MODELING AND CONTROLLER DESIGN OF PERMANENT MAGNET SYNCHRONIZING MOTOR (PMSM)

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Especially for:

My parent who offered me unconditional love, understanding and support throughout my life

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ABSTRACT

This dissertation describes design and simulation of permanent magnet synchronizing motor (PMSM) using Proportional Integral (PI) controller & Fuzzy Logic controller. The implementation of the speed control in the aircraft actuators system required an accurate, stable and precise output response. A correct derivation of mathematical model of permanent magnet synchronous motor (PMSM) vector controlled is very important and as fundamental of all analysis. In order to design a stable position loop, the fast and stable inner loop control need to be achieved first. Than followed by the outer loop control position. In order to have low percent overshoot of the response, the adjustment gain PI controller method is used. Implementing this method, a good response with zero steady state error will be achieved. Analysis of the output simulation response is performed to verify the quality of the design using PI & Fuzzy Logic is present in this dissertation.

ABSTRAK

Projek ini menerangkan rekabentuk dan simulasi magnet kekal motor segerak *(Permanent Magnet Synchronizing Motor, PMSM) menggunakan Proportional Integral (PI) Controller & Fuzzy Logic Controlle*r. Pelaksanaan kawalan kelajuan dalam sistem penggerak pesawat yang tepat dan stabil diperlukan. Terbitan yang betul model matematik magnet kekal motor segerak (PMSM) vektor kawalan adalah sangat penting dan sebagai asas bagi semua analisis. Dalam usaha untuk reka bentuk gelung kedudukan stabil, kawalan gelung dalaman yang cepat dan stabil perlu dicapai dahulu dan diikuti dengan kedudukan motor. Dalam usaha untuk mempunyai peratus terlajak rendah sambutan, keuntungan pelarasan nilai PI dan *fuzzy logic* controller digunakan. Melaksanakan kaedah ini, sambutan yang baik dengan sifar ralat keadaan mantap akan tercapai. Analisis simulasi pengeluaran dilakukan untuk mengesahkan kualiti reka bentuk antara PI dan *Fuzzy Logic Controller*

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LIST OF SYMBOLS

L_q	-	Quadrature inductance
L_d	-	Direct inductance
θ	-	Angle of the pendulum with respect to vertical axis
T_L	-	External load torque
J	-	Motor shaft inertia
D	-	Damping coefficient of viscous friction
ω_n	-	Natural frequency
ε	-	Damping ratio
K_i	-	Controller gain
a_i	-	Controller zero

LIST OF ABBREVIATIONS

PMSM	-	Permanent Magnet Synchronous Motor
EMA	-	Electro Mechanical Actuator
DC	-	Direct Current
FLC	-	Fuzzy Logic Controller
PI	-	Proportional Integral
AC	-	Alternating Current
RFO	-	Rotor Flux Oriented
PWM	-	Pulse Width Modulation
SPVM	-	Space Vector Modulation
EMF	-	Electromagnetic Force
EHA	-	Electro-Hydrostatic Actuator
VSI	-	Voltage Source Inverter
IGBT	-	Isolate Gate Bi-polar Transistor
SVM	-	Space Vector Modulation
MEA	-	More Electric Aircraft
CSE	-	Ground Support Equipment
IM	-	Induction Motor
PM	-	Permanent Magnet

CHAPTER 1

INTRODUCTION

1.1 Project Background

In this project a thorough analysis on design and simulation of a Matrix Converter fed Permanence Magnet Synchronous Motor (PMSM) for an Electro Mechanical Actuator (EMA) for Aircraft will be delivered. A 20kW at 4950 rpm PMSM is used, with an aircraft power supply of three-phase, 115V line to neutral, 400 Hz supplied to the Matrix Converter. The matrix converter supplies the motor with three-phase variable frequency and variable voltage ranging to a maximum of 150V at 300Hz. First, the model structure of PMSM is designed, followed by the overall control system in order to control the EMA position. All the parameters for the mechanical part of the actuator are included.

The flux vector control technique is the most popular method used in motor control nowadays. It offers a precise control method for all types of motor. In this project, the PMSM flux vector equations are derived and analysis for transient and steady state condition will be presented. Vector control can simplify analysis of PMSM by imitating the concept of the direct current (DC) motor. With the vector control method, the efficiency and dynamic performance can be maximized. In addition, the vector control for PMSM helps in improving the stability of the response. This model, the appropriate control method is applied for direct axis current (i_d), quadrature axis current (i_q), speed of the motor and position actuator arm, including the implementation of the mechanical gearing of the EMA. Finally, the control parameters providing the optimum results are chosen.

In this research, the major task is the controlling of the PMSM to give the required result. Discussion on the theory regarding the design of the permanent magnet in order to produce required L_d and L_q used in this simulation is included. Only minor explanation of the matrix converter operation and EMA system is provide. However, the design of this vector control depends on the matrix converter and EMA application.

The matrix converter is used to feed the stator currents. Transformations from three-phase stator quantities to two-axis d-q quantities method are applied to link the matrix converter and PMSM control strategy. The matrix converter can yield a superior current waveform, with low current harmonics and high power factor when compared to a conventional rectifier fed, dc link and constant voltage converter.

The EMA system may be used for actuating the rudder, ailerons, tail plane horizontal stabilizer, flaps and slats on the aircraft system. The output of the EMA system is a controlled position of this flight surface. Nowadays application, they are more commonly found on the secondary flight surface such as flap and slats. The rotary movement of the motor is connected to drive a lead screw through a gearbox and finally producing linear output movement. The mechanisms of these mechanical parts are considered the EMA system.

This research also can be used in other applications, which have similar specifications and requirements. In this project the theoretical analysis, design and simulation are on a realistic operation system can be applied to practical equipment.

1.2 Objectives

The purpose of this project is to control the position of the aircraft EMA by using PMSM and Matrix Converter. The objectives of this research are

- To gain an understanding of PMSM, Matrix Converter and EMA for aircraft system, operation and overall controlling system.
- Modeling Derivation of the PMSM system
- To design a model of PMSM base on vector control approached.
- To design stable i_d and i_q current loops and speed loops for the system.
- Controller design using proportional integral (PI) controller and Fuzzy Logic
- To simulate and analyze the resultsof the system by using Simulink Matlab.

1.3 Scope of Works

The particular literature reviews have been studied to make the decision on how to solve and what is the scope to be covered.

So, to accomplishing this research, a few scopes of works have been determined. The first scope of work is to design the PMSM controller, based on the mathematical model obtained, using Simulink.The controller design approach is using proportional integral (PI) controller and Fuzzy Logic.Then the results should be analyzed to make a comparison between PI andFuzzy Logic controller.

1.4 Methodology

The research works are undertaken in the following five (5) development stages. The first thing first is to implement the mathematical model for the IPC System. Secondly it has to be modelled in the Simulink. Then it comes to the study on how to apply the controller based on FLC algorithm in the Simulink. Here is the part that needs to determine the input and output for the system and develop a fuzzy rule based and its fuzzy set of membership function.All these things need to be simulating using some sort of software such as MATLABSimulink. After that the simulation using PID controller also need to be performed as a benchmarking for the FLC.Finally, both FLC and PID simulation results will be compared to meet the objectives.

1.5 Dissertation Overview

This report has a compilation of many chapters that will elaborate in stages the research work that have been carried out. As in general this report mainly consistsof six main chapters which arean introduction, literature review, theory of PMSM, simulation using PI and Fuzzy Logic Controller in MATLAB software, design of PMSM controlresults analysis and conclusion& recommendation.

Chapter 1

This chapter discusses the important aspect of the research work such as project background, objectives, scope of work, methodologyas well as the thesis outlineitself.

Chapter 2

This chapter will provide the Literature Review which discusses some papers of the related area in controlling of PMSM, Matrix Converter and EMA. This chapter also discusses the advantages of the three main devices above and some general operation of Matrix converter and EMA actuators.

Chapter 3

This chapter will be explaining the research methodology the required theory of the PMSM machine structure and operation. Mathematical Model of the dynamic equation used in the simulation is derived and developed. Further analysis on the power and torque of state condition also had been discussed.

Chapter 4

This chapter presents the design of PMSM Control using Proportional Integral (PI) & Fuzzy Logic controller. In PI controller design, simulation and analysis of the Mathematical Model designed the current control and speed control will be shown. The approached of the inner and outer loop control is used the proportion integral (PI) control method and optimization.. Process of developing the PMSM model structure using Matlab is clearly discussed. Verification on this structure also being done by comparing simulation results with calculations method.

In Fuzzy Logic controller design stated the logic membership function and rules are also been discussed. Comparisons between 2 types of fuzzy logic are used to see the good response between these 2 types.

Chapter 5

This chapter concludes the dissertation and includes recommendation for future research and study.

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