PID-HYSTERESIS VOLTAGE CONTROL TECHNIQUE FOR THREE PHASE INDUCTION MOTOR (MATLAB SIMULINK AND ARDUINO)

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ABSTRACT

These phase induction motors are the most widely used electric motors in industry for converting electrical power into mechanical power. They are considered to be simple, rugged, robust, efficient and suitable for applications in harsh environment. However, their controllability remains a difficult task using conventional control method. The control difficulty is associated with high nonlinearity of the motor's behavior, complexity of its analytical model and presence of interactive multivariable structures. Therefore, this project is proposed a design controller for three phase induction machines in high performance application. The PID Hysteresis controller is developed and simulates using MATLAB/Simulink software and downloads to Arduino where generates the PWM signal. The signals then send to gate driver of a three phase inverter to give a stable performance to the induction motor. The improvement of performance is by comparing the actual measured voltage of the motor with respect to their reference voltage. The difference is then corrected thus minimizing the voltage error. A simple hardware implementation of the PID Hysteresis voltage controller is designed and some simulation and experimental results are presented to demonstrate the validity of this approach.

ABSTRAK

Projek ini menerangkan pengawal untuk motor aruhan tiga fasa. Motor aruhan adalah sebuah penggerak elektromekanikal yang digunakan secara meluas kerana kos penyelenggaraan yang rendah dan boleh dipercayai. Walau bagaimanapun, masalah kawalan motor aruhan adalah kompleks kerana tidak linear, gangguan tork beban dan parameter yang tidak menentu. Elemen yang dimasukkan dalam projek ini adalah kawalan voltan, yang mahu mengawal voltan dari inverter tiga fasa ke motor aruhan tiga fasa. Pengawal histeresis telah digunakan dalam projek ini untuk mengurangkan ralat voltan. Pengawal histeresis dilihat sebagai mundur fasa input–output. Pelaksanaan histeresis direka sebagai pengawal dilakukan dalam simulasi menggunakan MATLAB Simulink. Di samping itu, perkakasan disediakan dan eksperimen dijalankan untuk memerhati dan menganalisis model tersebut.

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LIST OF SYMBOLS AND ABBREVIATIONS

V	-	Voltage
DC	-	Direct current
AC	-	Alternating current
Vac	-	Alternating current voltage
VSI	-	Voltage source inverter
CSI	-	Current source inverter
PID	-	Proportional integral derivative
PWM	-	Pulse width modulation
DSP	-	Digital signal processing
r.m.f.	-	Rotating magnetic field
DFO	-	Direct field-oriented
FFT	-	Fast fourier transform
IC	-	Integrated circuit
SMC	-	Sliding mode controller
DTC	-	Direct torque ratio
USB	-	Universal serial bus
ADC	-	Analog to digital converter
DAC	-	Digital to analog converter

IPM	-	Interior permanent magnet
ICSP-	-	In circuit serial programming

CHAPTER 1

INTRODUCTION

1.1 Project Background

One of the most common electrical motor used in most applications which is known as Induction Motor**.** This motor is also called as asynchronous motor because it runs at a speed less than synchronous speed. Induction motor is widely used in industry because of its reliability and low cost, either single phase or three phases. However, three phases induction is the most interesting and has attracted the attention of many researchers because of induction motor is strongly nonlinear [1].

The function of three phase inverter to Induction motor is produced the 6 pulse PWM signals where the three phase induction motor based on three phase with different shifting time. Many controllers have been developed, that can be divided into two classifications, passive and adaptive power controller. The example for passive power controller is hysteresis, relay and sliding mode control and for adaptive power controller is Proportional Integral Derivatives (PID), fuzzy, and P-resonant controller. Each of them has their advantages, such as simple structure and low maintenance cost [2].

Inverters that use PWM switching techniques have a DC input voltage that is usually constant in magnitude. The inverters job is to take this input voltage and output ac where the magnitude and frequency can be controlled. Many applications that require an inverter use three phase power. The example is an ac motor drive. One option for a three phase inverter is to use three separate single phase inverters but vary their output by 120° [3]. The three phase inverter setup consists of three legs, one for each phase. In three phase inverters PWM is used in the same way as it is before except that it much be used with each of the three phases. When generating power to three different phases one must make sure that each phase is equal, meaning that it is balanced.

Nowadays, an embedded system such as Arduino is rapidly developed in many applications. This is because the Arduino is the low cost other than else and it also an open source [3]. Furthermore the Arduino also can be directly interfaced to the MATLAB Simulink. In many applications of the induction motor, high performance voltage control is one of the fundamental issues [4]. However, induction motors are difficult to control because of their dynamics are intrinsically nonlinear and multivariable and for feedback, it has a critical parameter such as load torque, stator and rotor resistances which may considerably vary during operations [5]. That's the point why a strong controller like PID-Hysteresis control was chosen.

1.2 Problem Statement

The recent advances in the area of field-oriented control (FOC) bring the rapid development and cost reduction of power electronics devices for three phase induction motor give more economical for many industrial applications. However, the control problem of the induction motor is complex due to the nonlinearities. It has several parameters such as load torque, stator and rotor resistances which may considerably vary during operations. There are exists of control strategies such as even adaptive schemes tend to be sensitive but poor in the flux and torque estimation especially during low speed operation. So the proposed here is to implement a design PID-Hysteresis control modeling using MATLAB Simulink by injecting a corrected voltage to the three phase inverter. The challenge in induction motor is to run at the desired speed the voltage generated in the motor is the same as the applied operating voltage. The processes that drive the induction motor are hard because it has electric magnets in both side, the stator and in the rotor. The rotor windings are shorted and act like the secondary windings of a transformer. The magnetic field rotating in the stator induces a current in the shorted rotor windings, which then generates its own magnetic field [10].

1.3 Objective

The objectives of this project are listed as follows:

1. To develop the PID Hysteresis controller approach for motor control.
2. To implement hardware of induction motor drives that is voltage control using PID Hysteresis Controller carried by Arduino embedded devices.
3. To simulate and design the PID Hysteresis control model by using MATLAB Simulink.
4. To analyze the PID Hysteresis Controller.

1.4 Scope

In this project the scope of work will be undertaken in the following three developmental stages:

1. Study of the control system of induction motor for voltage control based on PID Hysteresis control.
2. Perform simulation of PID Hysteresis control. This simulation will be carried out on MATLAB platform with Simulink as it user interface.
3. Development of the target MATLAB Simulink model to Arduino and implements the hardware of voltage control of induction motor for PID Hysteresis Controller.

CHAPTER 2

LITERATURE REVIEW

2.1 Induction motor

The principles of motor is when a current-carrying conductor is located in an external magnetic field perpendicular to the conductor, the conductor experiences a force perpendicular to itself and to the external magnetic field.

2.1.1 Three phase induction motor

Induction motor also called asynchronous motor in motor. All the rotor's energy is produced from the magnetic field of the stator winding to electromagnetic induction . An induction motor not requires mechanical commutation for all or part of the energy transferred from stator to rotor. An induction motor's rotor can be both wound and the type. Three squirrel-cage induction motors are widely used in industrial drives because they are rugged, reliable and economical. Single-phase induction motors are used extensively for smaller loads, such as household appliances like fans. One of the advantages of an induction motor is its mechanical simplicity. This leads to not only to inherent reliability, but also to simpler design for shock requirements. Through careful motor and system design, it has been possible reduce structure borne noise signatures to levels that permit hard mounting of the motor to the hull of a surface combatant [5].It also easy to program for its various uses and low maintenance cost. The Hence for fine speed control applications dc motors are used in place of induction motors. Disadvantage is that speed control of induction motors is difficult.

In paper [6] had presented novel field-weakening scheme for the induction machine. The proposed algorithm, based on the voltage control strategy, ensures the maximum torque operation over the entire field-weakening region without using the machine parameters. Also, they had introduced the direct field-oriented (DFO) control, which is insensitive to the variation of machine parameters in the field-weakening region, the drive system can obtain robustness to parameter variations. Lastly, they founded Experimental results for the laboratory induction motor drive system confirms the validity of the proposed control algorithm.

In paper [7] had presented hysteresis control method for three-phase current controlled voltage-source PWM inverters. It minimizes interference among phases, thus allowing phase-locked loop (PLL) control of the modulation frequency of inverter switches. Then they had discussed about control theory, and described the controller implementation. Design criteria are also given. The results of experimental tests show excellent static and dynamic performance.

The advantages of the three phase induction motor are it has simple and rugged construction, it is relatively cheap, requires little maintenance, it also has high efficiency and reasonably good power factor. Lastly it has self starting torque. The disadvantages are it is essentially a constant speed motor and its speed cannot be changed easily. Its starting torque is inferior to DC shunt motor. The Figure 2.1 shows the three phase induction motor.

Figure 2.1: three-phase induction motor

2.2 Inverter DC to AC

An electrical power converter which is changes direct current DC to alternating current AC is called power inverter. It can be any required of voltage and frequency usually used in transformer , switching and control circuit. It also used from small switching power supplies to large high-voltage electric equipments applications that transport bulk power and solid-state inverters have no moving parts. Commonly inverter is used to supply solar panels or batteries and it perform the opposite function of a rectifier. The electrical inverter is high-power electronic oscillator because generally AC to DC converter was made to work in reverse and thus was inverted which is to convert DC to AC.

2.2.1 Three-phase inverter

Three-phase inverter circuit works at line-frequency, which the main output power. The switches work at line frequency, so the switching loss is small and the efficiency of output syetem is high [6].The three-phase inverter the main output power; three single-phase full-bridge inverters are used to improve the system dynamic performance. Compared with the traditional inverter circuit, the circuit can achieve high efficiency and low harmonics at the same time, and it can also reduce the voltage stress of the power switches. This is a new way for the combination of the inverters. The circuit can be controlled easily, so it was easy to be modularized. High frequency inverter used PWM modulation and line-frequency inverters worked.

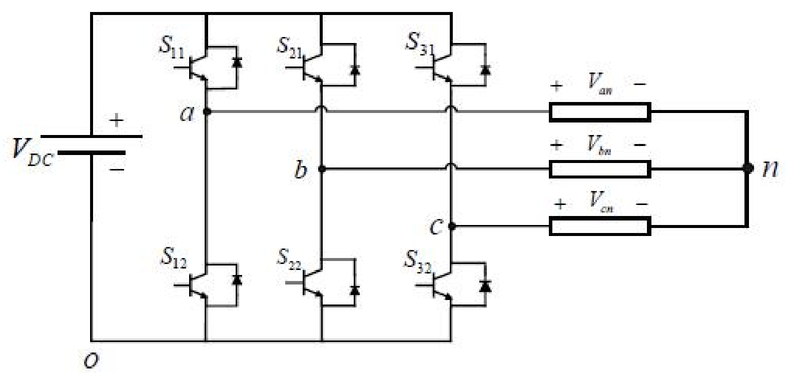

Figure 2.2. : standard three-phase inverter

The standard three-phase inverter shown in Figure 2.2. has six switches the switching of which depends on the modulation scheme. The input dc is usually obtained from a single-phase or three phase utility power supply through a diode-bridge rectifier and LC or C filter.The PWM inverter A has most applications such as unintermptible power systems (UPS'S), active filters, high power factor converters, and adjustable frequency drives.Almost all applications of PWM inverters with a current minor loop, and performance of the inverter system largely depends on the quality of the current minor loop. Therefore current control of PWM inverter is one of the most important subject of power electronics [7].

2.3 Adaptive controller

Basically controller devide into two categories which is adaptive and passive controller. The example of adaptive controller is PID, Fuzzy and Neural Network. Adaptive Control covers a set of techniques which provide a systematic approach for automatic adjustment of controllers in real time, in order to achieve or to maintain a desired level of control system performance when the parameters of the plant dynamic model are unknown and/or change in time [8]. The Figure 2.3 below shown the basic configuration for adaptive system.

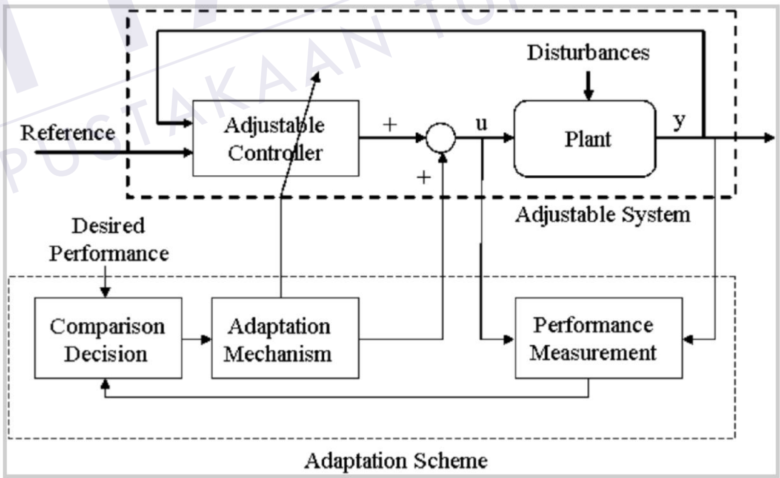

Figure 2.3 : Basic configuration for an adaptive control system

The advantages of Adaptive Control is convenience controller so that it can continuously adapt itself to the current behavior of the process and outperformed their fixed parameter counterparts in terms of efficiency. It also can eliminate the error faster and with fewer fluctuations. Allow the process to operate closer to its constraints where profitability is highest but the disadvantage is much more complex.

2.3.1 PID Controller (Proportional Intergral and Derivative)

Proportional-integral-derivative(PID) controllers have been the most popular and the most commonly used industrial controllers in the past years [9]. The popularity and widespread use of PID controllers are at tributed primarily to their simplicity and performance characteristics.Although linear fixed-gain PID controllers are often adequate for controlling a nominal physical process, the requirements for high-performance control with changes in operating conditions or environmental parameters are often beyond the capabilities of simple PID controllers [10][11]. The Figure 2.4 shows the PID controller block diagram.

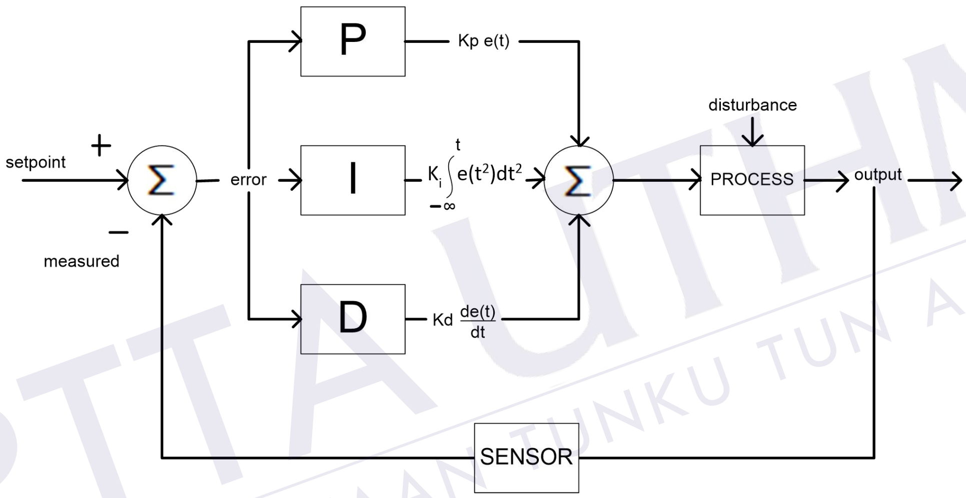

Figure 2.4 : PID controller Block Diagram

$$u(t) = MV(t) = K_p e(t) + K_i \int_0^t e(\tau)d\tau + K_d \frac{d}{dt} e(t) \qquad (2.1)$$

K_p = proportional gain, a tuning parameter.

K_i = integral gain, a tuning parameter.

K_d = derivative gain, a tuning parameter.

e = error.

τ = time or instantaneous time

In Proportional Derivative Integral mode, the controller make the following:

- Multiplies the Error by the Proportional Gain (Kp), Added to the Derivative error multiplied by Kd and Added to the Integral error multiplied by Ki, to get the controller output.

The advantages of PID controller is using both integral and derivative control (PID) has removed steady-state error and decreased system settling times while maintaining a reasonable transient response.

2.3.2 Fuzzy logic controller

Fuzzy logic control is one of the most interesting fields where fuzzy theory can be effectively applied. Fuzzy logic techniques attempt to imitate human thought processes in technical environments. Fuzzy control also supports nonlinear design techniques that are now being exploited in motor control applications. Initially fuzzy control was found particularly useful to solve nonlinear control problems or when the plant model is unknown or difficult to build. The present work includes application of fuzzy techniques to control the speed of an induction motor. Fuzzy rules can be obtained through machine learning techniques, where the knowledge of the process is automatically extracted or induced from sample cases or examples. Many machine learning methods developed for building classical crisp logic systems can be extended to learn fuzzy rules [12]. The adaptive fuzzy control can compensate for any under estimation of the bounds of the uncertainties [13]. However, the performance may still be unsatisfactory when the machine parameters vary too much. The basic reason for the unsatisfactory performance is that the control algorithms lack the ability to learn how to deal with the system complexity. Results of comprehensive computer simulation show that fuzzy model reference leaning control (FMRLC) has potential to improve the close-loop control performance [14][15].Limitations Of Fuzzy Logic Controller is hard to develop a model from a fuzzy system and require more fine tuning and simulation before operational.

2.4 Passive controller

Normally controller divides into two groups, they are adaptive and passive. The example the passive controller is consists of hysteresis, relay and sliding mode control. Passivity is a property of engineering systems, used in a variety of engineering disciplines, but most commonly found in analog electronics and control systems. A passive component, depending on field, may be either a component that consumes but does not produce energy thermodynamic passivity, or a component that is incapable of power gain (incremental passivity).

2.4.1 Hysteresis

The hysteresis is the dependence of a system not only on its current environment but also on its past environment. Some significant advantages of hysteresis controllers overother types of controllers designed with linear or nonlinear control techniques are as follows:

- switching behavior of the power inverter can be directlytaken into account at the design level.
- robustness to load parameters' variation can be proved.
- almost static response is achieved (the dynamics are obviously bounded by the dc-link voltage and by the actual switching frequency).
- simple hardware implementation, based on logical devices, is possible according to the Boolean nature of controller input/output variables.

However, conventional type of hysteresis controllers (with independent comparator for each phase of the load) suffers from some well known drawbacks, e.g., limit cycle oscillations, overshoot in current errors, generation of sub harmonic components in the current and random (non-optimum) switching[16]. The figure below shown the basic hyteresis controller. The Figure 2.5 shows the basic hysteresis controller.

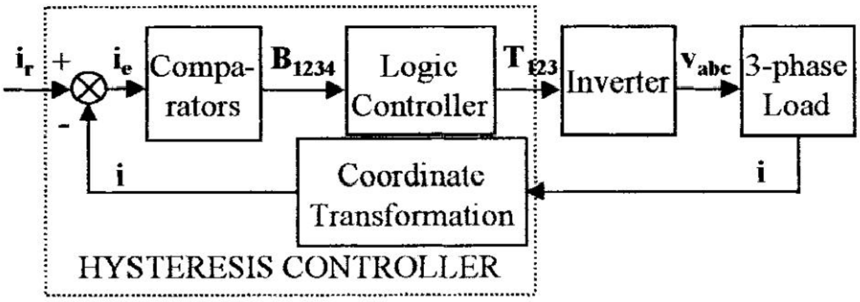

Figure 2.5 : basic hysteresis controller.

Hysteresis occurs in ferromagnetic materials and ferroelectric materials, as well as in the deformation of some materials (such as rubber bands and shape-memory alloys) in response to a varying force. In natural systems hysteresis is often associated with irreversible thermodynamic change. Many artificial systems are designed to have hysteresis: for example, in thermostats and Schmitt triggers, hysteresis is produced by positive feedback to avoid unwanted rapid switching. Based on the electrical engineering, Hysteresis can be used to filter signals so that the output reacts slowly by taking recent history into account.

A three-level inverter-fed induction motor drive operating under Direct Torque Control (DTC) is presented. A triangular wave is used as dither signal of minute amplitude (for torque hysteresis band and flux hysteresis band respectively) in the error block. This method minimizes flux and torque ripple in a three-level inverter fed induction motor drive while the dynamic performance is not affected. The optimal value of dither frequency and magnitude is found out under free running condition. The technique can reduces torque ripple by 60% (peak to peak) compared to the case without dither injection, results in low acoustic noise and increases the switching frequency of the inverter [17].

2.4.2 Sliding mode control (SMC)

The major advantage of a sliding-mode controller is its insensitivity to parainetcr variations and external load disturbance once on the switching surface.The SMC is found to be attractive in terms of robustness of the drive response but suffers from the problem of chattering,apart from being slightly difficult to realize [1]. The Figure 2.6 shows the baundary layer for SMC.

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