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A VOLTAGE BASED SPWM TECHNIQUE ON A NEW APPROACH FOR MULTILEVEL INVERTER

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Degree of Bachelor of Electrical Engineering (Control, Instrumentation and Automation)

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DECLARATION

I declare that this report entitle "A Voltage Based SPWM Technique on a New Approach for Multilevel Inverter" is the result of my own research except as cited in the references. The report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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Signature: ....

Supervisor's Name: DR. AZRITA BINTI ALIAS

Date : ....

DEDICATION

To my beloved parents,

for their enduring love, motivation and support

ACKNOWLEDGEMENT

I wish to express my deepest appreciation to various people for their contribution in completing this project. A special gratitue I would like to give to Dr. Azrita bt. Alias, my research supervisor, for her contribution in stimulating ideas and assisting the research. Also, her critiques, support, encouragement and patient guidance throughout this project.

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Finally, I wish to thank my parents for their love, support, encouragement and patience throughout my study.

ABSTRACT

Inverters are power electronic converters converting the several levels of direct current (DC) voltages into alternating current (AC) voltages required for loads. Multilevel inverters are the inverters with voltage level three or more. Recently, industries have begun to demand higher power equipment. Therefore, multilevel inverters started to gain popularity among industries since they are able to deal with higher voltage levels. There are few advantages of multilevel inverter: it produces nearly sinusoidal waveform, decreases the harmonic distortion, thus decreases the losses, can deal with high power ratings equipment, and needs a smaller filter to smooth the graph. Besides that, the system's complexity is also reduced and it became lighter and cheaper. This paper aims to investigate on SPWM switching strategy of 5- level cascaded hybrid multilevel inverter (CHMI) needed to develop a new sinusoidal pulse width modulating (SPWM) switching strategy for CHMI. This paper also aims to investigate on output voltage total harmonic distortion of conventional inverter and five- level inverter. In this paper, there will be a new switching strategy for a 5- level CHMI. The model of a 5-level CHMI will be simulated using MATLAB Simulink. The output of the simulation will be analysed.

ABSTRAK

Inverter adalah penukar kuasa elektrik yang menukarkan arus terus (DC) ke arus ulang-alik (AC) yang diperlukan untuk beban elektrik. Inverter Voltan Bertingkat adalah inverter dengan tiga atau lebih tingkat voltan keluaran. Baru-baru ini, industri telah mula memerlukan peralatan kuasa yang lebih tinggi. Oleh itu, Inverter Voltan Bertingkat mula mendapat populariti di kalangan industri kerana mereka mampu menangani voltan yang lebih tinggi. Terdapat beberapa kelebihan Inverter Voltan Bertingkat iaitu ia menghasilkan bentuk voltan keluaran berbentuk sinusoidal, mengurangkan harmonik, sekali gus mengurangkan kehilangan tenaga, boleh berurusan dengan peralatan berkuasa tinggi, dan memerlukan penapis yang lebih kecil untuk melicinkan bentuk voltan keluaran. Selain itu, kerumitan sistem juga dikurangkan dan ia menjadi lebih ringan dan lebih murah. Kertas kerja ini bertujuan untuk mengkaji strategi pensuisan SPWM untuk Inverter Voltan Bertingkat Lima. Kertas ini juga bertujuan untuk menganalisi voltan output, jumlah harmonik inverter konvensional dan tahap lima inverter. Dalam kertas ini, akan ada satu strategi pensuisan baru untuk tahap 5- CHMI. Model 5-tahap CHMI akan disimulasikan menggunakan MATLAB Simulink. Output simulasi akan dianalisis.

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LIST OF TERMINOLOGIES

AC	-	Alternating current
DC	-	Direct Current
PWM	-	Pulse width modulation
SPWM	-	Sinusoidal pulse width modulation
CHMI	-	Cascaded H- bridge multilevel inverter
VSI	-	Voltage source inverter
CSI	-	Current source inverter
MVSI	-	Multilevel voltage source inverter
THD	-	Total harmonic distortion
SDLC	-	System Development Life Cycle
PH Disposition	-	In phase
PO Disposition	-	In phase above zero, opposite phase below zero
APO Disposition	-	Alternatively in opposite phase

CHAPTER 1

INTRODUCTION

1.1 Project Background

The renewable energy resources are gaining industries more attention, since the shortage of fossil fuels and greenhouse effect crisis are worrying nowadays[1]. The demand for renewable energy sources such as solar, wind and hydro energy is one of the reasons of the fast development in power converters research. In most of the renewable resources power systems, an inverter system is needed for renewable energy conversion from DC (renewable resources) to AC for commercial use.

Inverters are power electronic converters that convert DC to AC. The inverters can be categorized into voltage source inverter (VSI) and current source inverter (CSI). In renewable resources systems, VSI is more suitable compared to CSI[2]. This is due to a VSI is fed by a fixed DC voltage and its components needed is lesser than of a CSI. Besides that, the output of a CSI has higher harmonics. A power system with a higher harmonics has the tendency to create additional switching losses. Therefore, to eliminate the harmonics, additional filters must be added at the input and the output sides.

There are conventional inverters and multilevel inverters. The conventional inverter output voltage waveform is the bipolar square wave with two levels of voltage which are the input voltage, V_{DC} and $-V_{DC}$. The multilevel inverter's output voltage waveform is a staircase-liked waveform with higher than two output voltage levels.

The most common way to control the output voltage of multilevel voltage source inverter (MVSI) is to implement sinusoidal pulse-width modulation (SPWM) switching strategies. The SPWM control is operating based on the concept of comparison of a modulating signal with triangular carrier waveforms.

Although the complexity of the SPWM switching circuits of multilevel inverter is higher than of conventional inverter, but there are many advantages of using MVSI for electric power system. It produces lower output harmonic compared to conventional inverters. Besides, it also puts less stress on the switching devices thus reduces switching losses.

1.2 Motivation

There are many pros of using multilevel inverters. The most important advantage is that multilevel inverters can reduce output total harmonic distortion (THD) which leads to switching losses reducing. The higher the number of output voltage levels, the smaller the THD. The power supplied can be used to perform other useful task.

Besides, the multilevel inverter can produce high output voltages with low harmonics. The arrangement of the power switches in the topology accumulates these multiple dc sources in order to achieve higher voltage at the output.

The comparison between conventional and multilevel inverter is shown in Table 1.1 below. The main difference that distinct multilevel inverter from conventional inverter is that it produces output with lower total harmonic distortion. This will lead to lower switching stresses in the inverter circuit and thus lower switching losses. Besides, output voltage of multilevel inverter is higher since the output voltage of it is equal to the summation of each H- Bridge cell's output voltage. Multilevel inverters have more than two output voltage levels while conventional inverters have two voltage levels. For multilevel inverters, they need lower switching frequency compared to the conventional inverters to produce the desired output waveform. Therefore, the switching losses are lower than that of the conventional inverter. The power supply can be used to perform other useful task.

Since there are many advantages of multilevel inverters, a topology of multilevel inverter will be simulated and analysed in this paper.

Table 1.1: Comparisons between conventional inverters and multilevel inverters

Comparison	**Conventional inverter**	**Multilevel inverter**
THD	Higher	Lower
Switching stress	Higher switching stresses	Reduced switching stresses
Output Voltage	Higher	Lower
Voltage levels	Two levels	Higher than two levels
Switching frequency	Needs higher switching frequency thus it has high switching losses	Needs lower switching frequency thus it has lower switching losses

1.3 Problem Statement

As the renewable energy resources are gaining people's concern nowadays, sunlight is treated as one of the important resources to generate electricity. Inverters are needed to convert sunlight which is direct current (DC) to alternating current (AC) which can be connected to power grid for domestic use. As the trend requiring higher power output and less total harmonic distortion, inverters are not able to cope with the requirement. Therefore, multilevel inverters are needed. The higher the level of multilevel inverters, the better the performance of the inverters since it produces nearly sinusoidal waveform [3]. However, the existing switching strategies for inverters can be a burdensome since it is quite complicated. Therefore, the proposed work shall include the new switching strategy which has a lower complexity compared to the existing switching strategies.

1.4 Objective

There are four objectives in this paper.

First, this project aims to investigate on types of inverter and to simulate it using MATLAB Simulink.

Second, the objective of this project is to simplify the switching strategy for multilevel inverter.

Third, this project aims to implement a voltage based SPWM technique for 5- Level Cascaded H- Bridge Multilevel Inverter.

Fourth, this project aims to analyse the multilevel inverter performance in terms of total harmonic distortion (THD) and the power factor.

1.5 Scope

The scopes of this project are:

1. This project will focus on the single phase 5- level cascaded H- bridge multilevel voltage source inverter.

2. The input DC voltage for the inverter is 60V; the peak voltage of the output sine waveform is 120V before adding filtering circuit.

3. A voltage based SPWM technique is implemented using modified PID controller.

4. This project will analyse the total harmonic distortion and power factor at the end.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Inverters are power electronic converters that convert direct current (DC) source into alternating current (AC) output. Since trend of industrials nowadays require higher output power, thus multilevel inverters are introduced. There are several types of multilevel inverters which are implemented by several techniques.

In this chapter, types of multilevel inverters and Pulse Width Modulation (PWM) techniques will be discussed.

2.2 Topologies of Multilevel Inverter

There are three common topologies of multilevel inverter which are:

i. Cascaded H- Bridge
ii. Flying Capacitors
iii. Diode- clamped

Thongprasri (2011) had tabulated the numbers of components needed by different types of multilevel inverters as in Table 2.1 below. Cascaded H-bridge inverter is the topology that requires least number of components.

Table 2.1: Components of Single Phase Multilevel Inverters[4]

Types of multilevel inverter	No. of switches	No. of diodes	No. of capacitors
Cascaded H- bridge	8	-	-
Flying capacitors	8	-	10
Diode- clamped	8	12	4

2.2.1 Cascaded H- Bridge

Cascaded H- Bridge Multilevel Inverter is popular topologies among all multilevel and multi- pulse inverters. This is due to the structures of H- bridges in a multilevel inverter are identical and it enables the H- bridge to be modularized, manufactured and packaged easily [5]. Low switching frequency and the ability to be modularized are the advantages of cascaded H-bridge inverter. There are some cons when using Cascaded H- Bridge topology too. When the output voltage level increases, the switches and dc sources have to be increased, which leads to increasing cost and weight of the circuit[6]. The levels of output voltages can be increased by two levels by cascading an H- bridge module to the existing one. The number of output voltage levels can be calculated using the formula, 2m+1; where m is the number of cells as shown in Figure 2.1. The idea of this inverter is connecting H-bridge inverters serially to get a sinusoidal output voltage. The output voltage can be calculated by summing the voltage produced by each H- Bridge. It needs fewer components compared to diode-clamped and flying capacitors type multilevel inverters.

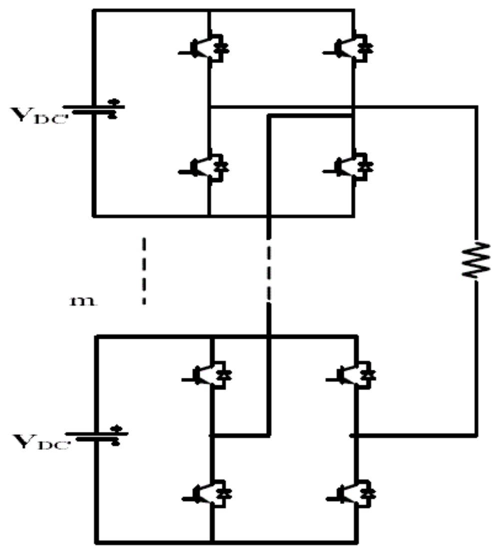

Figure 2.1: Cascaded H- Bridge Inverter Topology

2.2.2 Diode- Clamped

The Diode- Clamped Multilevel Inverter topology was proposed in 1981. This topology as shown in Figure 2.2 is also known as neutral point inverters and it is designed for low frequency applications [7]. The number of components needed in this topology depends on the number of output voltage levels desired. (n-1) voltage source, 2(n-1) switching device and [(n-1) (n-2)] diodes are needed for n level inverter; given n is the number of output voltage levels as stated by Varsha and Shraddha (2013). This inverter's idea is by using diodes, it limits bus voltage to reach the require steps in the output [8]. The advantage of using diode- clamped topology is that all phases using the common bus for its application in three phases. The disadvantage of using this topology is the difficulty faced in real power flow. This is due to the imbalanced capacitors and it made this topology less popular in industries.

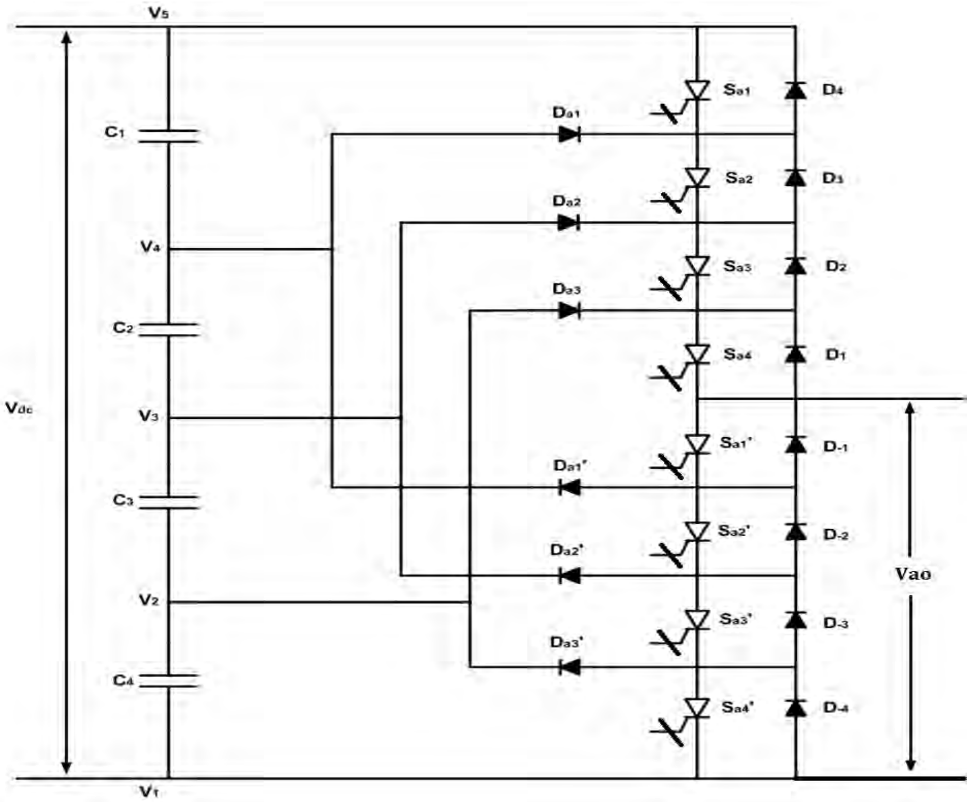

Figure 2.2: Diode- Clamped 5- Level Inverter Topology[7]

2.2.3 Flying Capacitors Clamped Multilevel Inverter

Flying Capacitors Clamped was proposed by Maynard and Foch in 1992 [9]. As stated by Ahmed (2014), the topologies of Flying Capacitors Clamped and Diode Clamped Multilevel Inverter are almost the same except that capacitors are used in Flying Capacitors Clamped topology and diodes are used in Diode Clamped topology. This topology needs the largest number of capacitors compared to Cascaded H- Bridge and Diode Clamped topologies to limit the output voltage to a certain level. Practically, this topology can produces only six levels output voltage although theoretically it can gives infinite levels. The arrangement of capacitors, switches and diodes is shown in Figure 2.3.

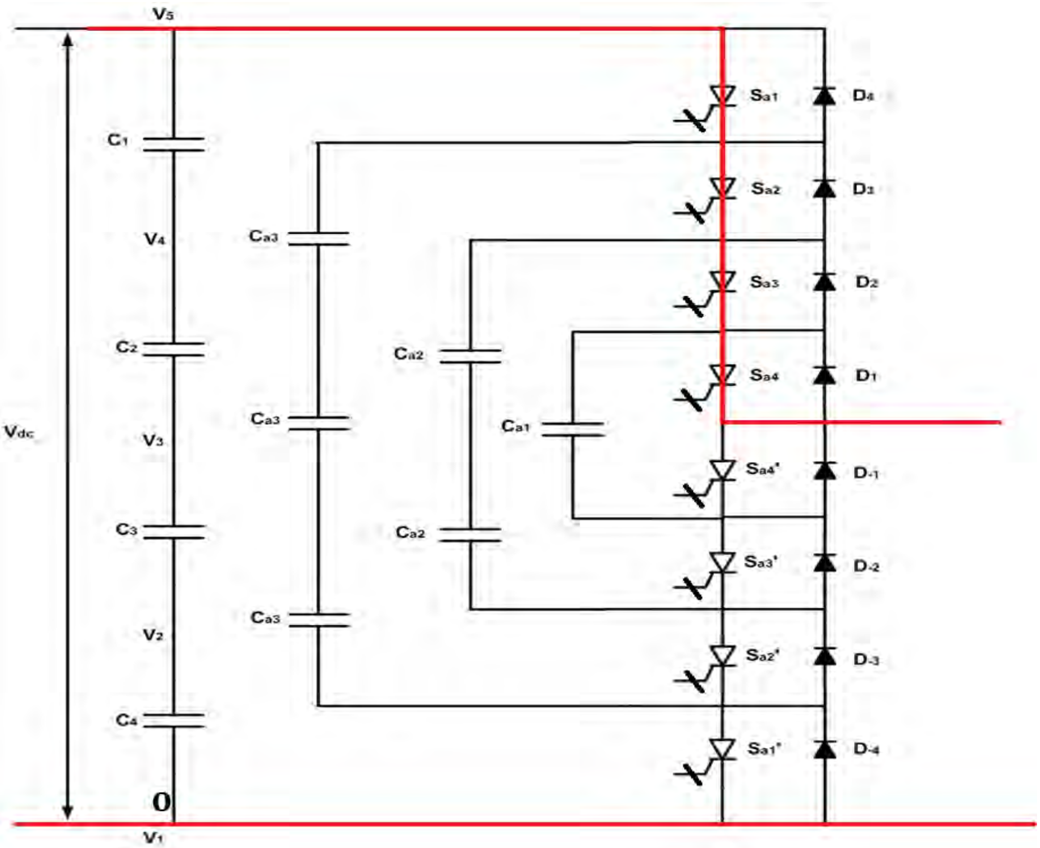

Figure 2.3: Flying Capacitors Clamped 5- Level Inverter Topology

2.3 Sinusoidal Pulse width modulation (SPWM)

Sinusoidal pulse width modulation (SPWM) is a switching method that gives alternating output voltage and current waveforms in an inverter circuit. It uses switching pulse to turn on and off the switches to perform this function. SPWM method is used to reduce the total distortion (THD). To generate the SPWM signal, two signals are compared, a lower frequency modulating sine-wave signal and the higher frequency carrier triangular signal. A simple voltage based inverter is shown in Figure 2.4.

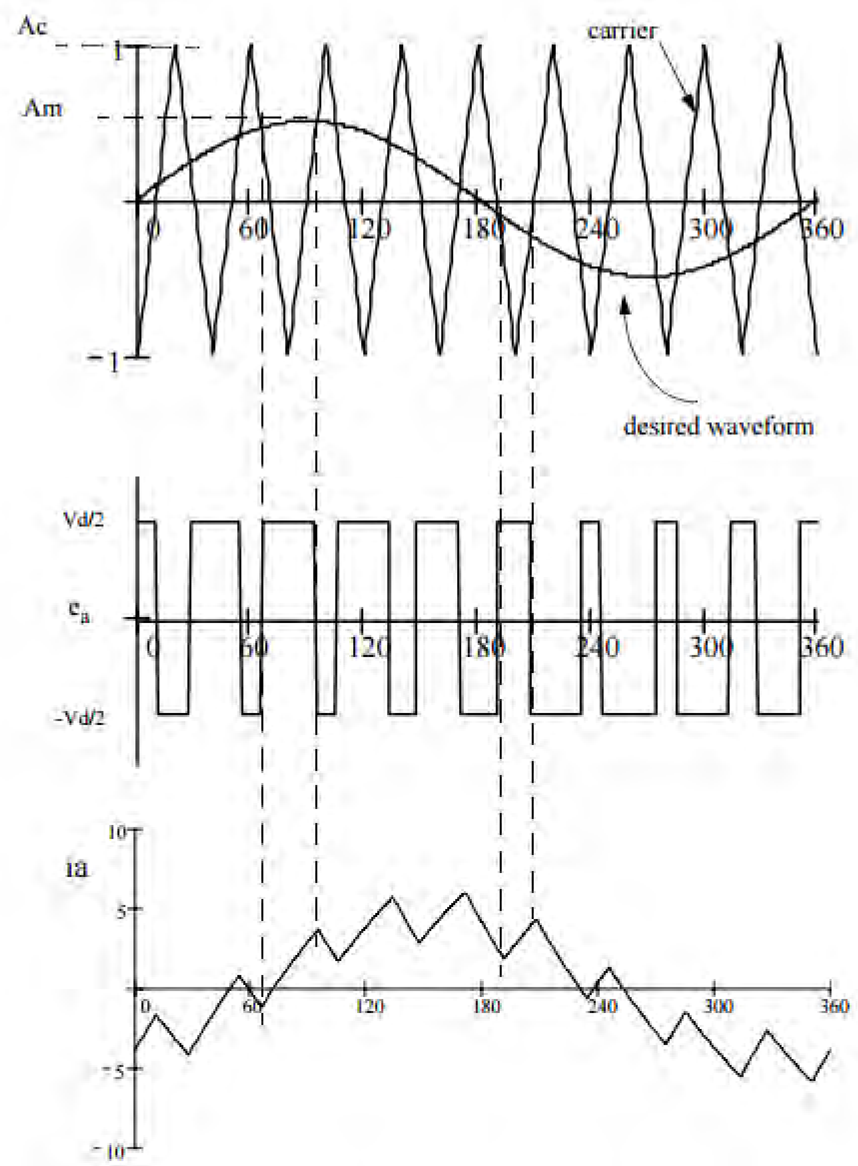

Figure 2.4: Principle of PWM

2.3.1 Sinusoidal Pulse Width Modulation for Multilevel Inverter

The difference between two level SPWM and SPWM for multilevel inverter is the number of carriers used. According to Aspalli and Wamanrao (2009), for 'm' level inverter, 'm-1' carriers are used [6]; m represents the number of output voltage level. In the most common implementation, comparison between the modulating signal and carrier signal is used to generate the desired output voltage. In certain condition, the switch will be switched ON or OFF depending on whether positive or negative dc bus voltage is applied at the output. In phase disposition where the carriers are shifted vertically as shown in Figure 2.5, all four carriers are at the same frequency, phase and amplitude. The comparison between the reference signal and the four carrier signals is performed.

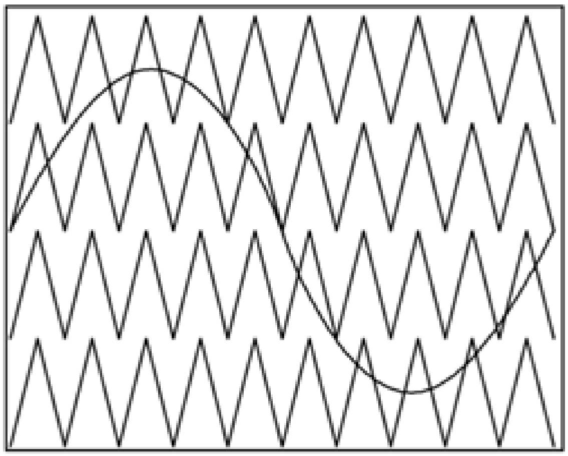

Figure 2.5: Carriers which are shifted vertically [6].

2.4 PID Controller

PID controller is a controller that get output value by reading a sensor, then control the output actuator to produce desired output by computing proportional, integral, and derivative responses. Figure 2.6 shows the position of a PID controller in a control system; while Figure 2.7 shows the block diagrams inside a PID controller.

In PID controller, there are three main components which are Proportional (P), Integral (I) and Derivative (D). The P component in PID controller multiply the error signal by the Proportional gain (K_p), I component is the sum of all the instantaneous error signal and D component functions as a future- predicting component. D component does the control action by calculating the future measured value and projecting the current measured value. However, D component will affect the output where it will cause noises. Therefore, the Derivative gain (K_D) must not be too large.