OUTPUT MEMBERSHIP FUNCTION TUNING OF FUZZY LOGIC SPEED CONTROLLER FOR INDUCTION MOTOR DRIVE APPLICATION

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A report submitted
in partial fulfillment of the requirements for the degree of
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2019

DECLARATION

I declare that this report entitled "OUTPUT MEMBERSHIP FUNCTION TUNING OF FUZZY LOGIC SPEED CONTROLLER FOR INDUCTION MOTOR DRIVE APPLICATION" is the result of my own research except as cited in the references. The report is not concurrently submitted in the candidate of any other degree programme and has not been for any degree.

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APPROVAL

I hereby declare that I have checked this report entitled “OUTPUT MEMBERSHIP FUNCTION TUNING OF FUZZY LOGIC SPEED CONTROLLER FOR INDUCTION MOTOR DRIVE APPLICATION” and in my opinion, this thesis it complies the partial fulfillment for awarding the award of the degree of Bachelor of Electrical Engineering with Honours

Signature	:	....
Supervisor Name	:	....
Date	:	....

DEDICATIONS

Dedicated to my beloved parents and family members for their love, patience, and support throughout my life

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ABSTRACT

Nowadays, induction motor are the most common type of motor used in industries because there are some advantages of induction motor that compared to DC motor which is Low maintenance, robustness, low cost, high efficiency, good self-starting, and design simplicity. The most problematic of induction motor is at the speed. The speed is constant varies to frequency and pole. So, the problems of induction motor can be solved by the present of speed controller such PI speed controller and fuzzy Logic Speed Controller. The traditional indirect vector control system uses conventional PI controller in the outer speed loop because of the simplicity and stability. However, unexpected change in load conditions or environmental factors would produce overshoot, oscillation of motor speed, oscillation of the torque, long settling time and thus causes deterioration of drive performance. PI controller however only provides good response at their design operating condition which normally obtain in rated speed operations. Besides, there are problems with tuning the gain parameter of this controller. The gain is quietly hard to tune to acheive the high performance variation of induction motor. To overcome this, an intelligent controller based on Fuzzy Logic can be used to place the PI controller. The fuzzy logic has certain advantages compared to classical controllers such as simplicity of control, low cost, and the possibility to design without knowing the exact mathematical model of plant. Fuzzy logic controller brain is like human logic knowledge. So, it is easier to tune for increasing the motor performance. But, in fuzzy logic there have too many ways to tuning and there are some research gap of this controller. So, this project aim is to investigate the research gap that is effect of output Membership Function(MF) and analyze the various rules of output MF in order to increases the performance of induction motor. The simulation model of induction motor and their speed controller is designed by using Simulink MATLAB.

ABSTRAK

Pada masa kini, motor induksi adalah jenis motor yang paling biasa digunakan di industri kerana terdapat beberapa kelebihan motor induksi yang dibandingkan dengan motor DC yang adalah penyelenggaraan yang rendah, ketahanan, kos rendah, kecekapan yang tinggi, permulaan diri yang baik, dan kesederhanaan reka bentuk. Motor induksi yang paling bermasalah adalah pada kelajuan. Kelajuan adalah tetap berterusan untuk frekuensi dan tiang. Oleh itu, masalah motor induksi boleh diselesaikan oleh pengawal kelajuan semasa seperti pengawal kelajuan PI dan Pengawal Kelajuan Logik fuzzy. Sistem kawalan vektor tidak langsung tradisional menggunakan pengawal PI konvensional pada gelung laju luar kerana kesederhanaan dan kestabilan. Walau bagaimanapun, perubahan yang tidak dijangka dalam keadaan beban atau faktor alam sekitar akan menghasilkan overshoot, ayunan kelajuan motor, ayunan tork, masa penyelesaian yang lama dan dengan itu menyebabkan kemerosotan prestasi memandu. Pengawal PI bagaimanapun hanya memberikan tindak balas yang baik pada keadaan operasi reka bentuk mereka yang biasanya diperolehi dalam operasi kelajuan undian. Selain itu, terdapat masalah dengan penalaan parameter keuntungan pengawal ini. Keuntungan secara senyap-senyap sukar untuk menyesuaikan diri dengan perubahan prestasi motor induksi yang tinggi. Untuk mengatasinya, pengawal pintar berdasarkan Logik Fuzzy boleh digunakan untuk menempatkan pengawal PI. Logik kabur mempunyai kelebihan tertentu berbanding pengawal klasik seperti kesederhanaan kawalan, kos rendah, dan kemungkinan untuk mereka bentuk tanpa mengetahui model matematik yang tepat. Penceramah logika fuzzy adalah seperti pengetahuan logik manusia. Oleh itu, ia adalah lebih mudah untuk menaikkan prestasi motor. Tetapi, dalam logika kabur terdapat terlalu banyak cara untuk menala dan terdapat beberapa jurang penyelidik pengawal ini. Oleh itu, matlamat projek ini adalah untuk mengkaji jurang penyelidikan yang berpengaruh terhadap Fungsi Keahlian keluaran (MF) dan menganalisis pelbagai peraturan output MF untuk meningkatkan prestasi motor induksi. Model simulasi motor induksi dan pengawal kelajuan mereka direka bentuk dengan menggunakan Simulink MATLAB.

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LIST OF SYMBOLS AND ABBREVIATIONS

FLSC	-	Fuzzy Logic Speed Controller
MF	-	Membership Function
IM	-	Induction Motor
VSD		Variable Speed Drive
AC		Alternating Current
FOC	-	Field Oriented Control
IFOC	-	Indirect Field Oriented Control
PI	-	Proportional Integral
DC	-	Direct Current
NL	-	Negative Large
NB	-	Negative Big
NM	-	Negative Medium
NS	-	Negative Small
ZE	-	Zero
PS	-	Positive Small
PM	-	Positive Medium
PB	-	Positive Big
PL	-	Positive Large

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CHAPTER 1

INTRODUCTION

1.1 Project Background

The most popular ac motor is the three-phase induction motor and it is very commonly used for industrial drives. This motor has high starting torque and good speed regulation. Besides, it robust, cheap, reliable and efficient [1]. The most problematic things of induction motor are its complex, it is not inherently capable of providing variable speed operation. The speed of induction motor is depending on the frequency and numbers of poles. This problem of induction motor can be solved using Variable Speed Drive (VSD) control.

One of the earlier methods for VSD is scalar method, Field Oriented Control (FOC) and Direct Torque Control (DTC). Basically V/F method is also known as scalar method. This method is good only for steady state condition but its poor for dynamic performance. To overcome this problem, Field Oriented Control (FOC) method was introduced. The performance of FOC can be greater than scalar control because it provides better performance for transient conditions and steady state. FOC transform the dynamic induction motor become similar to DC machines because its convert 3 axes to become d-q axes.

A well-designed control algorithm is necessary to control the speed and torque of the induction motor. FLC is one of the controllers that can improve the performance based on human understanding which could not easily be integrated into mathematical model on which conventional designs of controllers are generally based.

In this project, fuzzy logic speed controller (FLC) is used to investigate the different rules of FLSC and tuning of the output membership function (MF) and analysis performance speed of the induction motor. Surely, MF is one of the parameters that can impact the motor performance.

1.2 Problem Statement

AC performance drive is widely used in industrial to expose the Variable Speed Drive (VSD) application. VSD for Induction Motor (IM) require wide operating speed range along with a fast torque response, irrespective of the variations in load, thereby leading us towards more advanced methods of control to meet the real demand. There are many controllers that frequently used in order to control the speed of induction motor that are PID controller and Fuzzy Logic Speed Controller (FLSC). For the PID controller offers a very efficient solution to numerous control problems in the real world. The only problem associated with use of conventional PI, PD and PID controllers in speed control of induction motors is the complexity in design and tuning the gain arising due to the non-linearity of Induction Motor dynamics. The conventional controllers have to linearize the non-linear systems in order to calculate the parameters. To obtain a perfect non-linear model is almost impossible and hence the values of the parameters that are obtained from it are thereby approximate. Thus, to overcome the complexities of conventional controllers, fuzzy logic speed controller (FLSC) has been implemented in many motor control applications. In the last three decades, fuzzy control has gained much popularity owing to its knowledge-based algorithm, better non-linearity handling features and independence of plant modelling. The Fuzzy Logic Controller (FLC) owes its popularity to linguistic control. The performance of induction motor is affected by FLSC rule base designed, membership function (MF) of scaling factor and others. There are many ways to tune FLC and there is some research gap about the tuning method of FLC that is output membership function tuning.

1.3 Objectives

The objectives of this project are;

- To develop a dynamic model of induction motor using Field-Oriented Control (FOC) method for induction motor drive.
- To design a fuzzy logic controller for speed loop induction motor drive.
- To compare the speed performance for various number of MF of FLSC rules such as 3x3 matrix,5x5 matrix, and 9x9 matrix.
- To investigate the increase or decrease the number of the output Membership Function (MF) of fuzzy logic speed controller for induction motor towards speed performance.

1.4 Scopes of Project

The scope of this project is focused on induction motor, fuzzy logic speed controller, and motor driver. This project is develop using the mathematical model of induction motor drive fed by hysteresis current controller using MATLAB/SIMULINK. Fuzzy logic speed controller, fuzzy rules and membership functions are developed to be a controller for the speed performance of induction motor. The fuzzy Membership Function is limit from -1 to 1. Besides, the analysis of the project is about to analyze the comparison of fuzzy logic speed controller using different rules for input and output membership function such as 3, 5, 7 and 9 rules to the performance of induction motor drive. Next, the simulation is limit for high and low speed of the reference of the induction motor driver. The parameters of induction motor are based on real induction motor parameters

CHAPTER 2

LITERATURE REVIEW

2.1 Induction Motor

Induction motor is an AC motor that have two main part that is stator and rotor. It works in the principle of electromagnetic induction. The classification of induction motor can be determining by the type of rotating part of the motor that call rotor side that is situated inside the stator of the motor. The construction of the rotor is made up of a set slotted thin sheets known as laminations of electromagnetic substance like special core steel that are pressed together in the form of cylinder. The slots consist of the electrical circuit and the cylindrical electromagnetic substance acts as magnetic path. The rotor winding of an induction motor has classified into two types that is squirrel cage type and wound rotor type. For squirrel cage rotor it consists of copper bars, slightly longer than rotor, which pushed into slots. All bars are short circuited by welded the ends to the copper and rings. Besides, wound rotor has 3-phase winding that like stator winding. The terminal of the rotor is connected to three slip rings which turn with the rotor. The slip allows external resistors connected in series with the winding. External resistors are basically used during start up and under normal conditions, the windings are short circuited externally [3].

An induction motor consists of many parts, the stator and rotor are the basic subsystem of induction motor [4]. Stator parts mean the stationary part which located at the outer part of induction motor. The stator is covered by cylindrical frame, a set of insulated electrical windings and magnetic path. The cylindrical frame basically made up either from cast aluminum alloy, cast iron or welded fabricated sheet steel [5]. Besides, the magnetic path consists of a set of high-grade alloy steel lamination slot that attached with outer cylindrical stator frame. The advantage of laminating the magnetic path is to minimize the amount of heat produce and reduce the losses of eddy current [5].

The operation of three-phases induction motor is following the Faraday's law and Lorentz force on a conductor [3]. Next, the principle of operation of induction motor is based on generating a rotating constant magnetic field [6]. To make a constant rotating magnetic field, the orientation of the coils must 120 physical degrees apart in space and 3 phase voltages supplies on the windings also separated in time by 120 electrical degrees. When the three-phases voltage are applied to stator, three-phase set of currents is flowing and these current produces magnetic field that rotate in a counterclockwise direction. The conductors at the rotor are cut by the rotating magnetic field and produce induced voltage in them. The induced voltage produces currents that circulate in a loop around the conductors. The flowing of rotor currents produces a rotor magnetic field. This current interacts with the air gap flux to produce induced torque [3]. The resulting torque is counterclockwise. So, the rotor accelerates in that direction. The advantages of induction motor are able to connect directly to AC source, low maintenance cost, durability, flexible design, ruggedness, small size and weight and simpler protection [2]. Next, there are several disadvantages of this motor that is low starting torque, high have in rush currents. One of the main disadvantages of induction motors is that speed control of induction motors is difficult. Hence for fine speed control applications dc motors are used in place of induction motors.

2.2 Control Method

2.2.1 Scalar

Voltage, current and frequency are constant in motor speed range. Scalar control based on two parameters that vary simultaneously [10]. The speed can be varied by adjusting the supply frequency, but this result makes the impedance change. The change of impedance shows the current increase or current decrease. If the current small, the torque is small too. There are no angles in scalar control method [11]. Open-loop scalar control is almost used in industries because it is easy to implement with low desired on computational power. Open-loop control means that is no feedback from the output motor.

One of the weaknesses is the instability of drive after certain applied frequency. To overcome this weakness, the rotor needs to be implemented with damper windings [12]. Open-loop control not control the torque, so the desired torque only accessible at the nominal operating point. Close-loop control can overcome this problem, it can control the torque. Close-loop control method have a slip control loop and the slip is proportional to the torque.

2.2.2 Vector

One of the vector control methods is field oriented control (FOC). There are other methods that work with vectors that is known as direct torque control (DTC) and direct self-control [13]. FOC is famous techniques because of good and robust control in case of transient. To get a two-dimensional reference rotating frame (d-q) it required to convert the three-dimensional frame to (d-q) frame [14]. “d” component represent flux while “q” component represents torque.

Basically, vector control has divided to two categories that is direct and indirect. Direct vector control will be using the hall device to capture the flux measurement. The problem is the result will not accurate and hardware cost is expensive [11]. For indirect vector control, it is more preferred because the rotor angle is being measured indirectly. The method usually uses for estimating the rotor flux is slip relation. Some of the FOC advantages are improved torque response, torque control at low frequencies and low speed, dynamic speed accuracy and power consumption. FOC transform the dynamics of induction motor to become similar DC motor and it became easier to achieve the performance of the induction motor. Unlike FOC, DTC worked without external measurement of rotor mechanical position. To ensure the right rotational direction, rotor position must be known at motor start up. For DTC, any current regulator is not required. DTC produced high torque ripple, high current, high noise level and difficult to control torque at low speed [21]. There are some suggestions on improving the characteristic of DTC, such as; Improving switching tables, using multilevel hysteresis comparators.

2.3 Pulse Width Modulation Method

Pulse-Width Modulation (PWM) is a modulation technique used to encode a massage into a pulsing signal. The average value of voltage and current fed to the load by turning the switch between supply and load on and off. The longer the switch is on compared to the off periods, the higher the total supply to the load.

2.3.1 Hysteresis Current Control

The concept of hysteresis current method is the inverter output current forced to follow the reference current for each phase. This control method performs with limitation of upper and lower by the deviation between two quantities. The operation is like when actual current reach the upper limit of hysteresis band, the leg of inverter will be switch off for the decreasing of current and Figure 2.1 shows the hysteresis current band. If the actual current drop until it reaches the lower band, the inverter will quickly switch on, so the current can reach the upper band. The gap wide between upper and lower band can determined the magnitude of ripple. There are some advantages of hysteresis current control that is fast transient, excellent dynamic response, low cost and easy to be implement. Besides, there are some disadvantages using this method such as there was a large current ripple at the steady state, variation of switching frequency and no intercommunication between each hysteresis controller of three phases [15].

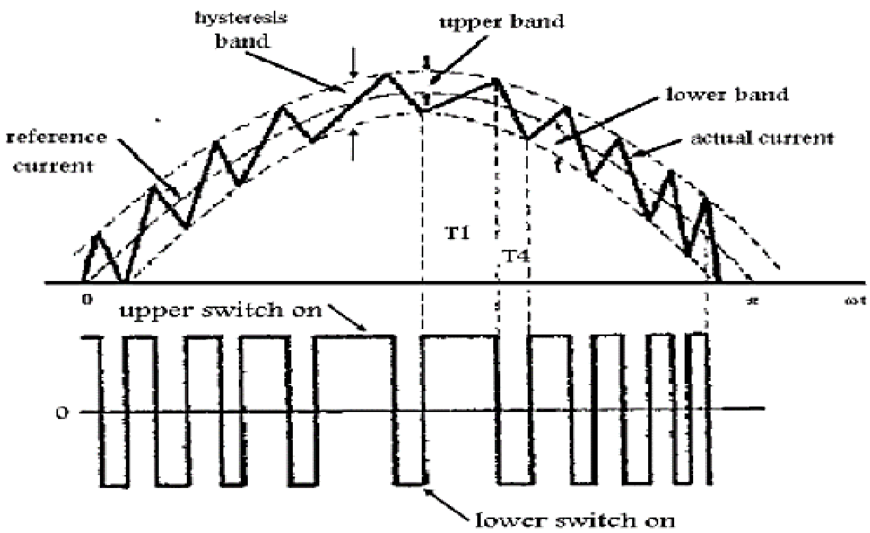

Figure 2.1 Hysteresis current band