Project Report

(Internship Semester January–June)

Design of Front end converter using SVPWM technique

Submitted by

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Under the Guidance of

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Declaration

I hereby declare that the project work entitled ”Design of Active Front End” is an authentic record of my own work carried out at Statcon Electronics India Ltd as requirements of six months project semester for the award of degree of B.E./B.Tech. Electrical Engineering, Punjab Engineering College (Deemed to be University), Chandigarh, under the guidance of Mr. Sarv Parteek Singh and Dr. Tejinder Singh Saggu, during January to June, 2024.

Date: April 30, 2024

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Certified that the above statement made by the student is correct to the best of our knowledge and belief.

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1. Summary

I got the opportunity to do my internship at Statcon Electronics India Ltd. Statcon Electronics established in 1986 is one of India's largest ISO 9001-20151 certified manufacturer of Static energy Conversion system. During my internship at Satcon Electronics India Ltd, Noida, I was first assigned to explore Space Vector Modulation technique and then make a simulation for a front end converter using Space Vector Modulation. I was part of the Embedded Software team and my task was to develop a control algorith for the front end converter.

The aim of the project to design a Active Front End converter for a Hybrid inverter,aiming to enhance its efficiency and performance while reducing harmonic distortions and improving the power factor.

1.1 Timeline

My internship at Statcon Electronics India Ltd started on 10th January, 2024. My mentor gave me the task of exploring Space Vector Modulation and developing control algorithm for the front end converter. This timeline will briefly explain the course of my internship from beginning to end.

1.1.1 January

In January, I started learning about Space Vector Pulse Width Modulation (SVPWM). This involved understanding two important things: the Clarke and Park transforms. These transforms help to change three-phase voltages into a simpler two-dimensional form, making it easier to control three-phase systems. The Clarke transform turns three-phase voltages into two-phase parts, while the Park transform changes these parts into a fixed frame of reference. I also learned about space vectors, which show how the three-phase voltages combine. This knowledge helped me understand SVPWM better. It's a technique that uses space vectors to control how inverters produce voltage. This exploration gave me a better grasp of how SVPWM works and its uses in power electronics.

1.1.2 Feburary

During February, I immersed myself in the study of the Clarke and Park transforms, essential mathematical tools used in analyzing three-phase electrical systems.The Clarke transform simplifies three-phase voltages into two-phase components, making it easier to understand and analyze complex electrical systems. Similarly, the Park transform further refines these components into a fixed frame of reference, streamlining the analysis and control of electrical signals. Alongside theoretical exploration, I practically experimented by developing Python code to implement and test these transformations. This hands-on approach not only deepened my understanding of the transforms but also provided valuable insights into their real-world applications and implementation challenges.

1.1.3 March

During March, I worked on developing and testing a three-phase Phase-Locked Loop (PLL) algorithm using Python. This algorithm used the Clarke and Park transforms to precisely estimate the angle of the space vector in the three-phase system. Following the initial testing phase of the PLL algorithm in Python, I transitioned to Simulink/MATLAB for further simulation. Within the Simulink environment, I used MATLAB function blocks to implement the PLL algorithm. Once this was completed, I proceeded to make a three-phase inverter in Simulink using IGBT components. Leveraging MATLAB function blocks and the output of the PLL, I then generated gate timing signals for the Front end of the inverter, ensuring precise control and synchronization of the electrical signals.

1.1.4 April

In April, I worked toward fine-tuning the Proportional-Integral (PI) controller for the Phase-Locked Loop (PLL) using the Ziegler–Nichols method. This involved adjusting the parameters of the PI controller to optimize the performance of the PLL algorithm. By employing the Ziegler–Nichols method, I aimed to achieve stability and responsiveness in tracking and synchronizing the phase of electrical signals effectively. Additionally, I implemented a control loop in MATLAB function blocks to measure the current flowing from the front end to the grid. This control loop allowed for the adjustment of the output voltage to either draw or supply the desired current, depending on the system requirements.

1.1.5 May

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2. Introduction

An active front-end (AFE) converter, also known as a Regen Inverter, is a grid interface converter that transfers power between an energy source and the utility grid, and between the utility grid and a load. It's a controllable rectifier that can exchange power between AC and DC power in both directions, and can regenerate power to the mains to reduce power costs.

2.1 Problem Statement

My team at Statcon Electronics India Ltd has been focusing on on enhancing the efficiency and performance of front-end converters. Presently, most active front-end converters utilize Silicon Controlled Rectifiers (SCRs) for rectification, employing a conventional 6-pulse converter configuration. My task was to explore and design a active front-end using Insulated Gate Bipolar Transistors (IGBTs) as alternatives to SCRs in the rectification process.

The primary objective of this project is to investigate the feasibility and advantages of using IGBTs instead of SCRs for rectification in active front-end converters. Specifically, we aim to implement a Space Vector Pulse Width Modulation (SVPWM) technique to control the IGBTs effectively. This technique offers precise control over the switching patterns of the IGBTs, allowing for optimized power conversion and reduced harmonic distortion.

Furthermore, the project involves the development of a sophisticated control algorithm to manage the operation of the IGBTs. This algorithm must facilitate seamless transition between pulling current from the grid (rectification mode) and supplying current to the grid (regeneration mode). The control system should ensure stable and efficient operation under varying load conditions while maintaining compliance with grid standards and regulations.

2.2 Overview

To understand the operation and control of the active front-end (AFE) converter utilizing Insulated Gate Bipolar Transistors (IGBTs), it's essential to understand concepts such as Space Vector Modulation (SVM), Clarke Transform, and Park Transform.

2.2.1 Space Vector Modulation

This technique, also known as Space Vector Pulse Width Modulation (SVPWM), is a method used to generate the switching signals for the IGBTs in the AFE converter. It offers precise control over the IGBT switching patterns by synthesizing the desired output voltage as a combination of multiple voltage vectors. SVM has eight space vectors, other space vectors are synthesized by alternating active and zero vectors over a switching period.

2.2.2 Clarke Transform

The Clarke Transform is a mathematical tool used to convert the three-phase AC currents and voltages into two-phase components. By decomposing the complex three-phase signals into simpler two-phase representations, the Clarke Transform simplifies the control and analysis of the AFE converter. This transformation is particularly useful in applications where two-phase control is more practical or where the control algorithms are designed based on two-phase references.

2.2.3 Park Transform

Building upon the Clarke Transform, the Park Transform further simplifies the control of the AFE converter by transforming the two-phase quantities into a stationary reference frame. This transformation aligns the reference frame with the voltage vector, enabling linear control strategies such as proportional-integral (PI) controllers.

2.3 Challenges

I faced many challenges in developing a Active front-end converter. Firstly, distinguishing between Sinusoidal Pulse Width Modulation (SPWM) and Space Vector Pulse Width Modulation (SVPWM) posed confusion due to their perceived similarity in operational principles. Secondly, reconciling the non-zero resultant vector in SVPWM with the traditional understanding of three-phase systems, where the vector sum equals zero, required conceptual clarification to ensure accurate system design and analysis. Another challenge was comprehending how rectification and regeneration can occur through the same IGBT bridge, as it involved bidirectional power flow management. Additionally, not knowing how to write code in MATLAB was another challenge, but learning it opened up new possibilities for simulating and analyzing our AFE converter designs.

2.4 Summary

This chapter addressed the problem statement concerning the exploration of active front-end converters (AFEs) and the transition from Silicon Controlled Rectifiers (SCRs) to Insulated Gate Bipolar Transistors (IGBTs) for rectification.It also highlighted various AFE converter topologies, providing brief distinctions between them. It discussed the challenges and difficulties encountered throughout this project, including understanding modulation techniques, reconciling operational principles, managing bidirectional power flow, and learning MATLAB coding.

3. Work

4. Industry

5. Review

5.1 Company review

5.2 Project review

6. Details of work and review

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