NEAR EAST UNIVERSITY

Faculty of Engineering

Department of Electrical and Electronic Engineering

MOTOR CONTROL

Graduation Project
EE – 400

Student:HALİL TIMBIL (990085)

Supervisor: Özgür Cemal Özerdem

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Finaly, I want to thank my family. Without their endless support and love for me, I would never achive my current position. I wish my mother and my father lives happily always.

ABSTRACT

Today's civilized word depends more heavily than ever on one of the most efficient and most important devices ever invented the electric motor. Without it, the wheels of industry would grind to a halt, and millions of time and labor-saving devices would be rendered useless. No day passes without the discovery of new ways to use and control this prime motive force.

Equally important is the device which drives the electric motor-the generator. From the smallest stand-by unit to the largest hydroelectric plant, the demands of today's world for light and power are answered.

There will always be a continually increasing demand for technicians knowledgeable in these important and still growing fields.

The electric motor is a simple device in principle. It converts electric energy into mechanical energy. Over the years, electric motors have changed substantially in design, however the basic principles have remained the same.

And we have a problem how we can control motor when it starting , running or stopping. We have many solution about motor controlling. When starting we can reduce voltage for big motors. When running we can protected our motors and system by overload relay and circuit breakers.

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Chapter I

Basic Motor Theory

1.1 Introduction

It has been said that if the Ancient Romans, with their advanced civilization and knowledge of the sciences, had been able to develop a steam motor, the course of history would have been much different. The development of the electric motor in modern times has indicated the truth in this theory. The development of the electric motor has given us the most efficient and effective means to do work known to man. Because of the electric motor we have been able to greatly reduce the painstaking toil of man's survival and have been able to build a civilization which is now reaching to the stars. The electric motor is a simple device in principle. It converts electric energy into mechanical energy. Over the years, electric motors have changed substantially in design, however the basic principles have remained the same. In this section of the Action Guide we will discuss these basic motor principles. We will discuss the phenomena of magnetism, AC current and basic motor operation.

1.2 Magnetism

Now, before we discuss basic motor operation a short review of magnetism might be helpful to many of us. We all know that a permanent magnet will attract and hold metal objects when the object is near or in contact with the magnet. The permanent magnet is able to do this because of its inherent magnetic force which is referred to as a "magnetic field". In Figure 1.1 , the magnetic field of two permanent magnets are represented by "lines of flux". These lines of flux help us to visualize the magnetic field of any magnet even though they only represent an invisible phenomena. The number of lines of flux vary from one magnetic field to another. The stronger the magnetic field, the greater the number of lines of flux which are drawn to represent the magnetic field. The lines of flux are drawn with a direction indicated since we should visualize these lines and the magnetic field they represent as having a distinct movement from a N-pole to a S-pole as shown in Figure 1.1. Another but similar type of magnetic field is produced around an electrical conductor when an electric current is passed through the conductor as shown in Figure 1.2-a. These lines of flux define the magnetic field and are in the form of concentric circles around the wire. Some of you may remember the old "Left Hand Rule" as shown in Figure 1.2-b. The rule states that if you point the thumb of your left hand in the direction of the current, yourfingers will point in the direction of the magnetic field.

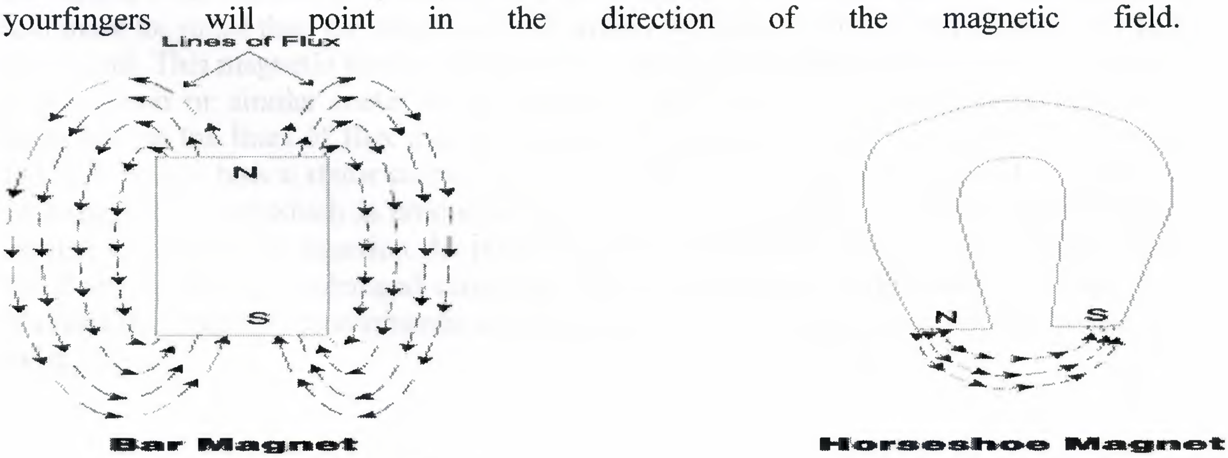

Figure 1.1 - The lines of flux of a magnetic field travel from the N-pole to the S-pole.

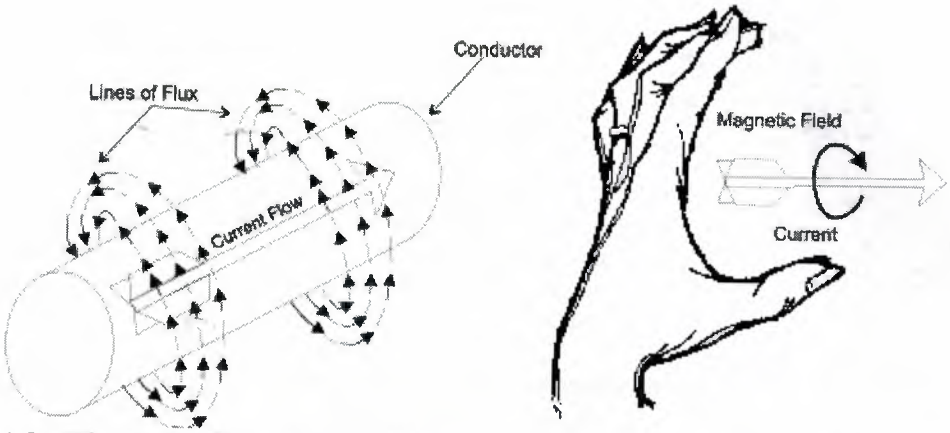

Figure 1.2 - The flow of electrical current in a conductor sets up concentric lines of magnetic flux around the conductor.

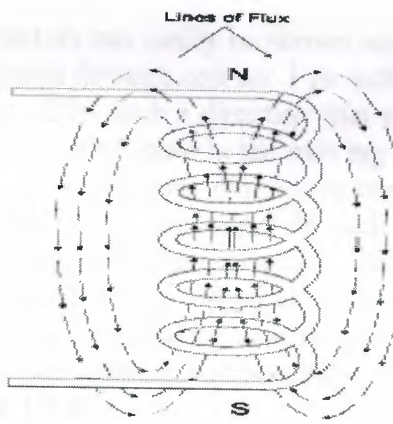

Figure 1.3 - The magnetic lines around a current carrying conductor leave from the N-pole and re-enter at the S-pole

When the wire is shaped into a coil as shown in Figure 1.3, all the individual flux lines produced by each section of wire join together to form one large magnetic field around the total coil. As with the permanent magnet, these flux lines leave the north of the coil and re-enter the coil at its south pole. The magnetic field of a wire coil is much greater and more localized than the magnetic field around the plain conductor before being formed into a coil. This magnetic field around the coil can be strengthened even more by placing a core of iron or similar metal in the center of the core. The metal core presents less resistance to the lines of flux than the air, thereby causing the field strength to increase. (This is exactly how a stator coil is made; a coil of wire with a steel core.) The advantage of a magnetic field which is produced by a current carrying coil of wire is that when the current is reversed in direction the poles of the magnetic field will switch positions since the lines of flux have changed direction. This phenomenon is illustrated in Figure 1.4. Without this magnetic phenomenon existing, the AC motor as we know it today would not exist.

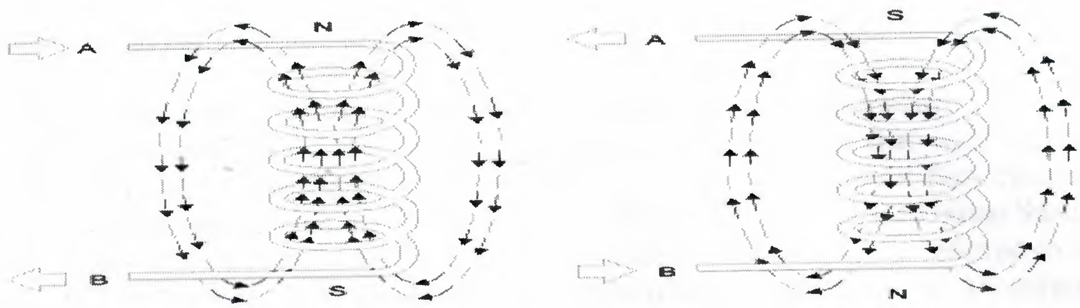

Figure 1.4 - The poles of an electro-magnetic coil change when the direction of current flow changes.

1.3 Magnetic Propulsion Within A Motor

The basic principle of all motors can easily be shown using two electromagnets and a permanent magnet. Current is passed through coil no. 1 in such a direction that a north pole is established and through coil no. 2 in such a direction that a south pole is established. A permanent magnet with a north and south pole is the moving part of this simple motor. In Figure 1.5-a the north pole of the permanent magnet is opposite the north pole of the electromagnet. Similarly, the south poles are opposite each other. Like magnetic poles repel each other, causing the movable permanent magnet to begin to turn. After it turns part way around, the force of attraction between the unlike poles becomes strong enough to keep the permanent magnet rotating. The rotating magnet continues to turn until the unlike poles are lined up. At this point the rotor would normally stop because of the attraction between the unlike poles. (Figure 1.5-b)

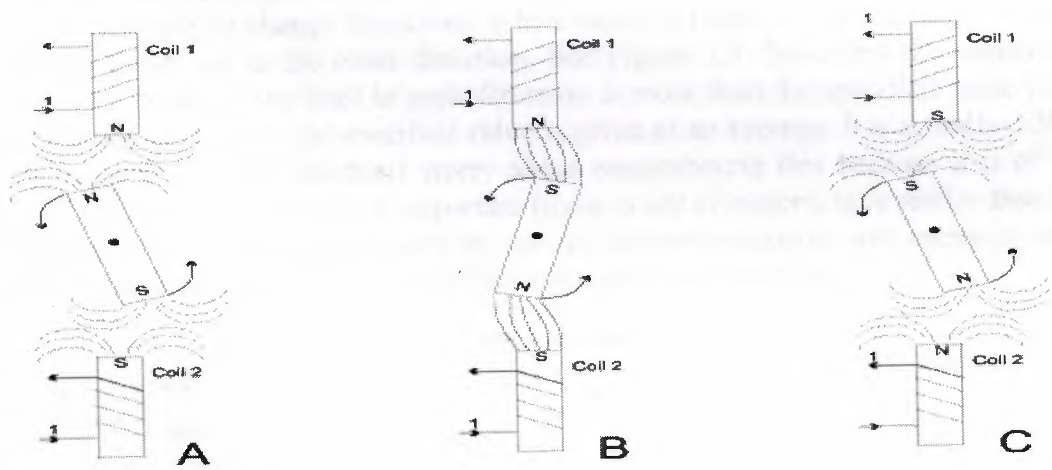

Figure 1.5 Attraction between the unlike poles

If, however, the direction of currents in the electromagnetic coils was suddenly reversed, thereby reversing the polarity of the two coils, then the poles would again be opposites and repel each other. (Figure 1.5-c). The movable permanent magnet would then continue to rotate. If the current direction in the electromagnetic coils was changed every time the magnet turned 180 degrees or halfway around, then the magnet would continue to rotate. This simple device is a motor in its simplest form. An actual motor is more complex than the simple device shown above, but the principle is the same.

1.4 AC Current

How is the current reversed in the coil so as to change the coils polarity, you ask. Well, as you probably know, the difference between DC and AC is that with DC the current flows in only one direction while with AC the direction of current flow changes periodically. In the case of common AC that is used throughout most of the United States, the current flow changes direction 120 times every second. This current is referred to as "60 cycle AC" or "60 Hertz AC" in honor of Mr. Hertz who first conceived the AC current concept. Another characteristic of current flow is that it can vary in quantity. We can have a 5 amp, 10 amp or 100 amp flow for instance. With pure DC, this means that the current flow is actually 5,10, or 100 amps on a continuous basis. We can visualize this on a simple time-current graph by a straight line as shown in Figure 1.6.

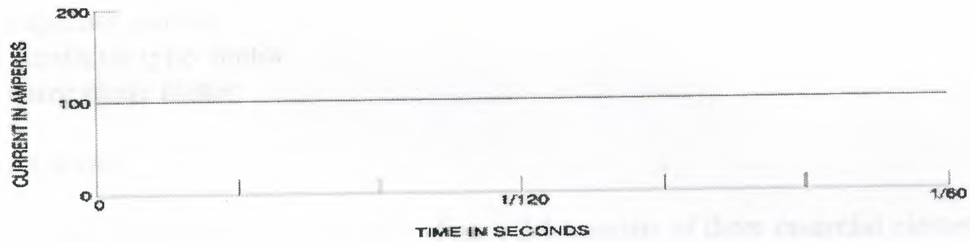

Figure 1.6 - Visualization of DC

But with AC it is different. As you can well imagine, it would be rather difficult for the current to be flowing at say 100 amps in a positive direction one moment and then at the next moment be flowing at an equal intensity in the negative direction. Instead, as the current is getting ready to change directions, it first tapers off until it reaches zero flow and then gradually builds up in the other direction. See Figure 1.7. Note that the maximum current flow (the peaks of the line) in each direction is more than the specified value (100 amps in this case). Therefore, the specified value is given as an average. It is actually called a "root mean square" value, but don't worry about remembering this because it is of no importance to us at this time. What is important in our study of motors, is to realize that the strength of the magnetic field produced by an AC electro-magnetic coil increases and decreases with the increase and decrease of this alternating current flow.

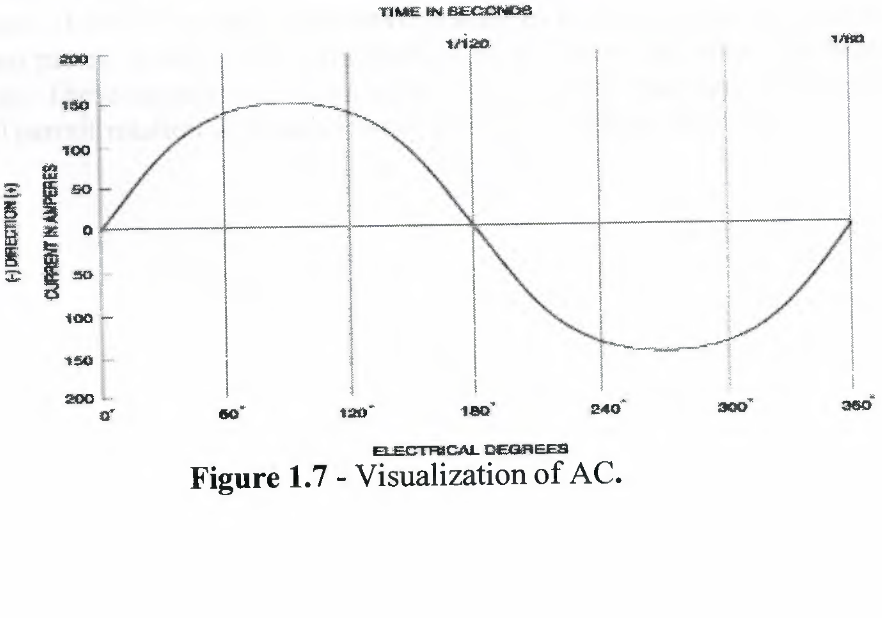

Figure 1.7 - Visualization of AC.

Chapter II

MOTORS

2.1 Main Part The Motor

Motor is a device which coverts electrical energy to mechanical energy. Motor has three main part. These are (1) a rotating part, called rotor; (2) a stationary part, called the stator; (3) end plate, or brackets, which fastened to the frame of the stator by means of screws blots. AC Motors are many type.

1 Single phase motor
a split phase motors
bcapacitor motors
c repulsion-type motor
2 Three phase motor

2.1.1 Rotor

The rotor, one of which is shown in figure 2.1 consists of three essential elements. One of these is a core that is made up of sheets of high-grade electrical sheet called laminations. Another is shaft on which the laminated iron core is pressed. The third element is a squirrel-cage winding consisting of heavy cooper bars which are placed in slots in the iron core and are connected to each other by means of heavy copper rings located on both ends of the core

2.1.2 Stator

The stator of motor is composed of a laminated steel core with semi closed stoles, a heavy cast-iron or steel frame into which the core is pressed and winding of insulated copper wire that are wound into the slot and are winding. A photograph of the stator is reproduced in figure 2.1

2.1.3 The End plates (End Shields or Brackets)

The end plates, one of which is illustrated in figure 2.1, are fastened to the stator frame by means of screws or bolts and serve mainly to keep the rotor in position. The bore of the end plates, in which the rotor shaft reset, is fitted with either ball bearing or sleeve bearings. These sustain the weight of the rotor, keep it precisely centered within the stator, and permit rotation without allowing the rotor to rub on the stator.

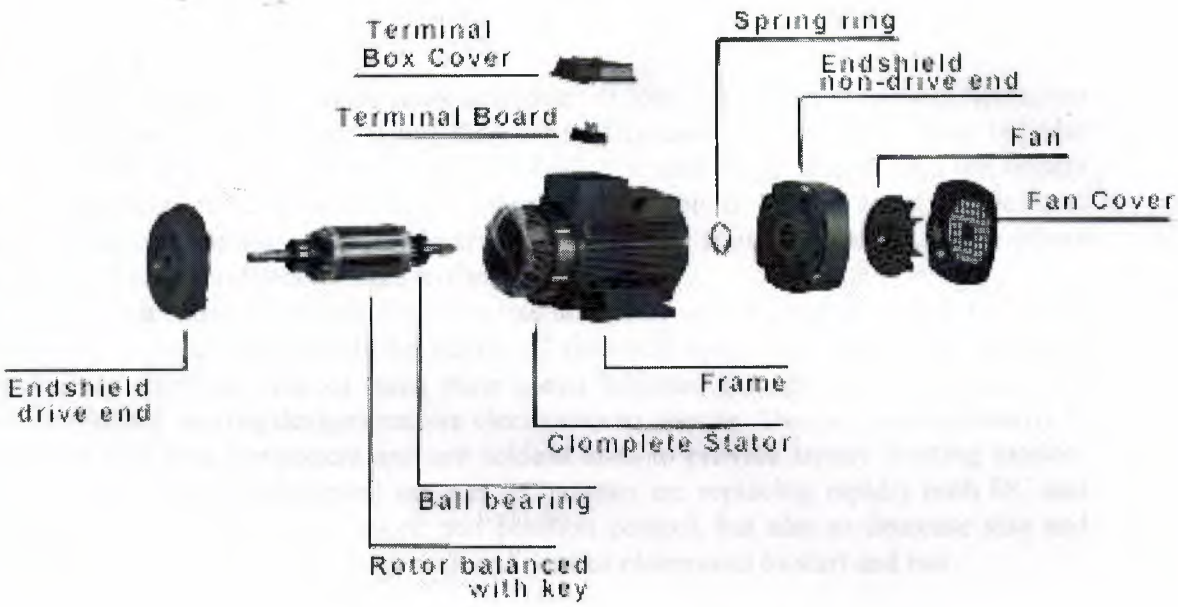

FIGURE 2.1 A photograph of the stator is reproduced. [3]

2.2 AC Motors

Single-phase ac motors occupy the low end of the horsepower spectrum and are offered commercially up to about 5 hp. Single-phase synchronous motors are only used below about 1/10 of a horsepower. Typical applications are timing and motion control, where low torque is required at fixed speeds. Single-phase induction motors are used for operating household appliances and machinery from about 1/3 to 5 hp.

Polyphase ac motors are primarily three-phase and are by far the largest electric prime mover in all of industry. They are offered in ranges from 5 up to 50,000 hp and account for a large percentage of the total motor industry in the world. In number of units, the three-phase squirrel cage induction motor is the most common. It is commercially available from 1 hp up to several thousand horsepower and can be used on conventional ac power or in conjunction with adjustable speed ac drives. Fans, pumps, and material handling are the most common applications.When the torque-speed characteristics of a conventional ac induction motor need to be modified, the wound rotor induction motor is used. These motors replace the squirrel cage rotor with a wound rotor and slip rings.External resistors are used to adjust the torque-speed characteristics for speed control in such applications as ac cranes, hoists, and elevators. Three-phase synchronous motors can be purchased with PM fields up to about 5 hp and are used for applications such as processing lines and transporting film and sheet materials at precise speeds. In the horsepower range above about 10,000 hp, three-phase synchronous motors with wound fields are used rather than large squirrel cage induction motors. Starting current and other characteristics can be controlled by the external field exciter. Three-phase synchronous motors with wound fields are available up to about 50,000 hp.

Introduction

Small electrical machines carry a substantial load in residential environments, but also in industrial environments, where they are mostly used to control processes. In order to adapt to the limitations of the power available, the cost requirements, and the widely varying operating requirements, small motors are available in a great variety of designs. Some of the small motors require electronics in order to start and operate, while others can start and run directly connected to the supply line.

AC motors that can start directly from the line are mostly of the induction type. Universal motors are also used extensively for small AC powered, handheld tools. They can either run directly from the line or have their speed adjusted through electronics.Stepping motors of many varying designs require electronics to operate. They are used primarily to position a tool or a component and are seldom used to provide steady rotating motion. Besides these motors, permanent magnet AC motors are replacing rapidly both DC and induction motors for accurate speed and position control, but also to decrease size and increase efficiency. They require power and control electronics to start and run.

2.2.1 Single Phase Induction Motors

To produce rotation, a multi-phase stator winding is often used in an AC motor, supplied from a symmetric and balanced system of currents. The magnetomotive force of these windings interacts with the magnetic field of the rotor (induced or applied) to produce a torque. In three-phase induction motors, the rotor field is created by currents that are induced due to the relative speed of the rotor and the synchronously rotating stator field.

In an induction motor that is supplied by a single-phase stator current, it is not as clear how a rotating magnetomotive force can be created and a torque be produced. Two different concepts will be used to generate torque.

The first, conceptually simpler design concept, involves the generation of a second current which flows in a second winding of the stator. This auxiliary winding is spatially displaced on the stator. This brings the motor design close to the multi-phase principle. The current in the auxiliary winding has to be out of phase with the current in the main winding, and this is accomplished through the use of increased resistance in it or a capacitor in series with it. A motor can operate in this fashion over its entire speed range.

Once the motor is rotating, the second design concept allows that one of the phases, the auxiliary one, be disconnected. The current in the remaining main winding alone produces only a pulsating flux, which can be analyzed as the sum of two rotating fields of equal amplitude but opposite direction. These fields, as seen from the moving rotor, rotate at different speeds, hence inducing in it currents of different frequency and amplitude. If the speed of the rotor is wr , the applied frequency to the stator is f and the number of pole pairs in the motor is p, the frequencies of the currents induced in the rotor are $pwr - f$ and $pwr + f$. These unequal currents in turn produce unequal torques in the two directions, with a nonzero net torque. The various designs of single-phase induction motors result from the variety of ways that the two phases are generated and by whether the auxiliary phase remains energized after starting.

2.2.2 Shaded Pole Motors

These motors are simple, reliable, and inefficient. The stator winding is not distributed on the rotor surface, but rather it is concentrated on salient poles. The auxiliary winding, which has to produce flux out of phase with the main winding, is nothing but a hardwired shorted turn around a portion of the main pole as Fig. 2.2. Because of the shorted turn, the flux out of the shaded part of the pole lags behind the flux out of the main pole. The motor always rotates from the main to the shaded pole, and it is not possible to change directions. Shaded pole motors are inefficient and have high starting and running current and low starting torque. They are used where reliability and cost are important, while their small size makes unimportant the overall effect of their disadvantages, e.g., small fans. Their size ranges from 0.002 to 0.1 h

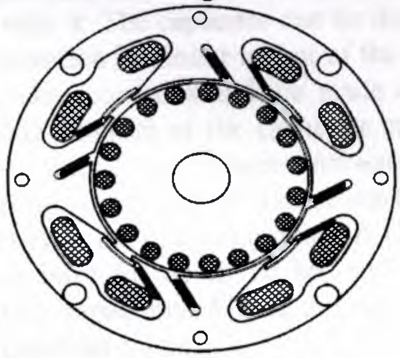

FIGURE 2.2 A shaded pole motor with tapered poles and magnetic wedges.[1.1]

2.2.3 Resistance Split-Phase Motors

These motors have an auxiliary winding which simply has higher resistance than the main winding and is displaced spatially on the stator by about 90°. Both windings are distributed on the stator surface and are connected to the line voltage, but the different time constants between them makes the

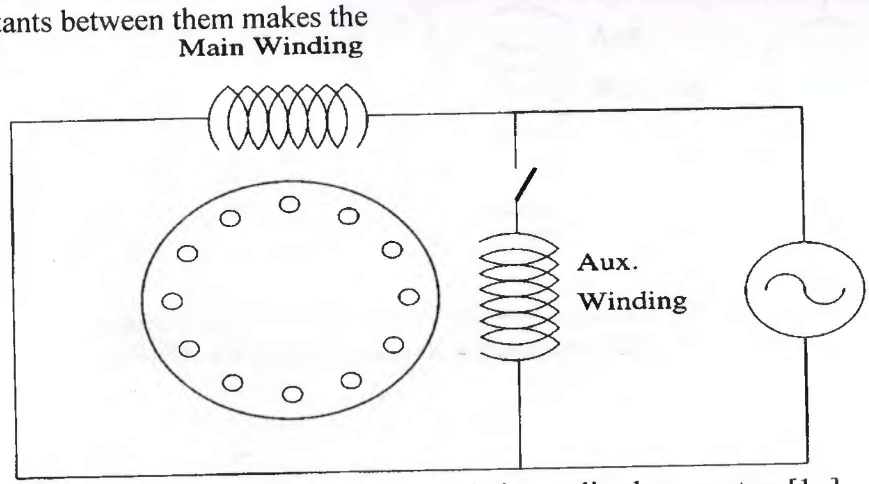

FIGURE 2.3 Connections of a resistive, split-phase motor. [1.1]

current in the auxiliary winding lead that of the main. This arrangement results in a nonzero, but relatively low starting torque and high starting current.
The use of the auxiliary winding is limited only to starting—the motor runs more efficiently without it, as a single phase motor described earlier. A switch, activated by speed (centrifugal) or by stator temperature, disconnects the auxiliary winding shortly after starting. Figure 2.3. represents schematically the connections of this type of motor.
These motors represent an improvement in efficiency and starting torque over shaded pole motors, at the expense of increased cost and lower reliability. They are built to larger sizes, but their application is limited by the high starting current.

2.2.4 Capacitor Motors

Another way to generate a phase angle of current in the auxiliary winding is to include a capacitor in series with it. The capacitor can be disconnected after starting in a capacitor start motor. Their operation is similar to that of the resistance split-phase motor, but they have better starting characteristics and are made as large as 5 hp. Figure 2.4 shows schematically the wiring diagram of the capacitor start motor. To optimize both starting and running, different values of the capacitor are used. One value of the capacitor is calculated to minimize starting current and maximize starting torque, while the other is designed to maximize efficiency at the operating point. A centrifugal switch handles the changeover. Such motors are built for up to 10 hp, and their cost is relatively high because of the switch and two capacitors. Figure 2.5 shows schematically the wiring diagram of the capacitor start and run motor.

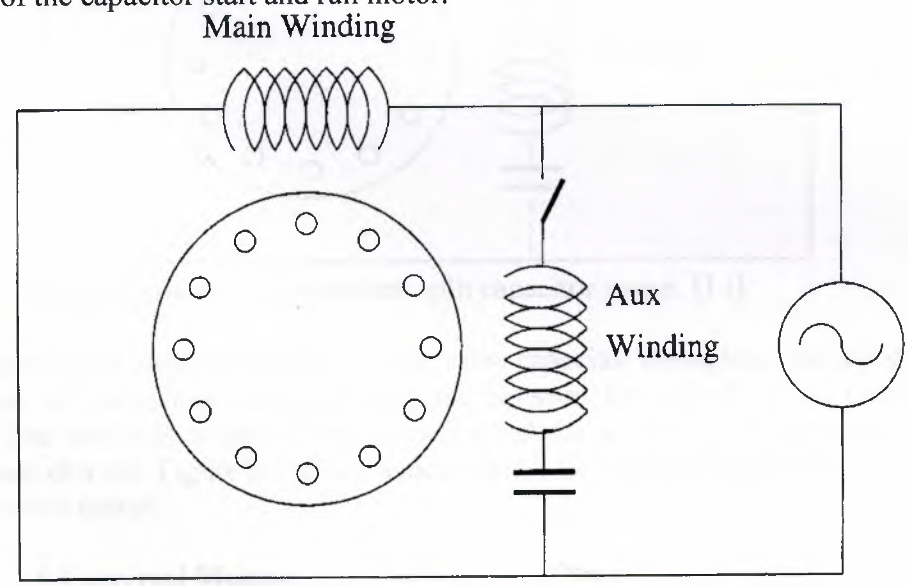

FIGURE 2.4 Conenctions of a capacitor start motor. [1.1]

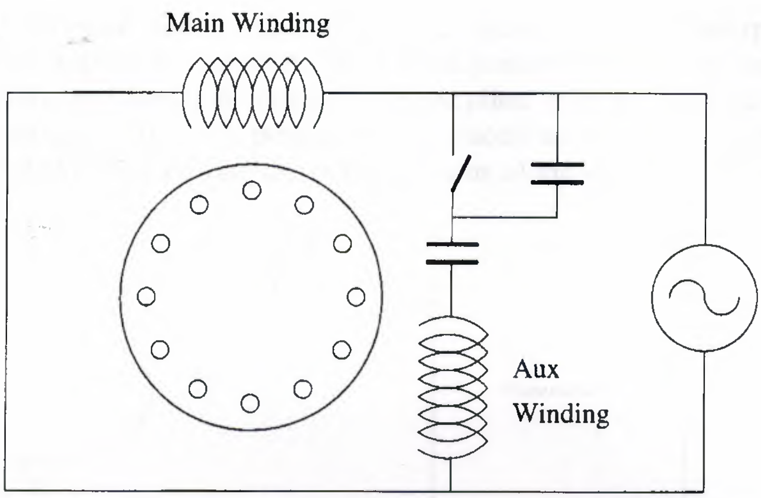

FIGURE 2.5 Connections of a capacitor-start, capacitor-run motor.[1.ı]

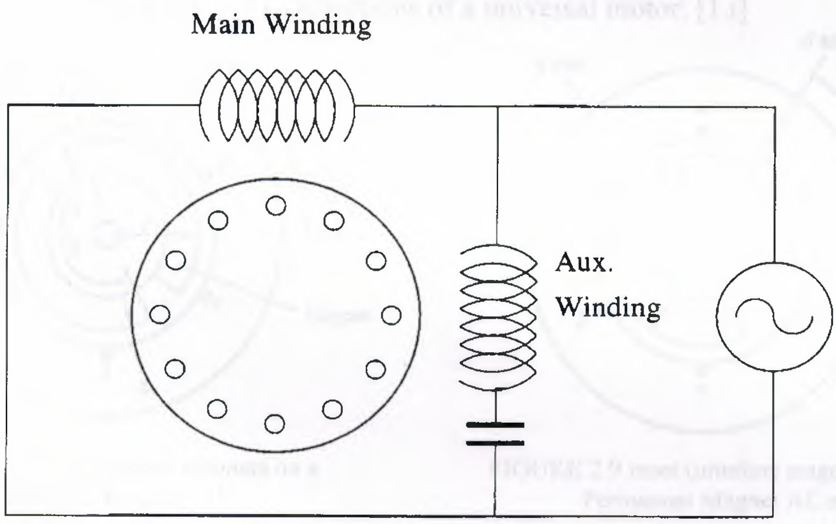

FIGURE 2.6 Connections of a permanent split capacitor motor. [1.ı]

A permanent split capacitor motor uses the same capacitor throughout the speed range of the motor. Its value requires a compromise between the values of the two-capacitor motors. The result is a motor design optimized for a particular application, e.g., a compressor or a fan. Figure 2.6 shows schematically the wiring diagram of the permanent split capacitor motor.

2.2.5 Universal Motors

These motors can be supplied from either DC or AC. Their design is essentially similar to a DC motor with series windings. When operated as AC motors, supplied say by a 60 Hz source, the current in the armature and the field windings reverses 120 times per second. As the torque is roughly proportional to both armature and field currents, connecting these windings in series guarantees that the current reverses in both at the same time, retaining the unidirectional torque. Figure 2.7 shows a schematic diagram of the connections of universal motors. They can run at speeds up to 20,000 rpm, thus being very compact for a given horsepower. Their most popular applications include portable drills, food mixers, and fans. Universal motors supplied from AC lend themselves easily to variable speed applications. A potentiometer, placed across the line voltage, controls the firing of a TRIAC thus varying the effective value of the voltage at the motor.

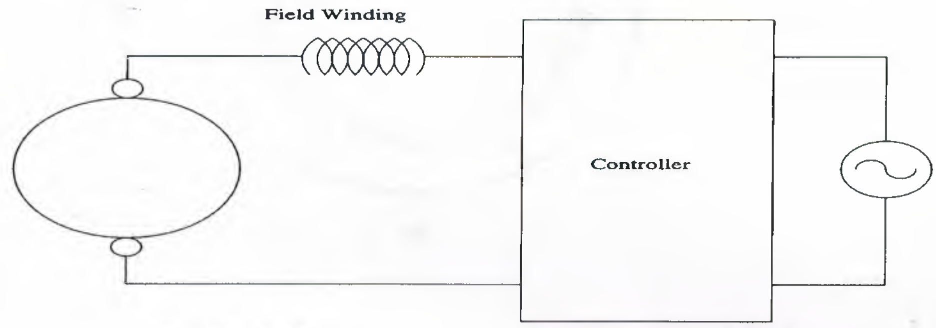

FIGURE 2.7 Connections of a universal motor. [1.1]

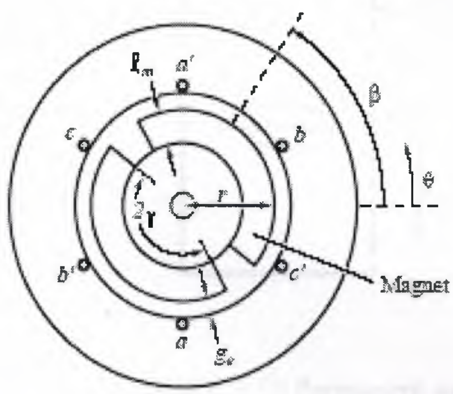

FIGURE 2.8 Surface mounted magnets on a Permanent Magnet AC motor. [1.1]

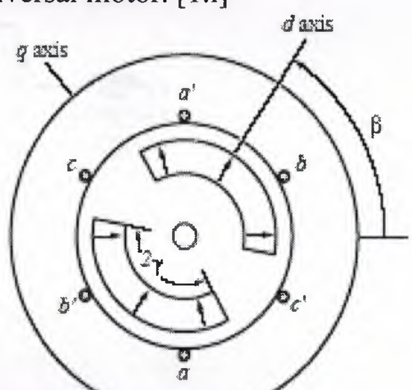

FIGURE 2.9 Inset (interior) magnets on Permanent Magnet AC motor.[1.1]

2.2.6 Permanent Magnet AC Motors

When compared to induction motors, permanent magnet motors have higher steady state torque for the same size and better efficiency. They carry a polyphase winding in the stator, which can be either rectangular or sinusoidally distributed. The rotor has a steel core, with permanent magnets mounted on it or inset. These magnets can be made from a variety of materials, such as rare earth, ceramic, etc. Figure2.8 shows a schematic of the cross-section of a motor with surface mounted magnets, and Fig. 2.9 shows a schematic of a motor with inset magnets. The stator windings are supplied by a DC source through power electronic switches that constitute an inverter. Which switches are to be conducting at any time is determined by a controller, which in turn uses as inputs a speed or torque command and a measurement or an estimate of the rotor position. Figure 2.10 shows a schematic of the motor cross-section and of the inverter

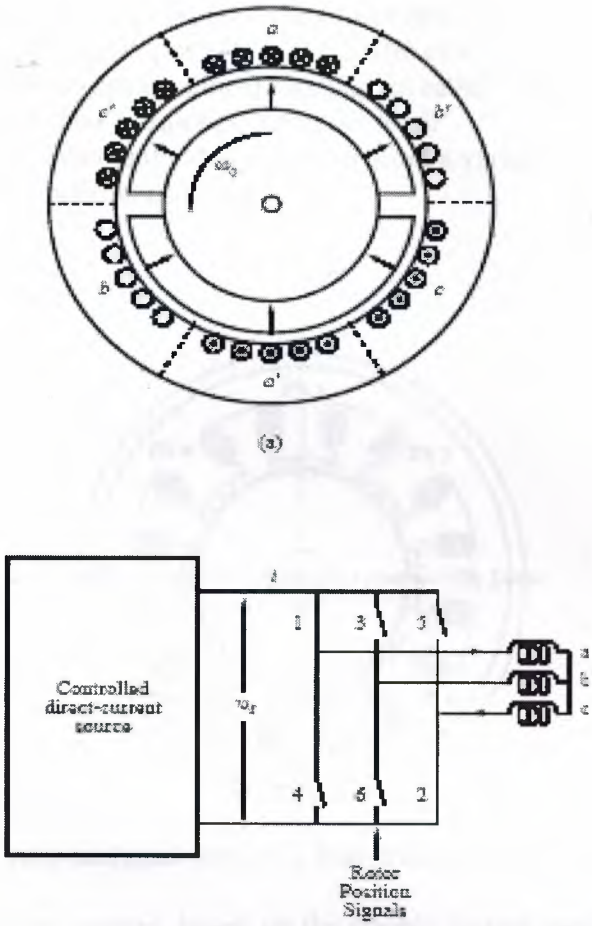

FIGURE 2.10 Permanent magnet AC motor and inverter. [1.1]

When the stator windings are rectangular and are energized based only on the rotor position, the resulting set of PM motor, inverter, and controller is called a brushless DC motor. The developed torque is proportional to the airgap flux, *Bg*, and the stator current, *Is*.

$$T = k B_g I_s$$

Due to the rotor speed, *w0* a voltage, *e*, (back emf) is induced to the stator windings.

$$e = k B_g w_0$$

2.2.7 Stepping Motors

These motors convert a series of power pulses to a corresponding series of equal angular movements. These pulses can be delivered at a variable rate, allowing the accurate positioning of the rotor without feedback. They can develop torque up to 15 Nm and can

handle 1500 to 2500 pulses per second. They have zero steady state error in positioning and high torque density. An important characteristic of stepping motors is that when one phase is activated they do not develop a rotating but rather a holding torque, which makes them retain accurately their position, even under load.
Stepping motors are conceptually derived either from a variable reluctance motor or from a permanentmagnet synchronous motor.

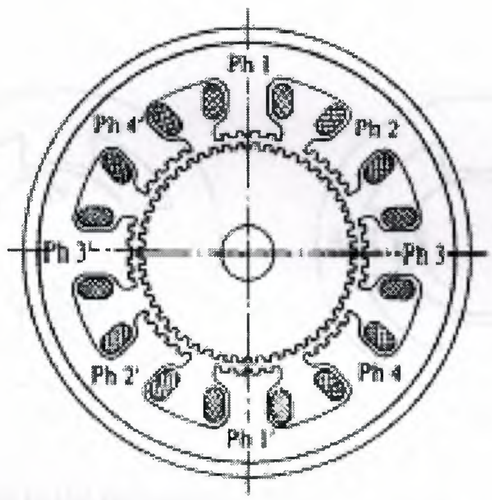

FIGURE 2.11 Cross-sectional view of a four-phase variable reluctance motor. [1.ı]

One design of stepping motors, based on the doubly salient switched reluctance motor, uses a large number of teeth in the rotor (typically 45) to create saliency, as shown in Fig. 2.11. In this design, when the rotor teeth are aligned in say Phase 1, they are misaligned in Phases 2 and 3. A pulse of current in Phase 2 will cause amrotation so that the alignment will occur at Phase 2. If, instead, a pulse to Phase 3 is given, the rotor will movethe same distance in the opposite rotation. The angle corresponding to a pulse is small, typically 3° to 5°, resulting from alternatively exciting one stator phase at a time.
A permanent magnet stepping motor uses permanent magnets in the rotor. Figure 2.12 shows the steps in the motion of a four-phase PM stepping motor. Hybrid stepping motors come in a variety of designs. One, shown in Fig. 2.13, consists of two rotors mounted on the same shaft, displaced by one half tooth. The permanent magnet is placed axially between the rotors, and the magnetic flux flows radially at the air gaps, closing through the stator circuit. Torque is created by the interaction of two magnetic fields, that due to the magnets and that due to the stator currents. This design allows a finer step angle control and higher torque, as well as smoother torque during a step.

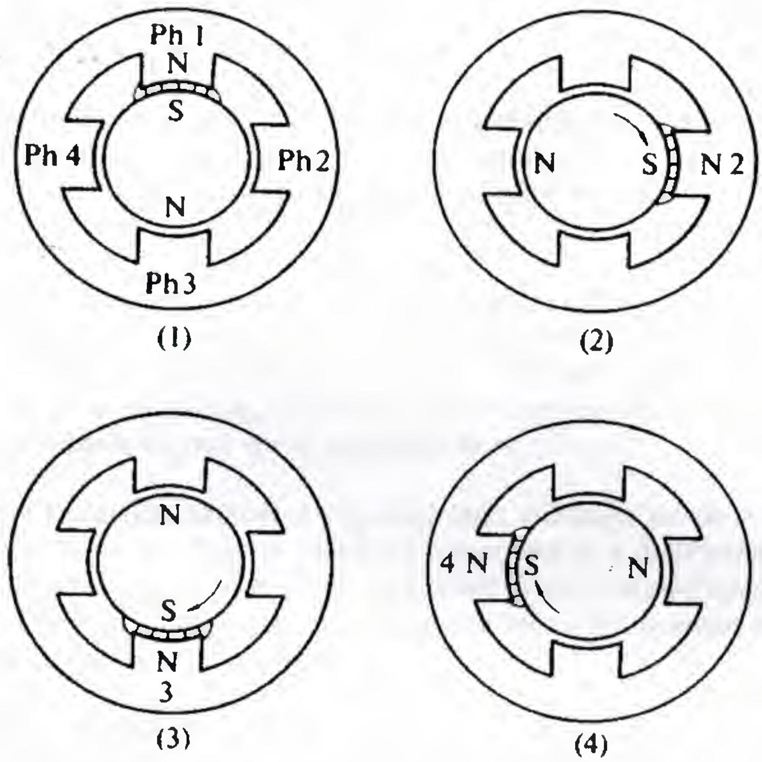

FIGURE 2.12 Steps in the operation of a permanent magnet stepping motor. [1.1]

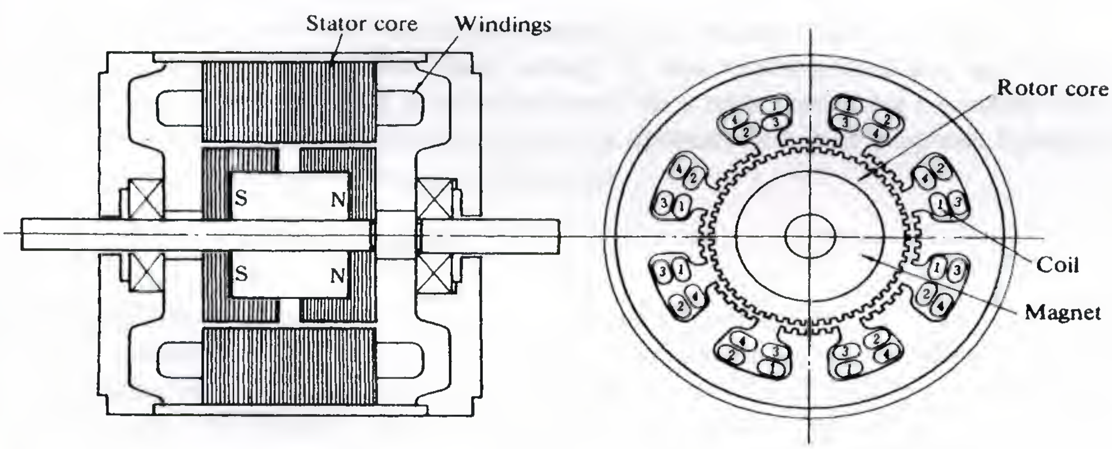

FIGURE 2.13 Construction of a hybrid stepping motor.[1.1]

Fundamental to the operation of stepping motors is the utilization of power electronic switches, and of a circuit providing the timing and duration of the pulses. A characteristic of a specific stepping motor is the maximum frequency it can operate at starting or running without load. As the frequency of the pulses to a running motor is increased, eventually the motor loses synchronism. The relation between the frictional load torque and maximum pulse frequency is called the pull-out characteristic.

2.2.8 Repulsion-Type Motor

In general, repulsion motor may be divided into three distinct classifications. These are 1the repulsion motor, 2 the repulsion-start, induction motor, and 3 the repulsion-induction motor. These motors are called single-phase wound-rotor and are defined and classified by NEMA as follows:

Repulsion Motor: A repulsion motor is a single-phase motor which has a stator winding arranged for connection to a source of power and a rotor winding connected to a commutator. Brushes on the commutator are short-circuited and are so placed that the magnetic axis of the rotor winding is inclined to the magnetic axis of the stator winding. This type of motor has a varying-speed characteristic.

Repulsion-start Induction Motor: A repulsion-start induction motor is a single-phase motor having the same windings as repulsion motor, but at a predetermined speed the rotor winding is sort circuited or otherwise connected to give the equivalent of a squirrel-cage winding. This type of motor starts as repulsion motor but operates as an induction motor with constant-speed characteristic.

Repulsion-induction Motor: A repulsion-induction motor is from of repulsion motor which has a squirrel-cage winding in the rotor in additional to the repulsion motor winding. A rotor of this type may have either a constant-speed or varying-speed characteristic.

These three classes are often confused by the beginner because of the similarity of names. But each is different from the other, having its own characteristic and applications. However, one feature common to all is that each has a rotor containing a winding that is connected to commotator. These motor generally operates from a single-phase lighting or power circuit, depending on the size of the motor.

2.2.8.1 Construction

Most repulsion-type motors generally consist of the following parts:
A stator similar to that of the split-phase or capacitor motor and one winding, usually of two sections, similar to the running winding of a dual-voltage split-phase or capacitor motor. Figure 2.14. Shows a stator of a repulsion-start induction motor.

Figure 2.14 Repulsion-type motor stator. [3]

A rotor having a stotted core into which a winding is placed and connected to commutator. The rotor is similar in construction to the armature of a DC motor and will henceforth be referred to, interchangeably, as the rotor or armature, the stols are generally skewed to produce the same starting torque regardless of the position of the armature and to reduce magnetic hum. Figure 2.15. Illustrates the armature of the repulsion-induction motor.

Figure 2.15 Repulsion-type motor rotor. [3]

The commutator may be a one of two types: an axial commutator, with bars parallel to the shaft, or a radial commutator, with bars perpendicular to the shaft.

Two end plates or brackets that support the bearing in which the armature shaft must turn.

Bushes made of carbon which fit in the brush holders. The brushers ride against the commutator and are used to conduct current through the armature winding.

Brush holders, supported either on the front end plate or on the armature shaft, depending on the particular type of motor.

The Repulsion-Start Induction Motor

This is a single-phase motor ranging in size from approximately ¼ to 10 HP. It has high stating torque and a constant-speed characteristic. It is used in commercial refrigerators, compressors, pumps, and other applications requiring high starting torque.

Repulsion-start induction motors are of two different designs. In one the brush-lifting type, the brushes are automatically moved away from commutator when the motor reaches approximately 75 percent of full speed. This type generally has the radial or vertical from of commutator. In the other, called the brush-riding type, the brush ride on the commutator at all times. This type has the axial from of commutator. In order operating principles, these motor types are identical.

The Repulsion Motor

This motor is distinguished from repulsion-start induction motor by the fact that it is made exclusively as a brush-riding type and does not have any centrifugal mechanism. This motor both stats and runs on the repulsion principle. In common with a DC series motor, it has high starting torque and a variable-speed characteristic. It is reversed by shifting the brush holder to either side of the neutral position. Its speed can be decreased by moving the brush holder further away from the neutral position. This motor is sometimes called an induction-series motor.
This stator of the repulsion motor is like that of repulsion-start induction motor, and the stator poles are connected in the same manner. The stator is generally wound for four, six, or either poles. Usually four leads are brought out for dual-voltage operation.
The rotors consist of an armature constructed in the same manner as the DC type. It is laminated and generally skewed. The winding may be either hand or coil wound and is connected either lap or wave. The commutator is the axial type and the brushes always ride on the commutator. The brushes are all connected together as in the repulsion-start motor.

The Repulsion-Induction Motor

It is sometimes impossible to tell the difference between the repulsion-induction motor and the repulsion motor and the repulsion motor by external appearance. However, the repulsion-induction motor has a squirrel-cage winding on the armature in the addition to the regular winding. The squirrel-cage winding is located underneath the slots of the armature. The armature is usually lap-wound and cross-connected.
To tell the difference between a repulsion and repulsion-induction motor, connect the motor to the line and permit it to reach full speed. Then raise all brushes so that they no longer contact the commutator. If the motor continues to operate at full speed, it is a repulsion-induction motor. Repulsion-induction motors are made in size up to about 10 HP. They are dual-voltage types and can be used for general-purpose duty. In the field of repulsion motors, this type is becoming very popular, because of their good all-round characteristics, which are comparable to those of the DC compound motor.
The advantage of this motor lies in the fact that no centrifugal short-circuiting mechanism is used. It has high starting torque and owing to the squirrel-cage winding, a fairly constant speed regulation. These motors are also made with compensating coils to increase the power factor of the motor circuit.

2.3. Three-Phase Motors

Three-phase motors vary from fractional-horse power size to several thousand horsepower. These motors have a fairly constant speed characteristic and are made in designs giving a variety of torque characteristic. Some three-phase motors have a high starting torque; others, a low starting torque. Some are designed to draw a normal starting current. They are made for practically every standard voltage and frequency and are very often dual-voltage motors. Three-phase motors are used to drive machine tools, pumps, elevators, fans, cranes, hoists, blowers, and may other machines.

2.3.1 Construction of Three-Phase Motor

A three-phase motor is shown in figure 2.16. It has three main parts: stator, rotor, and end plates. Its construction is similar to that of the split-phase motor, but it has no centrifugal switch.

The stator is shown in figure 2.16. And consists of a frame and a laminated steel core like that used in split-phase and repulsion motors and winding formed of individual coils placed in slots. The rotor may be die cast aluminum squirrel-cage type or a wound rotor. Both types contain a laminated core pressed onto a shaft. The squirrel-cage rotor is shown on figure 2.16 and is like that of split-phase motor.

Figure 2.16 Three phase motor. [3]

2.3.2 Basic Three phase AC Motor Operation

An AC motor has two basic electrical parts: a "stator" and a "rotor" as shown in Figure 2.17. The stator is in the stationary electrical component. It consists of a group of individual electro-magnets arranged in such a way that they form a hollow cylinder, with one pole of each magnet facing toward the center of the group. The term, "stator" is derived from the word stationary. The stator then is the stationary part of the motor. The rotor is the rotating electrical component. It also consists of a group of electro-magnets arranged around a cylinder, with the poles facing toward the stator poles. The rotor, obviously, is located inside the stator and is mounted on the motor's shaft. The term "rotor" is derived from the word rotating. The rotor then is the rotating part of the motor. The objective of these motor components is to make the rotor rotate which in turn will rotate the motor shaft. This rotation will occur because of the previously discussed magnetic phenomenon that unlike magnetic poles attract each other and like poles repel. If we progressively change the polarity of the stator poles in such a way that their combined magnetic field rotates, then the rotor will follow and rotate with the magnetic field of the stator.

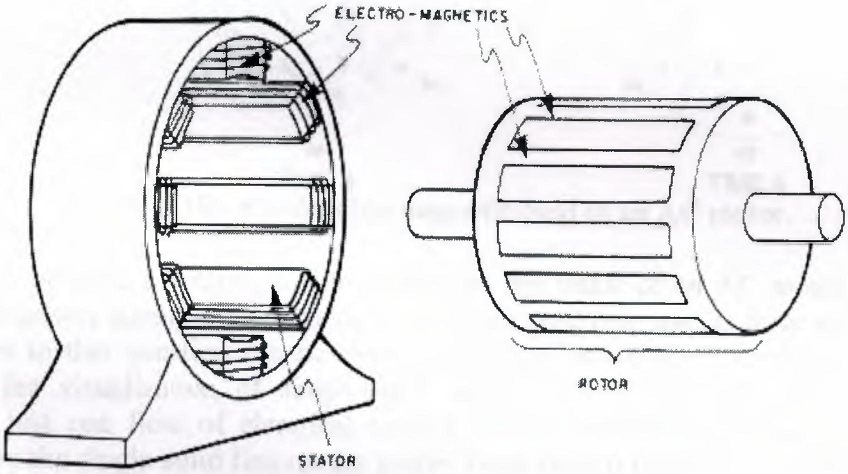

Figure 2.17 - Basic electrical components of an AC motor.

This "rotating magnetic fields of the stator can be better understood by examining Figure 2.18. As shown, the stator has six magnetic poles and the rotor has two poles. At time 1, stator poles A-1 and C-2 are north poles and the opposite poles, A-2 and C-1, are south poles. The S-pole of the rotor is attracted by the two N-poles of the stator and the N-pole of the rotor is attracted by the two south poles of the stator. At time 2, the polarity of the stator poles is changed so that now C-2 and B-1 and N-poles and C-1 and B-2 are S-poles. The rotor then is forced to rotate 60 degrees to line up with the stator poles as shown. At time 3, B-1 and A-2 are N. At time 4, A-2 and C-1 are N. As each change is made, the poles of the rotor are attracted by the opposite poles on the stator. Thus, as the magnetic field of the stator rotates, the rotor is forced to rotate with it.

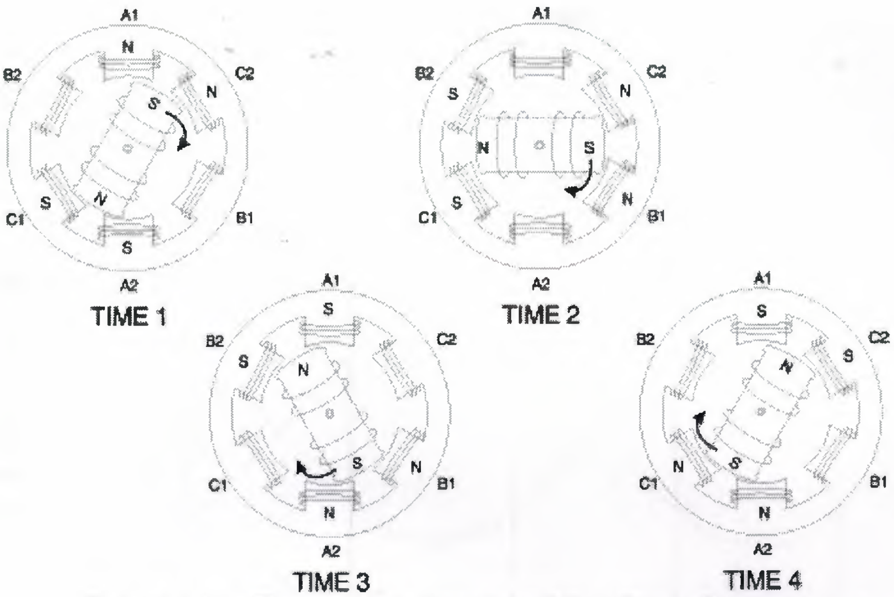

Figure 2.18 - The rotating magnetic field of an AC motor.

One way to produce a rotating magnetic field in the stator of an AC motor is to use a three-phase power supply for the stator coils. What, you may ask, is three-phase power? The answer to that question can be better understood if we first examine single-phase power is the visualization of single-phase power. The associated AC generator is producing just one flow of electrical current whose direction and intensity varies as indicated by the single solid line on the graph. From time 0 to time 3, current is flowing in the conductor in the positive direction. From time 3 to time 6, current is flowing in the negative. At any one time, the current is only flowing in one direction. But some generators produce three separate current flows (phases) all superimposed on the same circuit. This is referred to as three-phase power. At any one instant, however, the direction and intensity of each separate current flow are not the same as the other phases. This is illustrated in Figure2.17. The three separate phases (current flows) are labeled A, B and C. At time 1, phase A is at zero amps, phase B is near its maximum amperage and flowing in the positive direction, and phase C is near to its maximum amperage but flowing in the negative direction. At time 2, the amperage of phase A is increasing and flow is positive, the amperage of phase B is decreasing and its flow is still negative, and phase C has dropped to zero amps. A complete cycle (from zero to maximum in one direction, to zero and to maximum in the other direction, and back to zero) takes one complete revolution of the generator. Therefore, a complete cycle, is said to have 360 electrical degrees. In examining Figure 2.19, we see that each phase is displaced 120 degrees from the other two phases. Therefore, we say they are 120 degrees out of phase.

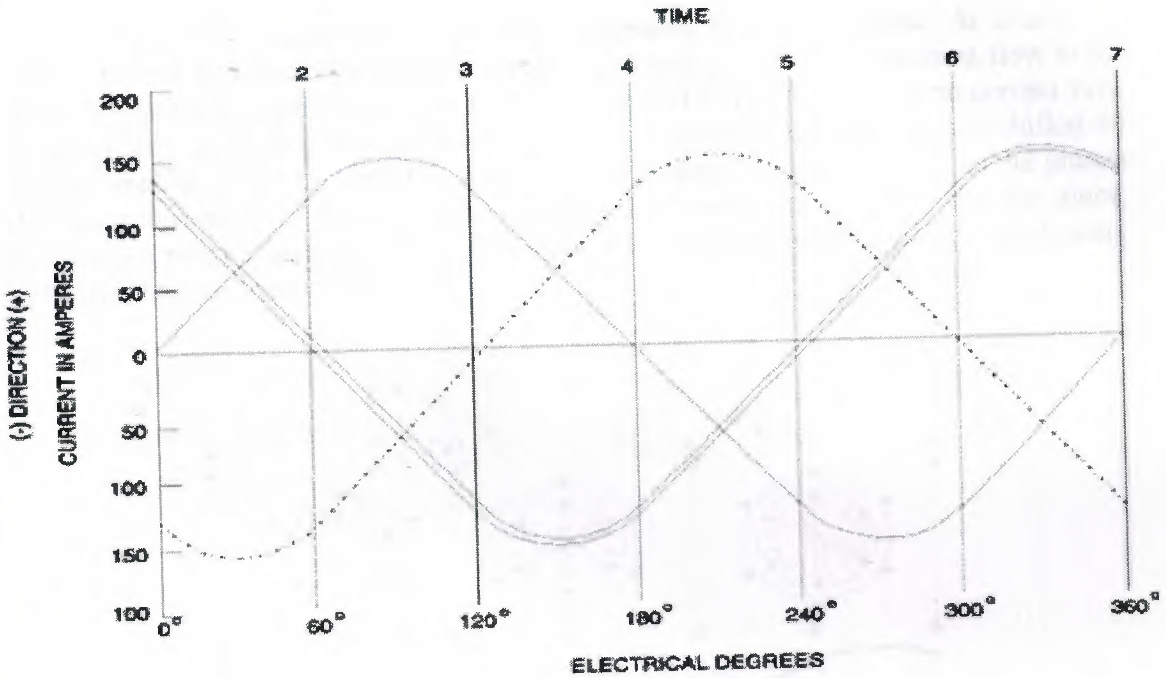

Figure 2.19 - The pattern of the separate phases of three-phase power.

To produce a rotating magnetic field in the stator of a three-phase AC motor, all that needs to be done is wind the stator coils properly and connect the power supply leads correctly. The connection for a 6 pole stator is shown in Figure 2.20. Each phase of the three-phase power supply is connected to opposite poles and the associated coils are wound in the same direction. As you will recall from Figure 4, the polarity of the poles of an electro-magnet are determined by the direction of the current flow through the coil. Therefore, if two opposite stator electro-magnets are wound in the same direction, the polarity of the facing poles must be opposite. Therefore, when pole A1 is N, pole A2 is S. When pole B1 is N, B2 is S and so forth.

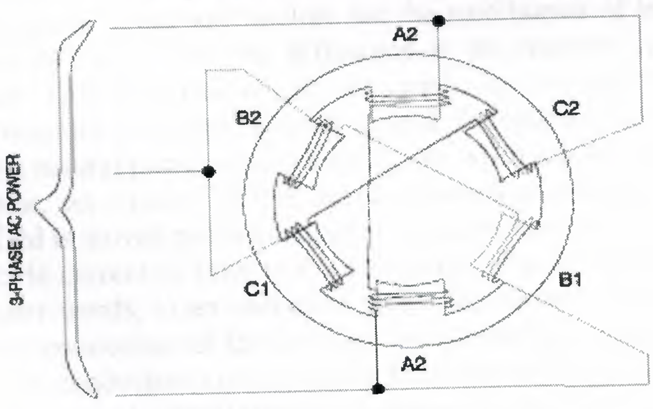

Figure 2.20 - Method of connecting three-phase power to a six-pole stator.

Figure 2.21 shows how the rotating magnetic field is produced. At time1, the current flow in the phase "A" poles is positive and pole A-1 is N. The current flow in the phase "C" poles is negative, making C-2 a N-pole and C-1 is S. There is no current flow in phase "B", so these poles are not magnetized. At time 2, the phases have shifted 60 degrees, making poles C-2 and B-1 both N and C-1 and B-2 both S. Thus, as the phases shift their current flow, the resultant N and S poles move clockwise around the stator, producing a rotating magnetic field. The rotor acts like a bar magnet, being pulled along by the rotating magnetic field.

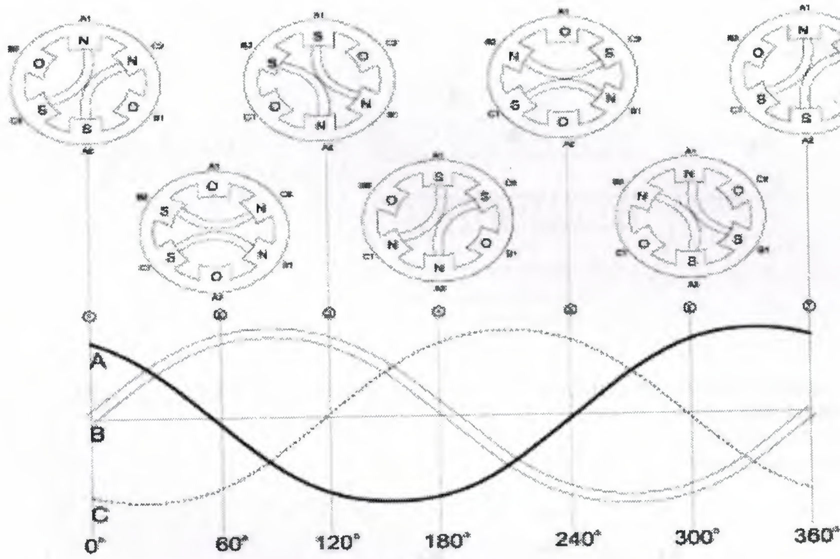

Figure 2.21 - How three-phase power produces a rotating magnetic field.

Up to this point not much has been said about the rotor. In the previous examples, it has been assumed the rotor poles were wound with coils, just as the stator poles, and supplied with DC to create fixed polarity poles. This, by the way, is exactly how a synchronous AC motor works. However, most AC motors being used today are not synchronous motors. Instead, so-called "induction" motors are the workhorses of industry. So how is an induction motor different? The big difference is the manner in which current is supplied to the rotor. This is no external power supply. As you might imagine from the motor's name, an induction technique is used instead. Induction is another characteristic of magnetism. It is a natural phenomena which occurs when a conductor (aluminum bars in the case of a rotor, see Figure 2.22) is moved through an existing magnetic field or when a magnetic field is moved past a conductor. In either case, the relative motion of the two causes an electric current to flow in the conductor. This is referred to as "induced" current flow. In other words, in an induction motor the current flow in the rotor is not caused by any direct connection of the conductors to a voltage source, but rather by the influence of the rotor conductors cutting across the lines of flux produced by the stator magnetic fields. The induced current which is produced in the rotor results in a magnetic field around the rotor conductors as shown in Figure 2.2.23. This magnetic field around each rotor conductor will cause each rotor conductor to act like the permanent magnet in the Figure 2.18 example. As the magnetic field of the stator rotates, due to the effect of the three-phase AC power supply, the induced magnetic field of the rotor will be attracted and will follow the rotation. The rotor is connected to the motor shaft, so the shaft will rotate and drive the connection load. That's how a motor works! Simple, was it not?

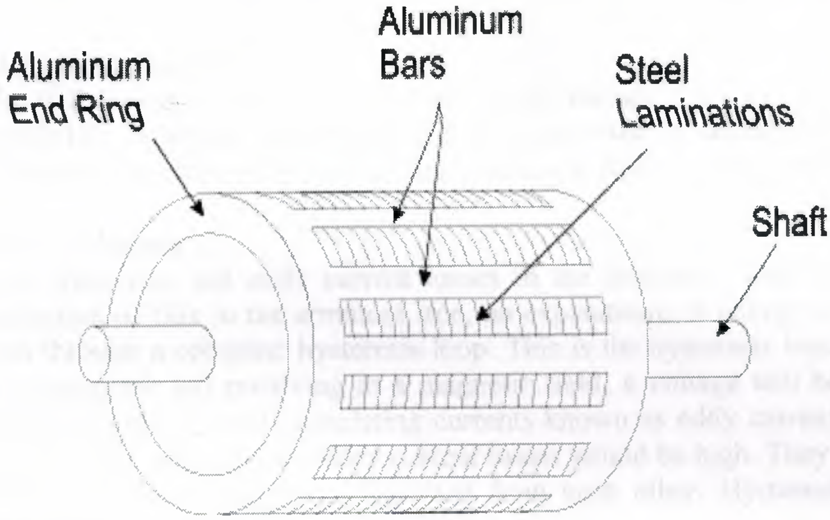

Figure 2..22 - Construction of an AC induction motor's rotor.

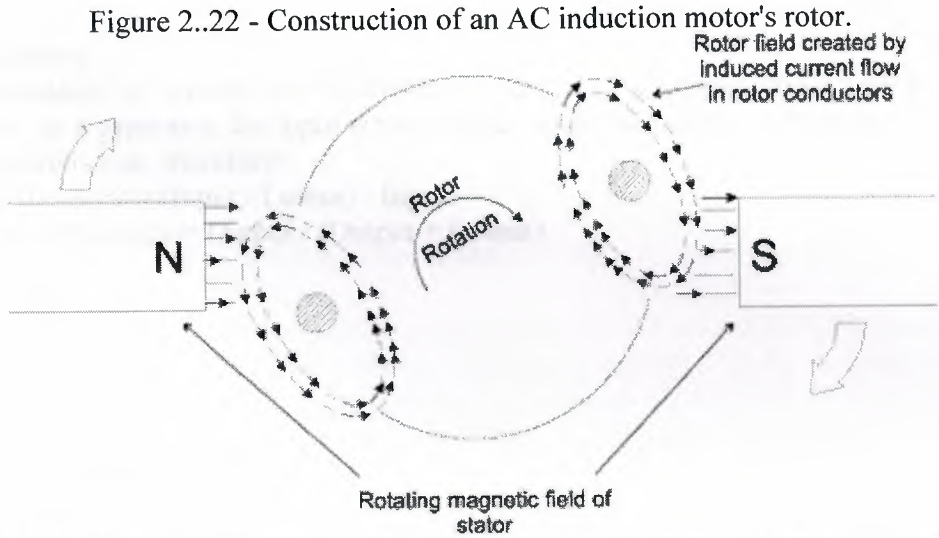

Figure 2.23 - How voltage is induced in the rotor, resulting in current flow in the rotor conductors.

2.4 Losses And Efficiency

2.4.1 Friction and Windage

These losses include bearing friction, brush friction, and windage. They are also known as mechanical losses. They are constant at a given speed but vary with changes in speed. Power losses due to friction increase as the square of the speed and those due to windage increase as the cube of the speed.

2.4.2 Armature Copper Losses

These are the I^2 R losses of the armature circuit, which includes the armature winding, commutator, and brushes. They vary directly with the resistance and as the square of the currents.

2.4.3 Field Copper Losses

These are the I^2 R losses of the field circuit which can include the shunt field winding, series field winding, interpole windings and any shunts used in connection with these windings. They vary directly with the resistance and as the square of the currents.

2.4.4 Core Losses

These are the hysteresis and eddy current losses in the armature. With the continual change of direction of flux in the armature iron, an expenditure of energy is required to carry the iron through a complete hysteresis loop. This is the hysteresis loss. Also since the iron is a conductor and revolving in a magnetic field, a voltage will be generated. This, in turn, will result in small circulating currents known as eddy currents. If a solid core were used for the armature, the eddy current losses would be high. They are reduced by using thin laminations, which are insulated from each other. Hysteresis and eddy current losses vary with flux density and speed.

2.5 Efficiency

For generations or motors, the efficiency is equal to the output divided by the input. However, in a generator, the input is mechanical while the output is electrical. In a motor the opposite is true, therefore:

Motor Efficiency = (Input - Losses) / Input

Generator Efficiency = Output / (Output + Losses)

Chapter III

Rewinding the Three-Phase Motor

Many separate steps are involved in rewinding are three-phase motor, as flows:
1. Taking data
2. Stripping the winding
3. Insulating the stator
4. Winding the coils
5. Placing the coils in the slots
6. Connecting the coils
7. Testing the winding
8. Varnishing and baking

3.1 Taking data

The following information is recorded:
1. Name plate data
2. Number of slots
3. Number of coils
4. Type of connection
5. Number of turns per coil
6. Size of coil
7. Pitch of coil
8. Kind of insulation
9. Size and kind wire

All these data must be recorded adequately enough to enable the repairman to rewind the motor without loss of time.

if the coils were wound groups or gang, as most small- to medium-sized motors are wound. All coils in three-phase motors have the same number of turns. It must be the number of coils is equal to the number of slots. These are counted and recorded. On some motors, there are half as many coils as slots; this type is a basket winding.

3.2 Stripping the Winding

During the process of stripping the winding, the remainder of the information necessary in taking data can be obtained. Before the wires are removed from the stator, type of connection must record. This can be only be obtained if one is familiar with methods of winding the three-phase motor and connection the phases and poles to one another. Three-phase motors are connected for single voltage, dual voltage, two speed, three speed, four speed, delta, star, series, parallel, and any combination thereof.

Large three-phase motors have open slots in the stator, as shown in figure 3.1. On these it is necessary to remove the slot wedges and pry out the oils one at a time. The small- and medium-sized stator has the semi closed slots shown in figure 3.2, and stripping the winding from these stators could be more difficult. Since the winding are usually hard-baked, some are encapsulated (covered with an epoxy compound for additional protection), it is necessary in most cases to char the insulating material on the winding by placing the stator in a burn-off oven. The temperature must be controlled. In many shops the winding is cut on one side of the stator and then pulled out from the other side after charring.

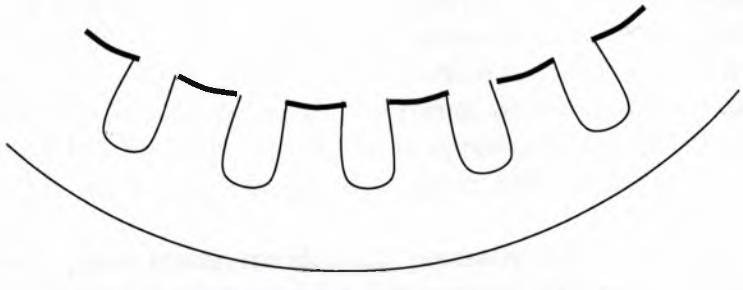

Figure 3.1 Open slots

Figure 3.2 Closed slots

One coil must be saved in order to provide the dimensions for the new coils. While stripping the winding, the pitch of the coils, the number of turns in each coil, the size of the coil, and the size and kind of wire are recorded.

It is very important to measure the end room of the coils before they are removed from the slots. This distance should be recorded and care taken that the new coils do not extend further than this distance from the ends of the slots.

3.3 Insulating the Stator

The stator insulation may be replaced with the same thickness and type used in the old winding. Many shops used cuffed insulation for the small- medium-sized motor, employing material applicable for the particular motor. Some shops use insulation without cuffs in roll in standard widths and can be cut to size with a paper-cutting machine and then shaped to fit the side of the slots. May shops use a small machine called an insulation former for this purpose.

3.4 Winding the Coils

Examination of a coil taken from a stator will reveal that it has six sides. This type is clad a diamond coil, and the winding is called a diamond-coil winding. However, coil of the smaller motor may have only four sides, two of which rounded. It should be understood that poly phase motor coils are always wound on forms, or coil winding heads as they are called, and then installed in the slots. Motors up to approximately 75 HP are wound with "mush"-type coils. This name has been given to these coils because they are wound in random rather in layers.

On the large three-phase motor, the slots are generally open, and the coils are usually completely taped. Cotton tape is often used for this purpose, although varnished cambric or fiberglass tape is preferable. Use tape combination with the class of insulation used in the motor.

On the medium-sized motor the slot generally are semi closed. The coils on the such motors cannot be completely tape because the turns of the coil must very often be fed into the slot one at a time. Only that part of coil which extends on either side of the slot is taped.

Most polyphase motors, with the exception of very large ones and those with open slots, use coils wound in group. The number of coils in each group will depend on the number of slots and number of poles. This practice of winding coils in groups is called group or gang winding. In group winding several coils are wound before the wire is cut. This saves time by elimination the necessity of connecting coils to one another or stubbing. . This type makes must-type coils for any three-phase motor up to 75 HP. The finished coils are easily removed simply by pulling the arms out slightly and turning them inward. This unlocks the coils which can then be slid off effortlessly. Group-wound coils are used almost exclusively on small and medium sizes three-phase motors.

3.5 Placing Coils In slots

The turns of the coils are inserted one by one into semi closed slots. The ends are sometimes taped after each coil is placed in to slot. Most shops do not tape coils for semi closed slots.

Use the flowing procedure: Spread or fan out the turns on one side of the coil, and hold the coil at an angle so that all the turns can be fed into slot. Make sure that each turns is placed inside the insulation. Sometimes the wires are placed between the insulation and the iron core by mistake, and a group result.

Pull the side of the coil thought the slot until all turns are in the slot. The other side of the coil remains free. Note that coil side occupies half a slot.

Continue by placing one side of the second coil in the slot beyond the first. Flowing coils are fitted in the same manner until the slots of a complete coil pitch hold one side of each coil. The second side of each coil is left out until the bottom half of a slot is occupied by a coil side. The second side of each coil is then fitted on top of the firs side of a coil several slots away, according to the pitch of the coil. When coils are wound in groups, the winder always works with a complete group of coils at a time, placing them into the slots as explained above.

In this method one side of each coil is the bottom half of a slot and the other side of the coil is in the top half of another slot several slots away, depending on the pitch of the coil. The number of coils of which the top side is left out is usually one or two more than the coil pitch, and they are not put into slots until the stator is nearly completed. Make certain that each coil side extends beyond the slot at both ends and does not press against the iron core at the corners.

Before inserting the second side of each coil, it is necessary to insulate it from the coil already in to slot.

To insulate between the coil sides in the same slot, follow the procedure: for both open and semi closed slots. A creased separator or insulation of the proper width and thickness is used to insulate between top and bottom coils sides in the slot. Slide a separator over the bottom sides of the coil in the slot before installing the top side. It should extend about 1.5cm beyond the slot ends. When the top side is placed into the slot, slip a wooden or formed fiber wedge (round or square) over the top coil. This should extend about a 30mm beyond the slot ends. As each group of coils is placed in the slots, phase insulation must be used between groups. Varnished or glass cambric or canvas is used for this purpose. Phase insulation between groups. Heavy separators are placed between coils in the slot and U-shaped insulators over the top coils. Slot wedges are inserted to hold the coils securely in place. Note also that coils are wound with three wires in parallel.

3.6 Connection the Three-phase Motor

All three-phase motors are wound with a number of coils, usually as many coils as slots. These coils are so connected as to produce three separate windings called phases, and each of which must have the same number of coils. The number of coils in each phase must be one-third the total numbers of coils in the stator.

Therefore, if a three-phase motor has 36 coils, each phase will have 12 coils. These phases are usually called phase R, phase S, and phase T.

Rule 1. To find number of coils in each phase, divide the total number of coils in the motor by the number of phases.

Rule 2. To find the number of coils in each pole, divide the total number of coils by the number of poles.

Rule 3. A simple method to determine the number of groups is to multiply the number of poles by the number of phases. For example, 4 pole X 3 phase = 12 groups, or groups=polseXphase.

If the number of groups is known, it is easy to determine the number of coils in each group.

Connection type of three-phase motor

1. Star(wye) connection
2. Delta connection
3. Parallel connection

3.7 Troubleshooting

The there-phase motors should be given tests for the following defects after a repair or winding job: grounds, opens, shorts and reverses.

Chapter IV

Alternating-current motor control

4.1.1 Contactors

Contactor is illustrated in figure 4.1 . A contactor, which a motor connects directly across line. Normally contactor has three normally open main contacts which when closed connect the directly on the line. It also has a magnetic holding coil, which closes the main contacts upon being energized, and also closes a normally open auxiliary or maintaining contact to maintain the current in the holding coil. It is obvious that any size of magnetic switch can be operated just by sending a small current through the coil.

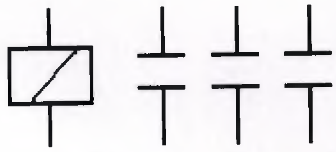

Figure 4.1 Contactor symbol [1]

The holding coil on an a-c magnetic is exited by a pulsating current, and therefore its pull is not continuous, but rather alternates according to the frequency of the current. This tends to cause chattering; to overcome this condition, the core of the magnet is equipped with a shading coil, which produces an-out-of-phase flux. The shading coil is a small, single-turn copper coil, which is embedded around a portion of the core tip. The current induced in this coil is sufficient for the magnet to retain the contactor during the reversal of current.

4.1.2 Overload Relays

Nearly all-magnetic starters are equipped with an overload device to protect the motor from excessive current. The thermal overload relay may be bimetallic type.

A thermal relay is illustrated in figure 4.2 . This bimetallic type of relay consist of small heater coil or strip which is connected in series with the line and which generates heat by virtue of the current flowing through it; the amount of heat generated depend on the current flow in the line. Mounted adjacent to, or directly inside, the coil is a strip formed of two metals. This is fixed at one end, the other end being free to move. The two metals have different degrees expansion, and the strip will bend when heated. The free end normally keeps two contacts of the control circuit closed. When an overload occurs, the heater heats the thermostatic bimetal so that it will bend and separate the two contacts, thereby opening the holding-coil circuit and stopping the motor. The bimetallic type of overload relay is usually designed with a feature, which permits automatic resetting, although it is also designed for manual resetting. Some overload relays are ambient-compensated to provide maximum protection where the temperature surrounding the relay differs from the temperature surrounding the motor. A number of manufactures feature a bimetallic overload relay, which can be converted from manual to automatic by positioning a reset selector lever. Automatic reset is desirable where control is not readily accessible or regularly attended. Some overload relays are trip free. This means that the starter contacts cannot be held closed during an overload and cause damage to the motor.

Figure 4.2 Overload relay symbol and photograph [2]

4.1.3 Time Relays

Time relay is illustrated in figure 4.3 . A device whit either mechanically or solid state output contacts that perform a timing function upon energization or control signal

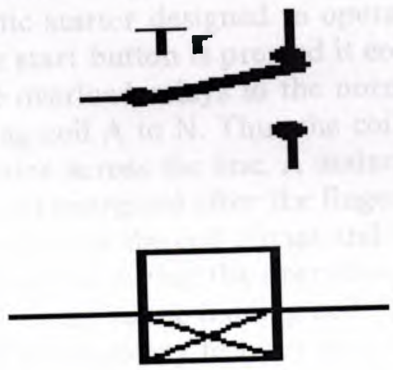

Figure 4.3 Time relay symbol and photograph [5]

4.1.4 Pushbutton Stations

Magnetic starters are controlled by means of pushbutton stations. The most common station has START and STOP buttons, as shown in figure 4.4 when the start button is pressed, two normally open contact are closed; and when stop button pressed, two normally closed contact are opened. Spring action returns the button to their original position when finger pressure is removed. To operate a magnetic switch by a START-STOP station, it is necessary to connect the holding coil to the station contacts so that when the start button is pressed, the coil will become energized; and when the stop button is pressed the holding coil circuit is opened.

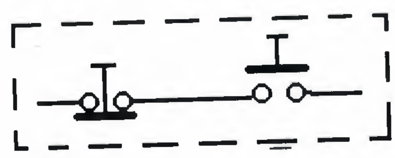

Figure 4.4. a Pushbutton station, START and STOP symbol and photograph

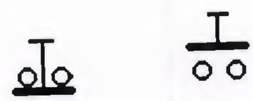

Figure 4.4. b START and STOP symbol and photograph

4.2 Starters

4.2.1 Dol starter

A starter, which connects a motor directly, the line is called a full-voltage starter. (dol starter) If this starter is operated magnetically, it is called a magnetic full-voltage starter. A magnetic starter designed to operate a three-phase motor is shown in figure 4.5 . When the start button is pressed it completes the circuit from L normally closed contact of the overload relays to the normally closed contact of the stop button through the holding coil A to N. Thus the coil is energized and it closes contact m and connects the motor across the line. A maintaining circuit is completed at point 2 to keep the holding coil energized after the finger is removed from the start button. Pressing the stop button opens the coil circuit and causes all contacts to open. If a prolonged overload should occur during the operation of the motor, the overload relay contacts will open and de-energize the holding coil. If an overload condition has caused the relay to trip, it will be necessary to reset the relay contact by hand before the motor can be restarted.

Figure 4.5 Dol starter photograph [4]

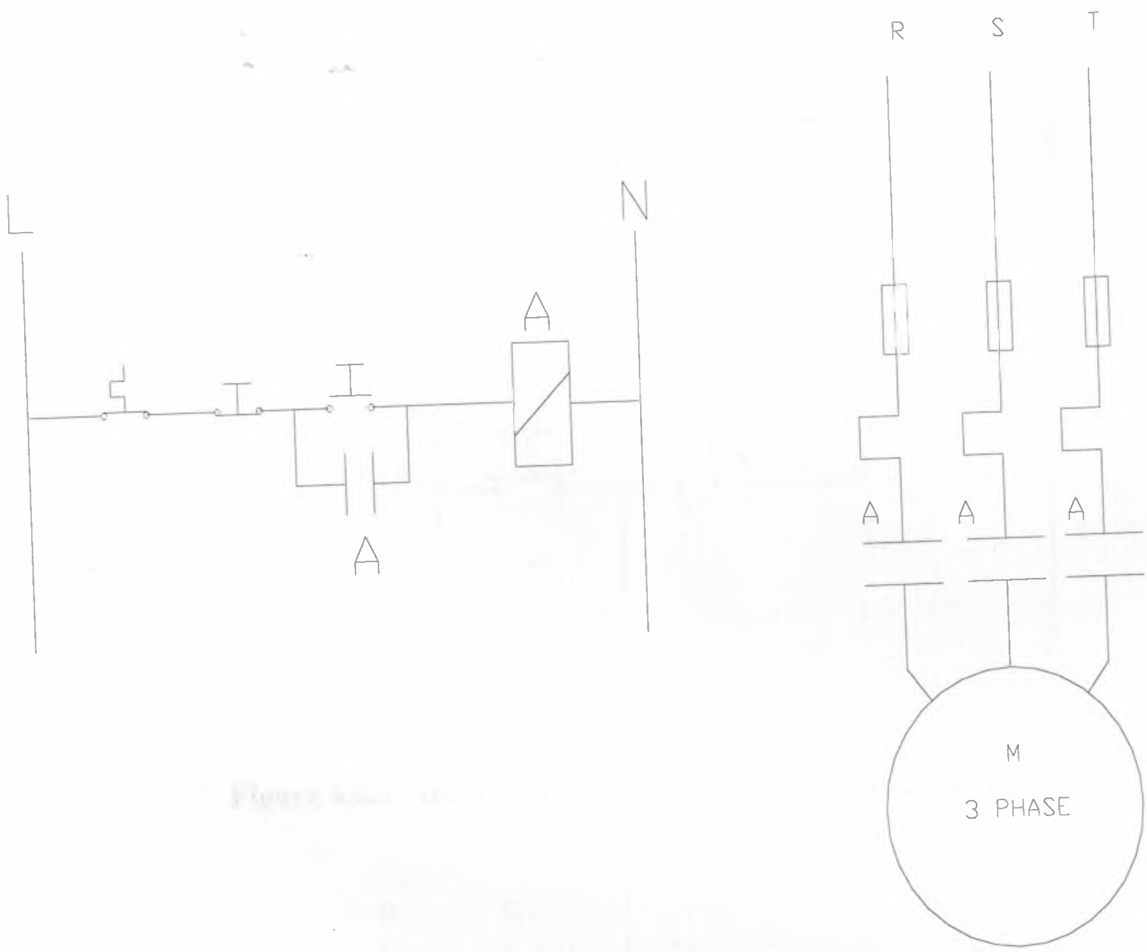

Figure 4.5 Dol starter control, power circuit

4.2.2 Full-Voltage Reversing Starter

The starter shown thus far are designed to operate the motor in one direction, ethier clokwise or counterclokwise. If it is necessary to reverse the motor , its connection must be changed.

Some application such as conveyors, hoists, machine tools, elevators, and others, require a motor starter that can reverse the motor when a botton is pressed. Thus, two od the line leads can be interchanged to reverse a three-phase motor by means of a magna etic reversing switch. The circuit is given in figure 4.6.a Note that it is necassary to use a stop-forvard-reverse station, with three butons, and that two operationg coils are used, one for forward rotation and the other for reverse rotation.

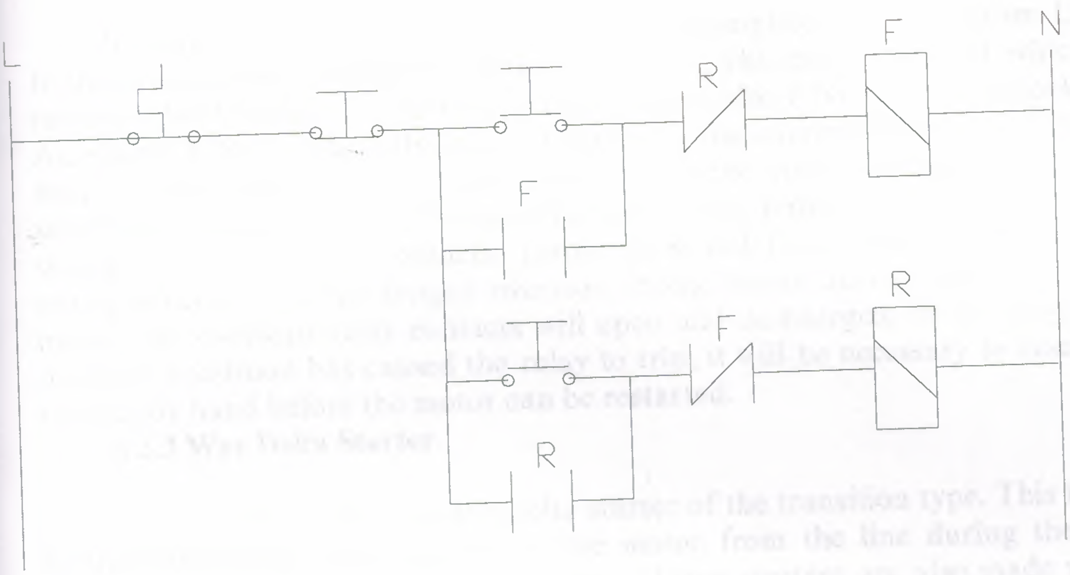

Figure 4.6.a Full-Voltage Reversing Starter control circuit

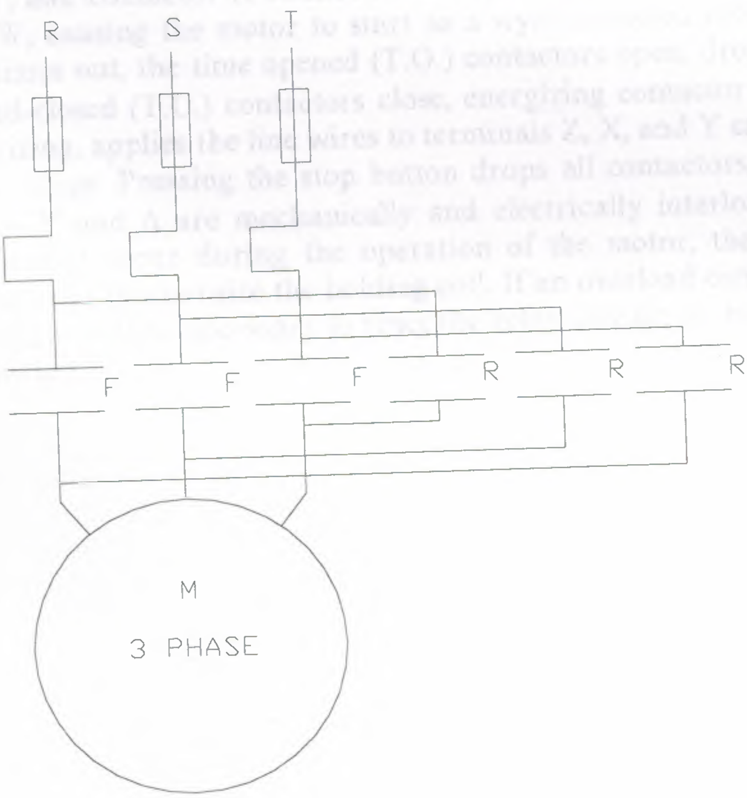

Figure 4.6.b Full-Voltage Reversing Starter power circuit

Two set of main and auxilary contacs are used. One set closes when forvard operation is desired; the other set closes for reverse rotation. These contacts are connected in such a manner that two line wires feeding the motor are interchabged when reverse the contact close.

In opretion, pressing the forward button completes a circuit from L, the stop button, the forward button, the farward coil to N. This engizes the coil, whic closes the contacts for forward operation of the motor, ans also F NC contact its locked R coil. Auxiliary F NO contact also close, maintining the current through coil F when the button is released. Pressing stop button opens the circuit throgh the forward coil which releasses all contact. Pressure on the reverse button energizes the reverse coil which closes the reverse contacts. Terminals R and T are now interchanged and the motor reverses. If a prolonged overload should occur during the operation of the motor, the overload relay contacts will open and de-energize the holding coil. If an overload condition has caused the relay to trip, it will be necessary to reset the relay contact by hand before the motor can be restarted.

4.2.3 Wye Delta Starter

Figure 4.7.a shows a wye delta starter of the transition type. This term refers to the momentary disconnection of the motor from the line during the period of changeover from star to delta connection. These starters are also made with closed transition. Closed transition is accomplished by placing resistors at the disconnecting point during the transition, thereby keeping the circuit closed. The operation of the open transition type of wye-delta starters is as follows; pressing the start button energizes contactors A, Y and time delay TR. The Y contactor connects motor terminals Z, X and Y, and contactor A connects the incoming power lines to motor terminals U, V, and W, causing the motor to start as a wye-connected motor. After the time-delay relay times out, the time opened (T.O.) contactors open, dropping out contactor Y, the timed-closed (T.C.) contactors close, energizing contactor Δ. The Δ contactor, upon energizing, applies the line wires to terminals Z, X, and Y causing the motor to run at full voltage. Pressing the stop button drops all contactors, stopping the motor. Contactors Y and Δ are mechanically and electrically interlocked. If a prolonged overload should occur during the operation of the motor, the overload relay contacts will open and de-energize the holding coil. If an overload condition has caused the relay to trip, it will be necessary to reset the relay contact by hand before the motor can be restarted.

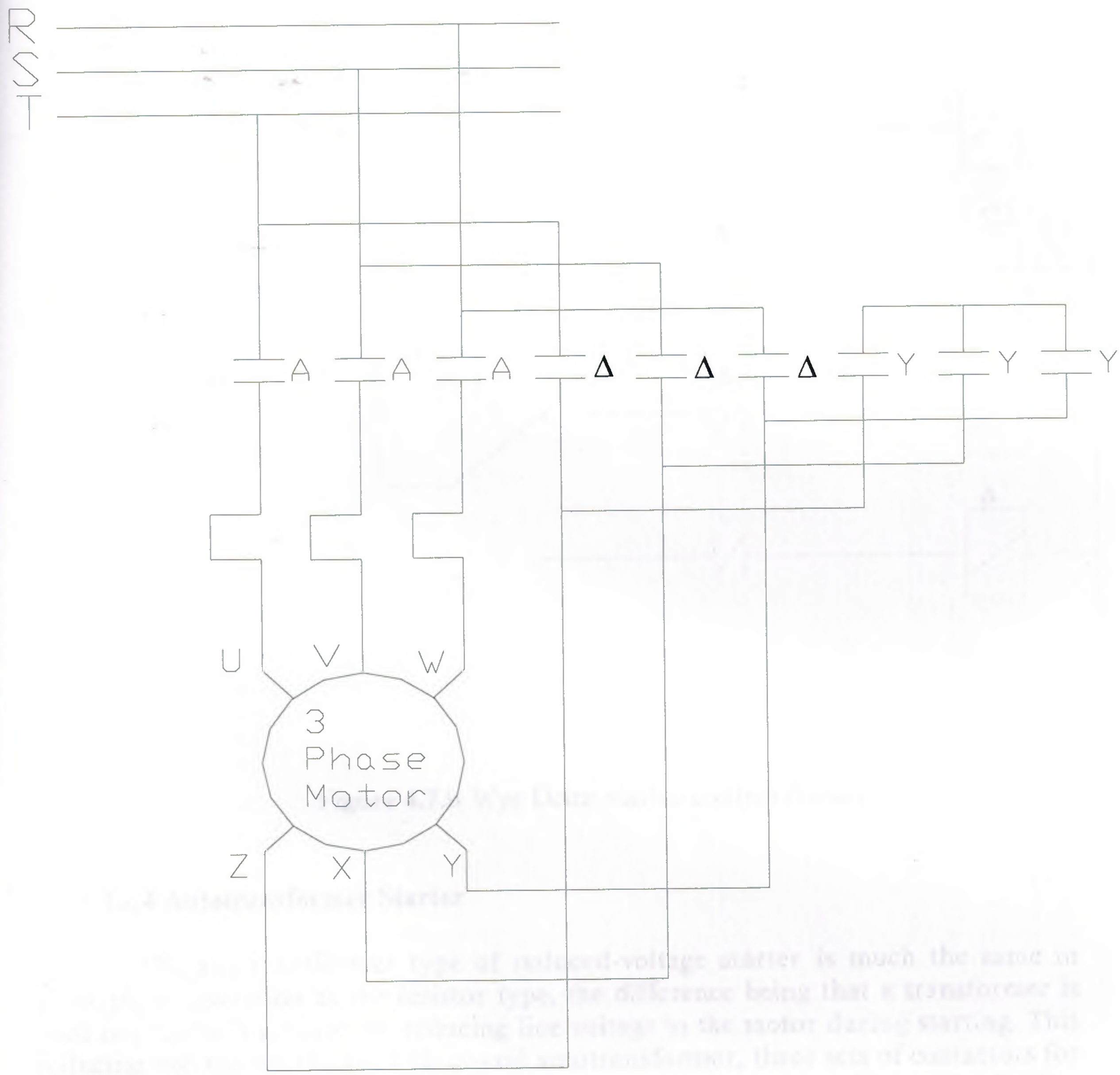

Figure 4.7.a Wye Delta starter power circuit

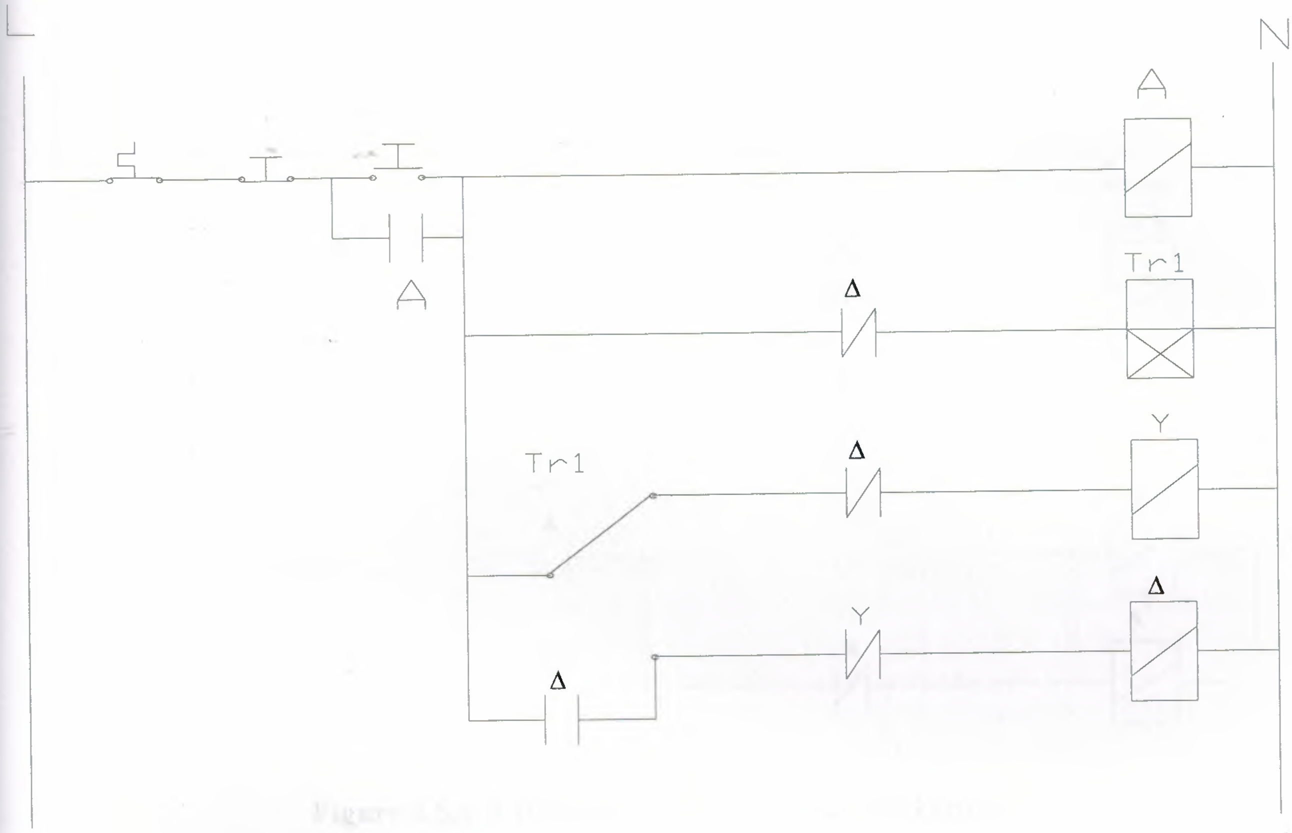

Figure 4.7.b Wye Delta starter control circuit

4.2.4 Autotransformer Starter

The autotransformer type of reduced-voltage starter is much the same in principle of operation as the resistor type, the difference being that a transformer is used in place of a resistor for reducing line voltage to the motor during starting. This reducing-voltage starter has a three-coil autotransformer, three sets of contactors for the start, run, and wye contacts, a pneumatic timing relay, bimetallic overload relay, and an overtemperature unit for the protection of the autotransformer against overheating. The run and wye contactors are mechanically and electrically interlocked.

The operation of this starter (see figure 4.8.a) is as follow; Pressing the start button energizes the K, Δ and Y contactor coils. The contactors for Δ and Y close, placing the motor on reduced voltage. The Y contactors connect the three coil ands of the autotransformers together to from the star point. After a present time interval, the pneumatic timing relay opens the Δ and Y contactors. The A contactor are closed, placing the motor directly across the line. The starter is mechanically and electrically interlocked. Pressing the stop button de-energizes all contactors and disconnects the motor from line. If a prolonged overload should occur during the operation of the motor, the overload relay contacts will open and de-energize the holding coil. If an overload condition has caused the relay to trip, it will be necessary to reset the relay contact by hand before the motor can be restarted.

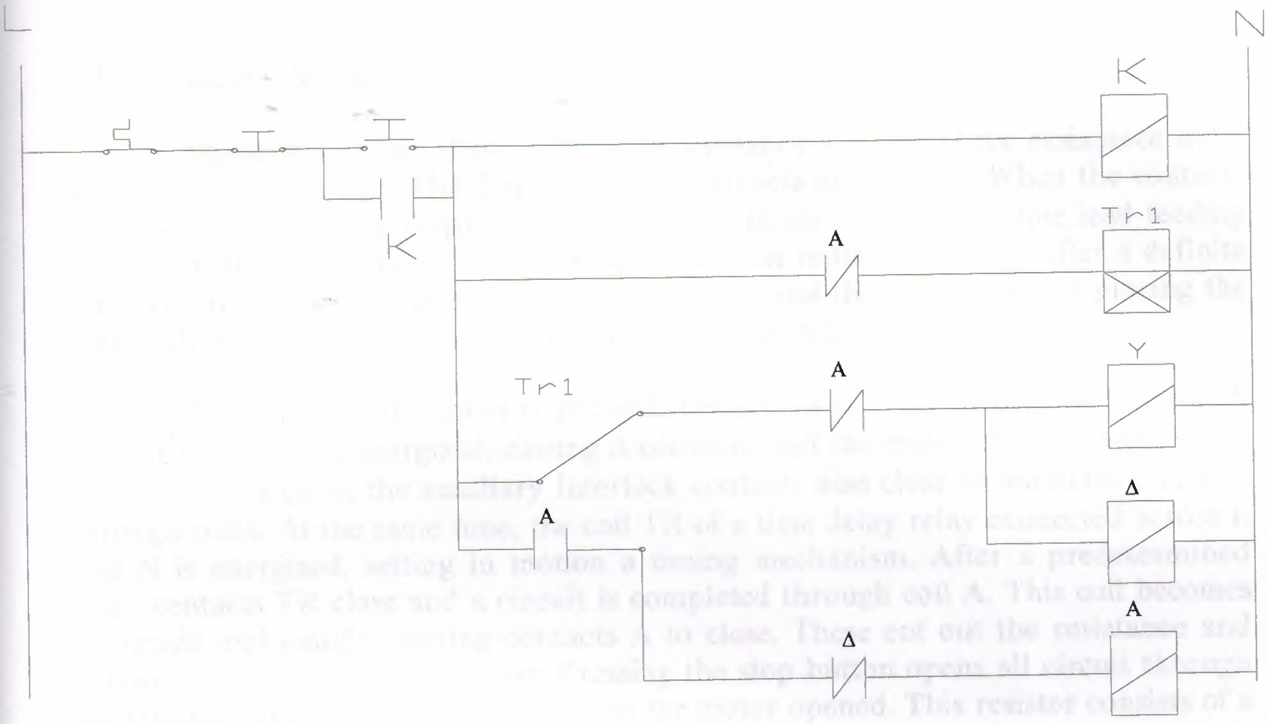

Figure 4.8.a Autotransformer starter control circuit

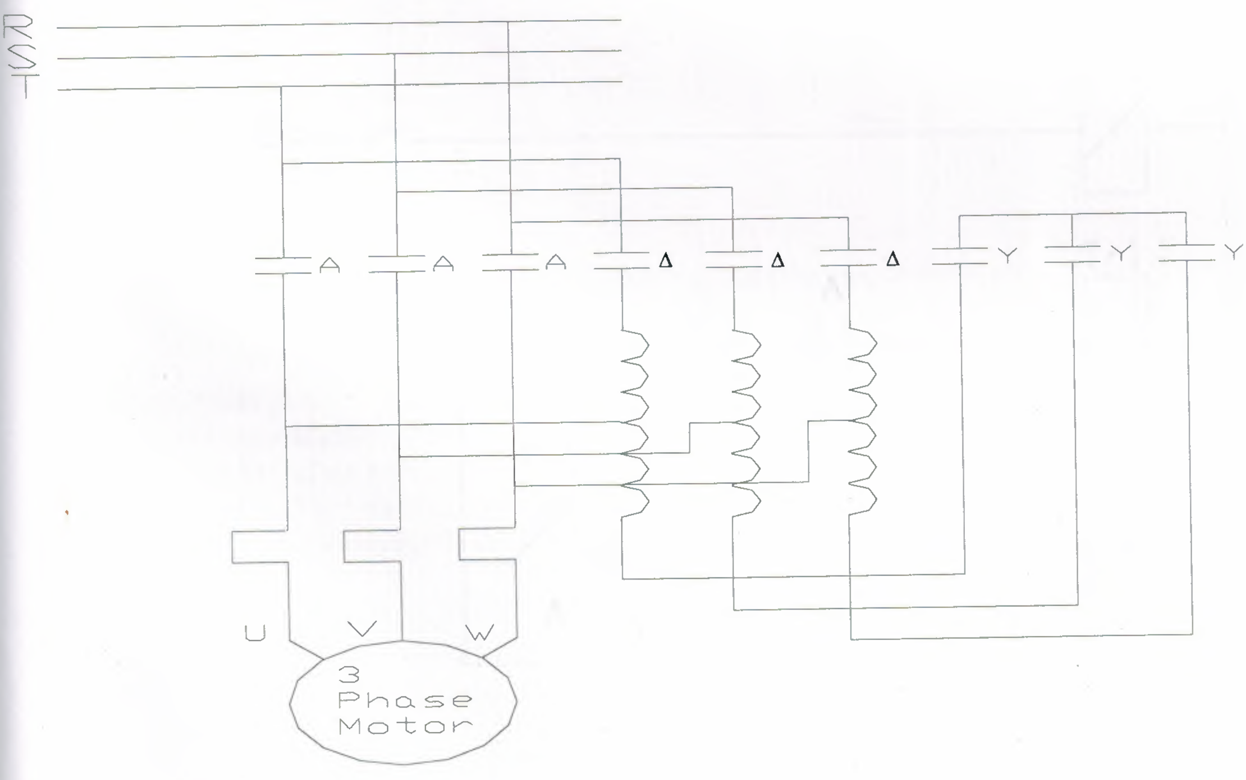

Figure 4.8.b Autotransformer starter power circuit

4.2.5 Resistance Starter

Figure 4.9.a is an illustration of a resistance starter. Three resistance units are used in this starter. The diagram shows two sets of contacts. When the contacts marked Δ are closed, a resistance unit is placed in series whit each line lead feeding the motor, thereby causing it to start slowly and on reduced voltage. After a definite time, another set of contacts, A, also close, cutting out the resistance and placing the motor directly across the line. Its operation is as follows;

When the start button is pressed, the circuit is completed from L through coil Δ to N, coil Δ is energized, closing Δ contacts, and the motor starts slowly. When the Δ contacts close, the auxiliary interlock contacts also close to maintain a circuit through coilΔ. At the same time, the coil TR of a time delay relay connected across L and N is energized, setting in motion a timing mechanism. After a predetermined time, contacts TR close and a circuit is completed through coil A. This coil becomes energized and causes running contacts A to close. These cut out the resistance and connect the motor across the line. Pressing the stop button opens all circuit through the holding coils, and thus all contacts to the motor opened. This resistor consists of a three-pole start contactor, s three-pole run contactor, a pneumatic timing relay, single step resistor, and bimetallic overload relays.

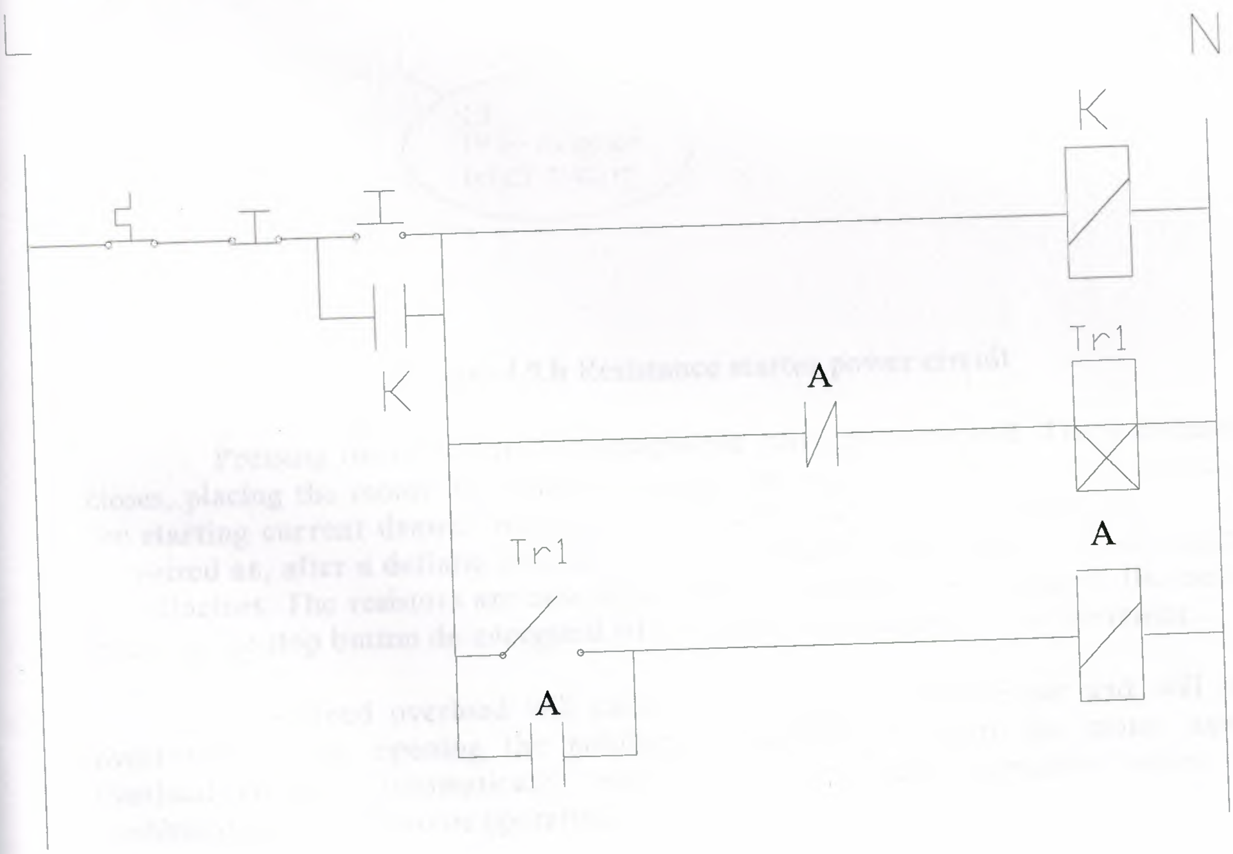

Figure 4.9.a Resistance starter control circuit

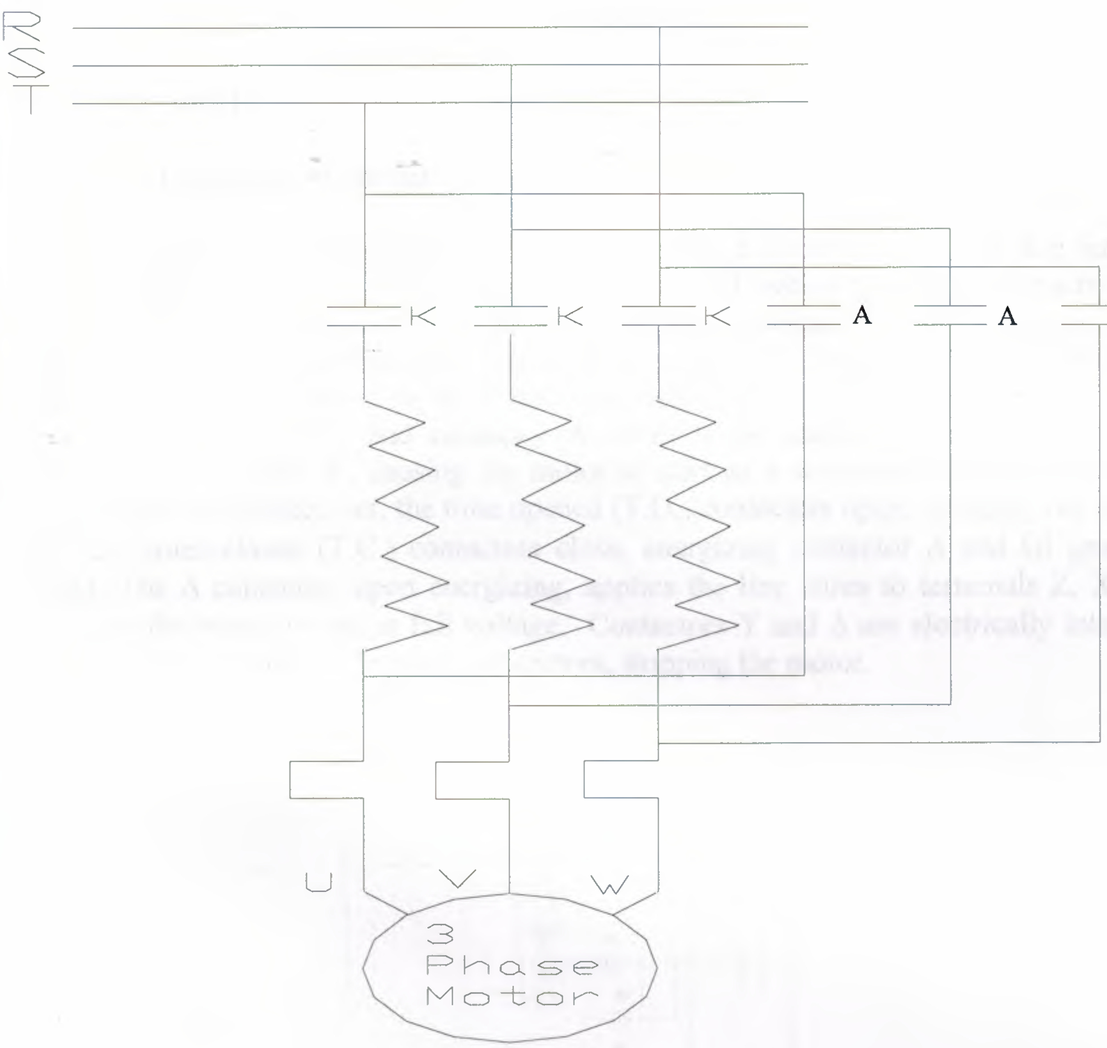

Figure 4.9.b Resistance starter power circuit

Pressing the start button energizes the start contactor coil. The Δ contactor closes, placing the motor on reduced voltage. The resistor in series with line reduce the starting current drawn from the line. At the same time the timing relay coil is energized an, after a definite time delay, the A contactor coil is energized, closing the A contactors. The resistors are now bypassed, thus sending full voltage to the motor. Pressing the stop button de-energized all contactors and stop power to the motor.

A sustained overload will cause the heaters to become hot and will trip overload contacts, opening the holding-coil circuits. To start the motor again, overload contacts automatically reset or must be reset manually before the pushbutton circuits become operative.

Chapter V

Project

5.1 Operation of circuit

In operation, pressing the left button completes a circuit from L, the stop button, the left button, the Ml coil to N. This energizes the coil, whice closes the contacts for left operation of the motor, and also Ml NC contact its locked Mr coil. Auxiliary Ml NO contact also close, maintining the current through coil Ml. when the Ml NO contact close released energizes contactors A, Y and time delay Tr1. The Y contactor connects motor terminals Z, X and Y, and contactor A connects the incoming power lines to motor terminals U, V, and W, causing the motor to start as a wye-connected motor. After the time-delay relay times out, the time opened (T.O.) contactors open, dropping out contactor Y, the timed-closed (T.C.) contactors close, energizing contactor Δ and Gl green lamp light. The Δ contactor, upon energizing, applies the line wires to terminals Z, X, and Y causing the motor to run at full voltage. Contactors Y and Δ are electrically interlocked. Pressing the stop button drops all contactors, stopping the motor.

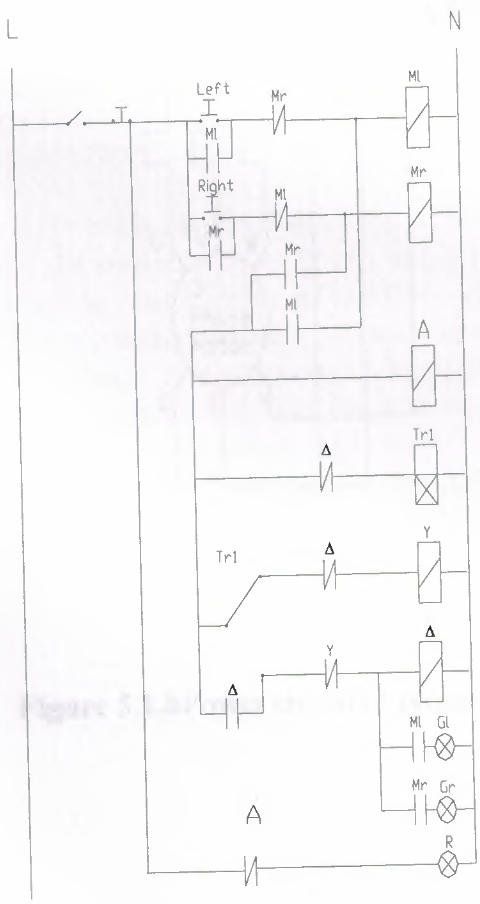

Figure 5.1.a Control circuit of project

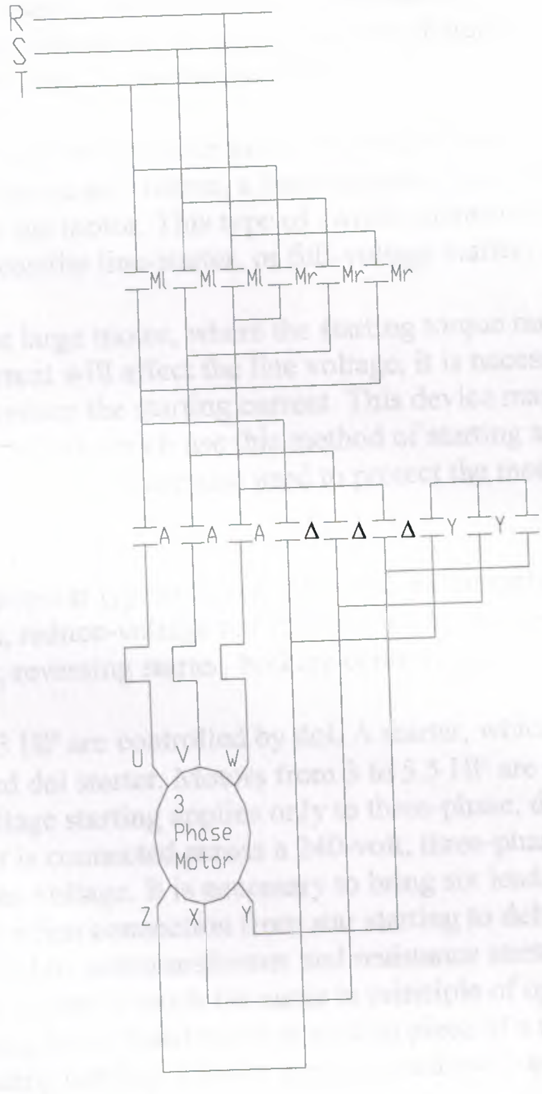

Figure 5.1.b Power circuit of project

CONCLUSION

If an a-c motor is started on full voltage, it will draw from two to six times its normal running current. Because the motor is constructed to withstand the shock of starting, no harm will be caused by this excessive flow of current. However, on very large motors, it is generally desirable to take some measure to reduce the starting current; otherwise, damage may be done the machinery driven by the motor, and line disturbances may be created that affect the operation of other motors on the same line.

For the small motor, or where the load can stand the shock of starting and no objectionable line disturbances are created, a hand-operated or an automatic starting switch can be used for control of the motor. This type of switch connects the motor directly across the line and called an across-the line-starter, or full-voltage starter.

In the case of the large motor, where the starting torque must develop gradually, or where the high initial current will affect the line voltage, it is necessary to insert in line same device which will reduce the starting current. This device may be a resistance unit or an autotransformer. Controllers which use this method of starting a motor are called reduce-voltage starters. Controllers are also used to protect the motor from overheating and overloading.

The following popular types of controllers will be described: pushbutton switch starters for small motors, reduce-voltage resistance starters, wye-delta starters, and autotransformers starter, reversing starter, braking controllers.

Motors from 0 to 3 HP are controlled by dol. A starter, which connects a motor directly, the line is called dol starter. Motors from 3 to 5.5 HP are controlled by Y-Δ starter. This method reduce-voltage starting applies only to three-phase, delta-connected motors. If a delta-connected motor is connected across a 240-volt, three-phase line, each phase will receive 58 percent of line voltage. It is necessary to bring six lead out of the motor so that they can be interchange when connection from star starting to delta running. Motors big than 5.5 Hp are controlled by autotransformer and resistance starter. The autotransformer type of reduced-voltage starter is much the same in principle of operation as the resistor type, the difference being that a transformer is used in place of a resistor for reducing line voltage to the motor during starting. Motors are protected overheat or overload by overload relay.

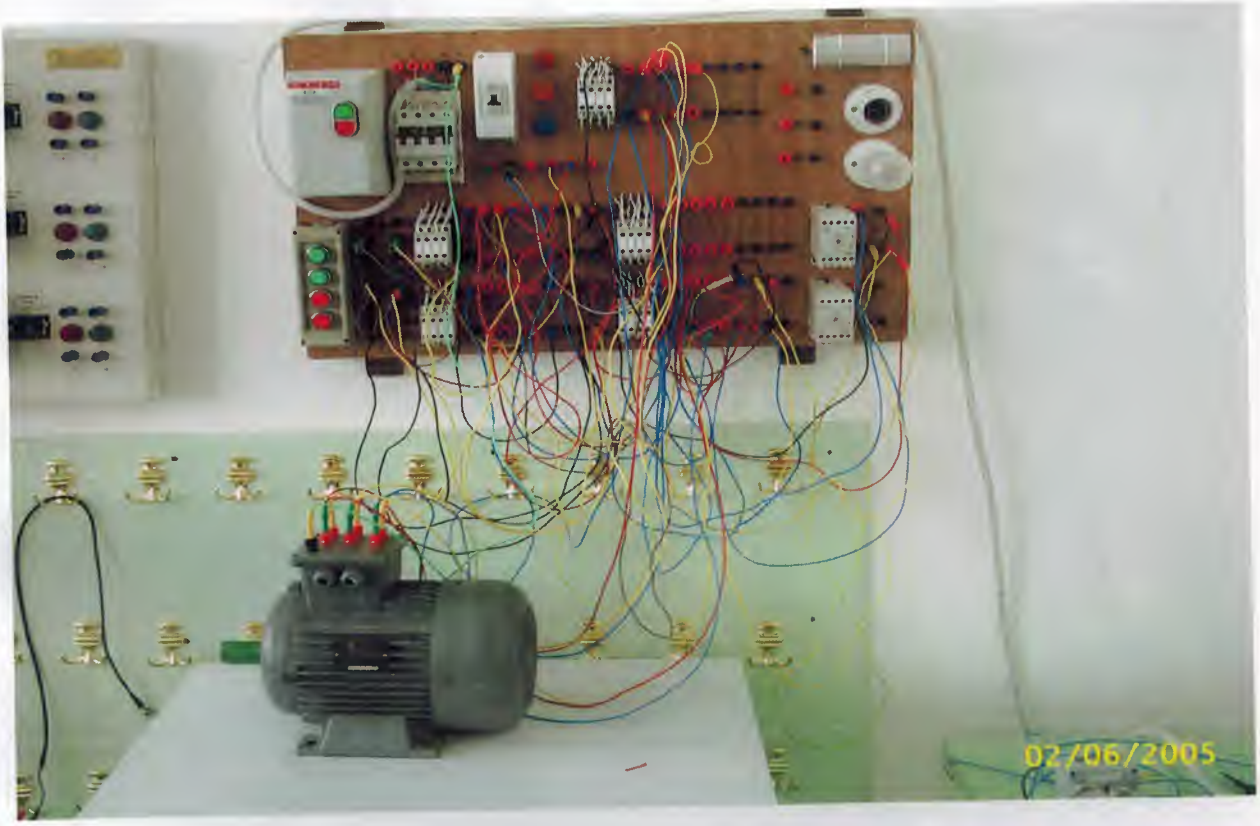

FİGURE 5.2 Practical part of circuit