UNIVERSITI PUTRA MALAYSIA

DEVELOPMENT OF SINGLE PHASE INDUCATION MOTOR ADJUSTABLE SPEED CONTROL USING M68HC11E9 MICROCONTROLLER

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Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the partial Requirements for the Degree of Master of Science

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DEDICATION

To my

Parents, wife, children, brothers and sisters

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfillment of the partial requirements of the degree of Master of Science

DEVELOPMENT OF SINGLE PHASE INDUCTION MOTORADJUSTABLE SPEED CONTROL USING M68HC11E9 MICRO-CONTROLLER

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JULY 2004

Chairman: **Associate Professor. Senan Mahmod Bashi, Ph.D.**

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Variable speed control of a single-phase induction motor could be obtained through voltage control method using semiconductor power devices. These methods suffer from the large harmonics that result from the switching operation. Besides that it has a limited speed control range. Pulse Width Modulation (PWM) technique is considered as one solution for harmonic reduction and increasing the motor efficiency.

The advances in domestic and commercial applications in modern life raised the urgent needs to use low power single-phase induction motor. As a consequence, the single-phase induction motor has become the most widely used type of low power ac motors for those applications where regulating speed is of essence and three- phase power source are not available.

This work investigates the performance of a closed-loop adjustable speed drive for single-phase induction motor using voltage amplitude control. A microcontroller

M68HC11E-9 has been used to implement such techniques. The microcontroller senses the speed's feedback signal and consequently provides the (PWM) signal that sets the gate voltage of the chopper, which in turn provides the required voltage for the desired speed. A Buck type chopper has been used to control the input voltage of a fully controlled single phase Isolated Gate Bipolar Transistor (IGBT) bridge inverter.

The proposed drive system is simulated using Matlab / Simulink, its results were compared with the hardware experimental results. The simulation and laboratory results proved that the drive system could be used for the speed control of a single-phase induction motor with wide speed range.

Abstrak tesis yang dikemukakan kepada Senat Unjiversiti Putra Malaysia sebagai memenuhi sebahagian keperluan untuk ijazah Master Sains

PEMBANGUNAN KAWALAN KELAJUAN BOLEH-UBAH BAGI MOTOR ARUHAN SATU FASA MENGGUNAKAN PENGAWALMIKRO MC68HC11

Oleh

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Kawalan kelajuan boleh laras motor aruhan satu fasa boleh dilakukan melalui kaedah kawalan voltan menggunakan peranti kuasa semikonduktor. Kaedah ini mengalami gangguan harmonik yang tinggi berpunca daripada operasi pensuisan. Selain dari itu, ianya mempunyai julat kawalan kelajuan yang terhad. Kaedah *PWM* adalah salah satu cara penyelesaian yang boleh mengurangkan harmonik dan meningkatkan kecekapan motor.

Kemajuan dalam aplikasi domistik dan komersil dalam kehidupan moden telah meningkatkan keperluan segera untuk menggunakan SPIM berkuasa rendah. Akibatnya, SPIM telah menjadi jenis yang digunakan secara meluas bagi motor-motor kuasa ac untuk aplikasi-aplikasi tertentu di mana halaju mengatur adalah penting dan sumber kuasa tiga fasa tidak boleh didapati.

Penyelidikan ini mengkaji prestasi kawalan kelajuan boleh laras gelung tertutup untuk motor aruhan satu fasa menggunakan kaedah kawalan amplitud voltan. Pengawalmikro M68HC11E-9 telah digunakan untuk melaksanatan kaedah tersebut.

Pengawalmikro mengesan suapbalik isyarat kelajuan dan kemudian memberikan isyarat *PWM* yang menentukan voltan get pada pemenggal. Isyarat ini akan membekalkan voltan yang diperlukan untuk kelajuan yang diingini. Pemenggal jenis *BUCK* telah digunakan untuk mengawal voltan masukan bagi satu penyongsang jejambat *IGBT* satu fasa yang dikawal sepenuhnya oleh pengawal mikro.

Sistem pemacu yang telah dicadangkan telah disimulasikan menggunakan Matlab / Simulink. Keputusannya telah dibandingkan dengan hasil yang diperolehi melalui kaedah eksperimen menggunakan perkakasan yang sebenar. Keputusan simulasi dan eksperimen di dalam makmal membuktikan bahawa sistem pemacu tersebut boleh digunakan untuk mengawal kelajuan motor aruhan satu fasa dengan julat kelajuan yang lebih besar.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

Symbols	Stands for
ac	Alternating current
ADC	A/D Control registers
ALU	Algorithm logic unit
C	Capacitor
CSI	Current source inverter
CPU	Central processor unit
dc	Direct current
Dm	Freewheeling diode
D	Diode
EMF	Electrical magnetic field
EVB	Evaluation board
f	Frequency
FCNT	Frequency count
HCMOS	High density complementary semiconductor
G	gate
IGBT	Insulated Gate Bipolar Transistor
Ia	Average load current
I_1	Rise inductor current
I_2	Fall inductor current
Ic	Capacitor current
$I_{g(erq.)}$	Required gate current
K	Duty cycle

Kp	Proportional constant
KP	Proportional coeffecient in percentage
L	Inductor
LCD	Liquid Crystal Display
MOSFET	Metal-Oxide Silicon Field Effect
MSD	Measured speed
PWM	Pulse width modulation
PWMM	Pulse width modulation module
PPR	Pulse Per Revolution
Q_g	Total gate charge
RPM	Revolution Per Minute
rms	Root mean square
ROM	Read only memory
RAM	Read access memory
R_G	Gate resistance
R_A, R_B	Timing resistance
SC	Start capacitor
SPC	Split phase capacitor
SS	Speed sensor
SMT	Speed measurement time
SPIM	Single-phase induction motor
SME	Speed measurement error
SMAX	Maximum speed
T	Switching period
T_{on}	On time

T_{off}	Off time
T_d	Delay time
TSD	Target speed
T_x	Interval time
UIM	User Interface Module
V	Voltage
Va	Average output voltage
Vs	Voltage source
Vin	Input voltage
Vout	Output voltage
V_G	Gate voltage
Vav	Voltage available to charge
VSI	Voltage Source Inverter
V_{ref}	Reference voltage
ΔI_{max}	Maximum ripple current
ΔI	Peak -to-Peak ripple current
ΔV	Peak -to-Peak ripple voltage

CHAPTER 1

INTRODUCTION

Loads driven by electrical prime movers often need to run at a speed that varies according to the operation they are performing. The speed in some cases such as pumping may need to be changed dynamically to suit the conditions, and in other cases it may only change as the duty of the load progresses.

In the past, the various techniques for controlling the speed of ac machines are available and often the use of auxiliary rotating machines may be necessary. These auxiliary machines have now been supplanted by static ac drives systems using various types of power semiconductor, operating as electrically controlled switches. High efficiency is attained because of the low "ON-state" conduction losses when the power semiconductor is conducting the load current and the low "OFF-state" leakage losses when the power semiconductor is blocking the source, or load, voltage. The transitions times between blocking and conducting, and vice versa, depend on the type of power semiconductor used. In practice, various types of power semiconductor devices for example, Thyristors, IGBT's, MOSFET's and Diodes are used for the control of ac motors [1].

Nowadays, manufacturers assemble several semiconductor components into a single package, or module. The use of such a module reduces the number of electrical interconnections necessary and heat sinks requirements. Various combinations of devices are assembled into a common package. These common packages are what is widely referred to as an integrated circuits (IC). The selling price of these modules and of the basic power semiconductors themselves has been declining as the market expands [1].

The pulses that a switching power converter delivers to a motor are controlled by means of Pulse Width Modulated (PWM) signals applied to the gates of the power transistors or IGBT's. This technique is employed in electrical circuits to reduce the effect of harmonics. PWM signals are pulse trains with fixed frequency and magnitude, and with variable pulse width. Furthermore, in every PWM period there is one pulse of fixed magnitude. However, the width of these pulses changes from one period to another, according to a modulating signal. When a PWM signal is applied to the gate of a power transistor, it causes the turn on and turns off intervals of the transistor to change from one PWM period to another PWM period according to the same modulating signal. The frequency of a PWM signal must be much higher than that of the modulating signal, the fundamental frequency, such that the energy delivered to the motor and its load will depend mostly on the modulating signal. The pulses of a symmetric PWM signal are always symmetric with respect to the center of each PWM period, while the pulses of an asymmetric edge-aligned PWM signal are correspondingly asymmetrical with respect to the center of each PWM period.

Another major factor in ac drives technology is the availability of microprocessor / microcontroller for the control of ac drive system. Microprocessor operates at an adequately high clock frequency to complete their calculations in sufficient time to directly control the firing of the power semiconductors circuit operating from the utility supply frequency. In addition to the direct calculation of the power semiconductors firing times, the microprocessor can perform lower priority tasks, such as diagnostics, self-test, start-up and shutdown sequencing, and fault monitoring [1].

1.1 Ac-Induction Motor

AC- induction motors are the most widely used type of electronic motor in the modern world. AC-motors are primarily used as a source of constant–speed mechanical power and they are increasingly being used in variable-speed control applications. They are popular because they can provide rotary power with high efficiency; no commutation is required, lighter in weight, low maintenance, and exceptional reliability, all at relativity low cost.

These desirable qualities are the result of two factors:

(1) AC motors can use the ac-power.

(2) Most ac motors do not need brushes as in dc motors.

In most cases, the ac power is connected only to motor's stationary field windings. The rotor gets its power by electromagnetic induction; a process that does not require physical contact. Maintenance is reduced because brushes do not have to be periodically replaced. In addition, the motor tends to be more reliable and last longer because parts malfunctioning are minimal and there is no "brush dust" to contaminate the bearings or windings [2].

1.2 Single-Phase Induction Motors.

In domestic applications, single-phase induction motors are commonly used in dishwashers, washing machines, hermetic compressors, fans, pumps, draft inducers, etc. A truly variable speed operation from this motor with a wide range of speed and loads would help applications designers to incorporate many new features in their products. It would also mean operation with high efficiency and better motor utilization. In industrial applications, three-phase induction motors have been used.

However, in residential applications with small power, single-phase induction motors are preferred due to the greater availability of single-phase power [3].

A single-phase motor can only produce an alternating field: one that pulls first in one direction, then in the opposite as the polarity of the field switches. The major distinction between the different types of single-phase ac motors is how they go about starting the rotor in a particular direction such that the alternating field will produce rotary motion in the desired direction. Some device that introduces a phase-shifted magnetic field on one side of the rotor is usually employed for this purpose. The Figure 1.1 shows the performance curves of the four major types of single-phase ac motors [4].

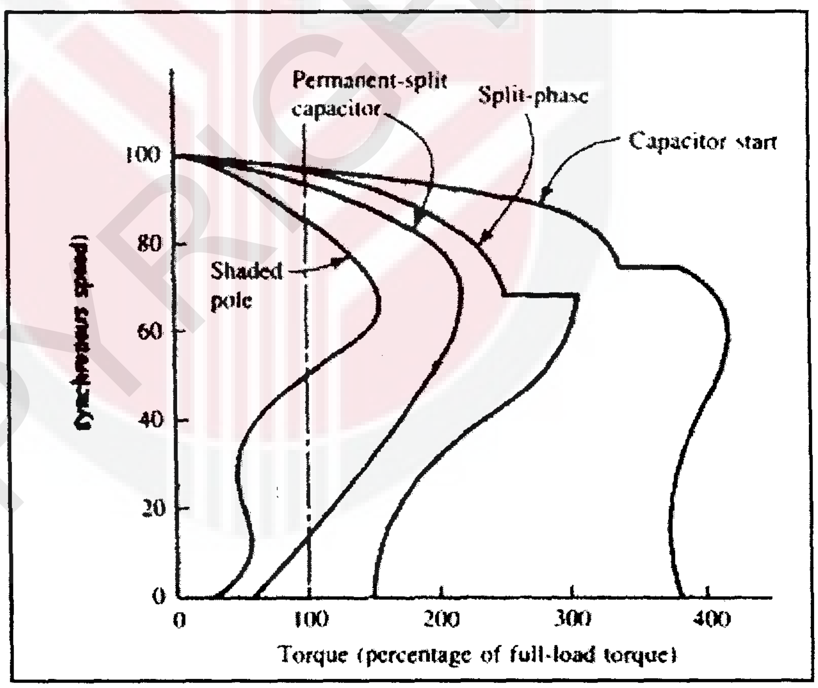

Figure1.1: Characteristic curves for single-phase induction motor

1.3 Aims and Objectives

The objective of this particular project is to design and build an adjustable speed drive system for a single-phase induction motor, to use M68HC11-microcontroller for closed-loop control system with Voltage amplitude control algorithm, to build a simulink model and simulated using Matlab/Simulink software and compare the results with the experiment results, and to investigate that the elements used in this system can be easily control the motor speed.

1.4 System Description

The experiment has been carried out using many components that made this work possible. The power supply of this circuit was fed via a variable transformer. The full bridge rectifier has been used to convert the ac supply to a dc voltage. The output of the rectifier is the input to the dc chopper which controls the voltage level. The microcontroller-based adjustable closed loop control system hardware has been implemented and tested in the laboratory. The M68HC11E9-microcontroller has been programmed to vary the PWM that controls the duty cycle of the dc chopper. The last component of this set up is the inverter which receives the dc signal from the chopper and converts it to ac power to feed the motor under control. Figure 1.2 shows the block diagram of system used in this work.