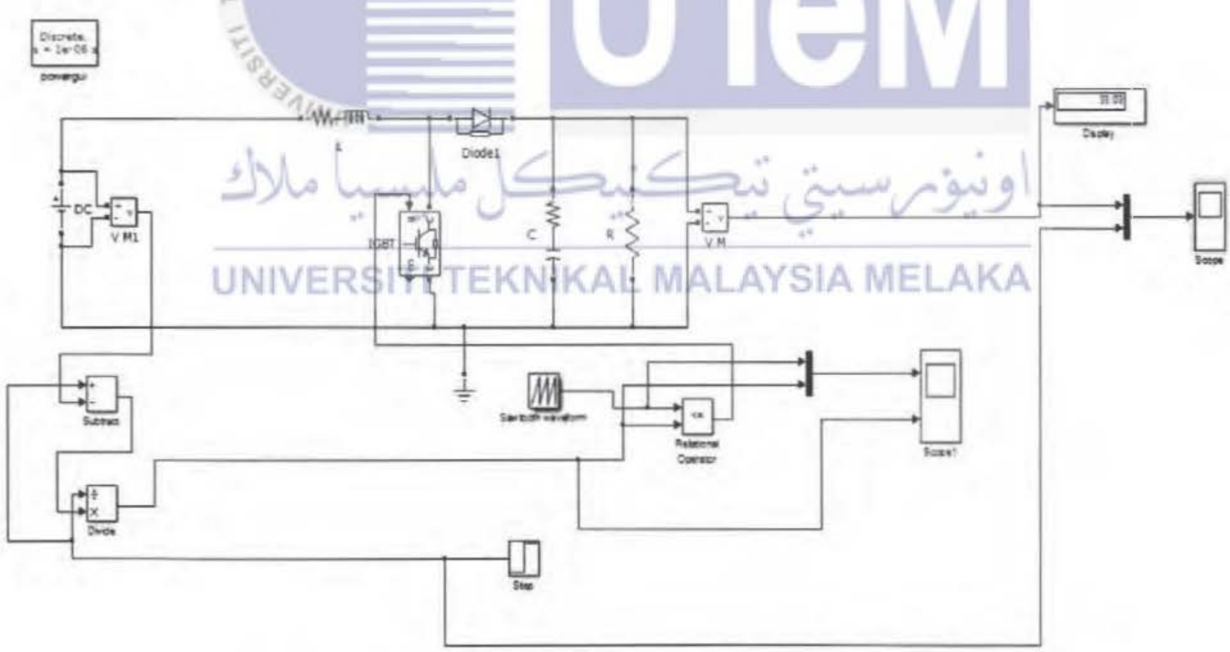

Figure 5.10: Boost converter circuit without controller

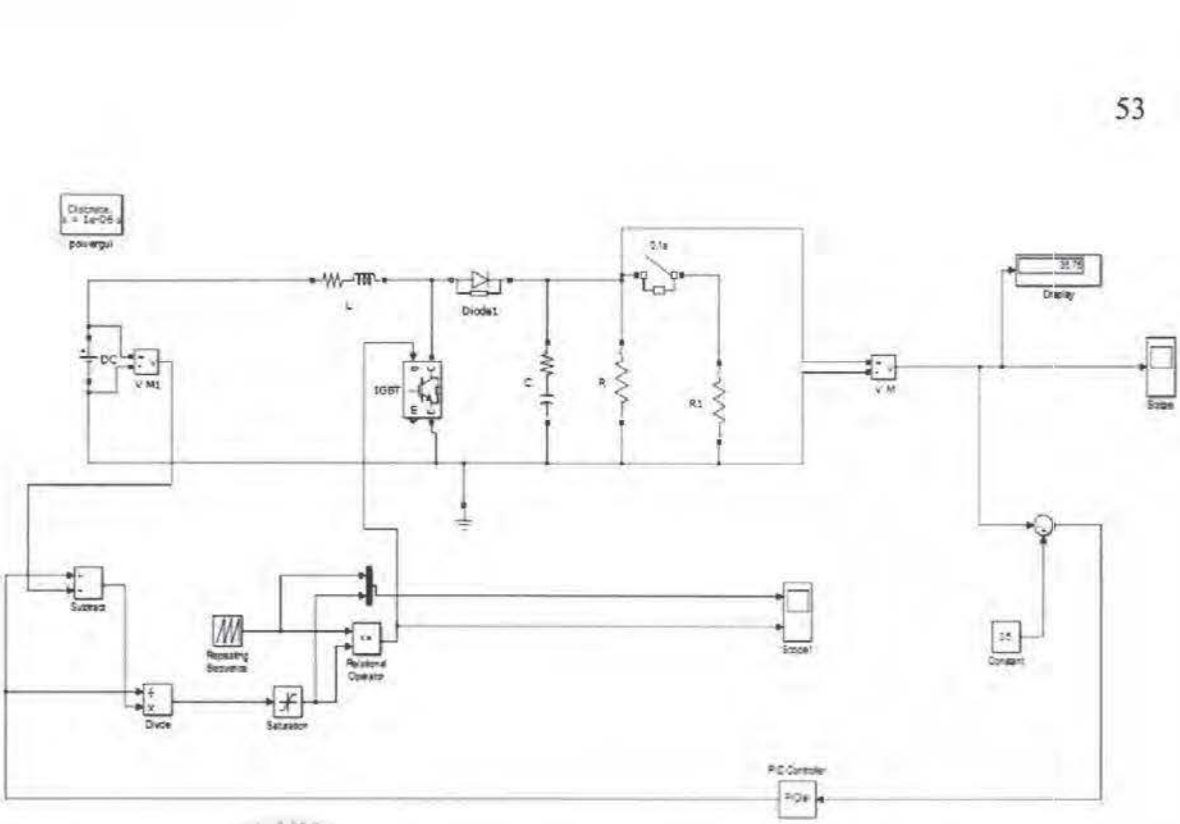

Figure 5.11: PID Controller of boost converter with additional R load

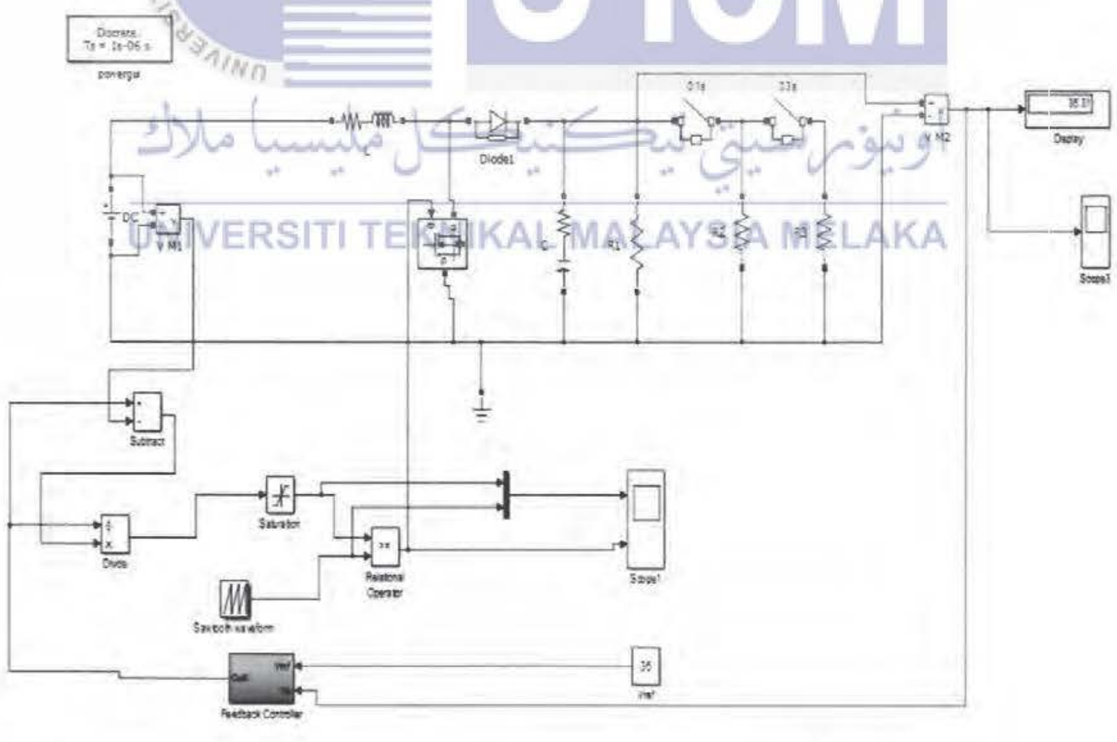

Figure 5.12: Modified PID Controller of boost converter with additional R load