SPEED CONTROL OF INDUCTION MOTOR USING FUZZY

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Speed Control of Induction Motor Using Fuzzy

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LIST OF ABBREVIATIONS

AC	Alternating Current
DC	Direct Current
DTC	Direct Torque Control
emf	Electo-Magnetics Field
FLC	Fuzzy Logic Controller
IM	Induction Motor
MF	Membership Functions
PI	Proportional Integrator
V/f	Volts per frequency

LIST OF SYMBOLS

B_m	Viscous friction coefficient. (pu)
d, q	Direct and quadrature axis
E_s	Electro-Magnetics Field
f	Frequency
H	Inertia constant (s)
i	Current
i_r	Rotor current (pu)
i_s	Stator current (pu)
L_m	Magnetizing inductance (pu)
L_r	Rotor inductance (pu)
L_{rl}	Rotor leakage inductance (pu)
L_s	Stator inductance (pu)
L_{sl}	Stator leakage inductance (pu)
N	Induction Motor Speed
N_s	Synchronous Speed
p	Number of poles
R_r	Rotor resistance (pu)
R_s	Stator resistance (pu)
T	Torque
T_e	Electromagnetic torque (pu)
T_L	Load torque (pu)
v_r	Rotor voltage (pu)
v_s	Stator voltage (pu)
λ_r	Rotor flux (pu)
λ_s	Stator flux (pu)
ω_0	Base frequency
ω_k	d-q frame frequency
ω_m	Rotor frame frequency
ω_s	Synchronous frame frequency (rad/sec)

Kawalan Kelajuan Motor Aruhan Menggunakan Fuzzi

ABSTRAK

Disertasi ini menerangkan mengenai kaedah yang digunakan bagi pelaksanaan peraturan asas dalam pengawal logik fuzzi yang diaplikasikan kepada kawalan kelajuan gelung tertutup voltan per hertz bagi motor aruhan fasa tunggal. Motor aruhan dimodelkan dengan menggunakan teori paksi d-q. Prestasi Pengawal Logik Fuzzi yang direkabentuk dibandingkan dengan Pengawal PI. Terdapat beberapa kelebihan pada Pengawal Logik Fuzzi berbanding pengawal-pengawal konvensyenal yang lain iaitu : (i) ia dari segi ekonomi mempunyai kelebihan dan mudah untuk dikembangkan, (ii) julat operasi yang lebih luas boleh dengan menggunakan Pengawal Logik Fuzzi ini, dengan anggaran set arahan permulaan secara dorongan oleh pengurusan kendiri Pengawal Fuzzi. Bagi kawalan kelajuan voltan per hertz motor aruhan fasa tunggal ini, kelajuan rujukan digunakan dan reka bentuk kawalan telah dimasukkan peraturan-peraturan yang berkaitan Erata dinilai berdasarkan peraturan-peraturan bagi memenuhi kefungsian ahli. Kefungsian ahli and peraturan yang telah ditakrifkan menggunakan Sistem Rumusan Fuzzi (FIS) yangh diberikan di dalam Matlab. Sistem tersebut telah disimulasikan dalam Matlab / Simulink dan keputusan diberikan. Keputusan yang diperolehi dianalisis dan dibincangkan.

Speed Control of Induction Motor Using Fuzzy

ABSTRACT

This dissertation presents a methodology for implementation of a rule based fuzzy logic controller applied to a closed loop volts/hertz single phase induction motor speed control. The induction motor is modelled by using d-q axis theory. The performance of FLC is compared with that of a PI controller. The advantages of the Fuzzy Logic Controller over the conventional controllers are : (i) they are economically advantageous to develop, (ii) a wider range of operating conditions can be covered using FLCs, and initial approximate set of fuzzy rules can be impulsively refined by a self-organizing fuzzy controller. For volts/hertz speed control of the single phase induction motor, a reference speed has been used and the control architecture includes some rules. The errors are evaluated according to the rules in accordance to the defined member functions. The member functions and the rules have been defined using the Fuzzy Inference System (FIS) editor given in Matlab. The system has been simulated in Matlab / Simulink and the results are given. Provide briefing results, analysis and discussed.

CHAPTER 1

INTRODUCTION

1.1 Introduction

The induction motors are characterized by complex, highly non-linear and time-varying dynamics. They are the most widely used electrical motors due to their reliability, low cost and robustness. However, induction motors do not inherently have the capability of variable speed operation.

The use of induction motor has increased tremendously since the day of its invention. They are being used as actuators in various industrial processes, robotics, house appliances and other similar applications. The reason for its day by day increasing popularity can be primarily attributed to its robust construction, simply in design and cost effectiveness; they have some unfavourable features like their time varying and non-linear dynamics.

When power is supplied to an induction motor at recommended specifications, it runs at its rated speed. With tremendous advances in power electronics devices over last couple of years, the speed and torque control are now commonly accomplished by supplying variable voltage and variable frequency via an adjustable frequency control to an induction motor.

Normally, three phase induction motor is designed at certain speed and frequency. There are several methods of speed control of induction motor, such as pole changing, frequency variation, variable rotor resistance, variable stator voltage, constant V/f control. The closed loop constant V/f speed control method is most widely used. But, the most efficient and inexpensive method is a frequency drive inverter. Besides helping user conserve electric power, the inverter offers precise speed control. Because of the speed control, the induction motor can completely be utilized in market.

1.2 Problem Statement

The field of power electronics has contributed immensely in the form of voltage-frequency converters which has made it possible to vary the speed over a wide range. The conventional controller types that are used are may be numeric or neural or fuzzy. The controller types that are regularly used are: Proportional Integral (PI), Proportional Derivative (PD) and Proportional Integral Derivative (PID). The conventional control methods possess the following difficulties:

(a) Dependence on the exactness of the mathematical model of the system.

(b) Expected performance not being met due to the load disturbance, motor saturation and thermal deviations.

(c) Decent performance exhibited only at one operating speed when classical linear control is employed.

(d) Adopting the right coefficients for acceptable results.

From the above, it can be deduced that in order to implement conventional control methodologies, it is necessary to have knowledge of the system's model that is to be controlled. The usual method of computation of mathematical model of the induction motor is difficult, due to non-linearity of motor dynamics. Whenever a variation in system or ambient parameters arises, provide high performance increase the design complexity along with the cost.

Thus, to overcome the complexities of conventional controllers, fuzzy control (Zadeh, 1965) 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.

1.3 Objectives of the Research

The main aim of this project is to develop a fuzzy logic based controller for speed control of induction motor. The specific objectives are as follows:

(a) To develop a simulation model for the fuzzy logic controller to control the speed of three phase induction motor using Matlab Simulink.

(b) To compare the motor performance between PI controller and fuzzy logic controller.

(c) To analyze the speed response of voltage / frequency controller using Matlab Simulink.

1.4 Scope of Research

The aim of this research is to develop the Matlab Simulink simulation model of fuzzy logic controller to control the speed of the induction motor, applying the scalar control model. The speed and torque of induction motor can be changed by varying the voltage and frequency supply to the stator, while the ratio of voltage to frequency must be kept constant to prevent the saturation of air gap flux.

1.5 Significant of Research

This research is focusing on application of Fuzzy Logic using Matlab Simulink for speed control. The FLC is used because to find out whether this type of controller have better performance compared to other regularly used controller such as Proportional Integral (PI), Proportional Derivative (PD) and Proportional Integral Derivative (PID). Here, performance is referred as value of speed, current and torque that achieve based on calculated value for them respectively or reference value.

1.6 Outlines of the Report

The dissertation report is divided into five chapters. Chapter 1 is an introduction which provides an overview of the project, the objectives and project scope.

Chapter 2 is the literature review that discusses briefly about types of speed control and concept of fuzzy logic. Chapter 3 is allocated for research methodology that explains the steps to achieve the objectives. The block diagrams that will be used to control the induction motor are included in this chapter. This chapter also encompasses the controller design with the help of Matlab Simulink and the various steps used for the same.

Chapter 4 is dedicated to the simulation of the induction motor speed control system in Matlab Simulink. Both Fuzzy Logic Controller and conventional PI controller have been used. The results obtained have been compared and discussed. This is followed by the Chapter 5 which presents conclusions and information about the future work of the designed controller.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Generally, induction motor is commonly used in industries because of its robustness and low cost for maintenance. Three phase induction motor can be classified into two types, which are squirrel-cage induction motor and wound rotor induction motor. But, because of its cheaper cost, the three-phase squirrel-cage type induction motor are commonly utilized in the industries from the capacity of several kilowatts to thousands of kilowatt as the driving units for fans, pump, and compressors. This motor has been favoured because of its good self-starting capability, simple and rugged structure, low cost and re-ability as mentioned by Moradi & Khorasani (2008).

The induction motor finds its place amongst more than 85% of industrial motors as well as in its single-phase form in various domestics' usages. Markedly a constant-speed motor with shunt characteristics, speed drops only by a few percent from no-load to full load. Hence in the past, induction motors have been used primarily in constant speed applications. Traditional methodologies employing speed control have either been high-priced or very inefficient, unlike the dc motor. Nonetheless, the presence of commutator and brushes in the latter, which require periodic maintenance make dc motor drives improper for use in hazardous and polluted environments. On the other hand, owing to the simple, rugged, cheaper, smaller and subsequently lighter build of induction motor drives (particularly squirrel-cage type), they are designed for fans, blowers, cranes, traction, conveyers, etc. In spite of finding stiff competition from dc drives for such applications.

There are different techniques involved for speed control of induction motor. Fuzzy technique is one such innovative technique indented mainly for non-linear system like motor speed control. In research by Dongle et. all (2012), the fuzzy system is designed using Mamdani's reasoning method.

The speed control of induction motor involves more complicacy than the control of DC motor, especially if comparable accuracy is desired. The main reason for the same can be attributed to the complexity of the mathematical model of the induction machine, as well as the complicated power converters supplying this motor. Variable speed induction motor drives employ various control algorithms.

However, the slip between the rotor and the synchronous speed stator field develops torque. It is the magnetic flux cutting the rotor conductors as it slips which develops torque. Thus, a loaded motor will slip in proportion to the mechanical load. If the rotor were to run at synchronous speed, there would be no stator flux cutting the rotor, no current induced in the rotor, no torque.

Basically, speed of induction motor is based on frequency of voltage and number of poles. It can be formulated as follows:

$$N_s = \left(120\ \frac{f}{P}\right) \tag{2.1}$$

Where :

N_s = synchronous speed, rpm.

f = frequency, Hz.

P = total number of poles.

Speed controlling of ac induction motor includes many parameters such as initial torque, initial current and voltage. Some conventional techniques consider such parameters for speed controlling purpose. Controlling one of these parameters or combination of these parameters provides speed controlling of ac motor.

In general, speed control can be categorizes as :

(a) Scalar Control. Low cost method described above to control only voltage and frequency, without feedback. The voltage per frequency is scalar control.

(b) Vector Control is also known as vector phase control. The flux and torque producing components of stator current are measured or estimated on a real-time basis to enhance the motor torque-speed curve. This is computational intensive.

2.2 Induction Motor Equivalent Circuit Analysis

The fundamental steady-state equivalent circuit of the induction motor is shown in Figure 2.1.

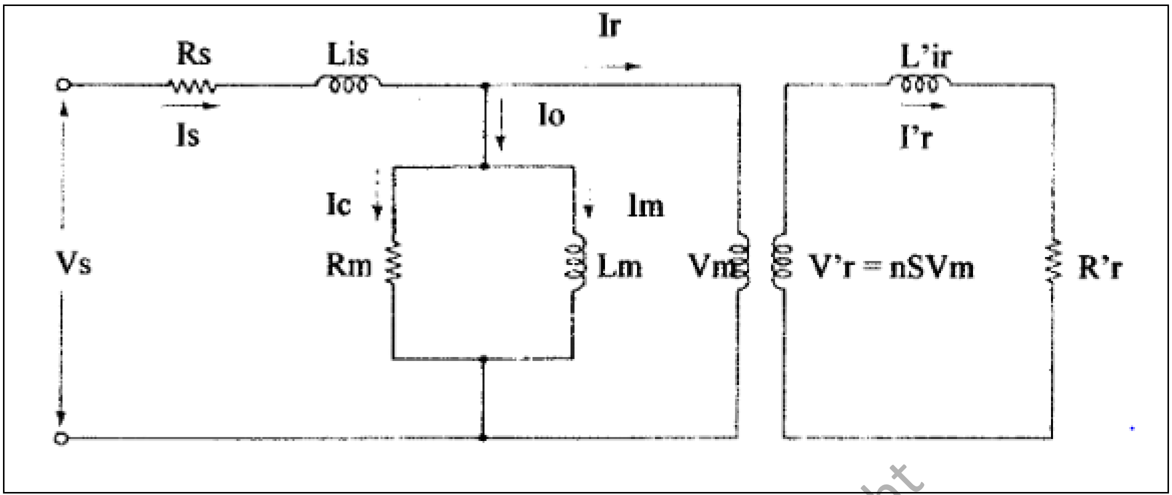

Figure 2.1: Equivalent Circuit of Induction Motor

Figure 2.1 shows the per phase equivalent circuit of induction motor. Counter emf V_m is generated from the synchronously rotating air gap flux. Then, it is converted to slip voltage V_r' in rotor phase. The stator voltage V_s differs from V_m because of the drop I_s on stator resistance R_s and leakage inductance L_{is}.

The no load excitation current I_o consists of two components which are a core loss component I_c and magnetizing inductance current I_m, where R_m is the equivalent resistance for excitation loss and L_m is the magnetizing inductance. When the three phase supply is connected to the stator, there will be a stator core loss I_c. The rotor current I_r' is created from the rotor induced voltage V_r'. This current is limited by rotor resistance R_r' and leakage inductance L_{ir}'.

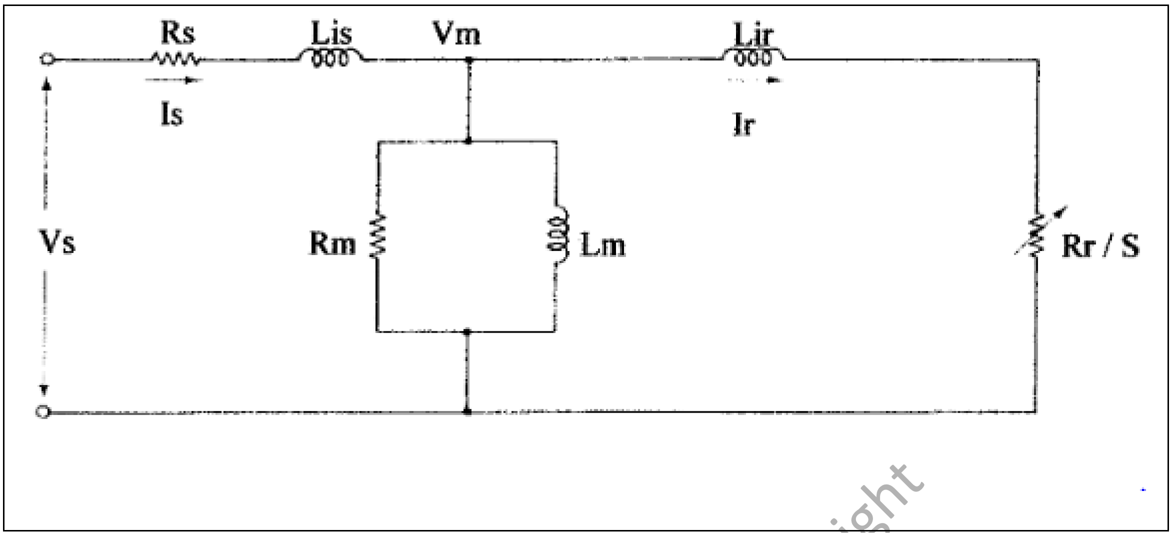

Figure 2.2 : Simplified Equivalent Circuit of Induction Motor 1

Figure 2.2 shows the equivalent circuit with respect to the stator which are the parameters R_r and L_{ir} are referred to the stator. Rotor reflected current I_r is given as

$$I_r = \frac{V'_r}{Z_r} = \frac{n^2 S V_m}{R_r + j\omega_{sl} L_{is}} \tag{2.2}$$

$$I_r = \frac{V_m}{\left(\frac{R_r}{S}\right) + j\omega_e L_{ir}} \tag{2.3}$$

Where

n = rotor to stator turn ratio

S = slip (pu)

ω_{sl} = slip frequency

ω_e = stator frequency

The loss and power expression of a motor can be summarized as:

Input power

$$P_{in} = 3V_s I_s \cos \emptyset \quad (2.4)$$

Stator Copper Loss

$$P_{is} = 3I_s^2 R_s \quad (2.5)$$

Power across air gap

$$P_g = \frac{3I_r^2 R_r}{S} \quad (2.6)$$

Rotor copper loss

$$P_{lr} = 3I_r^2 R_r \quad (2.7)$$

Output power

$$P_o = P_g - P_{lr} \quad (2.8)$$

Developed Torque

$$T_e = \frac{P_o}{\omega_m} \quad (2.9)$$

$$T_e = \frac{3I_r^2 R_r \left(\frac{1 - S}{S}\right)}{\omega_m} \quad (2.10)$$

$$T_e = 3\left(\frac{P}{2}\right) I_r^2 \left(\frac{R_r}{S\omega_e}\right) \quad (2.11)$$