SUPERVISOR'S ENDORSEMENT

"I hereby declare that I have read through this report entitled "Analysis and development of Grid Connected Front-End AC to DC Converter Using Voltage Oriented Control (VOC)" and found that it complies the partial fulfilment for awarding the degree of Bachelor of Electrical Engineering"

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Date	:	_____

ANALYSIS AND DEVELOPMENT OF GRID CONNECTED FRONT-END AC TO DC CONVERTER USING VOLTAGE ORIENTED CONTROL (VOC)

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A report submitted in partial fulfilment of the requirements for the degree of Electrical Engineering (Power Electronic and Drives)

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STUDENT DECLARATION

I declare that this report entitled “Analysis and Development of Grid Connected Front-End Ac to Dc Converter Using Voltage Oriented Control (VOC)” 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.

Signature : _____

Name : VIVIEN BALAN

Date : _____

DEDICATION

To my beloved mother and father

I will not complete without both of you

ACKNOWLEDGEMENT

In this moment, I would like to give big thanks and express my sincere appreciation to my supervisor, Dr. Azziddin bin Mohamad Razali, for his encouragement and guidance throughout this project. I was so grateful as he keeps on motivate and give advice that contribute to the completion of this report.

Besides, I would like to thank my beloved family as they support my project and until the end. Other than that, I am grateful to have my colleagues that help me with many ideas and tips on doing this project. Unfortunately, it is possible for me to list all of them in this limited space.

In a nutshell, I would like to thank both my panels, Dr. Zulhani Bin Rasin and En. Ahmad Aizan Bin Zulkefle, who gives great feedbacks and evaluation throughout my project. Through the both panels, I can improve my project in many aspects until I finish on doing my final year project.

ABSTRACT

This project is about the analysis and development of grid connected front end AC to DC converter using Voltage Oriented Control (VOC). Nowadays, the use of power electronic converters in industry are kept expanding. In industry, there is a problem in transmission and distribution lines as the harmonic and reactive currents are being injected into the system. Therefore, in electric power system, voltage control is important for proper operation for electrical power equipment. This is important to prevent any damage that might occur. Besides, the input current with non-sinusoidal shape drawn by conventional AC to DC converter generates significant harmonic components. The current harmonic components increase the current consumption and increase the power loss of utility equipment. As a result, overheating might happen in the generator and motor windings and the transmission line. One of the control methods for AC to DC converter is VOC. VOC controls the active and reactive power between grid and load by controlling approximately the three phase line currents and magnitude of the converter DC output voltage. Sinusoidal Pulse Width Modulation (SPWM) is used to determine the switching state of the converter. In addition, matrix transformations like Clarke Transformation, Park Transformation, Inverse Clarke Transformation and Inverse Park Transformation are used to simplify the development of the control method. The steady state performance and Total Harmonic Distortion (THD) of the line currents are analysed before and after the implementation of VOC method. The operation is kept at unity power factor with lower current THD. In a nutshell, by using VOC method, the three-phase input currents and voltages are almost in sinusoidal shape. Finally, a regulated DC power supply utilizing three-phase AC to DC converter can be constructed.

ABSTRAK

Projek ini adalah mengenai analisis dan pengubahan terhadap grid yang bersambung dari hujung AC sampai ke hujung DC dengan menggunakan Kawalan Berorientasikan Voltan (VOC). Pada masa kini, penggunaan kuasa penukar eletronik dalam industri terus berkembang. Dalam industri ini, terdapat masalah dalam talian penghantaran dan pengedaran sebagai arus yang harmoni dan reaktif yang bersambung dalam sistem. Oleh itu, dalam sistem kuasa eletrik, kawalan voltan adalah penting untuk operasi yang betul untuk peralatan kuasa elekrik. Hal ini sangat penting bagi megelakkan sebarang kerosakan yang mungkin berlaku. Selain itu, arus masuk dalam bentuk sinusoidal yang dibentuk oleh konventional AC kepada penukar DC menghasilkan komponen harmoni yang ketara. Ini menyebabkan terdapat peningkatan terhadap voltan peralatan utiliti. Komponen harmoni semasa meningkatkan penggunaan semasa dan meningkatkan kehilangan kuasa peralatan utiliti. Akibatnya, pemanasan melampau mungkin berlaku di penjana dan litar motor dan talian penghantaran. Salah satu kaedah kawalan AC untuk penukar DC ialah VOC. VOC mengawal kuasa aktif dan reaktif antara grid dan beban dengan mengawal kira-kira arus tiga arus fasa dan magnitud voltan keluar penukar DC. Modulasi Lebar Pulse Sinusoidal (SPWM) digunakan dengan menggunakan fungsi MATLAB. Di samping itu, matrik transformasi seperti Transformasi Clarke, Transformasi Park, Transformasi Songsang Clarke dan Transformasi Songsang Park digunakan untuk mempermuudahkan pembangunan kaedah kawalan. Kedudukan prestasi yang mantap dan Jumlah Masalah Harmoni (THD) arus elektrik dianalisis sebelum dan selepas pelaksanaan kaedah VOC. Operasi dikekalkan pada faktor kuasa satu dengan THD elektrik yang lebih rendah. Akhir sekali, dengan menggunakan kaedah VOC, arus dan tegangan masuk eletrik dan voltan tiga fasa hampir mencapai bentuk sinusoidal. Akhir sekali, bekalan kuasa DC yang dikawal menggunakan tiga fasa penukar AC ke DC boleh dibina.

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VOC	-	Voltage Oriented Control
DPC	-	Direct Power Control
VFOC	-	Virtual Flux Oriented Control
VF-DPC	-	Virtual Flux Direct Power Control
PWM	-	Pulse Width Modulation
SPWM	-	Sinusoidal Pulse Width Modulation
PLL	-	Phase Locked Loop
THD	-	Total Harmonic Distortion
A/D	-	Analogue to Digital
SVM	-	Space Vector Modulation
IGBT	-	Insulated Gate Bipolar Transistor

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CHAPTER 1

INTRODUCTION

1.1 Project Background

In industry, the harmonic pollution of power system is increased rapidly and reach a critical level that is beyond the tolerable limits. This pollution is mainly caused by nonlinear loads such as diode and thyristor rectifiers. There are several techniques can be used to reduce the harmonic pollution. There are from the application of active and passive filters and the use of Pulse Width Modulation (PWM) rectifiers. Throughout the studies, most of the researchers found out that PWM rectifiers have an additional advantage of the bi-directional power flow and hence PWM rectifiers becomes the best application amongst all.

Furthermore, the use of PWM rectifiers have presented four types of control techniques. Overall of control techniques can be distinguished as Voltage Oriented Control (VOC), Voltage-based Direct Power Control (V-DPC), Virtual-Flux Oriented Control (VFOC) and Virtual-Flux-based Direct Power Control (VF-DPC). For purpose of this study, a VOC is a method that been chosen for the analysis and development of grid connected front-end AC to DC converter.

Sinusoidal Pulse Width Modulation (SPWM) is used in VOC by properly control the pulses in the converter, thus assure the power flows are enough with stable frequency. The details of the process will be explained in this thesis. Other than that, VOC have no sensitive to line inductance variation with fixed switching frequency. Considering of all the advantages of VOC, VOC is one of the technique that can

overcome the rapid growth of ac adjustable speed drives (ASDs). Hence, VOC is the best method to convert from AC to DC.

1.2 Problem Statement

Power electronic systems are used wisely and very common usage in our daily life nowadays. Thus, same goes to AC to DC converter that are very common for most of us to hear about. However, there are problem that arise that might not be knowing by some of us when the converters are being connected in transmission and distribution lines. This problem is due to the harmonic and reactive currents that are injected into the system. The non-sinusoidal input currents that supply to the rectifier converter causes the significant harmonic components being generated. Finally, the volt-ampere rating of the utility equipment such as the transformers, generators and the transmission lines will then increase. A three-phase AC to DC converter can be controlled by a system known as the VOC scheme which produce a sinusoidal input current with a unity power factor.

1.3 Objective

The objectives are:

i. To design a complete scheme of Voltage Oriented Control (VOC) using MATLAB Simulink.
ii. To develop and test the control algorithm of the converter.
iii. To analyse and study on the steady-state performance of three-phase diode rectifier

1.4 Scope of Research

The scopes of this project are:

i. Design and simulate a complete VOC in MATLAB.
ii. Obtain a lower Total Harmonic Distortion (THD) of grid current.
iii. Able to obtain almost sinusoidal three-phase input current with almost unity power factor.
iv. Achieving the DC output voltage that is close to the DC reference voltage.

1.5 Research Methodology

Figure 1.1 shows the flow chart of the research of this project. A complete schedule is illustrated in a Gantt chart in Appendix A.

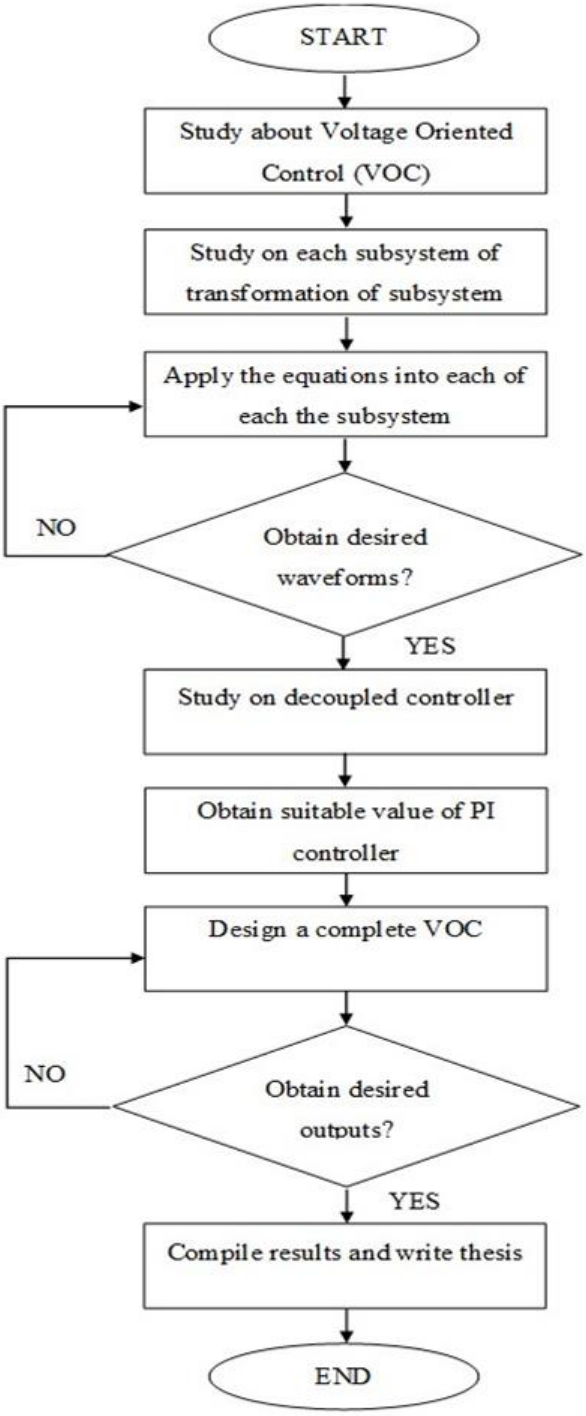

Figure 1.1: Flowchart of Research Methodology

1.6 Report Outline

In this report, there are six chapters as follows:

1. Chapter 1: Introduction
2. Chapter 2: Literature Review
3. Chapter 3: Analysis and Development of Voltage Oriented Control (VOC)
4. Chapter 4: Simulation Results and Discussions
5. Chapter 5: Conclusion and Recommendation.

In chapter 1, there are introduction that briefly describe about the design of the three-phase AC to DC converter. The objectives and the problem statements are described in this chapter. This will help to understand more and why is there needed to purpose and do this project. Besides, the flow of this project is shown as a guidance on doing and make the project more successful.

Chapter 2 is on the literature review that must be known and study before further on doing this project more deeply. Besides, through the fully understanding of the study, project becomes smoothly to work on. Other than that, the theory and calculations part are study to cover on the vector transformation, the control strategies and the mathematical modelling.

Chapter 3 covers the methodology being used to develop the regulated high voltage DC power supply utilizing the three-phase converter. All the models being use in order completing the design of VOC is shown this chapter. Thus, a complete simulation on VOC can be seen here.

All the simulation results of VOC are shown clearly in this chapter 4 with full explanations on each of the results which obtain from MATLAB Simulink. All the outputs and waveforms are organized to display the steady state and dynamic performance of the AC to DC converter either before nor after the introduction of VOC.

Lastly, this report is ended in chapter 5. In this chapter, it will summarise all the task been done in the project. Hence, there will be some recommendation in order having impressive performance of the project. Any future work for this project will be discuss in this chapter too.

CHAPTER 2

LITERATURE REVIEW

This chapter will review on research that been done by researches on Voltage Oriented Control (VOC). In the beginning, this thesis will start with an overview of three-phase controlled rectifiers. Next, will be move on to the mathematical modelling for each part of VOC, vector transformation, instantaneous power, control strategies and the Phase Locked Loop (PLL).

2.1 Three Phase Bidirectional AC to DC Converter

Higher harmonic content with lower of power factor effect the power distribution system. In order limiting the problems. Thus, there are new topologies that had been introduced for rectification applications. In this project, we will study on the most famous and universal topology, known as the universal bridge topology [1]. Through the analysis, three-phase voltage is connected to the two level of VSC. Basically, VSC consists of six insulated gates bipolar transistor (IGBT) with anti-parallel fast recovery diode.

Figure 2.1 shows the universal bridge topology which have the regulation of DC output voltage, low harmonic distortion of line current, near sinusoidal current waveforms, power factor correction, bidirectional power flow and unity power factor. The three-phase voltage is injected to each of the line inductors. A sinusoidal line currents and become the line filters by decrease the current ripples are the main function of the inductors.

The function of IGBTs is to boost the performance of the converter, where the IGBTs are suitable power switch as the gate driver can operates in high switching

frequency. The power switch can perform a continuous sinusoidal current from ac power supply with a lower Total Harmonic Distortion (THD) as mentioned before and minimum the grid needed for side power factor at unity in order obtaining the power transfer with a minimum current stress. In this project, the magnitude of Vdc need to be higher, where the minimum of DC link output voltage is required as of the equation (2.1).

V_{dc} > √2 x √3 x E_g, pahse, (rms) = 2.45 x E_g, pahse, (rms) (2.1)

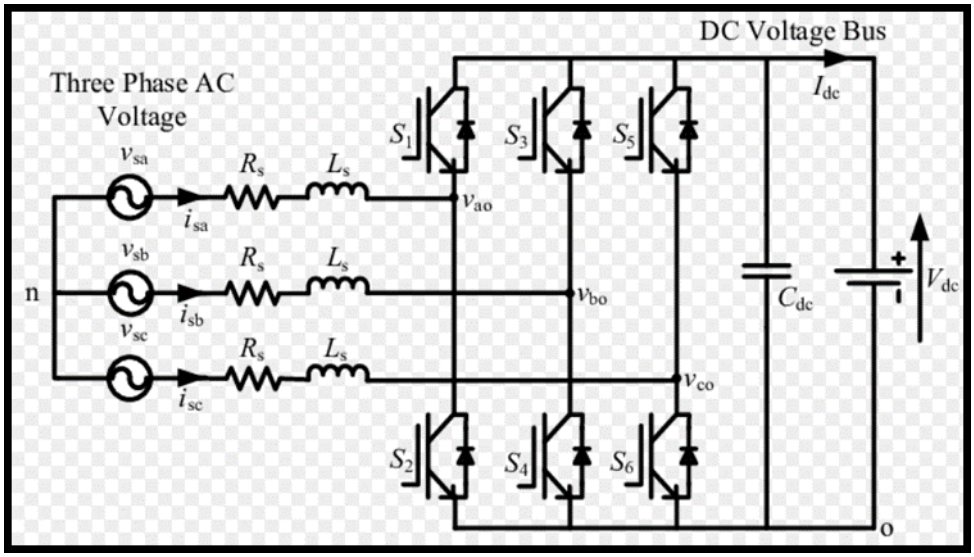

Figure 2.1: Three-phase bidirectional AC-DC converter topology

2.2 Mathematical Model

The three-phase line voltages and currents can be expressed in Equations (2.2) and (2.3) respectively as follow:

$$V_{sa} = V_m \cos(\omega t)$$
$$V_{sb} = V_m \cos(\omega t - \frac{2\pi}{3})$$
$$V_{sc} = V_m \cos(\omega t - \frac{4\pi}{3}) \quad (2.2)$$
$$I_{sa} = I_m \cos(\omega t + \varphi)$$
$$I_{sb} = I_m \cos(\omega t + \varphi - \frac{2\pi}{3})$$
$$I_{sc} = I_m \cos(\omega t + \varphi - \frac{4\pi}{3}) \quad (2.3)$$

With Vm as the input voltage and Im as the input current. However, since that there is no neutral connection, the current can be obtained as Equation (2.4) below:

$$I_{m,sa} + I_{m,sb} + I_{m,sc} = 0 \quad (2.4)$$

Next, Equation (2.5) shows the voltages of each phase that can be determined and expressed as [2]

$$V_{conv,sa} = (2S_a - S_b + S_c)\frac{V_{dc}}{3}$$
$$V_{conv,sb} = (2S_b - S_a + S_c)\frac{V_{dc}}{3}$$
$$V_{conv,sc} = (2S_c - S_a + S_b)\frac{V_{dc}}{3} \quad (2.5)$$

The three-phase system are then described with only the two components which are α, the real part and β, the imaginary part.