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ANALYSIS OF CONTROL METHODS FOR BOOST DC-DC CONVERTER

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This thesis is submitted as partial fulfillment of the requirements for the award of the Bachelor of Electrical Engineering (Power Systems)

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"I hereby acknowledge that the scope and quality of this thesis is qualified for the award of the Bachelor Degree of Electrical Engineering (Power Systems)"

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Specially dedicated to my beloved mother and father, brother and sister,
my beloved friends, for their encouragement and support.

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ABSTRACT

Boost converter is one of the types for power converters and inherently very nonlinear circuit due to the switching characteristics in the switching device. In this project, the performance of the output boost converter is analyzed by applies the proportional integral derivative (PID), two-level hysteresis and three level hysteresis controller. All simulation works are done by using MATLAB Simulink software. This project investigates and develops all three controllers and makes a comparison performance among these controllers. The comparisons are taking into account the transient response and load changes of the boost converter. It is show that the PID controller and hysteresis controller has a trade-off performance between the load changes and start-up transient response.

ABSTRAK

Penukar rangsangan adalah salah satu jenis penukar kuasa dan ianya litar tak linear kerana ciri-ciri penukaran di dalam alat penukaran. Dalam projek ini, prestasi penukar rangsangan dianalisis dengan menggunakan derivatif berkadar penting (PID) pengawal, histerisis dua tahap pengawal dan histerisis tiga tahap pengawal melalui simulasi. Semua kerja-kerja simulasi dilakukan menggunakan perisian MATLAB Simulink. Projek-projek ini menyiasat dan membangunkan ketiga-tiga pengawal dan membuat perbandingan prestasi di kalangan pengawal ini. Perbandingan dengan mengambil kira sambutan fana dan perubahan beban penukar rangsangan. Ia adalah menunjukkan bahawa pengawal PID dan pengawal histerisis mempunyai prestasi perdagangan antara perubahan beban dan permulaan sambutan fana.

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LIST OF ABBREVIATIONS

DC	-	Direct Current
CCM	-	Continuous Conduction Mode
DCM	-	Discontinuous Conduction Mode
P	-	Proportional
PI	-	Proportional-Integral
PID	-	Proportional-Integral-Derivative
PWM	-	Pulse-width Modulation
NSS	-	Non-steady State
MOSFET	-	Metal-oxide-semiconductor Field-effect Transistor
IGBT	-	Insulated Gate Bipolar Transistor

CHAPTER 1

INTRODUCTION

1.1 Background

Nowadays, as our life is getting more advances in technology, most of the technologies use power electronics to function. A so-called boost converter is including as one of the power electronic device. Due to the growing importance of the boost converter in technology, a detail study of boost converter is necessary to make an improvement for future technology. A good boost converter can make the technology more efficient in usage.

The key in controlling a DC-DC boost converter is the switching process that needs to be monitor frequently and perfectly. To gain a good output result, the switching process must be in a high switching frequency. Due to high switching frequency, it is hard to see the switching process, hence it need to be controlled by some appropriate controller such proportional integral derivative (PID) controller, hysteresis controller and others controller.

This project introduces three methods of controller to control the DC-DC boost converter, i.e, proportional integral derivative (PID) controller, two-level hysteresis controller (normally just called hysteresis controller) and three-level hysteresis controller. All controllers will be compared the transient response during start-up, steady-state and load changes. Each controller has the advantage and disadvantage that will be discussed in performance analysis.

1.2 Problem Statement

As mention earlier, it is important to have appropriate controller. The performance of boost converter is greatly depends on it switching process. In DC-DC boost converter, the switching process is operated in high switching state and it is hard to control the process. To encounter this problem, an appropriate controller needs to be designed so that the desired output voltage can be controlled appropriately and efficiently.

Furthermore, it is difficult to obtain a good transient response in boost converter due to the very nonlinear appeared in the circuit operation. The boost converter circuit needs to operate on continuous current mode (CCM) because the output has to produce a constant set voltage in both on-state and off-state of power switches. A perfect tuning of controller must obtain to produce a good transient response.

1.3 Objectives

In this project, three main objectives have been formed as follow;

i. To develop PID, two-level hysteresis and three-level hysteresis controllers for controlling boost converter.

ii. To do the comparison result between three different controller.

iii. To optimize the performance of the boost converter output voltage

1.4 Scope of Project

Scopes of the project are:

i. Study the boost converter topology, PID controller, hysteresis controller and three-level controller.

ii. Simulate the circuit and controller using MATLAB Simulink.

iii. Analyze the performance of all three different controllers in term of transient response and load changes.

1.5 Thesis Outlines

This thesis is organized into five chapters. The first chapter introduced the background, problem statement, objectives and scope of work of this project.

Chapter 2 reviews the literature reviews of this project. Operation and skill used in developing the system are also explained in this chapter.

Chapter 3 presents the research methodology, system design and application tool that have been used in this project.

Chapter 4 described the result for each comparison of the controllers and discussion of the overall result.

In the final chapter, the research work is summarized and the potential future works are given.

CHAPTER 2

LITERATURE REVIEW

2.1 DC-DC Boost Converter

A DC-DC boost converter also known as step-up converter is a DC-DC power converter with output voltage greater than input voltage. The basic topology for boost converter consist at least two semiconductor switches which are diode and transistor also consist at least one storage element, a capacitor, inductor or maybe both. Commonly the capacitor added to the output of the converter as a filter to reduce output voltage ripple. Boost converter use an inductor's magnetic field to alternately store energy and release it to the load at a different voltage.

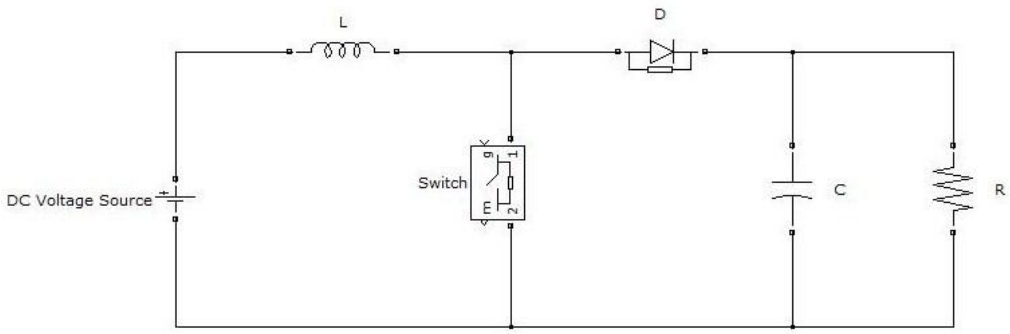

Figure 2.1 DC-DC Boost Converter Topology

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 (D), capacitor (C), resistor (R) and 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 the 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.

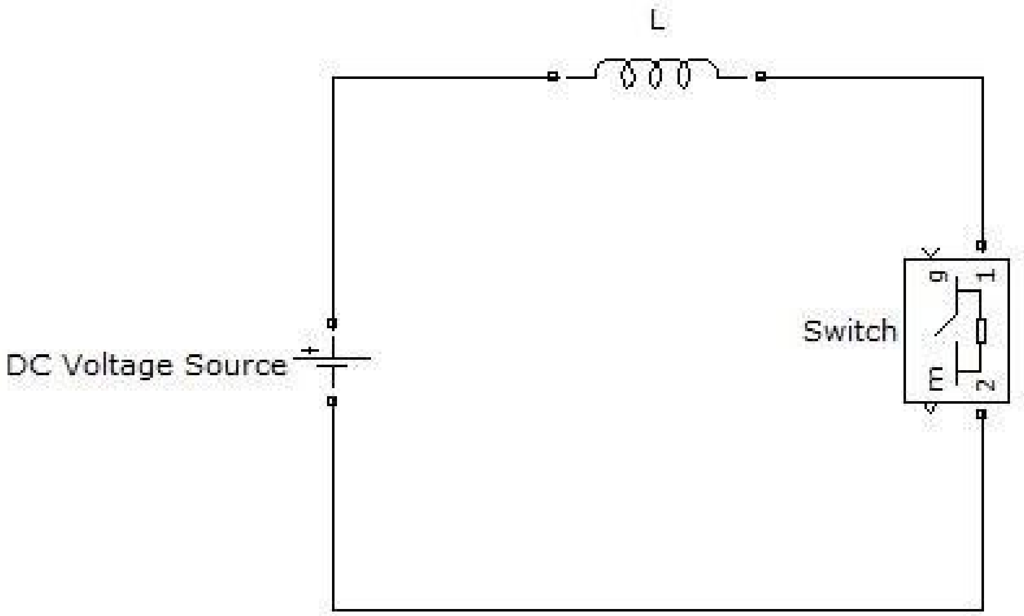

Figure 2.2 ON State of Boost Converter

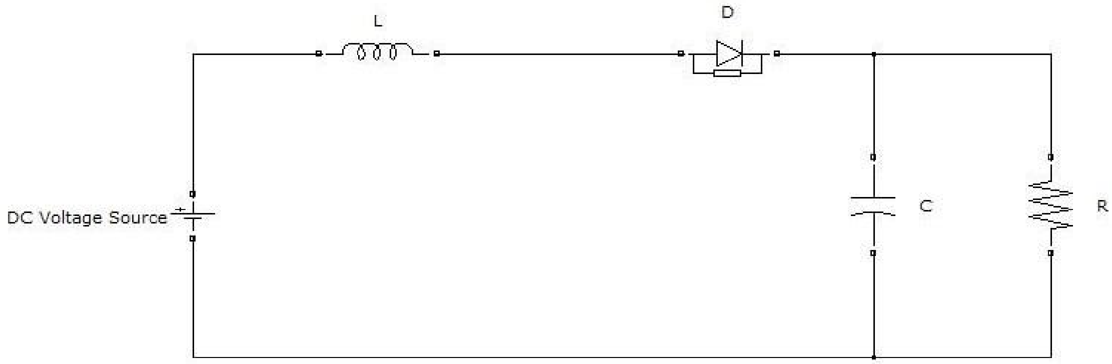

Figure 2.3 OFF State of Boost Converter

2.2 Continuous Conduction Mode

Boost converter can operate either in Continuous Conduction Mode (CCM) or discontinuous conduction mode (DCM). For high power application, CCM mode operation is more preferred than DCM because CCM has lower conduction loss and smaller current stress on the semiconductor devices [1]. When boost converter operate in CCM mode, the current through the inductor never falls to zero. The current flows continuously in the inductor during the entire switching cycle [2]. During the On-state, the switch is closed, which makes the input voltage appear across the inductor and causes a change in current flowing through the inductor during a time period (t). Hence, the current increase in inductor at the end of On-state. When the converter considers operates in steady state condition, the amount of current stored in inductor has to be same at the beginning and at the end of commutation of cycle. It means the change in current is zero.

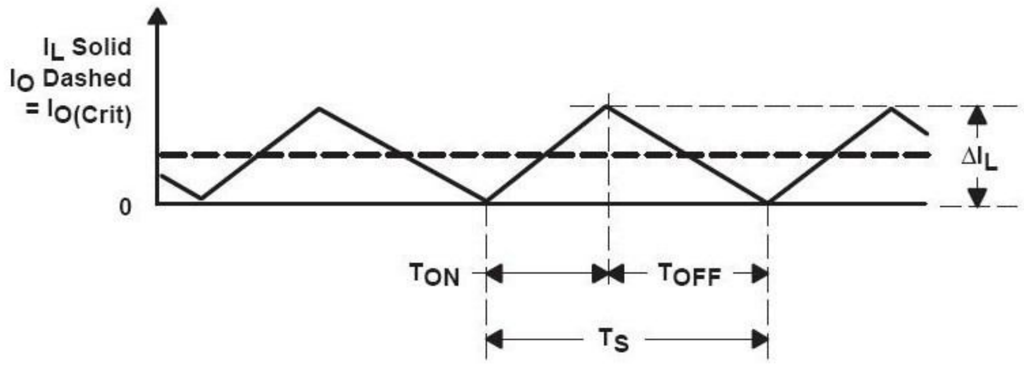

Figure 2.4 Continuous Current Mode

2.3 Discontinuous Conduction Mode

Some converter operates in discontinuous conduction mode (DCM). Usually DCM is use for low power or stand-by operation for example DC-DC converter that operating at light load (small load current). In DCM, the current through the inductor falls to zero during part of the period. It starts at zero, reaches a peak value, and return to zero during each switching cycle [2]. Although slight, the difference has a strong effect on the output voltage.

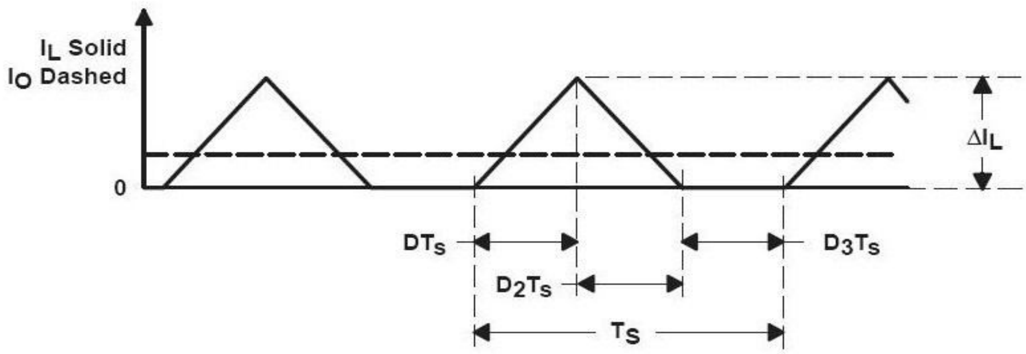

Figure 2.5 Discontinuous Current Mode

2.4 Proportional Integral Derivative (PID) Controller

Proportional integral derivative controller (PID controller) is one of controller that has been widely used in industrial and control system. The PID controller uses the input signal from the calculated error, where the error is obtained from the different between measured process variable and a desired set point (reference) [3]. The PID calculation involve three constant parameters; the proportional (denoted P), the integral (denoted I) and derivative (denoted D) value. In term of time, all these parameter can represent as present error, past error and future error. Some application may use only one or two gain only by setting the other gain to zero. PID controller may become PI, PD, P and I controller according the absence of the respective control gain.

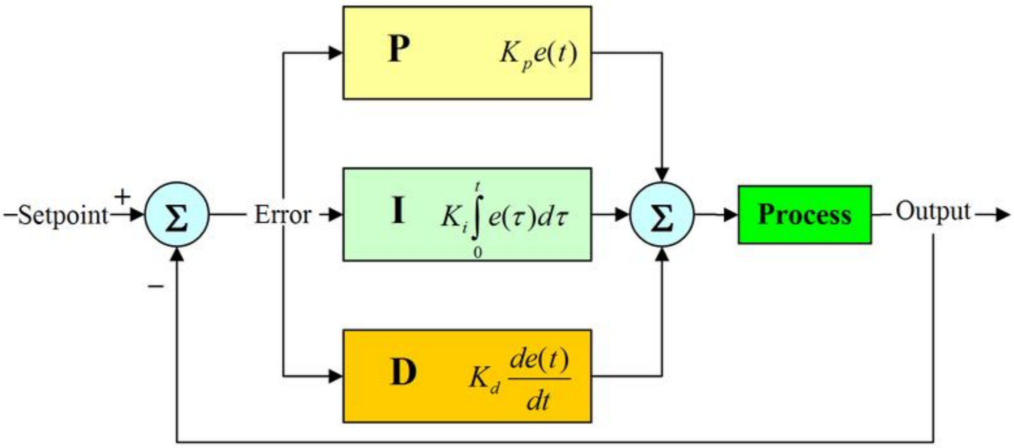

Figure 2.6 Block Diagram of PID controller

The PID controller uses the weight sum of three gains to calculate the output. The proportional gain produces an output value that is proportional to the current error value [3]. When tuning the proportional gain, if the gain is too high, the system becomes unstable. The output may have large overshoot and also make the rise time larger. If the proportional gain is too low, the control action may be too small when responding to system disturbances. Integral gain is the sum of the error over time. Decreasing the integral gain can lower the overshoot. However, since the integral term responds to accumulated errors from the past, it can cause the present value to overshoot if the values gain is too high. For derivative gain, it calculates the different between present and past error over time. The derivative slows the transient response of the controller but it also can reduce the overshoot that produced by the integral component and improve the combined controller-process stability. It is very sensitive to tuning PID; hence an appropriate method of tuning is needed to make the PID controller efficient with the system.

2.5 Proportional Integral Derivative (PID) Controller Tuning

There are several types of method in tuning PID controller. The most effective method is choosing P, I, and D based on the process model. The choice of method will depend largely based on type of the system whether or not the system can be taken "offline" for tuning, and the response time of the system [3]. If the system can be taken offline, a change of input and measuring the output can be done to determine the control parameters.

Table 2.1 Typical tuning methods with their advantages and disadvantages

Method	Advantages	Disadvantage
Manual tuning (try and error)	No math required. Online method.	Requires experienced personnel.
Ziegler-Nichols	Proven method. Online method	Process upset, some trial-and-error, very aggressive tuning.

Software tools	Consistent tuning. Online or offline method. Allow simulation before downloading. Can support non-steady state (NSS) tuning.	Some cost and training involved.
Cohen-Coon	Good process models.	Some math. Offline method. Only good for first-order processes.

The effective tuning for PID controller determine based on four major characteristic:

1. Rise time: the output must beyond 90% of the desired level for the first time.
2. Overshoot: the output level that is higher than the steady-state.
3. Settling time: the time for the system to takes to reach its steady state.
4. Steady state error: the different between the steady state output and the desired output.

In tuning the PID controller, increasing parameter Kp, Ki and Kd have its own effects, it can be summarized as [4]:

Table 2.2 Manual tuning system

Parameter	Rise Time	Overshoot	Settling Time	Steady State Error
Kp	Decrease	Increase	No Definite (Minor Change)	Decrease

Ki	Decrease	Increase	Increase	Eliminate
Kd	No Definite (Monir Change)	Decrease	Decrease	No Definite (Minor Change)

In many case, PID tuning can be done by increasing the parameters Kp, Ki and Kd one by one. Firstly, the system needs to be determining what its characteristic need to be improving. Then the Kp parameter is use to decrease the rise time. After that the parameter Kd is use to reduce the overshoot and settling time and lastly eliminate the steady steady-state error using Ki parameter. When done tuning the parameters, the system need to be examined either it obtain or not acceptable stability. Acceptable stability is when the undershoot that follow the first overshoot of the response is small, or barely observable [4].

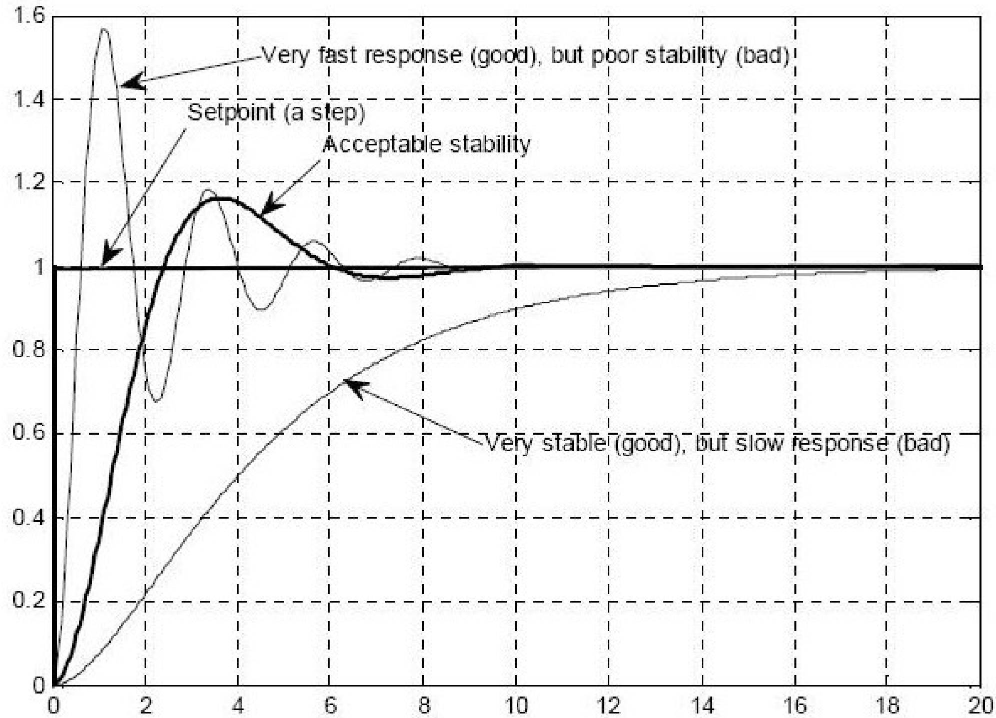

Figure 2.7 Acceptable Stability Graphs

2.6 Pulse-width Modulation (PWM)

Pulse width modulation (PWM) is a powerful technique for controlling analog circuits with a processor's digital outputs. PWM is employed in a wide variety of applications, ranging from measurement and communications to power control and conversion. PWM have its own role to control the output voltage by apply PWM signal [6]. The simplest way to generate a PWM signal is the intersective method, which requires only a sawtooth or a triangle waveform and a comparator. The triangle waveform will be compare with output signal from controller. From the intersection between triangle waveform and output controller will resulting either the PWM signal is in the high state or in the low state compare to reference signal [5].

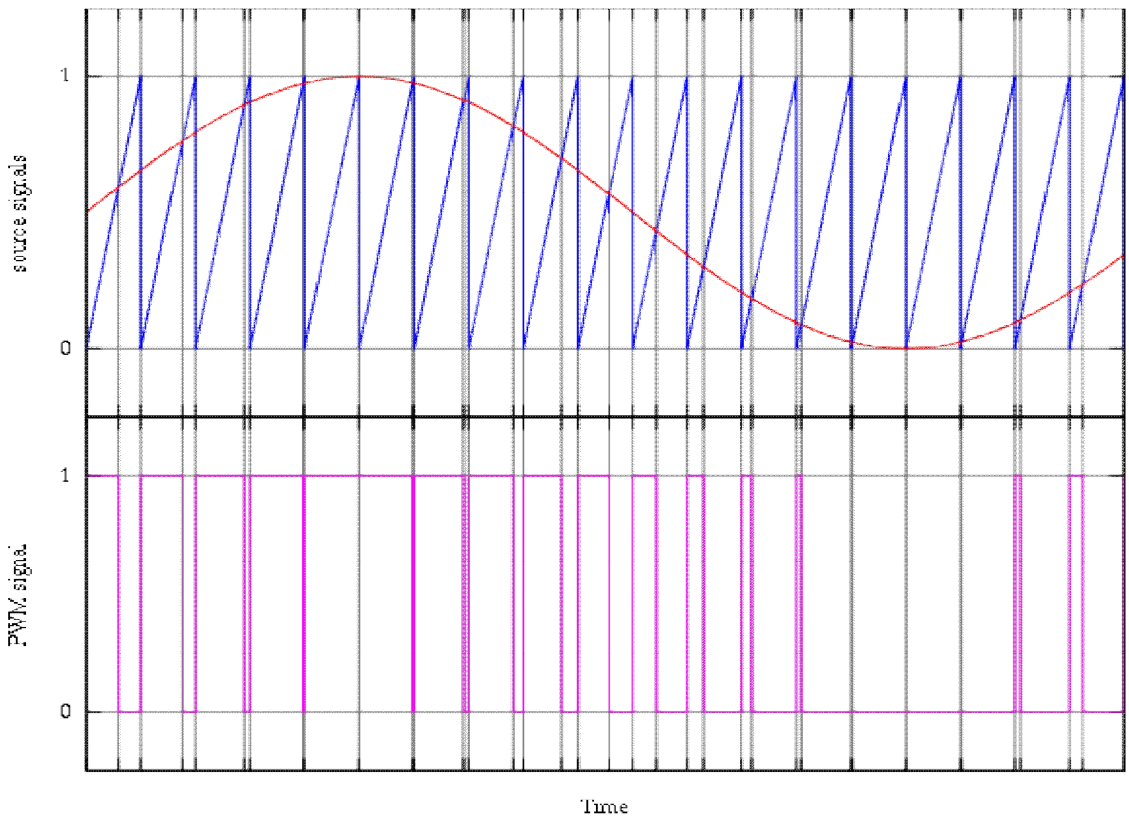

Figure 2.8 Source and PWM Signals

In boost converter, PWM signal will generate after receiving a signal from controller such as PID controller. A triangle waveform will be compare with the signal from controller to control the ratio of on to off time that required for the boost converter. When the triangle is above the signal, the output goes high. When the triangle is below the signal, the output goes low. The PWM then will be transfer to the switch device in boost converter to control the output voltage.

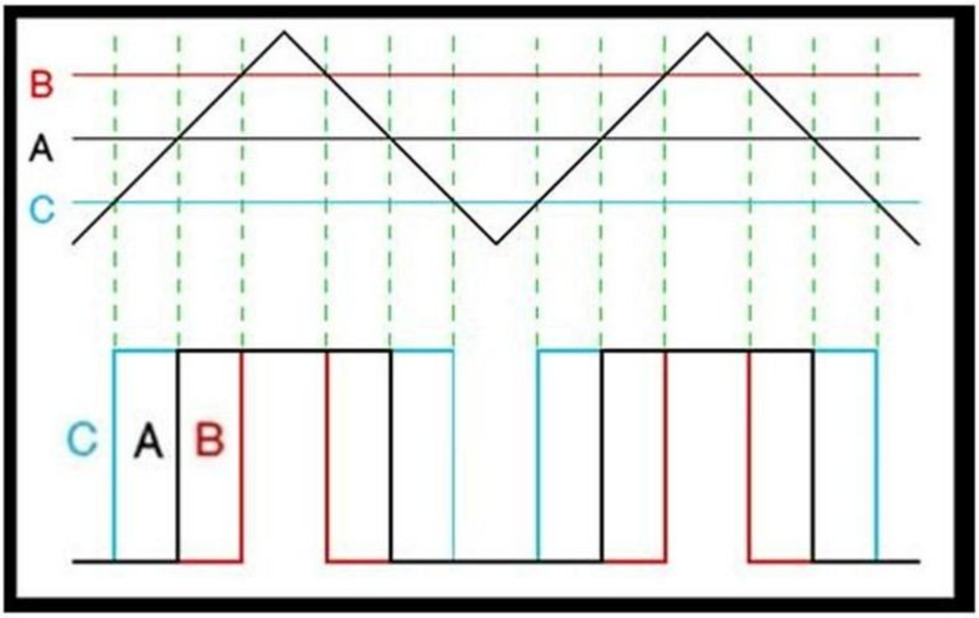

Figure 2.9 PWM Output

The A, B and C line shown in figure 2.9 represent signal from controller. The signal then will be compare with triangle waveform to produce PWM signal. The PWM signal produced differently according to the type of signal from controller. If the signal from controller is high when comparing with triangle waveform, the PWM signal produced has small duty cycle like line B in figure 2.9. When the signal from controller is low when comparing with triangle waveform, the PWM signal produced will has large duty cycle like line C.

2.7 Hysteresis Controller

Hysteresis controller is a feedback controller that switches abruptly between two states, high limit and low limit. This type of controller use two limit to decrease the steady-state error. It changes output states only when a given input goes below the low limit**, or** goes above the high limit**.** When the input goes above the high limit, the output will become low (=0). When the input goes below the low limit, the output will become high (=1).

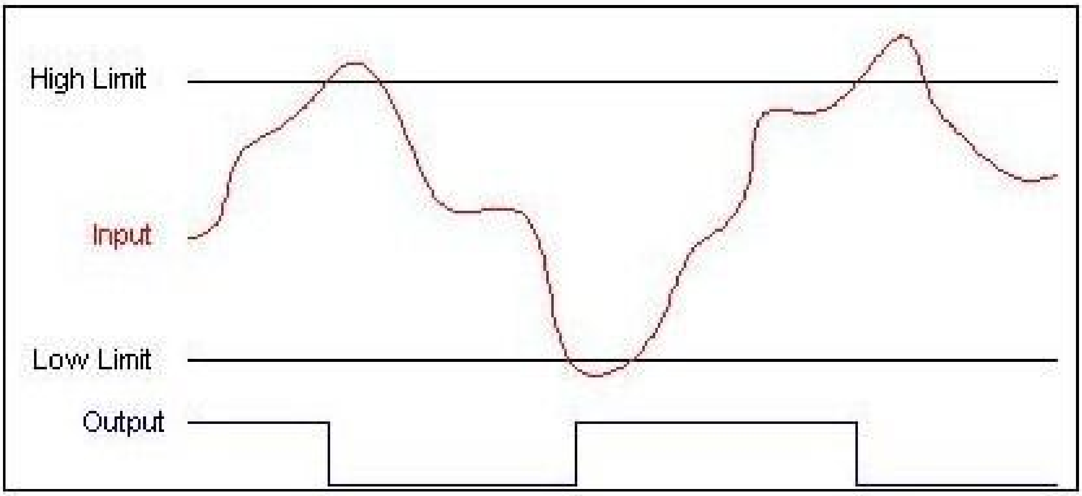

Figure 2.10 Boundary of Hysteresis Controller

In hysteresis controller, the controller can use either current or voltage as its reference. For basic operation current mode hysteresis controller, it use the output inductor current as reference and fed into a hysteresis window to control the switching frequency by controlling the time-delay trough the controller loop. The voltage mode hysteresis controller differs from the current mode controller by integrating the difference between the output voltage of the boost converter and the input reference voltage with an active integrator, which results in a sawtooth shaped carrier which is fed to a hysteresis window [7].

2.8 Three-Level Hysteresis Controller

The two-level hysteresis controller widely use in application because of its implementation is easy and fast dynamic response. However, the two-level hysteresis controller suffer from certain disadvantages of wide variation in switching frequency, which may be prohibitively high, and higher losses of the switches due to an increased number of switching per cycle [8]. To overcome this problem, the three-level hysteresis controller is proposing. The three-level hysteresis controller operates by adding more limits for high limit (upper bound) and low limit (lower bound). Whenever the current error crosses an outer hysteresis boundary, that time the output is set to an active positive or negative output to force a reversal of the current error [9]. When the current error reaches an inner hysteresis boundary, the current will be force reverse direction without reaching the outer boundary and that time the output is zero. If the output zero does not change the current direction, the current will surpass the inner boundary and reaches outer boundary. At this time, an opposite polarity inverter output will be commanded and the current will reverse anyway. This is mean the three-level hysteresis controller have more efficient limiter than two-level hysteresis controller.

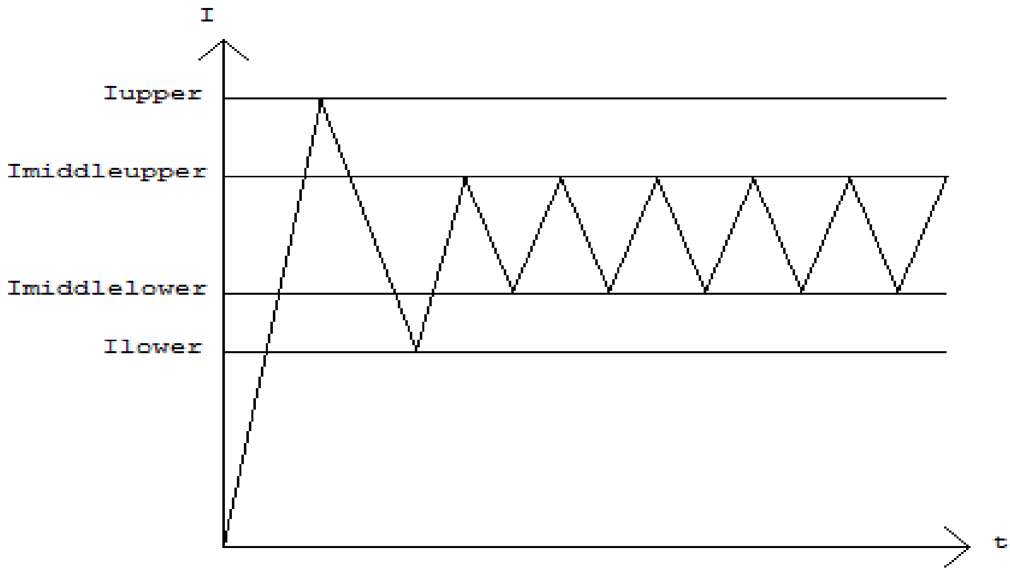

Figure 2.11 Boundary of Three-level Hysteresis Controller

CHAPTER 3

METHODOLOGY

3.1 Project Background

This project basically uses a DC-DC boost converter with three different controller i.e., proportional integral derivative (PID) controller, two-level hysteresis controller and three-level hysteresis controller. In this project, the three different types of controllers are compared in term of start-up transient response analysis and the load changes. All the controllers and boost circuit are implemented in MATLAB Simulink software. The detail controllers and circuit designed are presented in this Chapter. General feedback control of boost converter is shown in Figure 3.1 that has been used in this project.

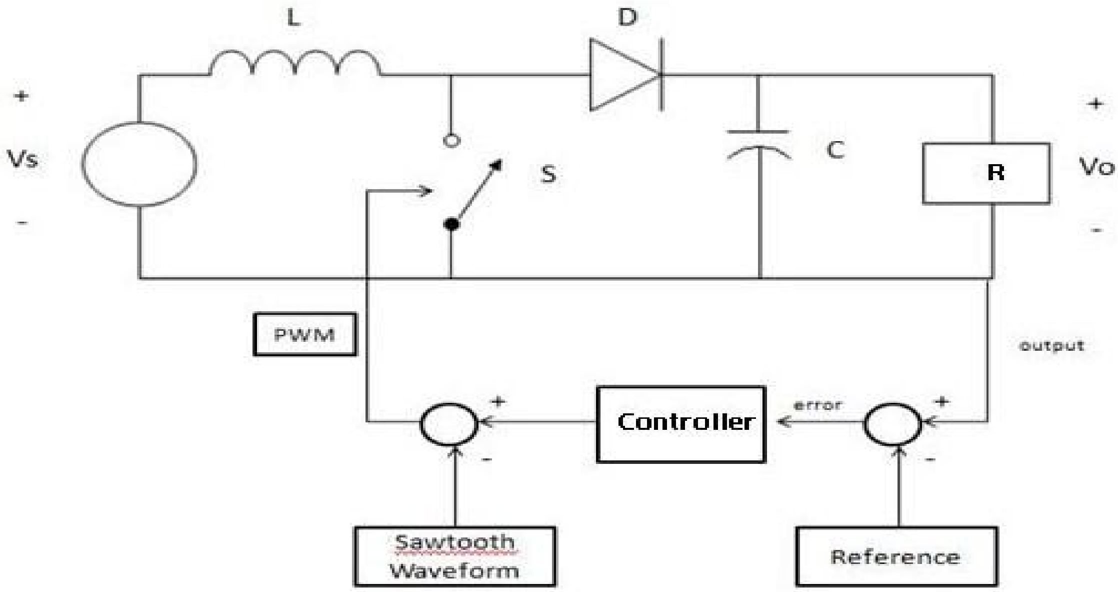

Figure 3.1 Boost Converter Topology with Feedback Controller

3.2 Build DC-DC Boost Converter

Initially the project is to constructs DC-DC boost converter using MATLAB Simulink software. In DC-DC boost converter, the circuit must contain at least two semiconductors which are switch and diode. Furthermore, the circuit also need storage element like inductor and capacitor. The inductor place in series with DC supply and capacitor is place parallel with load. These two component acts as a filter to the boost converter by reduce the output voltage ripple. In this project, an ideal switch is use instead of using other type switch like metal–oxide–semiconductor field-effect transistor (MOSFET) and insulated gate bipolar transistor (IGBT). The MOSFET and IGBT also can be use depending on situation of the boost converter circuit. The switch is place parallel with capacitor and in between of switch and capacitor, the diode is place. The boost converter circuit is shown in Figure 3.2.

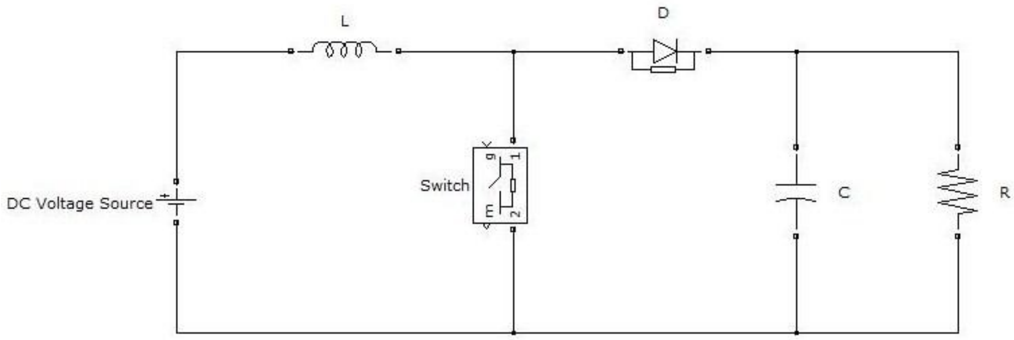

Figure 3.2 Basic Boost Converter Topology

Each component in boost converter must have specific parameter. It is wise to study and do some research about the suitable parameter for boost converter first. For this project, all components parameters are taken literature reviews as depicted in Table 3.1. The parameters are not everlasting; it can be change time to time according to the condition of the output voltage. For example, if the output voltage have ripple, it can be reduce by increasing the value of the capacitor or inductor. Switching frequency also play an important role in DC-DC boost converter. A suitable switching frequency need to determine to gain a desire output. The range of switching frequency for the boost converter is between 10 kHz until 100 KHz.

Table 3.1 List of Components and Parameter

Component	Parameter
Inductor	0.00389 H
Resistor Inductor	0.23 Ohm
Capacitor	0.000220 F
Resistor Load	5 Ohm
Switching Frequency	20,000 Hz
DC Voltage Source	5 V

3.3 Build Proportional Integral Derivative (PID) Controller

For second phase in this project, a controller of PID needs to be constructing for controlling the switching of the boost converter. The PID controller is constructing by building three different gains which are proportional, integral and derivative. At integral gain, an integrator is place and ideal derivative is place at derivative gain. After that, the three gains will be sum to produce an output of controller.

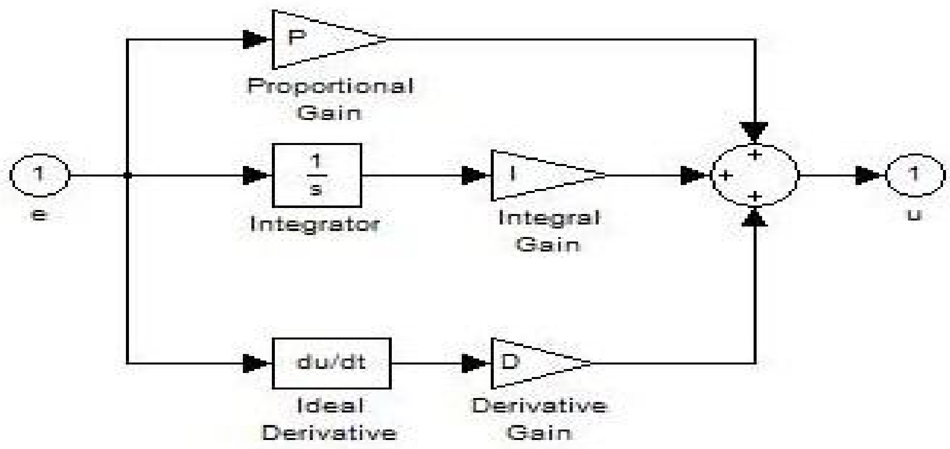

Figure 3.3 Proportional Integral Derivative (PID) Controller

After done constructing PID controller, PWM circuit need to build to produce PWM waveform for input of switch. As known, PWM waveform is important to control the switching process. It controls the open and close of the switch which affect the output of the boost converter. PWM circuit is constructing by compare the output signal of PID controller with repeating sequence (triangle or sawtooth waveform). The output PWM is high (1) when the triangle waveform is above the output signal of controller. When the triangle waveform is below the output signal of controller, it produces a low (0) PWM output.

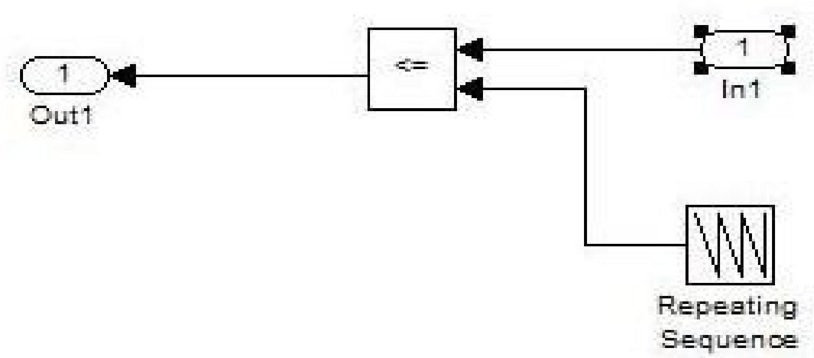

Figure 3.4 Pulse-Width Modulation (PWM) Topology

Appropriate and suitable values of switching frequency need to be set. For this project, the suitable switching frequency is between 10 kHz till 100 kHz. The try and error method is use to determine the right switching frequency of the boost converter. When the boost converter use high switching frequency like 100 kHz, the output voltage become too dense, so the switching frequency need to decrease. The switching frequency can be change in powergui block. In powergui block, the value is set in sample time. To get the switching frequency, the following equation is use.

Frequency (f) = 1/sample time (T),

Sample time (T) = 1/Frequency (f)

As the value of sample time (T) is use in time value of repeating sequence, the sample time (T) need to be declared. When declaring the sample time, the value of switching frequency must be included and set in subsystem of PWM.

3.4 Tuning Proportional Integral Derivative (PID) Controller

When done with constructing and set parameter for both boost converter and PID controller, a tuning of PID controller need to be conduct. In tuning of PID controller, the three different parameters which are proportional, integral and derivative need to be tune consistent to gain targeted output. In this project, the manual tuning of PID controller is choosing. Firstly, all parameters are set to zero. Then the value of proportional parameter is increased till the output voltage start overshooting and ringing significantly. After that, the value of derivative parameter is increased till the overshoot is reduced. Lastly, the value of parameter integral is increase until the final error equal to zero. For better result, any parameter component and PID controller can be change slightly according to the condition of output voltage.

3.5 Build Hysteresis Controller

In two-level hysteresis controller, M-file is use to build the controller as shown in figure 3.5. In M-file, an equation, declaration and some coding of hysteresis are constructing. An upper bound and lower bound coding include in the M-file. After the M-file is done constructing, it needs to use in simulink boost converter as a controller for controlling the boost converter. A specific block name MATLAB function is use to call the M-file into the simulink by state the name of M-file. For two-level hysteresis controller, the input of the controller is current. It is differing from PID controller that uses voltage output of boost converter as it input. This is because, for hysteresis controller, using current instead of voltage as input is more accurate in obtaining a good output result.

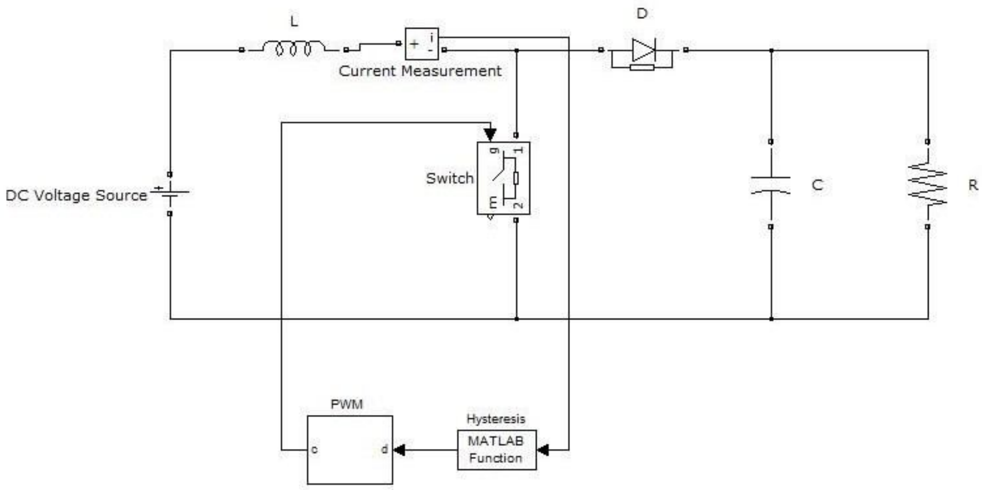

Figure 3.5 Basic Topology of Boost Converter with Hysteresis Controller

In hysteresis control as shown in Figure 3.5, each bound is set by using the calculated output current from the converter plus tolerance tuning ripple as follow;

$$Iinf = \frac{Vinf}{(1-Dinf)R} \tag{1}$$

$$Upper\ Bound = Iinf + 0.05 \tag{2}$$

$$Lower\ Bound = Iinf - 0.05 \tag{3}$$

From the setting bounds, the output control switching is set to low (= 0) if the sensed output current exceeds the upper bound. While, the output switching is set to high (=1) if falls below the lower bound, otherwise the output switching is set on the average.

3.6 Build Three-Level Hysteresis Controller

Three-level hysteresis controller is quiet same as two level hysteresis controller as shown in Figure 3.6. It only has addition of boundary that make it three-level controller. In M-file of three-level hysteresis controller, a coding for boundary is added. Hence in the M-file has inner and outer bound coding. To use the M-file, it need to call in the simulink same as two-level hysteresis controller. MATLAB function block is use to call the M-file three-level hysteresis controller.

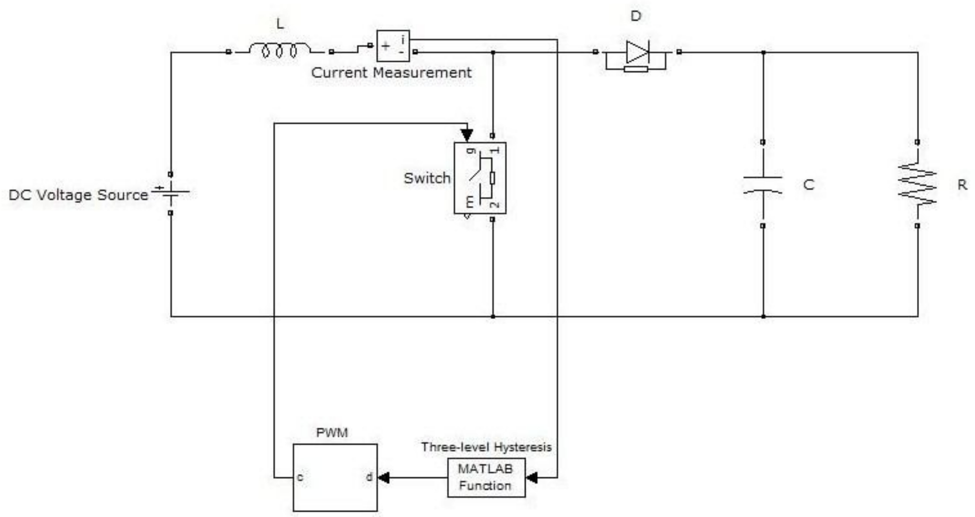

Figure 3.6 Basic Topology of Boost Converter with Three-level Hysteresis Controller

In three-level hysteresis control, each bound is set by using the calculated output current from the converter plus tolerance tuning same as two-level hysteresis controller. The differ of three-level hysteresis controller from two-level hysteresis controller is it has an additional bound, middle upper and middle lower bound. The middle upper and middle lower bound have plus minus of very small value.

$$Middle\ Upper\ Bound = Iinf + 0.005 \qquad (4)$$

$$Middle\ Lower\ Bound = Iinf - 0.005 \qquad (5)$$

From the setting bounds as shown in equation 4 and 5, the output control switching is set on the average when the sensed output current in the middle of middle upper bound and middle lower bound. The output switching control is calculated on the average ($Dinf$).

$$Dinf = \frac{\left(2 - \frac{E}{Vr}\right) - \sqrt{\left(\frac{E}{Vr}\right)^2 - \frac{4r}{R}}}{2} \qquad (6)$$

3.7 Analyze the Performance of All Three Controllers

The last phase for this project is analyzing the performance of all three controllers. In this phase, all controllers will be comparing its performance for controlling the boost converter in term of transient response and load changes of the boost converter. The output voltages of boost converter using three different controllers are analyzed its rise time, overshoot, settling time and steady-state error. Then, a simple load changes circuit is added to the boost converter for analysis the performance of controllers in event of load changes. All data collected then will be comparing to determine the advantage and disadvantage for each type of controllers. A detail result and discussion will be made according to the data collected from the analysis.

CHAPTER 4

RESULT AND DISCUSSIONS

This chapter presents the results and discussion for each controllers. The comparisons are carried out and the analyses of the comparisons are given.

4.1 Rise Time

Rise time is refer to the time required for a signal to change from specific low value to a specific high value which low value is 10% and high value is 90%. The rise time for boost converter is shown in figure 4.1, figure 4.2 and figure 4.3 respectively with different types of controllers which is PID controller, two-level hysteresis controller and three-level controller.

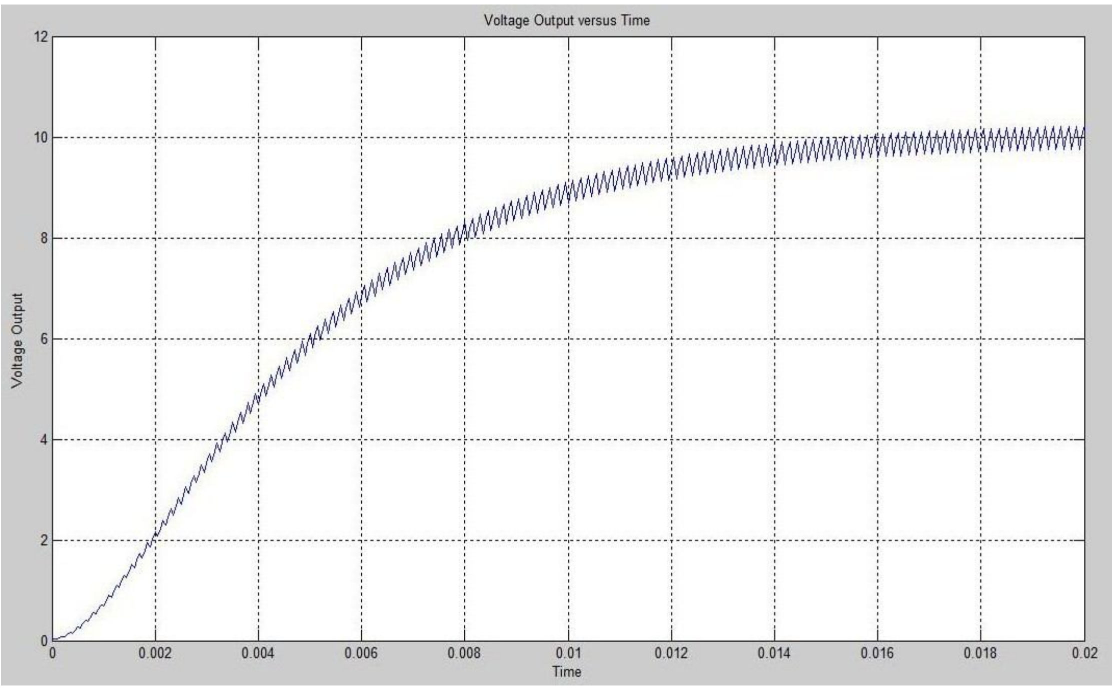

Figure 4.1 Rise Time of Voltage Output Boost Converter with PID Controller

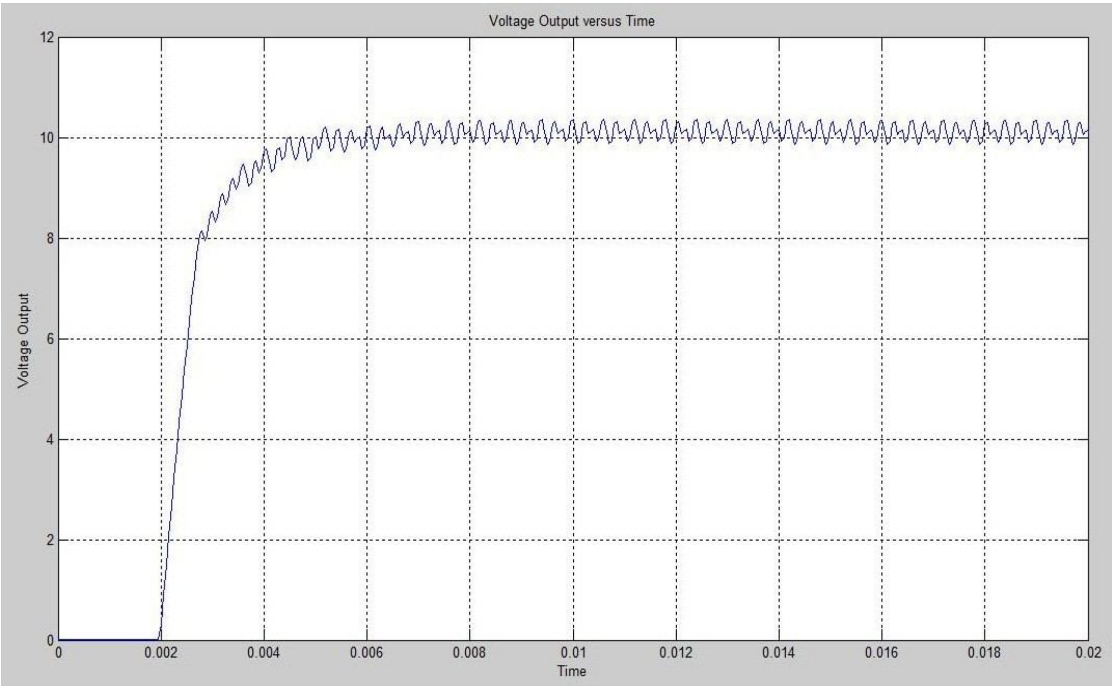

Figure 4.2 Rise Time of Voltage Output Boost Converter with Hysteresis Controller

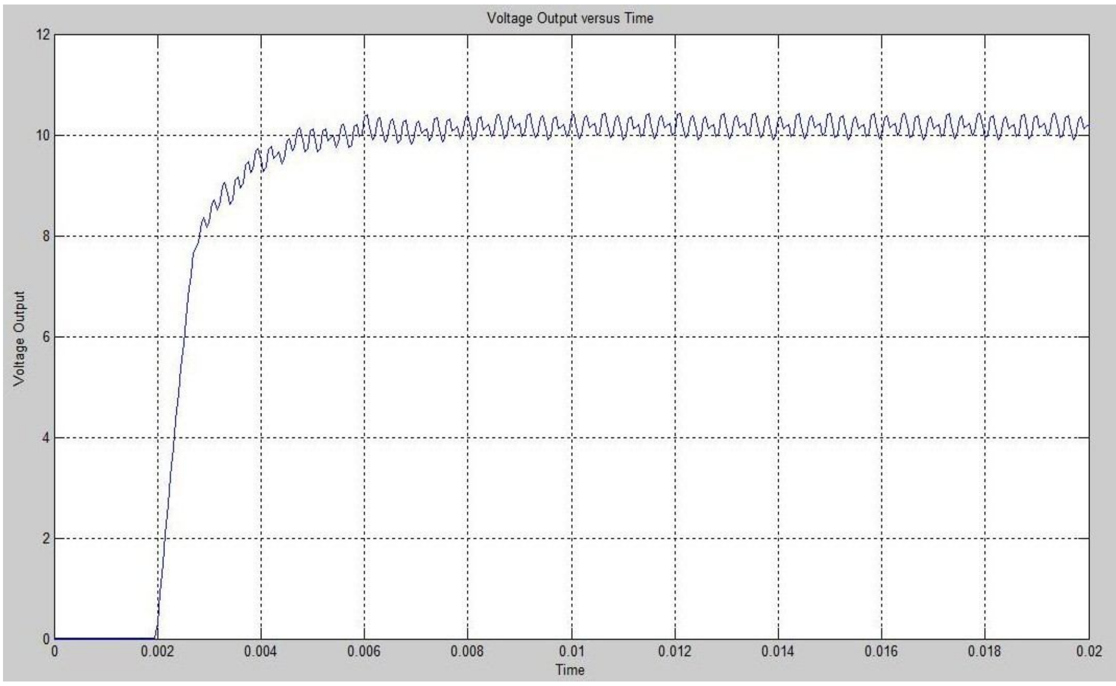

Figure 4.3 Rise Time of Voltage Output Boost Converter with Three-level Hysteresis Controller

Rise time for each different type of controllers is varies. For PID controller, the rise time is from 0.001 second to 0.012 second like shown in figure 4.1. For two-level hysteresis controller, its rise time is start from 0.002 second to 0.003 second like shown in figure 4.2. While three-level hysteresis has risen time same as two-level hysteresis controller which is from 0.002 second until 0.003 second. This time indicate the signal to produce 10% to 90% of its highest output value. It means this time show the time taken to produce output from 1V to 9V as the highest output value is 10V. PID controller takes about 0.012 second to produce 90% of highest output voltage differ from two-level and three-level hysteresis controller which only take 0.003 second. However, the PID controller start to rise faster than the other two controller where it start at 0.001 second and the other two controller start to rise 0.001 second late from PID controller at 0.002 second. This result shows that between PID controller, two-level hysteresis controller and three-level hysteresis controller have trade-off performance. PID controller has advantage in starting rise time but poor in period of rise time while two-level and three-level hysteresis controller poor in starting rise time but have advantage in period of rise time.

4.2 Overshoot

Overshoot is define as the output level that higher than steady-state of a signal. Overshoot occur when the transitory values exceed steady-state value. When a signal has an overshoot, it represents a distortion of the signal. Figure below show the analysis about overshoot for PID controller, two-level hysteresis controller and three-level hysteresis controller in controlling boost converter.

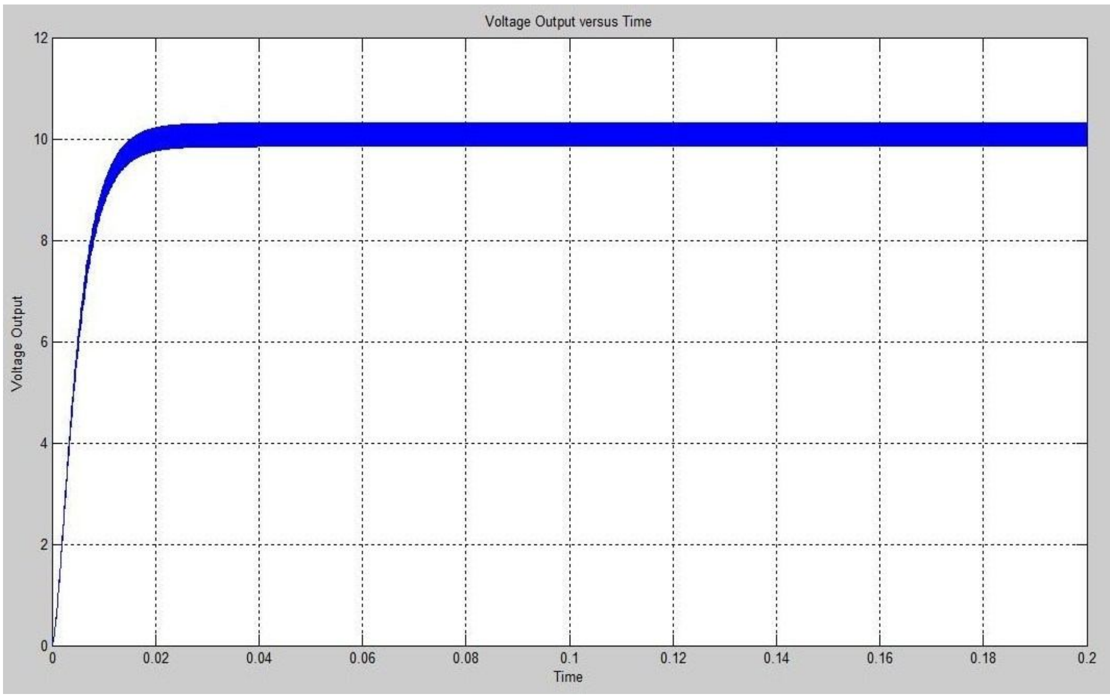

Figure 4.4 Overshoot Analysis for PID Controller

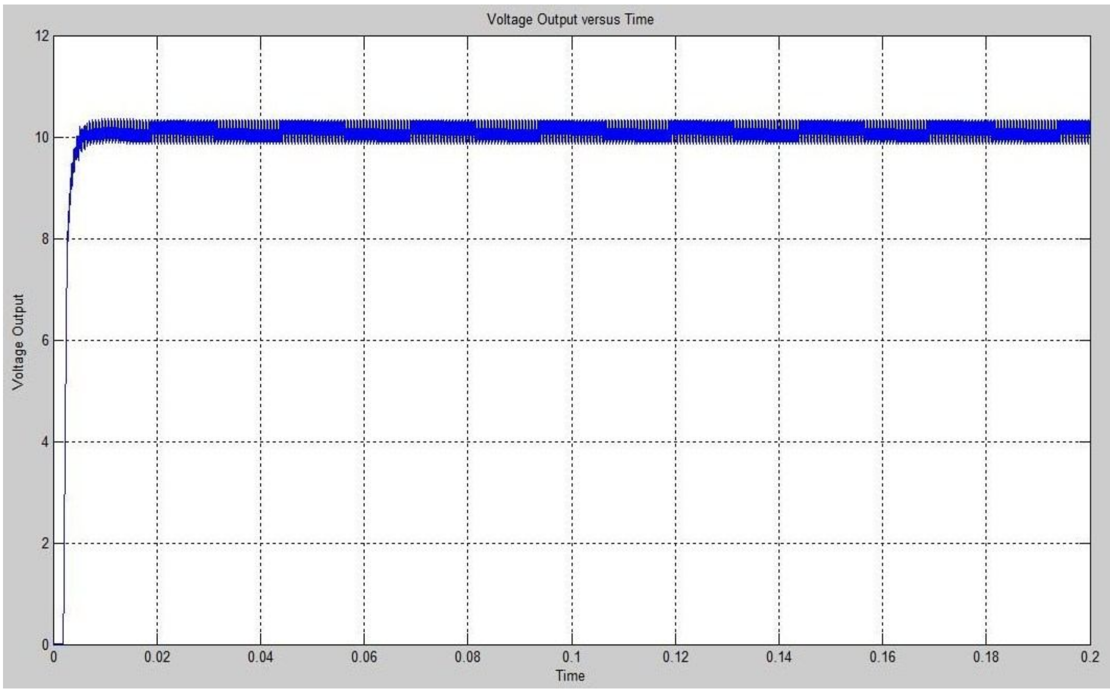

Figure 4.5 Overshoot Analysis for Hysteresis Controller

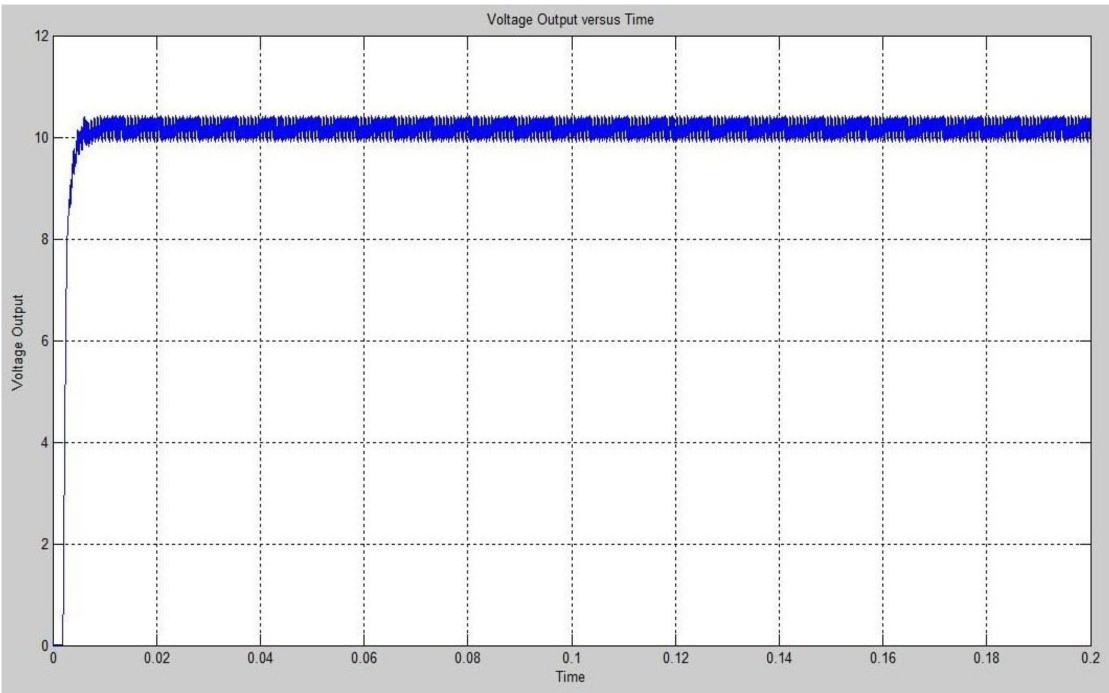

Figure 4.6 Overshoot Analysis for Three-level Hysteresis Controller

Form figure 4.4, figure 4.5 and figure 4.6, it is observe that none of the output voltage have an overshoot. The voltage output for three controllers not exceeding the final value of each output voltage. This shown that all these three types of controller are suitable for controlling boost converter which the output voltage produces does not have an overshoot.

4.3 Settling Time

Settling time is a time that an output to takes to reached its steady-state. Settling time also best describe as a starting time that require for an output to reach and remain constant following its steady-state. An analysis about settling time is like figure below for all three different type of controller. The value of time is change to suitable range to get the value of settling time more accurate.

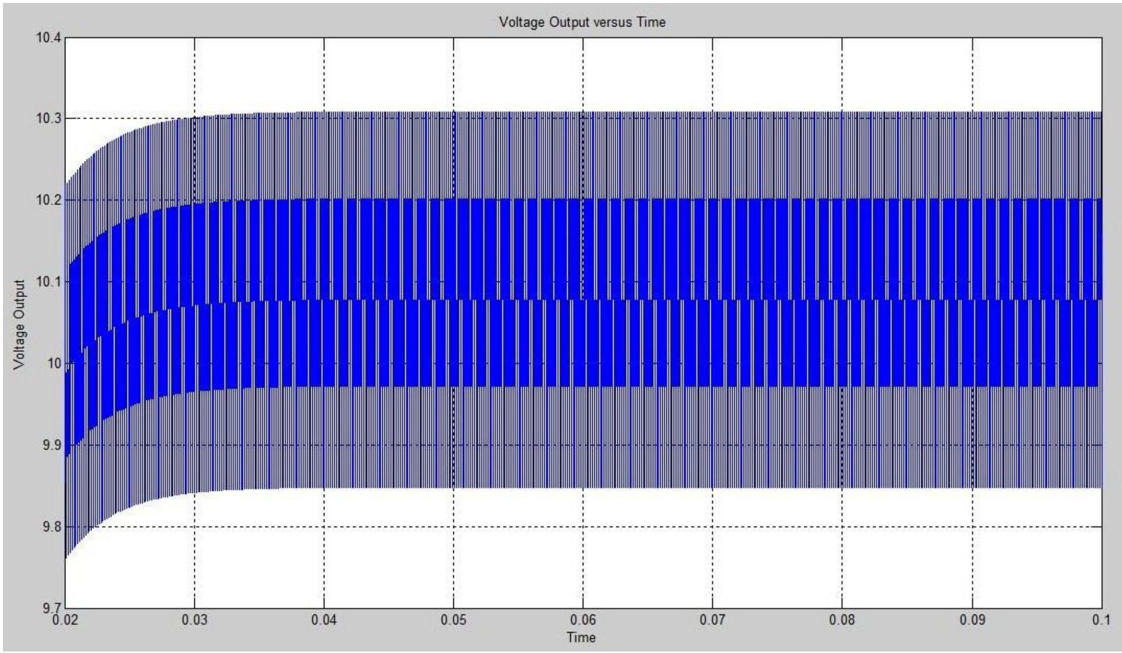

Figure 4.7 Settling Time for PID Controller

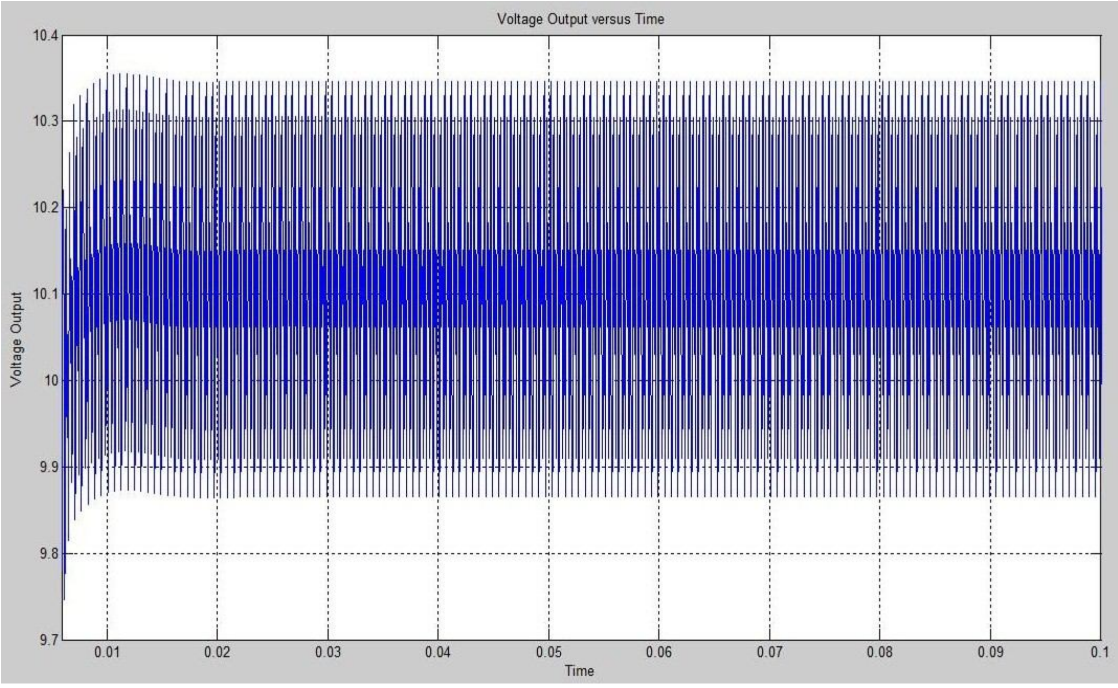

Figure 4.8 Settling Time for Hysteresis Controller

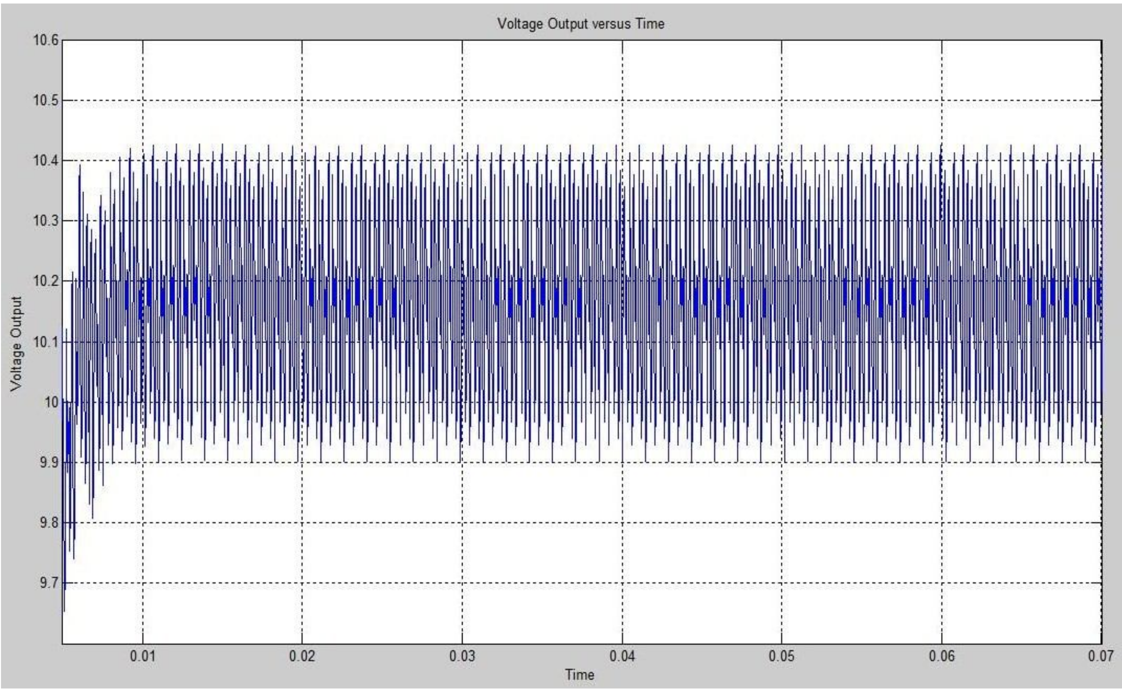

Figure 4.9 Settling Time for Three-level Hysteresis Controller

From figure 4.7, figure 4.8 and figure 4.9 show the settling time for PID controller, two-level hysteresis controller and three-level hysteresis controller. Settling time for voltage output of boost converter using PID controller recorded at 0.03 second. When boost converter using two-level hysteresis controller, its settling time change to 0.018 second and 0.012 second when using three-level hysteresis controller. The settling time recorded for using three different types show that three-level hysteresis controller is more efficient in controlling boost converter than PID controller and two-level hysteresis controller. It is because using three-level hysteresis controller, the output voltage response fast to its steady-state than the other two controllers.

4.4 Steady-state Error

Steady-state error plays an important role in determining a suitable and efficient controller for controlling boost converter. Steady-state error shows the different between the steady state output and the desired output. In this project, the desired output is set to 10V which the boost converter will step up the voltage from 5V. For steady-state error analysis, figure 4.4, figure 4.5 and figure 4.6 are referring. From the figures, all voltage output does not have steady-state error. All voltage output remains constant and smoothly follows the desired output. These conclude that PID controller, two-level hysteresis controller and three-level hysteresis controller are suitable in controlling boost converter.

Table 4.1 Comparison of Transient Response between Three Different Type Controllers

Type of controller	PID controller	Two-level Hysteresis Controller	Three-level Hysteresis Controller
Rise Time	Fair	Good	Good
Overshoot	None	None	None
Settling Time	Poor	Fair	Good
Steady-state Error	None	None	None

4.5 Load Changes

Aside from analysis about transient response, the three different type of controller also will be compared with load changes. Boost converter will be added with specific circuit of load changes with three different value of load. The value of load is plus minus 20% up till 50% of origin load value. For the first value of load, it is set the origin value of load with period of time from 0 second to 0.05 second. The next change of load is minus 20% of origin value of load with period of time from 0.05 second until 0.13 second. Lastly the load will increase 20% from origin value of load from 0.13 second until 0.2 second. Figure 4.10, figure 4.11 and figure 4.12 show the voltage output when a boost converter have load changes for PID controller, two-level hysteresis controller and three-level hysteresis controller.

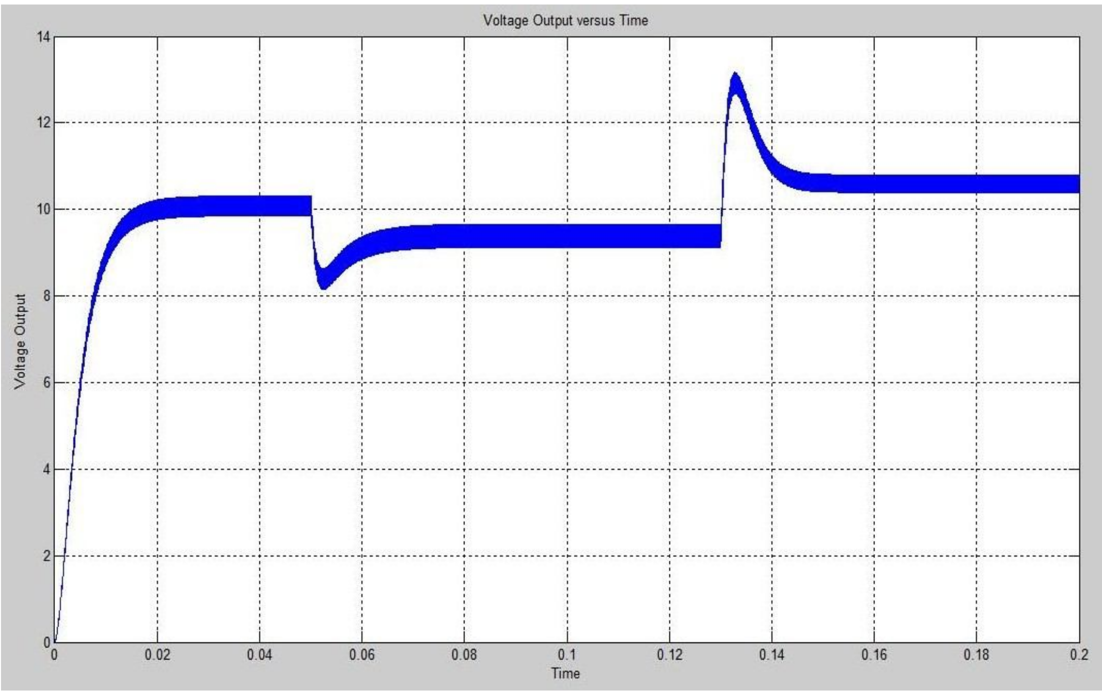

Figure 4.10 Load Changes of PID Controller

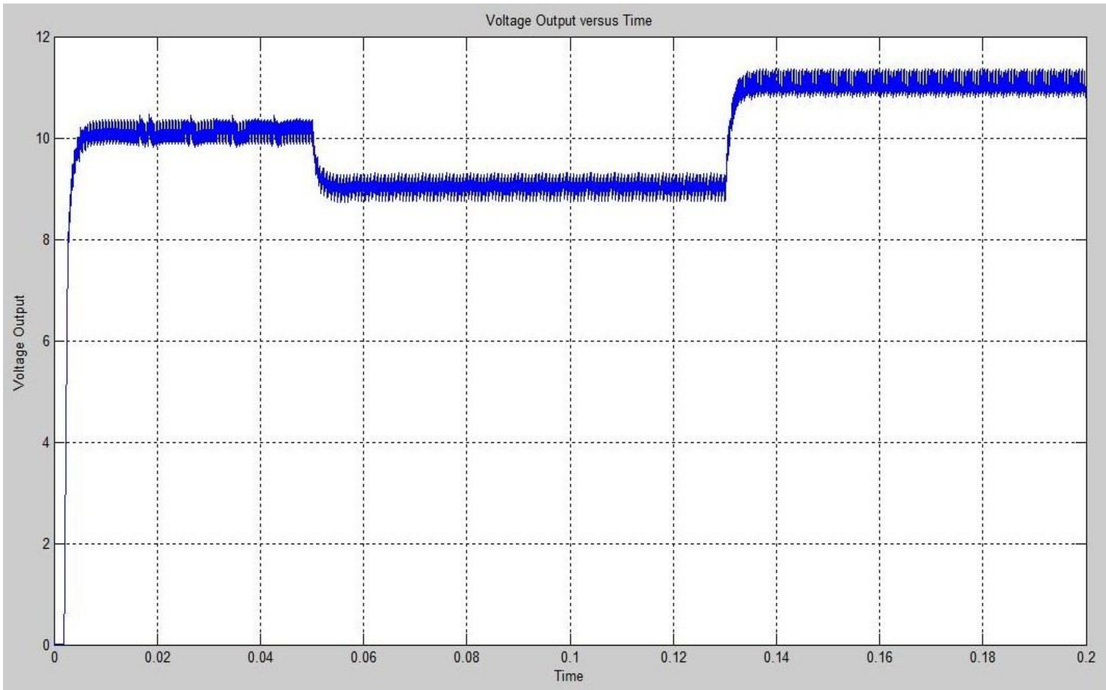

Figure 4.11 Load Changes of Hysteresis Controller

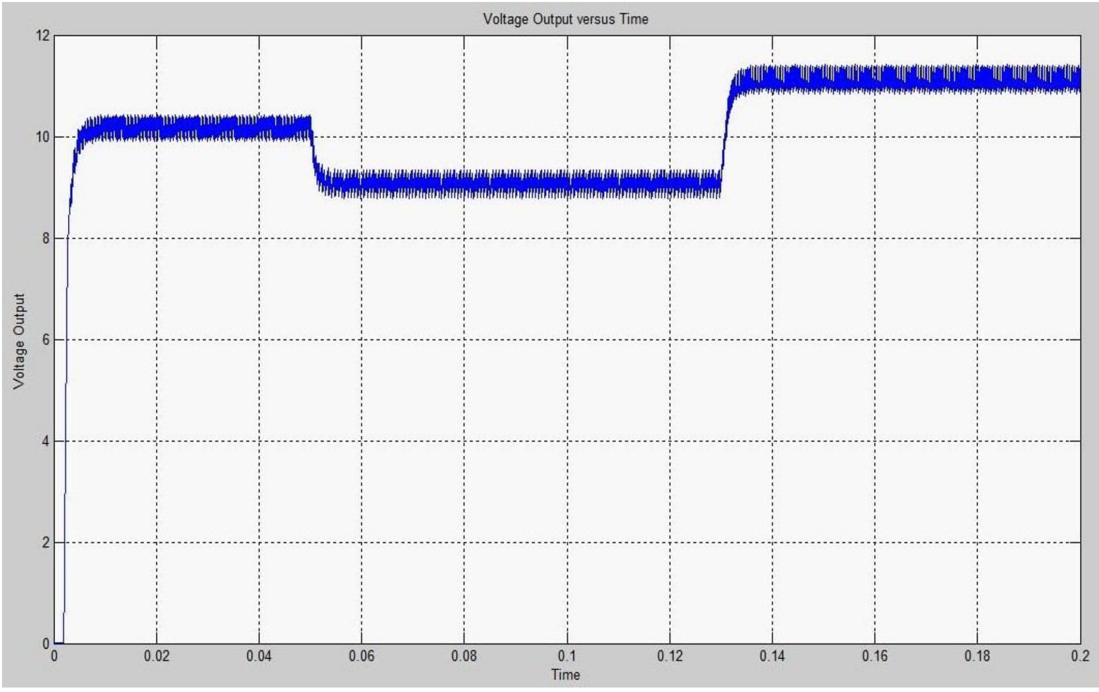

Figure 4.12 Load Changes of Three-Level Hysteresis Controller

PID controller has advantage over the other two controllers in load changes event like shown in figure above. The PID controller has ability to produce the output voltage revert to its desired output when having load changes. Even the output produces not exactly back to desire output but the ability to revert the output is an advantage for PID controller. The PID controller maybe needs to retune to gain the desired output. Two-level hysteresis controller and three-level hysteresis controller cannot maintain the output when having a load changes. The output voltage remains to new value of voltage output. In figure 4.11, it is observe that the output voltage has steady-state error when having load changes. The origin output without load changes does not have steady-state error. This show a disadvantage of two-level hysteresis controller when having load changes where the output will has steady-state error.

4.6 Reference Changes

Reference changes are an additional analysis for this project to determine the performance of three different types of controllers in controlling the boost converter. For scope of this project, the output voltage is set to 10V which is the boost converter step up 100% of its input, 5V. This analysis changes the reference value to produce another desired output which is 8V and 12V. The performance of the three different types of controllers are determines whether the boost converter produce same output voltage with reference or not.

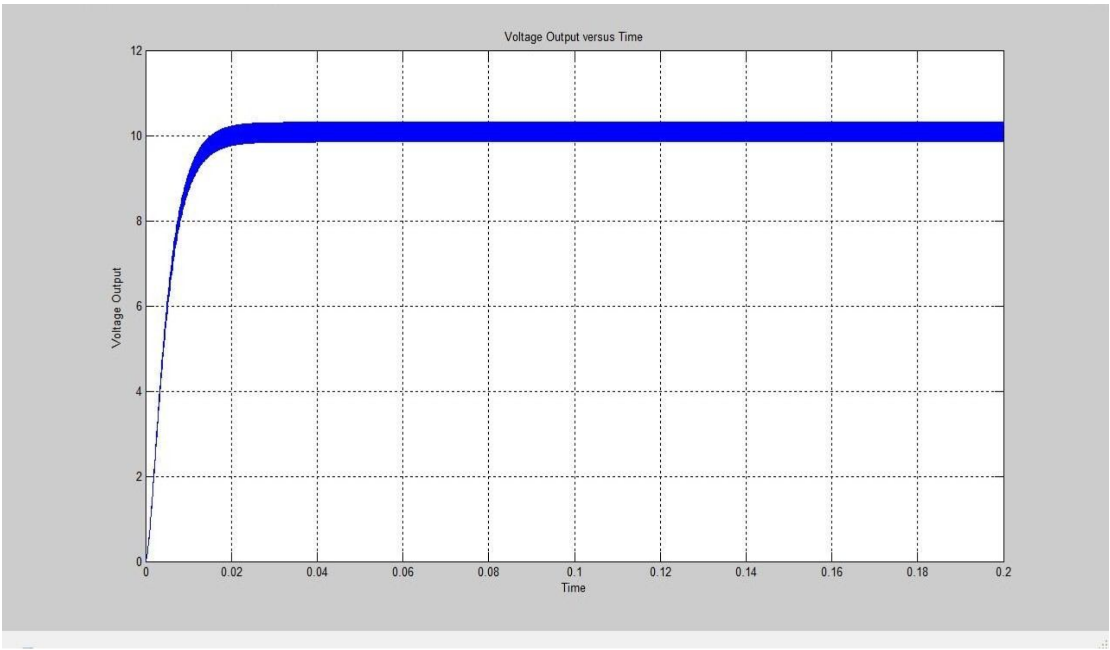

Figure 4.13 Output Voltage Using PID Controller with 8V Reference

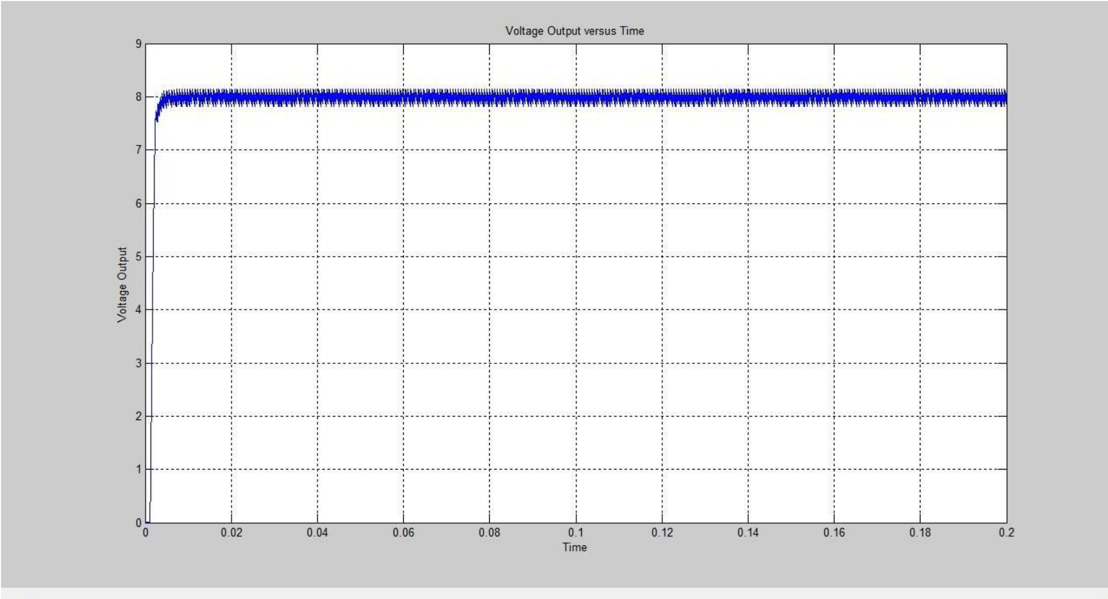

Figure 4.14 Output Voltage Using Hysteresis Controller with 8V Reference

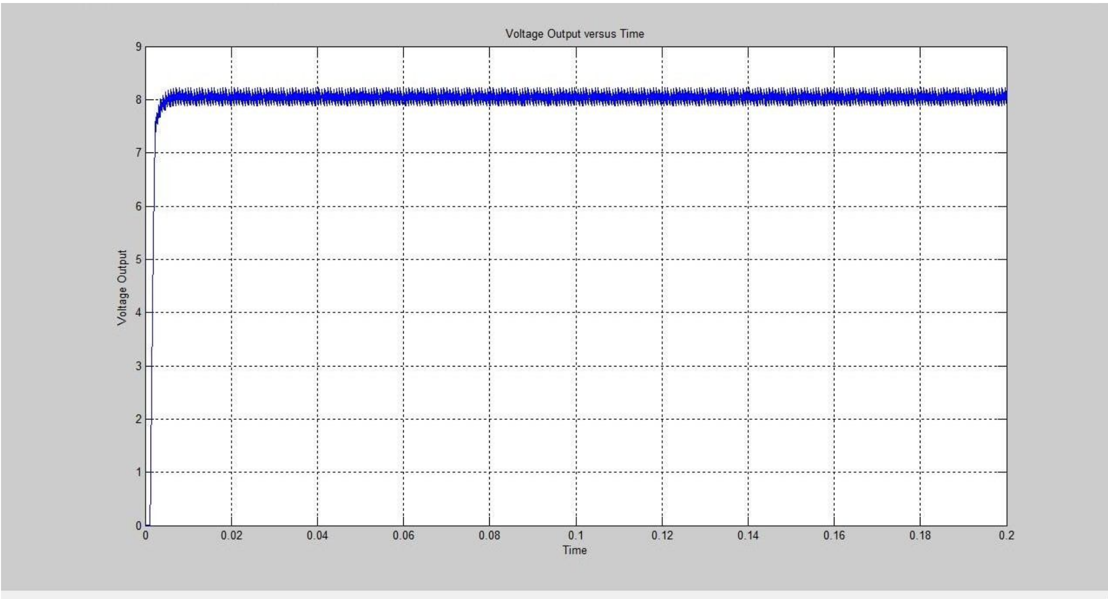

Figure 4.15 Output Voltage Using Three-level Hysteresis Controller with 8V Reference

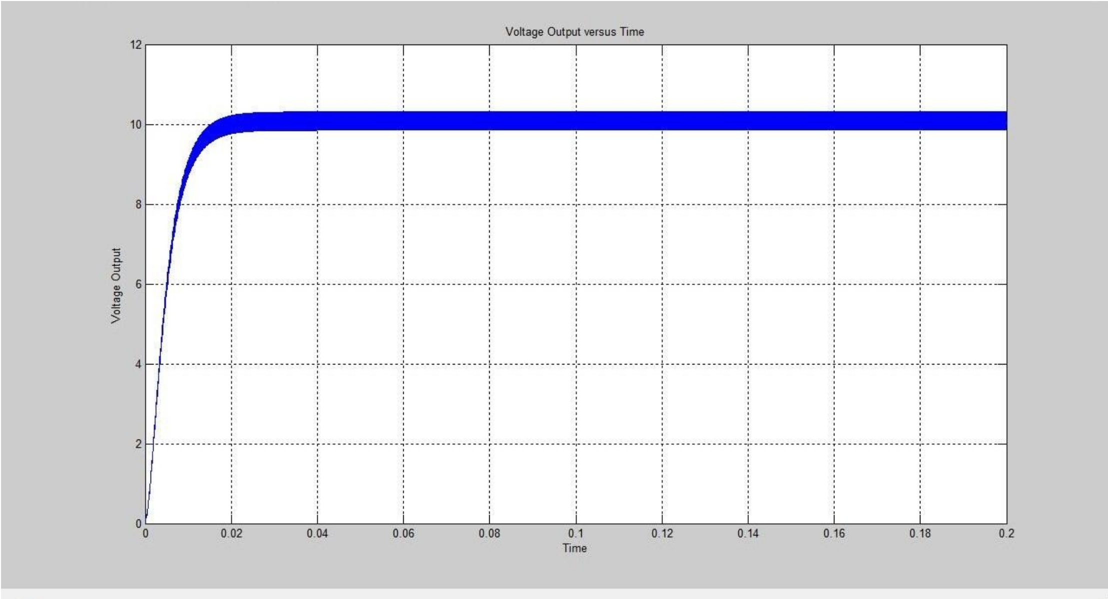

Figure 4.16 Output Voltage Using PID Controller with 12V Reference

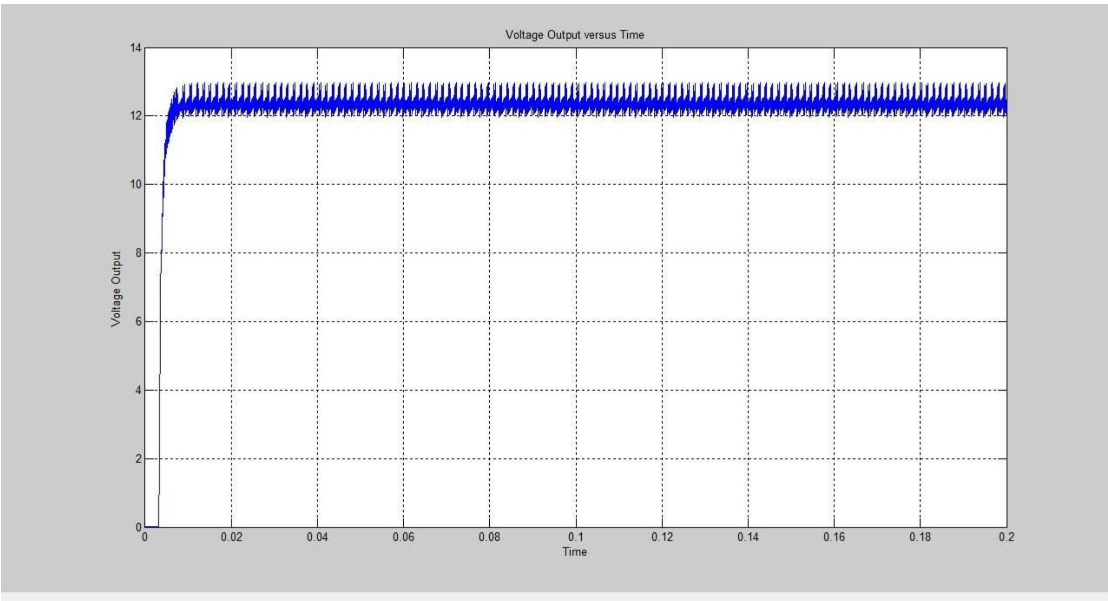

Figure 4.17 Output Voltage Using Hysteresis Controller with 12V Reference

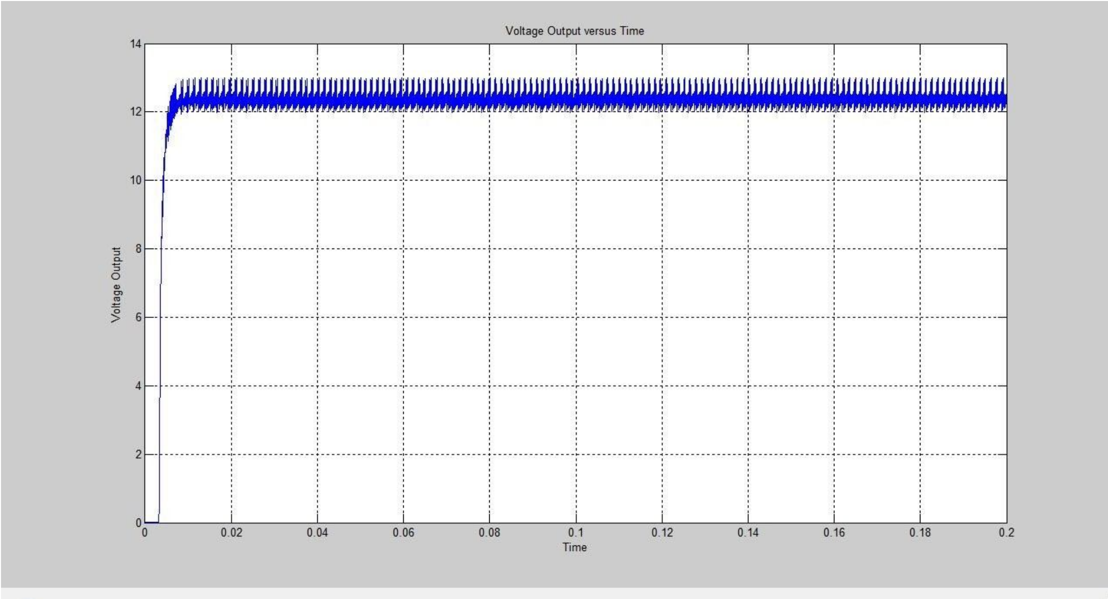

Figure 4.18 Output Voltage Using Three-level Hysteresis Controller with 12V Reference

From result above, when reference value changed to 8V and 12V, the output voltage when using PID controller is not same with value of reference. The output voltage remains to 10V. When the boost converter is use hysteresis controller and three-level hysteresis controller, the output voltage from boost converter change according to reference value. This is show the disadvantage of PID controller when having reference change. The PID controller need to re-tune to obtained the desired output.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Concluding Remark

The proposed of this project is to analysis the control methods for DC-DC boost converter. The system needs to step up the input DC voltage from 5V to 10V DC. A suitable and efficient feedback controller needs to choose to make the boost converter produce desired output. An analysis about the control method using different type of controller is important to make a comparison and determined the advantage and disadvantage for each type of controller. The controller that use in this project is PID controller, two-level controller and three-level controller.

The main focus of this project is to determine the advantage and disadvantage for PID controller, two-level hysteresis controller and three-level controller. All these controllers are developing and make a comparison performance in term of transient response and load changes. It is show that the PID controller, two-level hysteresis controller and three-level controller has a trade-off performance between the load changes and transient response.

5.2 Recommendation of Future Work

The work in this project suggest that future enhancement can be carried out to further improvement and to achieve better performance in controlling DC-DC boost converter. Below are some of the proposed future works:

The first recommendation is the improvement of procedure to analysis control method for DC-DC boost converter. This project work fully using simulation via software MATLAB Simulink. For better and accurate analysis, it is recommended doing hardware work also to make comparison between PID controller and hysteresis controller. At the end of the project, an additional analysis to compare result from simulation and experimental can be included to get better result analysis.

The second recommendation is the improvement of PID controller. The PID controller is hard to tune using manual methods due to many possibility gain value. It is suggest using other popular method like Ziegler-Nichols or Software tools method to tuning the PID controller. With other method, it can safe time to get the best tuning of PID controller and also can obtain better result in controlling boost converter.

The last recommendation is to make improvement of hysteresis controller. In load changes event, the hysteresis controller is not able to produce output reverts to its steady-state. It might be implemented by adding load identification algorithm since the hysteresis control is depends on the parameter of the load

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