EEEE3001

Final Year Individual Project Dissertation Draft

Diode Clamped Inverter for Vehicle AC Machine Drive

AUTHOR: Mr. Pengyuan Shu

ID NUMBER: 20321149

SUPERVISOR: Dr. Alan Watson

MODERATOR: Dr. Gaurang Vakil

DATE: 28 March 2024

This third year project Dissertation is submitted in part fulfilment of the requirements of the degree of Bachelor of Engineering.

**Table of Contents**

**Abstract**

**Chapter 1: Introduction**

* 1. Background
  2. Literature Review

*1.3* Objectives

**Chapter 2: Simulation and Controller Design**

*2.1* Control Diagram and Topology Overview

*2.2* PMSM Motor Modelling

*2.3* SPWM and SVPWM

*2.4* Design of Current and Speed Controllers

*2.5* Design of DC-Link Voltage Balance Controller

*2.6* Thermal Management

**Chapter 3: Hardware Design: Diode Clamped Inverter**

*3.1* PCB Layout

*3.2* Gate Drive Circuit

*3.3* DC-Link Capacitors

**Chapter 4: Hardware Design: Control Board and its Peripherals**

*4.1* PCB Layout

*4.2* ADC Sampling

**Chapter 5: Software Design: Implementation on MCU**

*5.1* Files Structure and IDE Configurations

*5.2* Algorithm Implementation

**Chapter 6: System Testing, Validation, and Analysis**

*6.1* Testing and Validation

*6.2* Results Analysis

**Chapter 7: Conclusion and Reflection**

*7.1* Consideration of System within Wider Context

*7.2* Reflection on Management

**References**

**Appendix**

**Abstract**

**Chapter 1: Introduction**

* 1. **Background**

In the contemporary landscape characterized by a growing emphasis on clean and sustainable energy sources, the integration of battery-connected Permanent Magnet Synchronous Machine (PMSM) drives assumes a pivotal role across diverse applications, most notably in the domain of electric vehicles. These systems leverage the distinctive architecture of multilevel converters, enabling the generation of multi-level AC voltage waveforms sans the requirement of transformers. Diode Clamped Inverter is one of the types of multilevel topologies, which is commonly used as drives for high frequency motors as a result of their superior waveform quality [1]. This intrinsic characteristic empowers it to produce high-frequency AC voltages for the PMSM, characterized by notably diminished harmonic distortion. Consequently, the need for extensive filtering and the associated pulsations stemming from these harmonics is substantially reduced.

A fundamental aspect of the PMSM motor is its rotor, which comprises permanent magnets, thus obviating the need for magnetizing current. In this configuration, the motor's torque is solely generated by the stator current. Owing to this inherent efficiency, PMSM motors find widespread application in fields such as robotics and aerospace, where minimizing losses in the rotor is of paramount importance. The control of PMSM motors typically hinges on the Field Oriented Control (FOC) methodology, which can be used to control the AC quantities (voltage, current) [2, 3]. Against this backdrop, the primary focus of this project is to explore the integration of the Diode Clamped Inverter into the PMSM drive [4]. For safety reasons, only low-power scenario (2kW) is considered. The potential ramifications of this endeavour extend to a wide array of domains, including electric vehicles, renewable energy systems, robotics, and beyond. The successful execution of this project bears the promise of delivering more efficient energy solutions, and in so doing, opens the door to commercial opportunities and contributes to broader economic growth.

* 1. **Literature Review**
  2. **Objectives**

The objective of this project is to utilize Field-Oriented Control (FOC) on a 3-Phase Diode Clamped Inverter, which serves as a drive for a battery-connected Permanent Magnet Synchronous Machine (PMSM) within a simulation environment. Additionally, the project involves designing a four-layer printed circuit board (PCB) to create a low power variant (2kW, 320V) of the inverter. The control algorithm developed will undergo testing in PLECS before its eventual implementation on the TMS320F28379D micro-controller. The project's goal is to accomplish current and speed closed-loop control for the PMSM.

**Chapter 2: Simulation and Controller Design**

***2.1* Topology Overview and Control Diagram**

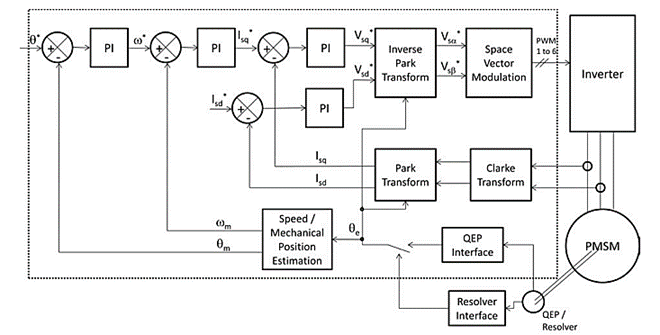
The main topology of the circuit for simulation in the PLECS is shown in **Figure 1**. The controller takes the 3-phase current and PMSM motor’s angle and speed as input, and output the PWM for each IGBT in the diode clamped inverter. The controller contains two closed loops in series: current loop and speed loop. The most fundamental loop is current loop, which also can be referred to as torque loop, as the torque of the PMSM motor is proportional to its stator current. This is where the FOC algorithm can be applied, combined with the PI controller to control the three-phase current in a closed loop to generate target torque based on the mechanical position of the rotor. Building upon the foundation of current closed loop, the speed loop can be implemented by using the serial PI controller.

图示, 示意图

描述已自动生成

**Figure 1.** Main Topology: Three-Level Diode Clamped Inverter (Three-Phase)

Control Diagram:



***2.2* PMSM Motor Modelling**

Electrical modelling parameters:

* Stator Resistance
* Stator Inductance (d-axis) and (q-axis)
* Flux induced by magnet
* Number of pole pairs p
* Electromotive force constant

Mechanical modelling parameters:

* Inertia of the rotor
* Friction coefficient
* Motor torque constant

Electromagnetic torque :

Mechanical rotor speed :

***2.3* SPWM and SVPWM**

Make comparation

***2.4* Design of Current and Speed Controllers**

The motor torque and back emf constants are equal: (represented by K)

Newton’s 2nd law:

Kirchhoff’s voltage law:

Laplace transform:

Thus, plant’s transfer function of current control:

Plant’s transfer function of speed control:

Continuous -> discrete

***2.5* Design of DC-Link Voltage Balance Controller**

***2.6* Thermal Management**

**Chapter 3: Hardware Design: Diode Clamped Inverter**

***3.1* PCB Layout**

Just figure? And how to put schematic (too big!)

* Choose of vias size, copper thickness, track width -> calculation?

***3.2* Gate Drive Circuit**

* Why IGBT, instead of MOSFET
* Why use DC/DC converter

***3.3* DC-Link Capacitors**

* Calculation:

图片包含 文本

描述已自动生成

* But in fact, it is hard to satisfy high voltage and larger capacitance at same time

**Chapter 4: Hardware Design: Control Board and its Peripherals**

***4.1* PCB Layout**

***4.2* ADC Sampling**

**Chapter 5: Software Design: Implementation on MCU**

***5.1* Files Structure and IDE Configurations**

***5.2* Algorithm Implementation**

**Chapter 6: System Testing, Validation, and Analysis**

***6.1* Testing and Validation**

***6.2* Results Analysis**

**Chapter 7: Conclusion and Reflection**

***7.1* Consideration of System within Wider Context**

***7.2* Reflection on Management**

**References**

[1] B. Wu, “High Power Converters and AC Drives”, Wiley IEEE, 2nd Edition, 2016

[2] G. Abad, “Power Electronics and Electric Drives for Traction Applications”, Wiley, 2016

[3] A. Hughes “Electric Motors and Drives: Fundamentals, types, and applications”, 5th Edition, Elsevier, 2019

[4] S. N. Vukosavic, “Electrical Machines”, Springer, 2012