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

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ABSTRACT

This project describes a controller for three phase induction motor. Induction motor is an electromechanical actuator widely used as due to reliable and relatively low maintenance cost. However, the control problem of the induction motor is complex due to the nonlinearities, the load torque perturbation, and the parameter uncertainties. An element that include in this project is voltage control, which is to control the voltage fed from three phase inverter to three phase induction motor. Hysteresis controller has been used in this project to minimize the voltage error. Hysteresis controller is seen as an input–output phase lag. The implementation of designed hysteresis controller is performed in simulation using MATLAB Simulink. On the other side, the hardware will be setup to observe and analyze the model.
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<tr>
<td>V</td>
<td>Voltage</td>
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<tr>
<td>DC</td>
<td>Direct current</td>
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<tr>
<td>AC</td>
<td>Alternating current</td>
<td></td>
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<tr>
<td>Vac</td>
<td>Alternating current voltage</td>
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<tr>
<td>VSI</td>
<td>Voltage source inverter</td>
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<tr>
<td>CSI</td>
<td>Current source inverter</td>
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<tr>
<td>PID</td>
<td>Proportional integral derivative</td>
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<tr>
<td>PWM</td>
<td>Pulse width modulation</td>
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<tr>
<td>DSP</td>
<td>Digital signal processing</td>
<td></td>
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<tr>
<td>r.m.f.</td>
<td>Rotating magnetic field</td>
<td></td>
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<tr>
<td>DFO</td>
<td>Direct field-oriented</td>
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<tr>
<td>FFT</td>
<td>Fast fourier transform</td>
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<tr>
<td>IC</td>
<td>Integrated circuit</td>
<td></td>
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<tr>
<td>SMC</td>
<td>Sliding mode controller</td>
<td></td>
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<tr>
<td>DTC</td>
<td>Direct torque ratio</td>
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<tr>
<td>USB</td>
<td>Universal serial bus</td>
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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

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]. Many controllers have been developed, that can be divided into two classifications, passive and adaptive power control. The example for passive power control is hysteresis, relay and sliding mode control and for adaptive power control is PID, fuzzy, and P-resonant controller [2, 3]. Each of them has their advantages, such as simple structure and low maintenance cost [4].

Inverter is a device which supplies variable frequency of power supply on equipments [5]. Base on this function, motor revolution speed can be controlled and it leads to reduce energy consumption. Basically the motor is driven by the inverter. The induction current is generated on the cage according to the rotating magnetic field, so the rotor will be driven accordingly without detecting rotor position.

Power electronics have moved along with these developments with such things as digital signal processors being used to control power systems. An Inverter is basically a
converter that converts DC to AC power. A voltage source inverter (VSI) is one that takes in a fixed voltage from a device, such as a dc power supply, and converts it to a variable frequency AC supply [6].

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.

Induction machine has the same physical stator as a synchronous machine with a different rotor construction [7, 8]. Induction machines can be operated as both motors and generator. Induction machines are by far the most common type of motor used in industrial, commercial or residential settings.

So the inverter is one of the solutions to control the induction motor. An inverter can easily control the speed of the three-phase induction motor. The main principle is to switch the motor on and off very rapidly, much more rapidly than any mechanical switch could do. The AC output of the inverter can be controlled both in amplitude and frequency that commit the requirements of induction motor at any desired point of operation [9]. Speed and torque can now be controlled independently of each other. The switching operation in inverter is connect the power switches when line voltage is low and disconnect when it is high. Therefore, the energy can go either way even though the line voltage is constant.

In many applications of the induction motor, high performance voltage control is one of the fundamental issues. The purpose of the voltage control is to control the flux or the torque of the induction motor. Therefore, many researchers and practitioners had
developed various controller algorithms to improve the response of induction motor. But only a few of them had included the Arduino into their research. Basically, Arduino is an embedded device that can be use as a digital signal processing (DSP) [10].

1.2 PROBLEM STATEMENT

The recent advances in the area of field-oriented control that 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. The principle of an electric motor is always to create a rotary movement by attracting and repelling magnetic forces. Therefore the current is excessively high at the first instance of switching on when the motor is not yet running. As the motor speeds up, this induced voltage increases [11]. In fact when exceeding the speed where the applied voltage and the mains voltage are equal the motor will generate a higher voltage than that found in the line. Current will flow the other way round, and the motor has inversed its function as generator.

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

1.4 **SCOPE**

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

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

LITERATURE REVIEW

2.1 INDUCTION MOTOR
An electrical motor is such an electromechanical device which converts electrical energy into a mechanical energy. In simple words, the electrical motor is a device that produces rotational force. The induction motor is one of the electrical motor.

2.1.1 THREE PHASE INDUCTION MOTOR
A three phase induction motor is one of an electric motor that converts electrical energy into a mechanical energy which is then connected with different load, also described as transformer type. The three phase induction motors are most widely used for industrial applications mainly because they do not require a starting device. The operating principle of a three phase induction motor is based on the production of r.m.f.[12]. It has a stator that carries a three phase winding and rotor that carries a short circuited winding. Only the stator winding is fed from three phase supply. The rotor winding derives its voltage and power from the externally energized stator winding through electromagnetic induction. The advantages and disadvantages of the three phase induction motor are stated below:

Advantages:
(i) It has simple and rugged construction.
(ii) It is relatively cheap.
(iii) It requires little maintenance.
(iv) It has high efficiency and reasonably good power factor.
(v) It has self starting torque.
Disadvantages:
(i) It is essentially a constant speed motor and its speed cannot be changed easily.
(ii) Its starting torque is inferior to DC shunt motor.

Three phase induction motor is very popular electrical and mechanical equipment and get more attention from researchers and practitioners due to the nonlinearities.

In paper [13] 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 [14] had presented a direct field-oriented induction motor drive with a sliding mode controller. In this paper, they had considered about rotor speed estimation from measured stator terminal voltages and currents. Besides that, they used function “sat” to limit chattering effects. Then they had evaluated the consistency and performance of the proposed control technique.
In paper [15] had proposed adaptive sliding-mode control system to control the position of an induction motor drive. The sliding mode control presents an adaptive switching gain had been designed to relax the requirement for the bound of uncertainties. They also performed Lyapunov theory in order to guarantee the closed loop stability. Then they had discussed about simulation results of the proposed controller.

In paper [16] 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.

### 2.2 INVERTER

The inverter performs the opposite function of a rectifier, also known as dc to ac converter. An inverter is a device that takes direct current (DC) and changes it to alternating current (AC) [6]. The electrical inverter is a high-power electronic oscillator, can classified as voltage source inverters (VSIs) and current source inverters (CSIs). It can be dividing into 2, which are single phase inverter and three phase inverter. It depends on the user load requirement whether in the industrial applications, transportations and home appliances. The output voltage of an inverter has a periodic waveform which is not purely sinusoidal, but with number of techniques it can be designed to closely approximate to this desired waveform. Example of the technique is to put lowpass filter. In most circumstances, three phase inverter offered better performances as compared to single-phase inverter. Power semiconductors switches are the basic component of the inverter. In this paper, the three phase inverter will be proposed.
2.2.1 THREE PHASE INVERTER

A three-phase inverter will cover medium to high power applications. The three-phase dc/ac voltage source inverters are extensively being used in motor drives to generate controllable frequency and ac voltage magnitudes using various pulse width modulation (PWM) strategies. The standard three-phase inverter shown in figure 2.2 has six switches. The purpose of the topology is to provide a three-phase voltage source, where the amplitude, phase and frequency of the voltages can be controlled.

![Figure 2.2: Three phase full bridge inverter.](image)

In figure 2.3, one inverter leg’s state changes after an interval of 60° and their state remains constant for 60° interval. Thus it follows that the leg voltages will have six distinct and discrete values in one cycle (360°).

![Figure 2.3: Leg voltage waveform of a three-phase.](image)
2.2.2 VOLTAGE SOURCE INVERTER

Generally there were two types of inverter topology, named as Voltage Source Inverter and Current Source Inverter. Voltage waveform is the independently controlled AC output in the VSI topologies. Meanwhile, in CSI topologies, the independently controlled AC output is a current waveform. VSI can be further divided into three categories which are PWM Inverter, Square Wave Inverter and Single-phase Inverters with Voltage Cancellation. The structure of VSI is more widely used in the industrial application due to the voltage source requirement.

In paper [5] had invented a three phase inverter producing a stepped voltage between each two output terminal which approximates the sinusoidal form. She had included two three phase inverter system of the type comprising pairs of parallel arranged controllable rectifier and three transformers each have a primary winding and two secondary windings.

In paper [16] had proposed a simple, novel alternative approach for a variable-hysteresis-band current controller which uses feed forward and feedback techniques to achieve constant switching frequency with good dynamic response. They said the method is easily implemented in hardware, the resultant controller is easily tuned to a particular load, and has good immunity to variations in motor parameters and dc supply voltage. Lastly, they presented an analytical, hardware implementation, simulation, FFT analysis and experimental results.

2.3 PASSIVE CONTROL

There is several type of controller that has been made from researcher. It’s given the positive growth in controller design and makes the power electronics more interesting to explore. The type of the controller is as follows:
2.3.1 RELAY CONTROLLER

In the early days of control engineering, relays were commonly used as they provided a cheap form of power amplification. The difference between switching nonlinearities and other nonlinearities is their input does not control the output continuously but only determines the instant of switching. The input has not control of output between switching instants. This feature will allows a unique theory to develop for analyzing limit cycles in feedback loops with relays elements [17].

In paper [17] are considered the relay control systems with time delay. They had found that the time delay does not allow realizing an ideal sliding mode, but implies oscillations, whose stability is determined by oscillation frequency. They had considered the problem of stability of steady modes in three main cases autonomous, quasi autonomous and periodic. Lastly, they had investigated the structural stability of steady modes in the periodic case.

![SPDT relay.](image)

Figure 2.4: SPDT relay.

In figure 2.4 shows that the relay component. There are two commonly used types of relay which are normally open (NO) and normally close (NC). The advantages and disadvantages of relay are stated below:

Advantages of relays:

- Relays can switch AC and DC, transistors can only switch DC.
- Relays can switch higher voltages than standard transistors.
- Relays are often a better choice for switching large currents (> 5A).
- Relays can switch many contacts at once.
Disadvantages of relays:

- Relays are bulkier than transistors for switching small currents.
- Relays cannot switch rapidly (except reed relays), transistors can switch many times per second.
- Relays use more power due to the current flowing through their coil.
- Relays require more current than many ICs can provide, so a low power transistor may be needed to switch the current for the relay's coil.

2.3.2 SLIDING MODE CONTROLLER

Sliding mode control is one of the controllers suitable for nonlinear system such as induction motor. Background of this controller is founded in the former Soviet Union as a variable structure control system, and appeared outside Russia in the mid 1970s. The concept of sliding mode is proposed by Russian mathematician, Lyapunov and had discussed his theory about nonlinear systems. The main of the sliding mode controller is to adjust feedback by previously defining a surface. The system which is controlled will be forced to that sliding surface, then the behavior of the system slides to the desired equilibrium point. The main feature of this control is that we only need to drive the error to a switching surface. When the system is in sliding mode, the system behavior is not affected by any modeling uncertainties or disturbances [14].

There is definition of terms in sliding mode controller:

(i) State Space – An n-dimensional space whose coordinate axis consist of the $x_1$, $x_2$ axis until $x_n$ axis.
(ii) State trajectory- A graph of $x(t)$ verses t through a state space.
(iii) State variables – The state variables of a system consist of a minimum set of parameters that completely summarize the system’s status.
(iv) Disturbance – Completely or partially unknown system inputs which cannot be manipulated by the system designer.
(v) Sliding Surface – A line or hyperplane in state-space which is designed to accommodate a sliding motion.
(vi) Sliding Mode – The behavior of a dynamical system while confined to the sliding surface.

(vii) Reaching phase – The initial phase of the closed loop behavior of the state variables as they are being driven towards the surface.

In paper [4] had proposed integrated sliding mode controller to achieve high performance speed control of an induction motor. A flux SMC is established first to achieve fast direct flux control and then a speed SMC is presented to enhance speed control by the direct torque method. Both of the SMC are designed in light of predetermined load disturbance and parameter uncertainties. Then they had verified the effectiveness of the proposed control by simulation results and compared with the direct torque control (DTC) and proportional-integral direct torque control (PIC) approaches.

The main feature of sliding mode controller is that we only need to drive the error to a switching surface.

Consider the nonlinear system is:

\[ \dot{x}_1 = ax_1 + bu + d \]
\[ \dot{x}_2 = x_1 \]
The system in the state space structure is:
\[
\begin{bmatrix}
\dot{x}_1 \\
\dot{x}_2
\end{bmatrix} = \begin{bmatrix} a & 0 \\ 1 & 0 \end{bmatrix} \begin{bmatrix} x_1 \\
 x_2 \end{bmatrix} + \begin{bmatrix} b \\ 0 \end{bmatrix} u + \begin{bmatrix} 1 \\ 0 \end{bmatrix} d
\]
\[\dot{x} = f + gu + hd\]

Where \( \dot{x} = \begin{bmatrix} \dot{x}_1 \\
\dot{x}_2 \end{bmatrix} \), \( f = \begin{bmatrix} a & 0 \\ 1 & 0 \end{bmatrix} \begin{bmatrix} x_1 \\
 x_2 \end{bmatrix} = \begin{bmatrix} ax_1 \\
 x_2 \end{bmatrix} \), \( g = \begin{bmatrix} b \\ 0 \end{bmatrix} \), and \( h = \begin{bmatrix} 1 \\ 0 \end{bmatrix} \)

The switching surface is then defined by:
\[\sigma(x) = c_1 x_1 + c_2 x_2\]

The goal of sliding mode controller is to keep the system motion on the manifold, \( \sigma(x) = 0 \). The state trajectory of the sliding mode controller can be control with:
\[e = x_d - x\]

Where \( e \) is the tracking error, \( x_d \) is the desired state vector and \( x \) is the state vector. In order to ensure the stability of sliding mode controller, the Lyapunov stability criteria will be adapted:
\[v(x) = \frac{1}{2} \sigma^2(x)\]

### 2.3.3 HYSTERESIS CONTROLLER

The other word of hysteresis is deficiency or lagging behind [18]. Hysteresis refers to systems that have memory, where the effects of the current input to the system are experienced with a certain lag. Hysteresis phenomena occur in magnetic materials, ferromagnetic materials and ferroelectric materials, as well as in the elastic, electric, and magnetic behavior of materials, in which a lag occurs between the application and the removal of a force or field and its subsequent effect. Electric hysteresis occurs when applying a varying electric field and elastic hysteresis occurs in response to a varying force.

In a deterministic system with no dynamics or hysteresis, it is possible to predict the system's output at an instant in time, given only its input at that instant in time.
Hysteresis control is not possible to predict the output without knowing the system's current state, and there is no way to know the system's state without looking at the history of the input. This means that it is necessary to know the path that the input followed before it reached its current value [18]. In electrical engineering, Hysteresis can be used to filter signals so that the output reacts slowly by taking recent history into account.

In paper [6] had presented a hysteresis controller method for three-phase current controlled voltage-source PWM inverter. They had concluded that the control minimizes interference among phases, thus allowing phase-locked loop (PLL) control of the modulation frequency of inverter switches. They also discussed about the control theory and described the controller implementation.

### 2.3.3.1 PROPOSED CONTROLLER (HYSTERESIS CONTROLLER)

Hysteresis controller derives the switching signals of the inverter power switches in a manner that reduces the voltage error. The switches are controlled so that it follows the reference. The voltage ramping up and down between two limits is illustrated in figure 2.6. [19] When the voltage through the induction motor exceeds the upper hysteresis limit a negative voltage is applied by the inverter to the induction motor. This causes the voltage in the induction motor to decrease. Once the voltage reaches the lower hysteresis limit a positive voltage is applied by the inverter to the induction motor and this causes the voltage to increase and the cycle repeats.

The voltage controllers of the three phases are designed to operate independently. Each voltage controller determines the switching signals to the inverter. The switching logic for phase A is formulated as below:

- If $V_a < (V_{a_{\text{ref}}} - HB)$ upper switch (G1) is OFF and lower switch (G4) is ON
- If $V_a < (V_{a_{\text{ref}}} + HB)$ upper switch (G1) is ON and lower switch (G4) is OFF

In the same action, the switching of phase B and C are derived but in different phase shift that is phase B in 120° shift and phase C in 240° shift.
In paper [20] had described an adaptive hysteresis-band current control method where the band is modulated with the system parameters to maintain the modulation frequency to be nearly constant. Although the technique is applicable to general ac drives and other types of load, an interior permanent magnet (IPM) synchronous machine load is considered. Then systematic analytical expressions of the hysteresis band are derived as functions of system parameters. Lastly, a voltage-fed current-controlled PWM inverter has been simulated on computer to study the performance of the proposed method.

### 2.4 ARDUINO

Arduino is one of the embedded devices that are increasing in used. It’s very popular for beginner and has attracted the people who are already working with other microcontrollers. Arduino is best known for its hardware, but we also need software to program that hardware. Both the hardware and the software are called Arduino [10]. The combination enables us to create projects that sense and control the physical world. Arduino is easy to used and explore because of it is open source. In this project, Arduino is used to create prototypes, to carry out the duty of controller to control the switching of three phase inverter.
In order to bring the MATLAB model to the hardware setup, Arduino Uno is chosen. The Arduino Uno is a microcontroller board based on the ATmega328. It has 14 digital input/output pins, which 6 can be used as PWM outputs, 6 analog inputs, a 16 MHz ceramic resonator, a USB connection, a power jack, an ICSP header, and a reset button [9]. The summary of the Arduino Uno is as following:

<table>
<thead>
<tr>
<th>Microcontroller</th>
<th>Atmega328</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operating Voltage</td>
<td>5V</td>
</tr>
<tr>
<td>Input Voltage (recommended)</td>
<td>7-12V</td>
</tr>
<tr>
<td>Input Voltage (limits)</td>
<td>6-20V</td>
</tr>
<tr>
<td>Digital I/O Pins</td>
<td>14 (of which 6 provide PWM output)</td>
</tr>
<tr>
<td>Analog Input Pins</td>
<td>6</td>
</tr>
<tr>
<td>DC Current per I/O Pin</td>
<td>40 Ma</td>
</tr>
<tr>
<td>DC Current for 3.3V Pin</td>
<td>50 Ma</td>
</tr>
<tr>
<td>Flash Memory</td>
<td>32 KB (Atmega328) of which 0.5 KB used by bootloader</td>
</tr>
<tr>
<td>SRAM</td>
<td>2 KB (Atmega328)</td>
</tr>
<tr>
<td>EEPROM</td>
<td>1 KB (Atmega328)</td>
</tr>
<tr>
<td>Clock Speed</td>
<td>16 MHz</td>
</tr>
</tbody>
</table>

Table 2.1: The summary of the Arduino Uno.

The advantages of the Arduino are stated below:

(i) Inexpensive – Arduino embedded devices are inexpensive compared to other microcontroller embedded devices.

(ii) Cross-platform – Most microcontroller systems are limited to Windows. Different with Arduino, it can runs on Windows, Macintosh OSX, and Linux operating systems.

(iii) Simple, clear programming environment – The Arduino programming environment is easy to use for beginners.

(iv) Open source – The Arduino software is published as open source tools, so the user easy to get the information experienced programmers.
In paper [21] had observed the problem of voltage levels, which affects the speed of induction motor. In this paper a novel open loop phase control method is developed by coding a program using Arduino software in which Arduino controller takes input from the user and generates firing pulses for the TRIAC which controls the speed of the Induction motor. They had executed with the help of an Arduino controller kit.

Simulink support for Arduino Uno includes the following driver blocks [21]:
- Digital Input and Output
- Analog Input and Output
- Serial Receive and Transmit
- Servo Read and Write

To run simulink models on Arduino, the target to Arduino installer must be install. Hence, simulink block library can configuring and accessing Arduino sensor, actuators and communication interfaces. It will provide support for various peripherals available on the Arduino hardware.
In Arduino, the list of port that can be use in order to build controller, are as below [21]:

<table>
<thead>
<tr>
<th>Block</th>
<th>Purpose</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Analog input</td>
<td>Measure voltage of analog input pin</td>
<td>Measure the voltage of an analog pin relative to the analog input reference voltage on the Arduino® hardware. Output the measurement as a 10-bit value that ranges from 0 to 1023.</td>
</tr>
<tr>
<td></td>
<td>Pin 0 to 5</td>
<td></td>
</tr>
<tr>
<td>• Pwm</td>
<td>Generate PWM waveform on analog output pin</td>
<td>Use pulse-width modulation (PWM) to change the duty-cycle of square-wave pulses output by a PWM pin on the Arduino® hardware. PWM enables a digital output to provide a range of different power levels, similar to that of an analog output. The range of valid outputs is 0 to 255.</td>
</tr>
<tr>
<td></td>
<td>Pin 3, 5, 6, 9, 10 and 11.</td>
<td></td>
</tr>
<tr>
<td>• Serial receive and transmit</td>
<td>Get one byte of data from serial port and Send buffered data to serial port.</td>
<td>Serial receive: Get one byte of data per sample period from the receive buffer of the specified serial port. Serial transmit: Send buffered data to the specified serial port.</td>
</tr>
<tr>
<td></td>
<td>Port 0</td>
<td></td>
</tr>
</tbody>
</table>

Table 2.2: The Arduino pin assignment.

2.5 ANALOG TO DIGITAL AND DIGITAL TO ANALOG CONVERTER
Electronic equipment is frequently used in different fields such as communication, transportation, entertainment, etc. Analog to Digital Converter (ADC) and Digital to Analog Converter (DAC) are very important components in electronic equipment. Since most real world signals are analog, these two converting interfaces are necessary to allow digital electronic equipments to process the analog signals.
Figure 2.8: The ADC and DAC function.

Figure 2.8 above illustrate how the converter is functioning. An Analog to Digital Converter (ADC) is a device for converting an analog signal such as current or voltage to a digital binary code. In the real world, most of the signals sensed and processed by humans are analog signals. ADC is the primary means by which analog signal are converted into digital data that can be processed by computers for various purposes. DAC is an inverse function of ADC. In order to get back the signal that can be processed or sensed by humans or equipment.

In paper [22], a new method of cyclic analog-to-digital (A/D) and digital-to-analog (D/A) conversion using switched-capacitor techniques is described. By periodically modifying the reference voltage to compensate for the non ideal signal transfer loop gain, it is possible in principle to build A/D and D/A converters whose linearity is independent of component ratios and that occupy only a small die area. These converters require two moderate-gain MOS operational amplifiers, one comparator, and a few capacitors. Then they had built and evaluated a test chip for A/D conversion. Lastly they had tested the data and observed that the A/D performs as a monotonic 13-bit converter with maximum 1-LSB differential and 2-LSB integral nonlinearity.
CHAPTER 3

METHODOLOGY

3.1 BLOCK DIAGRAM OF THE PROJECT

In the figure 3.1 above, it describe how the connection of each part. The main setup is the input, three phase inverter and the three phase induction motor. Arduino will carry out the task of controller. The control setup is at the feedback of the system, start from voltage reading from connection between three phase inverter and three phase induction motor, then will compared with reference voltage. The error from that comparison will send to Hysteresis Controller. The Hysteresis Controller will control the PWM and give switching control to the three phase inverter.
3.2 THE PROJECT FLOWCHART

Figure 3.2: Project flowchart.
The flowchart in figure 3.2 shows the framework to achieve the project objectives. For early stage, the task will divide into two parts, which is hardware and software. For hardware part, MATLAB simulink is the major part that must be covered. It starts from modeling based on equation, and then simulate to get the observation. Hardware part is the task to setup the prototype. Both of them will carry out simultaneously so that the information and progress we get is parallel. Lastly, the hardware and software part will be combine, and analysis can be done.

3.3 PROJECT DESIGN

To achieve the project hardware, some of designs have been made. In hardware development, inverter and their gate driver are the first to be design. Then the software part is the controller design.

3.3.1 THREE PHASE INVERTER DESIGN

The basic three phase inverter topology has 3 leg power switches. Each leg consist of two power switches. In this project, MOSFET SPP11N60C3 are used. Figure 3.3 shows the arrangement of three phase inverter in PROTEUS software. Each gate of the MOSFET needs to give a signal to switching. That’s why 6 PWM must be built to give signal to the gate of MOSFET.

![Figure 3.3: The three phase inverter in PROTEUS.](image-url)
Figure 3.4: The hardware of three phase inverter.

Figure 3.4 above shows the hardware’s picture of the three phase inverter. The 2 port at the left hand side below the capacitor is the Vdc input, the six positive and negative (red and black wire) is the PWM switching signal and the three ports at right hand side is the output phase A, B and C in Vac that will fed to induction motor.
3.3.2 GATE DRIVER DESIGN

Figure 3.5: The gate driver in PROTEUS software.

Figure 3.5 shows the gate driver for three phase inverter. The function of the gate driver is to produce 6 pulse PWM signal from three different phase inputs from Arduino. The gate driver also will power up the voltage from 5V to 15V by voltage regulator IL0515S before sending it to the three phase inverter. The other main component in the gate driver is Hex Schmitt trigger Inverters SN7414, HCF4081 and Gate Drive Optocoupler HCP3120. The picture of the gate driver hardware is shown in figure 3.6.
REFERENCES


