MODELING AND CONTROLLER DESIGN OF A HYBRID STEPPER MOTOR

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Especially for:

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

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ABSTRACT

Hybrid stepping motors are being used extensively over a wide range of application especially for precise positioning. This is due to their advantages of having higher efficiency, maintain very high resolution due to the small step angle and other advantages over other types of stepping motor. Therefore this project takes for granted to model their transient performance over various situations. This project is mainly based on modeling and controller design of two phase hybrid stepping motor. The presented model and controller is able to perform the transient performance. The model is developed in Matlab-Simulink with conventional PID controller and Fuzzy Logic controller. The conventional PID controller and Fuzzy logic controller used to reduce the settling time and overshoot. The model described the motor current and voltages as well as performing the speed and track position responses for the rotor during each excitation. Using this model, it is capable of performing the simulation of hybrid stepping motor with various parameters. The simulations results are presented with a detail explanation on each part of the study conducted. The results show that hybrid stepping motor can be used for precise positioning especially when small step angle are required.

ABSTRAK

Hibrid motor langkah banyak digunakan secara meluas dalam pelbagai aplikasi terutamanya untuk menentukan kedudukan yang tepat. Ini adalah kerana motor ini mempunyai kecekapan yang lebih tinggi, dan resolusi langkah yang tinggi disebabkan oleh sudut langkah yang lebih kecil. Dalam projek ini, dua fasa hybrid motorlangkat telah digunakan untuk menentukan kedudukan dan juga halaju motor. Dua bentuk pengawal telah direka untuk mencapai objektif yang telah ditetapkan. Model hybrid motor langkah telah dibangun dalam Matlab-Simulink dengan dikawal oleh pengawal PID konventional dan pengawal logic kabur. Pengawal PID konventional dan pengawal logic kabur yang digunakan telah dapat mengurangkan masa untuk sampai ke keadaan stabil dan reaksi yang terlajak. Model yang dibangunkan membolehkan motor dapat melaksanakan kelajuan dan tindak balas kedudukan trek untuk pemutar pada setiap pengujaann. Menggunakan model ini, ia mampu melaksanakan simulasi hybrid motor langkah dengan dua pengawal yang berbeza. Keputusan simulasi dibentangkan dengan penjelasan yang terperinci mengenai setiap bahagian kajian yang telah dijalankan untuk pengawal hibrid motor langkah yang berlainan. Dari hasil projek ini, keputusan menunjukan bahawa hibird motor langkah boleh digunakan untuk menentukan kedudukan yang lebih tepat terutamanya apabila sudut langkah kecil.

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LIST OF SYMBOLS

p	-	number of rotor teeth
S	-	steps per revolutions
m	-	number of stator phases
N	-	number of rotor pole pairs
F	-	stepping rate
ζ	-	damping ratio
ω_n	-	natural frequency of oscillation (rad/s)
θ_m	-	stepping angle
ω	-	speed of rotation
J	-	motor inertia
B	-	viscous friction
Km	-	motor Emf constant
$\wp oj$	-	location of the winding j
τ	-	time constant
Vj	-	supply voltage
R	-	resistance of the winding
L	-	inductance of the winding
Ij	-	phase current
K_d	-	amplitude of the release torque
Tij	-	torque produces in each phases
T'	-	stiffness of torque-angle characteristics
T	-	time

LIST OF ABBREVIATIONS

FIS	-	Fuzzy Inference System
FLC	-	Fuzzy Logic Controller
FLO	-	Flex or Cross-Over
LOM	-	Largest of Maximum
MF	-	Membership Function
MOM	-	Mean of Maximum
SOM	-	Smallest of Maximum
PID	-	Proportional, Integral and Derivative

CHAPTER 1

INTRODUCTION

1.1 Introduction

Conventionally a DC motor with servo is used for precise positioning. However in early 1960s many found that this was not very practical since the cost was very high and presented a series of disadvantages. When this problem arises they turn to stepper motor. Stepper motor as their name suggests they ‘step’ a little bit a time. They produce the highest torque at low speed. This is completely different from the DC motor where it produces low torque with low speed. Furthermore stepper motors have ‘holding torque’ characteristics which are not present in DC motors. Holding torque allows a stepper motor to hold its position firmly when not turning. In particular DC motors present the problem of mechanical wear of brushes whereas stepper motors do not have brushes at all.

Hybrid stepper motor are widely used more an application of robotics and in the numerical of machine tool where they have to perform high-precision positioning operation. Before this, DC motor was used. But the DC motor has disadvantages of some kind of operation.

In stepper motor have a various type with different characteristic, advantages and disadvantages. Hybrid stepper motor is one of the type stepper motor. Hybrid mean is combination of characteristic permanent magnet and variable-reluctance. Therefore, hybrid stepper motor has the smaller step size (typically 1.8˚ per step) than other kinds of stepper motors [1].

In stepping mode operation also have a various type like wave drive (1 phase on), full step drive (2 phase on), half step drive (1 & 2 phase on) and micro-stepping (continuously varying motor current). So, in hybrid stepper motor can operate at all type of stepping mode.

Therefore, more application hybrid stepper motor is highly in speed repetitive motion, so it very important to reduce the settling time in order to increase the speed of operation. Other than that, overshoot also need to reduce to overcome the transient response and make it very fast steady state condition with minimum error steady state.

1.2 Research Objectives

Following are the objectives that hopefully to be achieved at the end of this project implementation. Those objectives are:-.

- To control hybrid stepper motor using Conventional PID and Fuzzy Logic Controller.
- To reduce significantly the settling time and overshoot.
- To track the position and speed of Hybrid Stepper Motor

1.3 Research Scope

In accomplishing this research, the work has been divided into a few parts. As a beginning part, the literature review on the stepper motor type as Permanent Magnet, Variable-Reluctance and hybrid stepper motor. Literature review to study the characteristic, circuit design, operation, advantages and disadvantages of the

stepper motor type. After study 3 three type of stepper motor, and choose the hybrid stepper motor to this project.

In real world have so many controller is used in robotic and machine application. So in this research, Conventional PID controller and Fuzzy logic controller is used to overcome the entire problem and to archive the objective. Reason why choose the two of controller it because the controller it suitable and can control nonlinear system and generating very good result. Whereby, Fuzzy logic controller also can design without knowing the exact mathematical model of the process. Apart from that, the fuzzy logic controller is simplicity to control the process.

Therefore, when the hybrid stepper motor combine with the conventional PID and fuzzy logic controller to control the speed, position and reduce settling time and overshoot. So the simulation result can be analyzed with proper tuning and verification.

1.4 Methodology

This research works are undertaken in the following five (5) development stages. The first thing is to study the literature review regarding to this research. Secondly, apply the mathematical model of a Hybrid Stepper Motor in Matlab-Simulink. Then it comes to the design the controller based on conventional PID controller and Fuzzy Logic controller in the Matlab-Simulink. After that, both of controller design will simulated with the model. Lastly, all result will be compared and analyze the performance of both controller to meet the objectives. Figure 1.1 show the flow chat of this methodology.

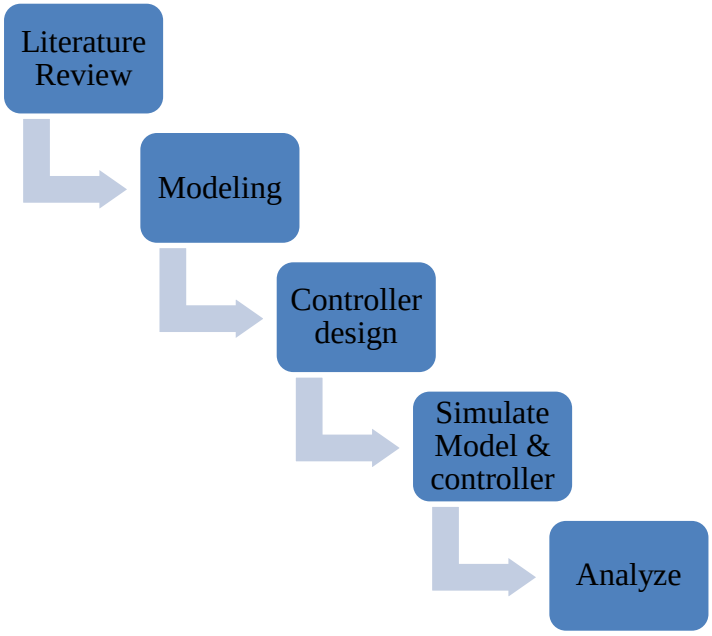

Figure 1.1: Flow Chart of Methodology

1.5 Thesis Outline

The dissertation is divided into several sections which illustrates the outline of the project. Each section is explained in details in order to give an overall idea of the project. The sections are as follows:

CHAPTER 1 Present the introduction, overview and objectives of the project

CHAPTER 2 Discuss the background theory of stepper motor. This includes the types of stepper motor, advantages and disadvantages of the hybrid stepper motor compared to Variable Reluctance, principles of operation, mode of operation and its system.

CHAPTER 3 Describe and explain about methodology that has been used to complete this project. The discussions are concentrating about the mathematical model, and controller involved.

CHAPTER 4 Explain with detailed about the design controller that used in this project. The controllers are conventional PID controller and Fuzzy Logic Controller.

CHAPTER 5 Present the project result. This section covers the result and comments.

CHAPTER 6 Conclusions and Future Plan

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