UNIVERSITI TEKNIKAL MALAYSIA MELAKA

SOFT STARTER DESIGN FOR SINGLE PHASE AC MOTOR USING MICROCONTROLLER – BASED PHASE ANGLE CONTROL

This report is submitted in accordance with the requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor of Electrical Engineering Technology (Industrial Power) with Honours.

by

NGAN CHOON WANG

B071410684

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APPROVAL

This report is submitted to the Faculty of Engineering Technology of UTeM as a partial fulfilment of the requirement for the degree of Bachelor of Electrical Engineering Technology (Industrial Power) with Honours. The member of the supervisory is as follow:

…….

(DR. MOHD BADRIL BIN NOR SHAH)

ABSTRAK

Apabila sebuah motor arus ulang alik (AU) dihidupkan menggunakan pemula berasaskan penyentuh/geganti, motor tersebut akan menghasilkan arus elektrik yang tinggi. Keadaan seperti ini tidak digemari di dalam sistem pengagihan kuasa kerana akan berlakunya kejatuhan kuasa untuk satu tempoh yang pendek dan juga boleh menyebabkan peranti perlindungan untuk memutuskan litar bekalan elektrik. Menghidupkan atau mematikan sesebuah motor AU secara mengejut akan menghasilkan gegaran yang menjurus kepada tekanan mekanikal terhadap struktur asas motor tersebut. Untuk mengatasi keadaan tersebut, sebuah peranti pemula lembut telah direka dan dibangunkan dengan menggunakan pengawal sudut fasa berasakan pengawal mikro.

Simulasi projek ini dibuat menggunakan perisian Proteus 7. Prototaip projek ini dihasilkan dengan menggunakan Arduino Uno sebagai pengawal dan disambungkan bersama paparan cecair kristal dan pengesan silang sifar sebagai isyarat masukkan. Litar berasaskan Triode for Alternating Current (TRIAC) akan digunakan untuk konduktiviti sudut fasa bekalan AU untuk memacu motor AU satu fasa.

Pada akhir projek ini, prototaip yang dihasilkan mampu menyediakan operasi pemula lembut pada motor AU seterusnya mengurang gegaran serta kejatuhan kuasa dalam sistem pengagihan kuasa. Dengan itu kos penyelenggaraan dapat dikurangkan dan jangka hayat sesebuah motor AU dijangka dapat ditingkatkan.

ABSTRACT

An AC motor draws high initial starting current that is many times greater than the rated current of the motor by using contactor/relay-based starter. This condition is not favourable in power distribution system since it can lead to power sags for a short period, and also may cause protection device to trip. Sudden start and stop of AC motor also can cause harsh vibration thus lead to mechanical stress of motor base structure. To overcome these problem, a soft starter device will be designed and developed based on microcontroller-based AC phase angle control.

The simulation work of this project is performed by using Proteus 7 software. The prototype is developed by using Arduino Uno as main controller interfaced with Liquid Crystal Display (LCD) display and zero-cross detector as input signal. Triode for alternating current (TRIAC) – based circuit to control AC conductivity phase angle is used to drive single phase AC motor.

In the end of the project, the developed prototype is successfully able to provide soft start operation of AC motor which can minimize vibration and the occurrence of power sags. Subsequently, the maintenance cost can be reduced and the life span of an AC motor is expected to be much longer.

DEDICATION

To my beloved parents

Acknowledgement

First and foremost, I, Ngan Choon Wang, B07140684 would like to thank Unversiti Teknikal Malaysia Melaka and Faculty of Engineering Technology for giving me the opportunity to conduct this project in my final year project. I start this project on February 2017 and I have gain lots of knowledge about the operation of soft start of an AC motor. Hopefully, this knowledge and understanding will be helpful in the future.

Furthermore, I would like to express my highest gratitude to my supervisor, Dr Mohd Badril bin Nor Shah for supporting and providing encouragement throughout the completion of this project.

Finally, my thanks goes to both of my parents for supporting me in financial and mentally help while completing this project. My gratitude goes to both of the examiner lecturer En Muhammad Falihan bin Bahari and Madam Nurbahirah binti Norddin for their positive comments. I would like to once again thank all the lecturer and staff in the Faculty of Engineering Technology and friends in assisting me during the progression of my projects.

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LIST OF ABBREVIATIONS, SYMBOLS AND NOMENCLATURES

AC	-	Alternating Current
LCD	-	Liquid Crystal Display
TRIAC	-	Triode for Alternating Current
IDE	-	Integrated Development Environment
SCR	-	Silicon Controlled Rectifier
DOL	-	Direct On – Line
R1	-	Resistor 1
R_2	-	Resistor 2
N_S	-	Synchronous Speed
C_R	-	Permanent Capacitor
C_S	-	Starting Capacitor
HP	-	Horsepower
I – V	-	Current against Voltage
WSCC	-	With Starting Current Control
WOSCC	-	Without Starting Current Control
LED	-	Light Emitting Diode
⌊...⌋	-	Floor
amp	-	Ampere

CHAPTER 1

INTRODUCTION

1.0 Project Background

Single phase AC motor is a machine that convert electrical energy in a form of alternating current into mechanical energy. Furthermore, AC motor is cheap, excellent operation and high efficiency in executing the daily tasks, therefore it is widely used in industrial and domestic applications such as air compressor, hoist and centrifugal pump.

Aside from the advantages, there are issues related to AC motor which are the inrush current is relatively high during initial starting condition and vibration due to the sudden development of high starting torque which eventually reduce the life span of the motor. Thus, the solution to this problems is to implement a soft starter device.

Soft starter is a device that used power electronic devices such as silicon control rectifier (SCR) or triode for alternating current (TRIAC) to perform the soft starting or stopping operation for the motor through phase angle modulation. Subsequently, the high inrush current during initial starting condition is minimized and the vibration is reduced, thus the life span of the motor is increased.

1.1 Problem Statement

It is well known that upon activation of high-power asynchronous and synchronous motors, large starting current is generated, which may leads to drops in the voltage of the supplying network (Williams et.al , 1978). This condition will reduce the life span of the motors. Besides that, the sudden inrush current will produce high torque that cause vibration and indirectly give mechanical stress toward the base structure of the motor thus increases maintenance costs on the motor.

1.2 Objective

The primary objective of this project is to develop a soft starter design for single phase AC motor using microcontroller – based phase angle control. At the end of this project, the objective that are going to be achieved are as follow:

(i) To design microcontroller based circuit of AC phase control to provide the operation of soft starter on single phase AC motor.
(ii) To develop soft starter algorithm based on designed circuit.
(iii) To build hardware prototype of this project to verify the efficiency of the designed circuit and soft start algorithm.

1.3 Project Scope

The project scope briefly described the boundaries of this project which is focused on single phase AC motor, microcontroller programming with Arduio IDE, simulation and the purpose of developing the hardware. The details of the project scopes are explained as the following:

(i) Single Phase AC Motor

The prototype is developed by using microcontroller to provide soft starting to an AC motor by modulating the AC phase angle. Air conditioning and refrigerator compressor, water pump and centrifugal fan are some application that using single phase AC motor.

(ii) Microcontroller Programming

The platform that use to create the AC phase angle modulation algorithm is Arduino IDE software since the microcontroller that used to execute the algorithm is Arduino Uno.

(iii) Simulation

The developed algorithm simulation and the designed circuit will be virtually simulated using Proteus 7 software.

(iv) Hardware

A hardware prototype is built to verify the efficiency of the designed circuit and algorithm.

CHAPTER 2

LITERATURE REVIEW

2.0 Introduction

Literature review is an important part before commencing any project. It provide all required information that related to the project and based on that, the correct direction in developing the project can be performed efficiently.

In this chapter, topics that will be explained are basic construction of AC motor, induction motor, starting methods and previous related works.

2.1 Basic Construction of AC Motor

AC motor are machines that taking electrical energy through slip ring and convert it into mechanical energy. Todays, the usage of single phase AC motor are widely used in domestics and small industries application such as water pumps, compressor and conveyor system. The operation of AC motor are based on Faraday's law of electromagnetic induction. According to Klempner and Kerszenbaum (2004), when the stator windings are energised, a rotating magnetic field will produced and rotates at synchronous speed, N_s. Based on Faraday's law of electromagnetics induction, the rotating magnetics field cuts through the rotor conductor, which induced electromotive force in the rotor. Consequently, current will be induced in the rotor coil. As the current carrying conductors placed in the magnetic field generated by the stator,

catapult force will acts on the rotor, which produce a net torque to rotate the motor in the same direction as the rotating magnetic field.

Figure 2.1 shows the parts of an AC motor. AC motor consists of two main parts, which are stator and rotor. Stator is a fix part of the ac motor that located inside of the motor frame and consists of bundles of laminated copper winding that filled on the stator slots. The purpose of stator are used to create magnetic field for the motor through the process of electromagnetism. While rotor is a hollow laminated core consists of slots on its external periphery that mounted on the shaft of the motor. These slots will be filled with rotor windings. There are two type of rotors which are squirrel cage rotor as shown in Figure 2.2 and wound rotor as shown in Figure 2.3, and are explained as the followings:

2.1.1 Squirrel Cage Rotor

Consists of laminated cylindrical iron core with parallel slot on it external periphery. The parallel slots are placed with either copper or aluminium bar and joined at each end by a pair of end rings. The construction of the rotor are similar with a squirrel cage, that how the name came from. This type of rotor basically used in induction motor because the current produced in the rotor are through induction process. The absent of slip ring in the construction of squirrel cage rotor, will cause high staring torque due to the addition of external resistance to the rotor are impossible.

2.1.2 Wound Rotor

Wound rotor consists of bundles of copper wires placed in the skewed rotor slots of laminated cylindrical iron core. The open ends of the windings are joined to the insulated slip rings mounted on the rotor shaft with one carbon brushes resting on each slip rings. With the present of slip ring the addition of

external resistance are made possible. Thus, the speed and starting torque of wound motor are possible to control.

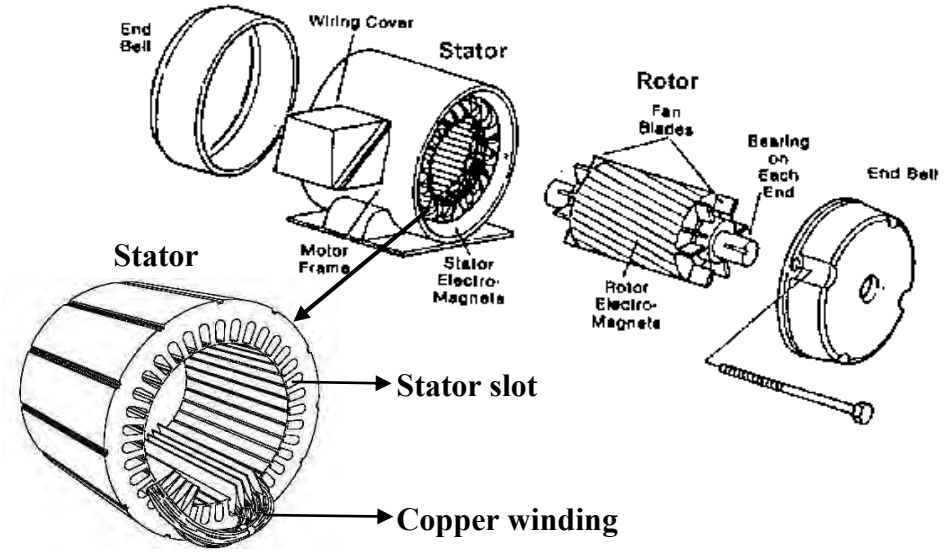

Figure 2.1: Parts of AC motor (Stephen, 2012)

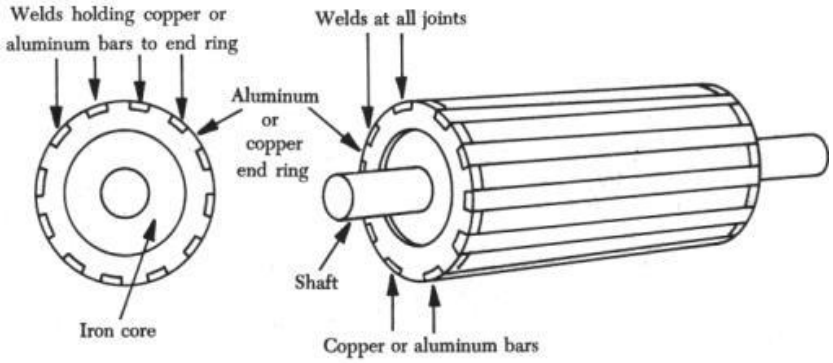

Figure 2.2: Squirrel cage rotor

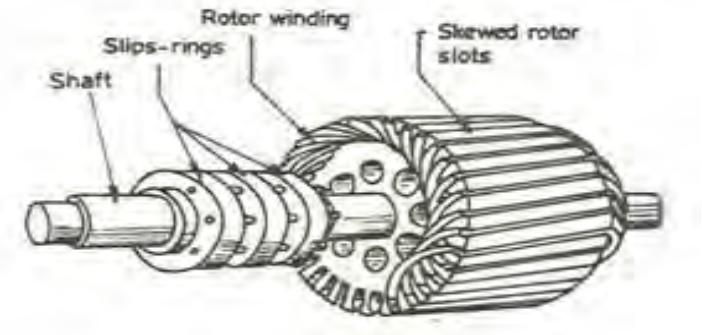

Figure 2.3: Wound rotor

2.2 Induction Motor

Induction motor is a motor where torque is produced through the process of varying magnetic field in the stator and induced current in the rotor coil. Most of the induction motor are using squirrel cage rotor, thus it only depends on electromagnetic induction to induce voltage and current to rotate the motor. Furthermore, the characteristics of single phase induction motor that producing a pulsating magnetics field cause the motor to stay in stationary condition (Stephen, 2012). In order for the induction motor to create revolving magnetic field, auxiliary winding that controlled by a centrifugal switch is added to the main winding, after the motor attain it nominal speed, the auxiliary winding are removed. Generally, the induction motor is classified as split phase induction motor, capacitor start motor, capacitor start capacitor run motor, and shaded pole motor, and are explained as follows:

2.2.1 Split Phase Motor

This motor are constructed with 2 winding on it stator, the auxiliary winding and the main winding. The auxiliary winding are arranged perpendicularly (90º) from the main winding as shown in Figure 2.4. Auxiliary winding has relatively high resistance and low reactance, and vice versa for main winding. These condition will provide 25 to 30 degree phase shift between the main current (I_M) and auxiliary current (I_A) to create a revolving magnetic flux as indicated in Figure 2.5. Consequently, a starting torque are produced for the rotor to rotate. During starting both main and auxiliary winding are energised from single phase supply. As the motor approximately reach 80% of synchronous speed, the centrifugal switch will disconnect the auxiliary winding from the main winding and the motor will continue to rotate.

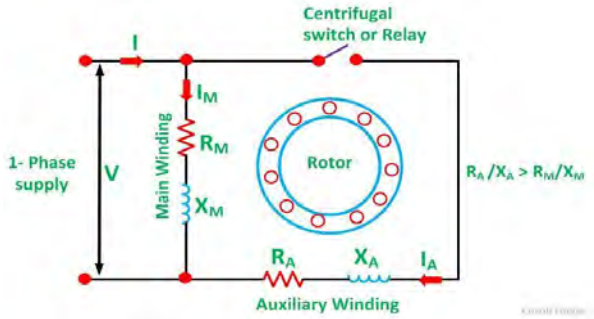

Figure 2.4: Split phase motor schematic diagram

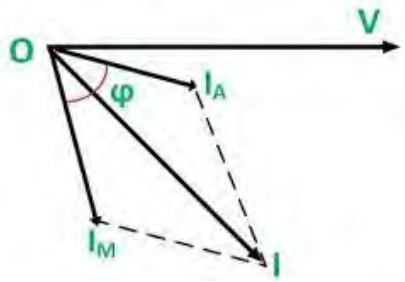

Figure 2.5: Phasor diagram between I_A and I_M

Characteristic of split phase motor is as the following:

- Starting torque are approximately 1.5 to 2 times the full load torque and the starting current is about 6 to 8 times the full load current.
- Most popular single phase motor, because split phase motor are cheap.
- The speed variation of this motor between 2 to 5% from no load to full load, thus they are basically a constant speed motor.
- This motor are widely used in application where moderate starting torque is needed and motor start-up are less such as washing machine, small machine tools, oil burner, blower and domestic refrigerators.
- Power rating of these motor are between 60 to 250 Watts (W).

2.2.2 Capacitor Start Motor

The construction and the generation of revolving magnetic flux of capacitor start motor is similar to a split phase motor except that a capacitor, C_S with rating between 3μF to 20μF is connected in series with the auxiliary winding. Capacitor is added, so that auxiliary current, Ia will lead main current,

Im approximately by 80º. Subsequently, a greater net torque will be produced compared to split phase motor. During starting, both the winding are energised for the input, then the motor will start to rotate with less humming noise because of the capacitor. After the, motor reach about 75 to 80 percent of the synchronous speed the centrifugal switch, Sc will cut off auxiliary winding from the main winding and the motor will continue to rotate. The above statement are referring on Figure 2.6 and Figure 2.7

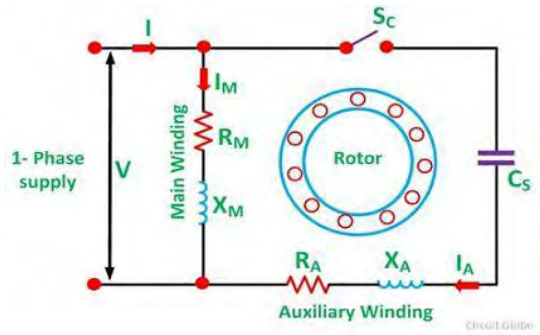

Figure 2.6: Capacitor start motor schematic diagram

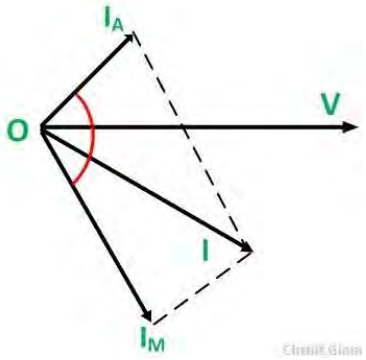

Figure 2.7: Phasor diagram of capacitor start motor

Characteristics of capacitor start motor are:

- Due to the addition of capacitor, C_S the current in auxiliary winding is reduced to half compare to the current in split phase motor for the same starting torque.
- Therefore, auxiliary winding in capacitor start motor heat up slower compare to split phase motor
- Have high starting torque, thus these motor are suitable in high inertia load and frequent starting application such as compressor, large fans and pumps.
- Usually, these motor has a power rating between 120W and 7.5kW.

2.2.3 Capacitor Start Capacitor Run Motor

Capacitor start capacitor run motor is a balanced 2 phase motor. They are designed with a main and auxiliary winding permanently connected together as shown in Figure 2.8. Since both of the windings are permanently connected, the revolving magnetic field that created by this motor are constant. The motor has 2 capacitor, the permanent capacitor (C_R) and the starting capacitor (C_S). Permanent capacitor is typically between 10 to 20 percent of the size of the starting capacitor. As a result, the power factor and efficiency of the motor are improved. For optimum starting C_S will connected in parallel with C_R and remains in the circuit during starting. As the rotor speed are approaching 80 percent of synchronous speed, centrifugal switch will disconnect C_S from C_R and the motor will continue to run as 2 phase induction motor.

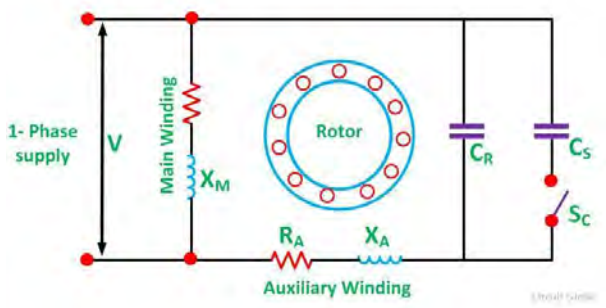

Figure 2.8: Capacitor start capacitor run schematic diagram

Characteristics of capacitor start capacitor run motor are:

- Ideal 2 phase motor that operated on any load.
- The motor produce a constant torque due to the main and auxiliary winding are permanently connected.
- Since the motor having a constant torque, the motor are vibration free and suitable to use in hospital, studios and places where silence is importance.

2.2.4 Shaded Pole Motor

Shaded pole motor is a self-starting single phase induction motor that designed with only a main winding in the stator. It has salient poles stator that divided into 2 part the shaded part and unshaded part and the shaded part of each pole is surrounded by a copper ring or short circuited coil named as shading coil. The stator is constructed in a special way to produce a moving magnetic field as the magnetic field varies. As the moving magnetic field sweep across the surface of the rotor a smell net torque is produced and the motor will start to rotate. The magnetic field will varies from the unshaded part to shaded part. Figure 2.9 indicate the schematics diagram of shaded pole motor

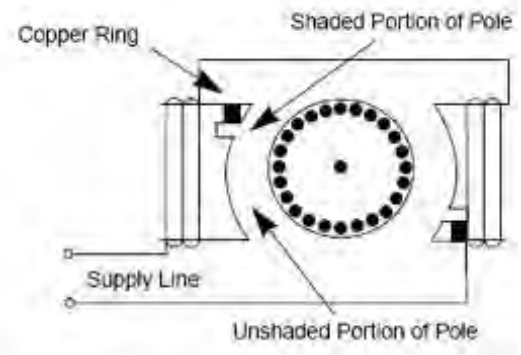

Figure 2.9: Shaded pole motor schematic diagram

Characteristics of shaded pole motor are provided as the following:

- The motor is simple in construction, cheap, but poor efficiency
- Has low starting torque, thus it is suitable to apply in low power application such as small fans, toys and desk fan.

2.3 AC Motor and Starting Issues

Single phase induction motor had been widely applied in the daily appliances from domestic application to heavy industries application. It is a common machinery that comes in cheaper price with high efficiency in performing the daily task. AC motor offer a verity of usage from heavy industrial application to domestic