



**NEAR EAST UNIVERSITY**

**Faculty of Engineering**

**Department of Electrical and Electronic  
Engineering**

**MOTOR CONTROL**

**Graduation Project  
EE - 400**

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# CONTENTS

<b>ACKNOWLEDGMENT</b>	<b>i</b>
<b>ABSTRACT</b>	<b>ii</b>
<b>1. Basic Motor Theory</b>	<b>1</b>
1.1. Introduction	1
1.2. Magnetism	1
1.3. Magnetic Propulsion Within A Motor	3
1.4. AC Current	4
<b>2. MOTORS</b>	<b>6</b>
2.1. Main Part The Motor	6
2.1.1. Rotor	6
2.1.2. Stator	6
2.1.3. The End plates (End Shields or Brackets)	6
2.2. TYPE THE MOTOR	7
2.2.1. Single phase	7
i. Split phase motors	7
i.1. The Centrifugal Switch	8
i.2. Operation of the Split-Phase Motor	8
ii. Capacitor Motors	8
ii.1. The Capacitor	9
ii.1.1. The Oil-Filled Capacitor	10
ii.1.2. The Electrolytic Capacitor	10
ii.2. Capacity	10
ii.3. Operation	11

iii. Repulsion-Type Motor	12
iii.1. Construction	13
iii.1.1. The Repulsion-Start Induction Motor	14
iii.1.2. The Repulsion Motor	14
iii.1.3. The Repulsion-Induction Motor	14
2.3. Three-Phase Motors	15
2.3.1. Construction of Three-Phase Motor	15
2.3.2. Basic Three phase AC Motor Operation	16
2.4 Losses And Efficiency	21
2.4.1. Friction and Windage	21
2.4.2. Armature Copper Losses	21
2.4.3. Field Copper Losses	21
2.4.4. Core Losses	21
2.5. Efficiency	21
<b>3. Rewinding the Three-Phase Motor</b>	<b>22</b>
3.1. Taking data	22
3.2. Stripping the Winding	22
3.3. Insulating the Stator	23
3.4. Winding the Coils	24
3.5. Placing Coils In slots	24
3.6. Connection the Three-phase Motor	25
3.7. Troubleshooting	25
<b>4. Alternating-current motor control</b>	<b>26</b>
4.1.1. Contactors	26
4.1.2. Overload Relays	26
4.1.3. Time Relays	27

4.1.4. Pushbutton Stations	28
4.1.5. Limit Switch	29
4.1.6. Transformer	30
4.1.7. The Bridge Rectifier	31
4.2. Starters	32
4.2.1. Dol starter	32
4.2.2. Full-Voltage Reversing Starter	34
4.2.3. Quick-Stop AC Starters	36
4.2.4. Wye Delta Starter	38
4.2.5. Autotransformer Starter	40
4.2.6. Resistance Starter	42
<b>5. Project</b>	<b>45</b>
5.1. Operation of circuit	45
<hr/>	
<b>CONCLUSION</b>	<b>49</b>
<b>REFERENCES</b>	<b>50</b>

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## **ABSTRACT**

Today's civilized world 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. When stopping we can stop motors by low DC voltage.

# **1 Chapter**

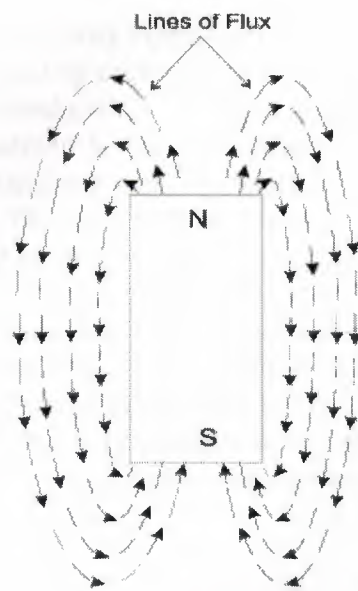
## **Basic Motor Theory**

### **1.1 Introduction**

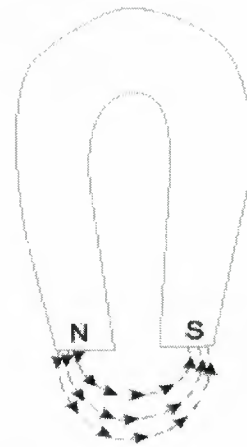
It has been said that if the Ancient Romans, with their advanced civilization and knowledge of the sciences, had been able to develop a steam motor, the course of history would have been much different. The development of the electric motor in modern times has indicated the truth in this theory. The 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, your fingers will point in the direction of the magnetic field.

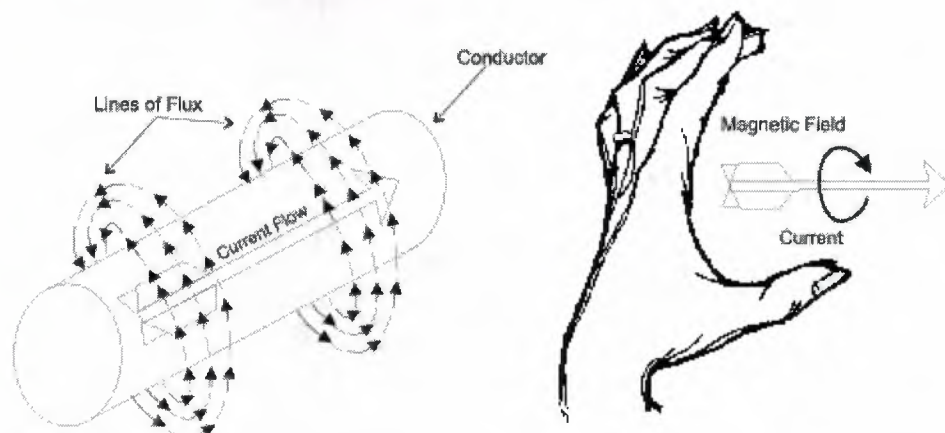


**Bar Magnet**

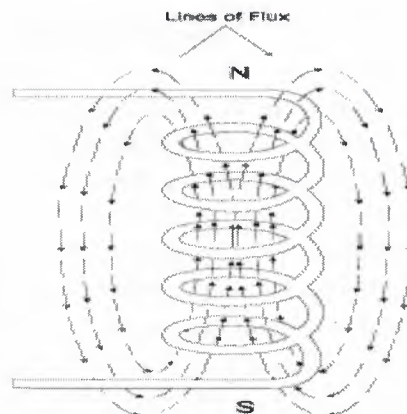


**Horseshoe Magnet**

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



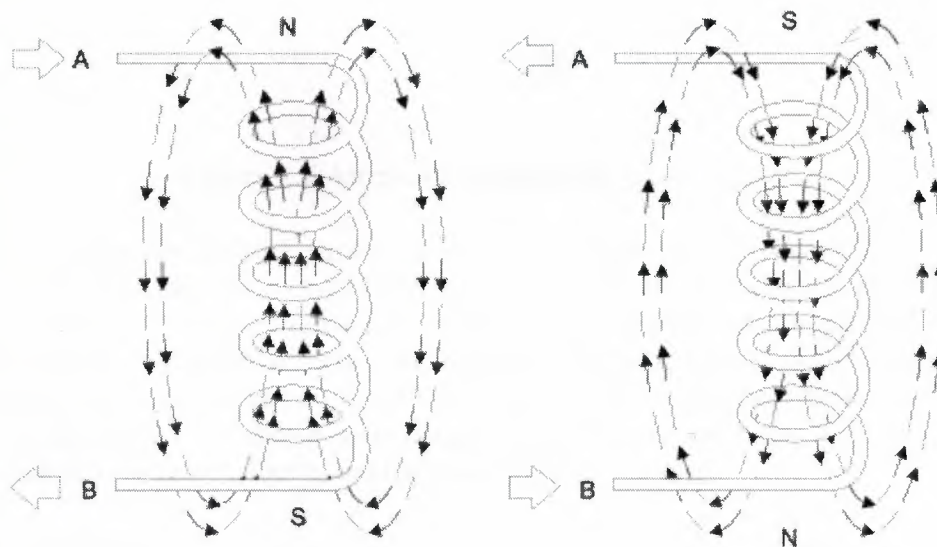
**Figure 1.2** - The flow of electrical current in a conductor sets up concentric lines of magnetic flux around the conductor.



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



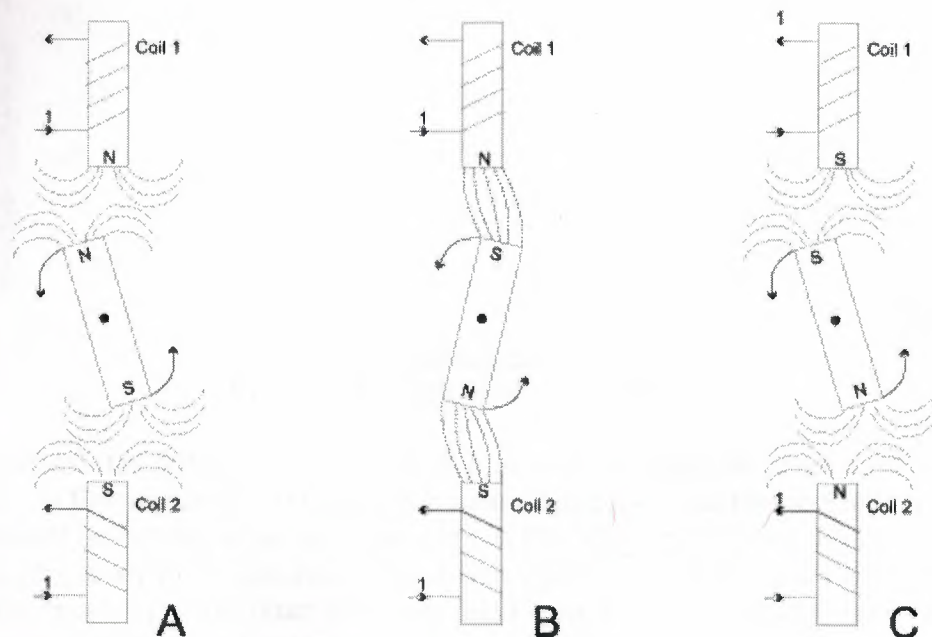
When the wire is shaped into a coil as shown in Figure 1.3, all the individual flux lines produced by each section of wire join together to form one large magnetic field around the total coil. As with the permanent magnet, these flux lines leave the north of the coil and re-enter the coil at its south 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)

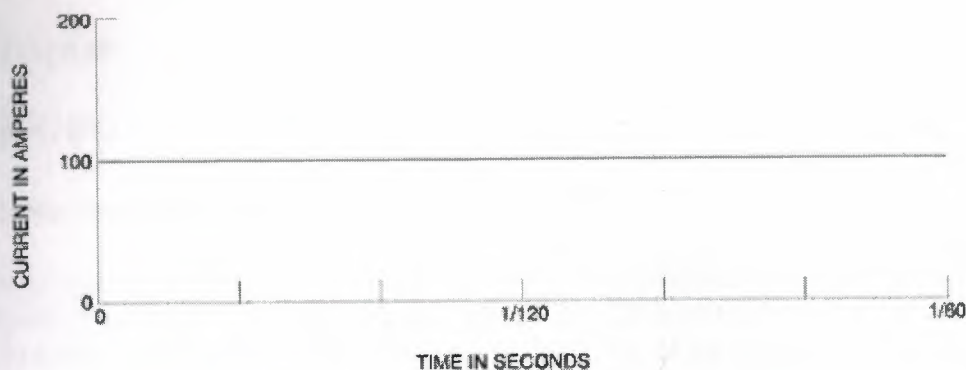


**Figure 1.5** Attraction between the unlike poles

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.

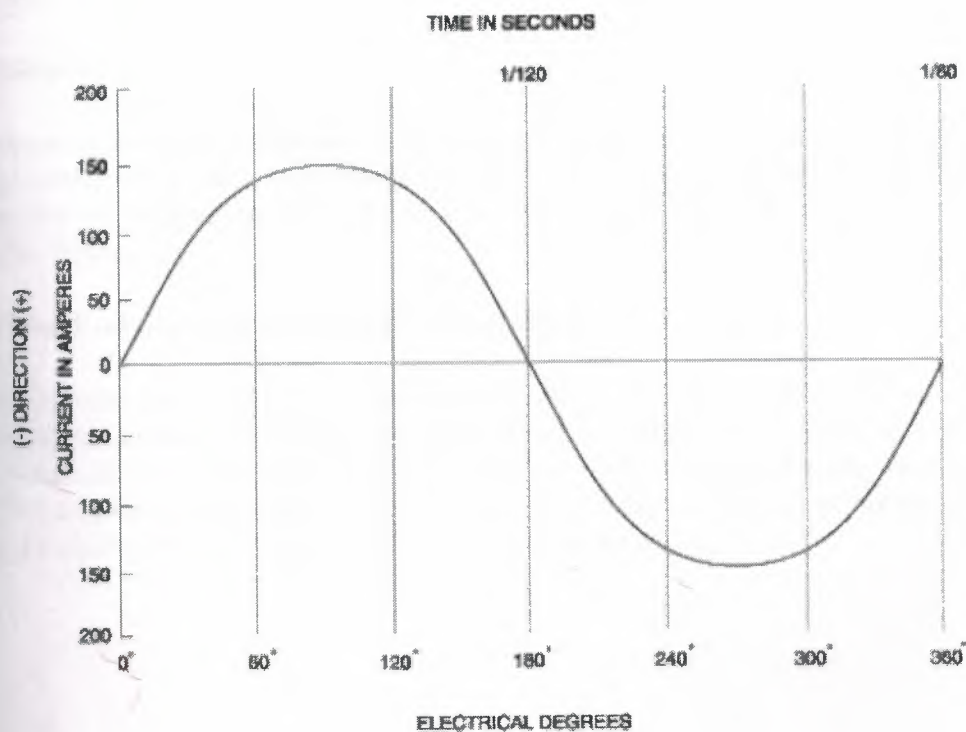
#### 1.4 AC Current

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.**



## **2 Chapter**

### **MOTORS**

#### **2.1. Main Part The Motor**

Motor is a device which converts 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 bolts. 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 copper 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

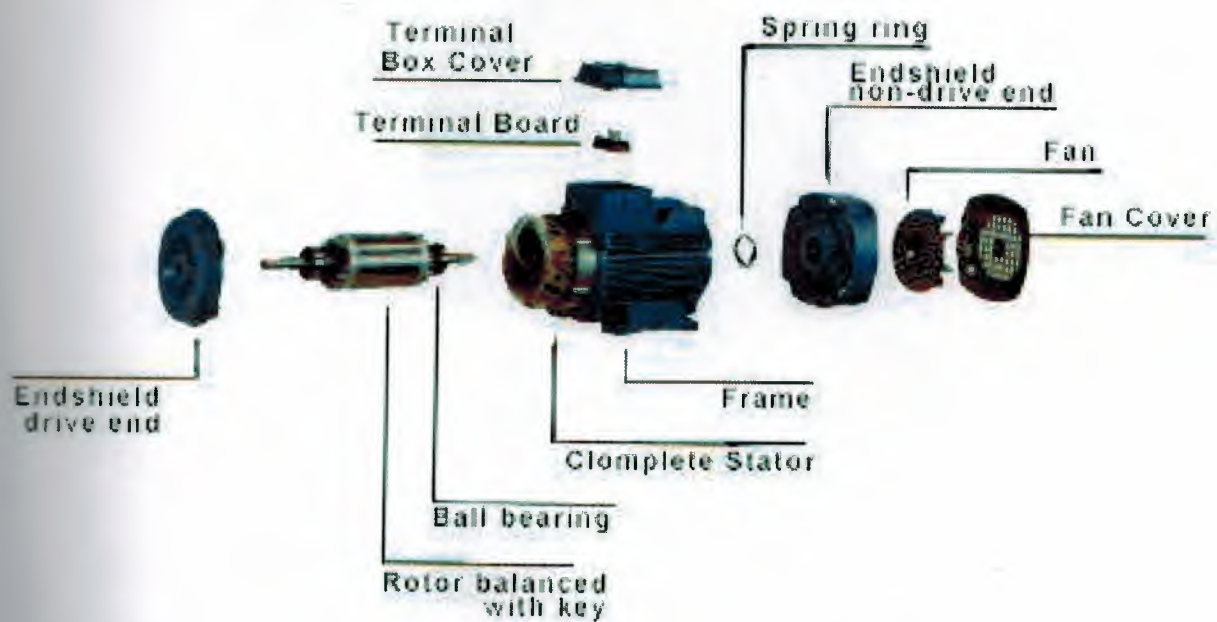
##### **2.1.2 Stator**

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** AC Motor

## **2.2 TYPE THE MOTOR**

### **2.2.1 Single phase**

#### **i. Split phase motors**

The split-phase motor is an AC motor of fractional horsepower size and is used to operate such device as washing machines, oil burners, and small pumps. A centrifugal switch is located inside the motor. The general appearance of split-phase motor is shown in figure 2.2. This motor is generally operated from single-phase lighting or power circuit and is used where the starting torque requirements are moderate. The National Electrical Manufacture Association (NEMA) defines a split-phase motor as a single-phase motor as a single-phase induction motor equipped with an auxiliary winding displaced in magnetic position from, and connected in parallel with, the main winding split-phase motor has two winding and are called the main or running winding and auxiliary or starting winding. Both winding are connected to the power line when the motor is started; however, after the motor has reached a predetermine speed, the stating winding is automatically disconnected from the power line by means of a centrifugal switch located inside the motor.



**Figure 2.2** Split phase motors

### **i.1. The Centrifugal Switch**

The centrifugal switch is located inside the motor. Its function is to disconnect the starting winding after the rotor has reached a predetermined speed. The usual type consists of two main parts, namely a stationary part and a rotating part, the stationary part is usually located on the front end plate of the motor and has two contacts, so that it is similar in action to single-pole, single-throw switch.

The action of a centrifugal switch is explained as follows: when the motor is at a standstill, the two contacts on the stationary part of the switch are kept closed by the pressure of the rotating part. At approximately 75 percent of full speed, the rotating part releases its pressure against the contacts and causes them to open, thus automatically disconnecting the starting winding from the circuit.

### **i.2. Operation of the Split-Phase Motor**

At the start, the current flowing through both the running and the starting winding causes a magnetic field to be formed inside the motor. This magnetic field rotates and induced a current in the rotor winding, which in turn causes another magnetic field. These magnetic fields combine in such manner as to cause rotation of the rotor. The starting winding is necessary at the start in order to produce the rotating field. After the motor is running the starting winding is no longer needed and is cut out of the circuit by means of the centrifugal switch.

## **ii. Capacitor Motors**

The capacitor motor operates on alternating current and is made in sizes ranging from 1/20 HP to 10 HP. It is widely used to operate such machines as refrigerators, compressors, oil burners, washing machine, pumps, and air conditioners.

The construction of the capacitor motor is similar to that of the split-phase motor, but an additional unit, called a capacitor, is connected in series with the starting, or auxiliary,



winding. The capacitor is usually mounted top of the motor, and inside connection box, as shown in figure 2.3.



**Figure 2.3** Capacitor Motors

According to NEMA standards a capacitor motor is defined as follows; A capacitor motor is a single-phase induction motor with a main winding arranged for direct connection to source of power and an auxiliary winding connected in series with a capacitor. There are three types of capacitor motors, as follows;

- 1 CAPACITOR-START Motors A capacitor-start motor is a capacitor motor in which the capacitor phase is in the circuit only during the starting period.
- 2 PERMANENT-SPLIT CAPACITOR Motor. A permanent-split capacitor motor is a capacitor motor having the same value of capacitance for both starting and running conditions.
- 3 TWO CAPACITOR Motor. A two capacitor motor is capacitors using different effective capacitance for the starting and running conditions.

### **ii.1. The Capacitor**

A capacitor is formed when two conductors, usually of aluminum, are separated by an insulator such as paper or gauze. For use in motor the strips are rolled together into a compact unit and placed into a sealed metal or plastic container. This may be either cylindrical, or rectangular in shape and may be mounted on, in, or away from motor, two terminals or leads are provided for connection. The capacitor is descriptive of the operation of the device. The capacitor acts essentially as a storage unit; that is, it has capacity to store electricity and provides a leading current to the auxiliary or starting winding. All capacitors have this quality and all are electrically the same; they differ only in mechanical construction. Figure 2.4 illustrates a capacitor



**Figure 2.4 Capacitor**

### **ii.1.1. The Oil-Filled Capacitor**

This capacitor is used mainly in the permanent-split capacitor motor and for two capacitor motor. These capacitors used an oil-impregnated paper as the dielectric and are permanently connected in the circuit. They are capable of constant duty and are substantially larger than equivalent microfarad value in an electrolytic type. Different manufacturers used various types of oil or synthetic liquids as the impregnating medium. Capacities range from 2 microfarads to 80 microfarads (abbreviated  $\mu\text{f}$ ).

### **ii.1.2. The Electrolytic Capacitor**

Electrolytic capacitors are used mainly in capacitor-stars and two capacitor motors. This type consists of sheets of aluminum foil that are separated by one or more layers of gauze. The gauze has previously been saturated with a chemical solution called an electrolyte. The electrolyte forms a film which acts as the insulating medium of the electrolytic capacitor. These layers are rolled together and fitted into an aluminum or plastic container. Motor-starting electrolytic capacitor should not be kept in a circuit more than a few seconds at a time because they are designed for only intermittent duty.

## **ii.2. Capacity**

Capacitors are rated in microfarads. A capacitor for starting may be having a capacity ranging from 2 to 800  $\mu\text{f}$  or more, depending on its use, size and type. Capacitors may be losing some capacity because of excessive use, overheating, or other conditions. In such a case, it must be replaced with one of approximately the original value of capacity and voltage; otherwise the motor may not have the required starting torque.

When replacing a defective capacitor on capacitor motor, be certain to use a replacement with a voltage rating at least as high as the original. Wherever any question exists, it is always safer to use a capacitor of high voltage rating.

There are three types of capacitor motor, and each employs capacitors in conjunction with the winding. These are the capacitor-start motor, the permanent-split capacitor motor, and the two capacitor motor. Capacitor-start motors have a relatively high starting torque and use the electrolytic capacitor. The capacitor must not be used for continuous duty and must be switched out of the circuit when the motor attains a predetermined speed. The permanent-split capacitor motor has a relatively low starting torque and uses an oil-impregnated paper as the dielectric. These capacitors remain in the circuit at all times. The



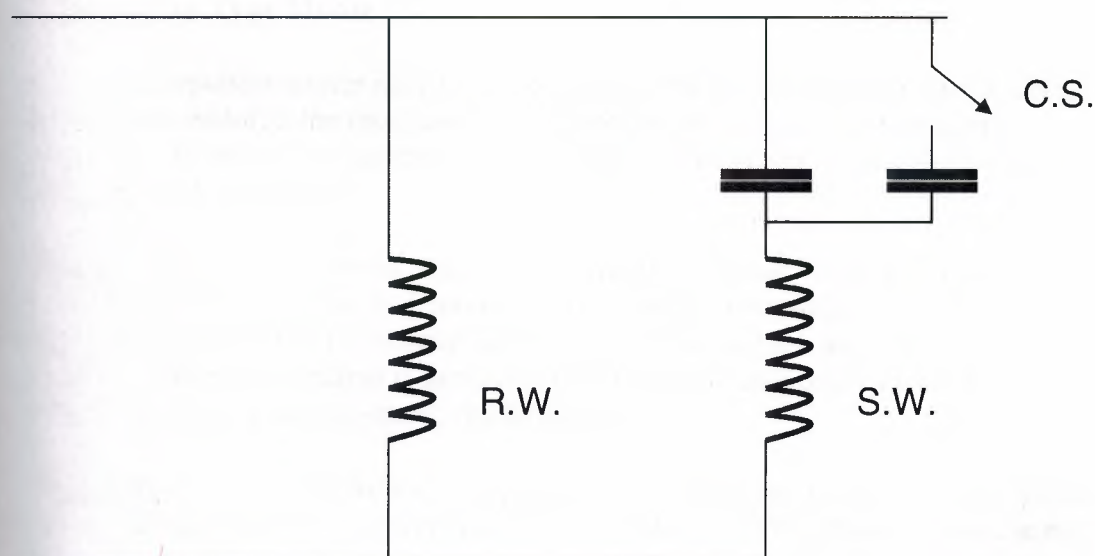
two capacitor motor has a high starting torque and uses the electrolytic and oil capacitor in parallel at start. When the motor reaches the required speed, the electrolytic capacitor is cut out of the circuit, permitting the motor to operate as a permanent-split motor.

### ii.3. Operation

The circuit of the capacitor motor is shown in figure 2.4 and slot connection shown in figure 2.5. During the starting period, both the running (main) and starting (auxiliary) windings are connected across the line since the centrifugal switch is closed. The starting winding, however, is connected in series with the capacitor and the centrifugal switch.

When the motor reaches approximately 75 percent of full speed, the centrifugal switch opens. This action cuts out both the starting winding and the capacitor from the line circuit and leaves only the running winding across the line.

To produce a starting torque in a capacitor motor, a revolving magnetic field must be established inside the motor. This is accomplished by placing the starting winding 90 electrical degrees out of phase with the running winding. The capacitor is used to permit the current in the starting winding to reach its maximum. In other words, the capacitor causes the current in the starting winding to lead the current in the running winding. This condition produces a revolving magnetic field in the stator, which in turn induces a current in the rotor winding. As a result, the magnetic field acts in such a manner as to produce rotating of the rotor.



**Figure 2.5** Connection capacitor motors

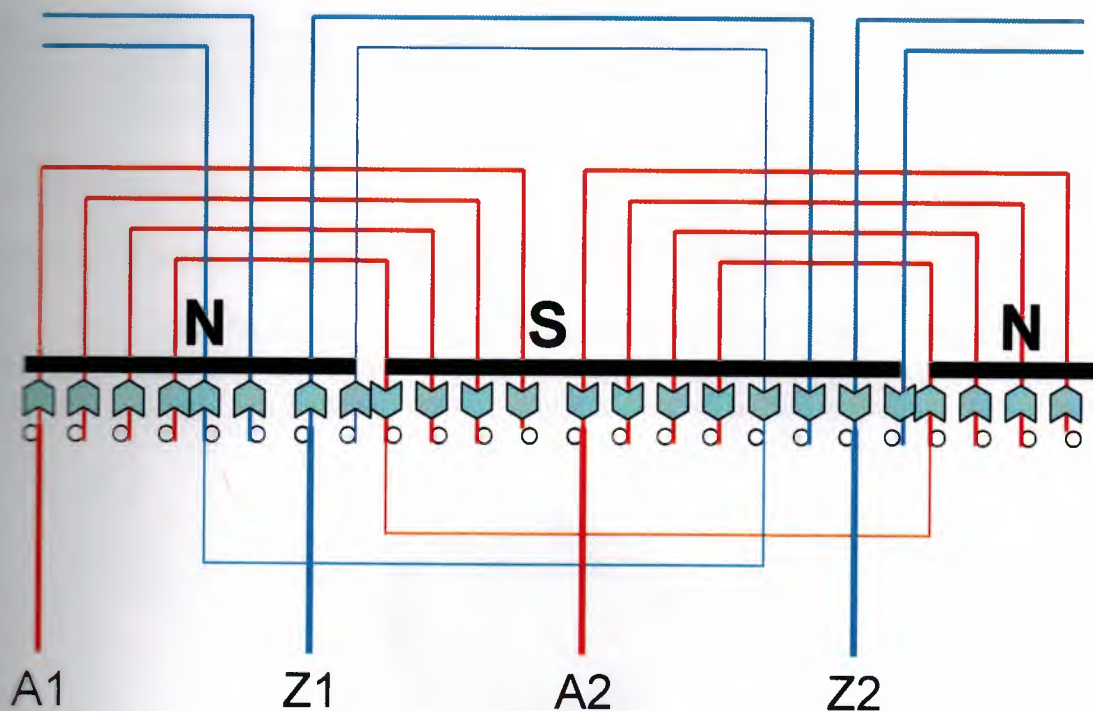


Figure 2.5 Slot connection

### iii. Repulsion-Type Motor

In general, repulsion motor may be divided into three distinct classifications. These are 1 the 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 short 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 addition to the repulsion motor winding. A rotor of this type may have either a constant-speed or varying-speed characteristic.

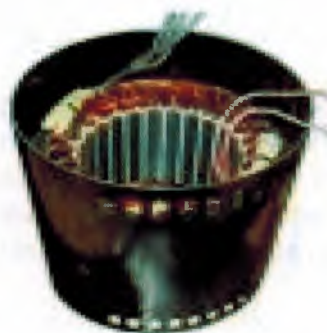
These three classes are often confused by the beginner because of the similarity of names. But each is different from the other, having its own characteristic and applications.

However, one feature common to all is that each has a rotor containing a winding that is connected to commutator. These motor generally operates from a single-phase lighting or power circuit, depending on the size of the motor.

### iii.1. Construction

Most repulsion-type motors generally consist of the following parts:

1. 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 2.6. Shows a stator of a repulsion-start induction motor.



**Figure 2.** Repulsion-type motor stator

2. 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 2.7. Illustrates the armature of the repulsion-induction motor.



**Figure 2.7** Repulsion-type motor rotor

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.

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



4. 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.

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

### **iii.1.1. The Repulsion-Start Induction Motor**

This is a single-phase motor ranging in size from approximately  $\frac{1}{4}$  to 10 HP. It has high starting 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.

### **iii.1.2. 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.

### **iii.1.3. 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 in 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 many other machines.

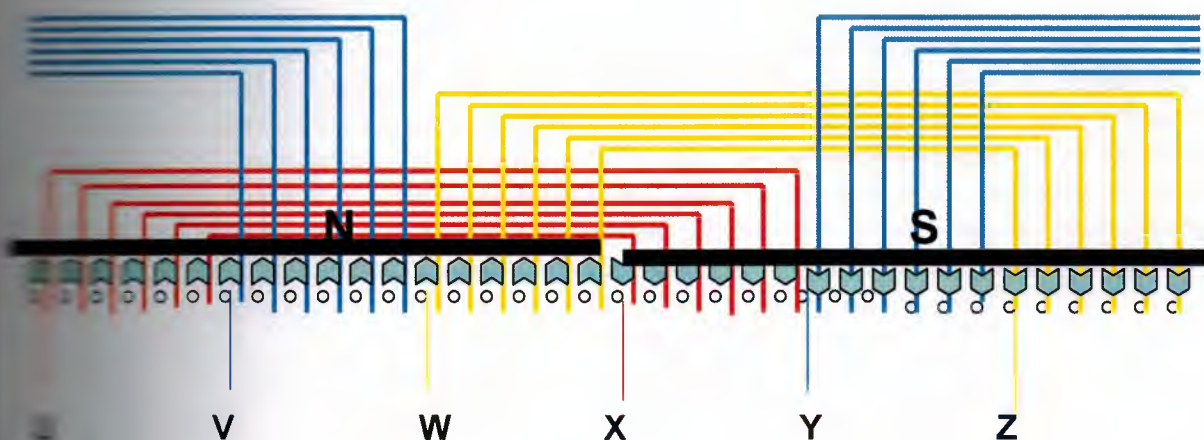
#### **2.3.1. Construction of Three-Phase Motor**

A three-phase motor is shown in figure 2.8. 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 2.8 and slot connection shown in figure 2.9. 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 2.8 and is like that of split-phase motor.



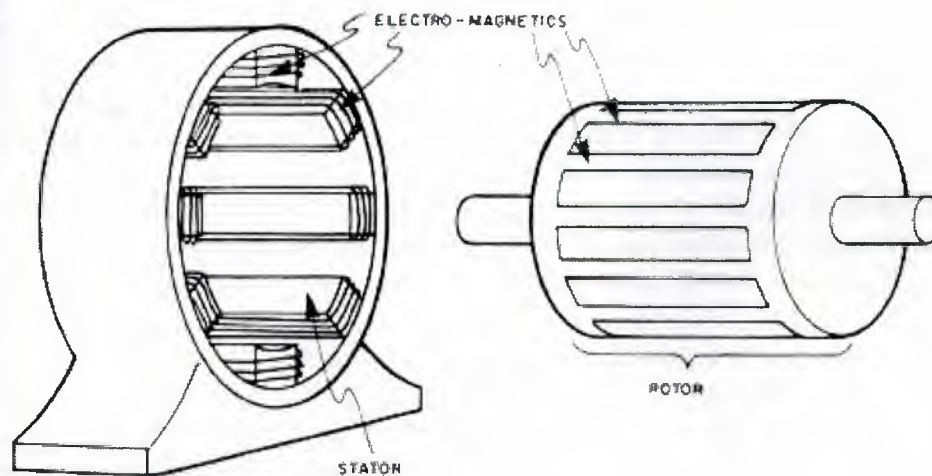
**Figure 2.8** Three phase motor



**Figure 2.9** Three phase motor slots connection

### 2.3.2. Basic Three phase AC Motor Operation

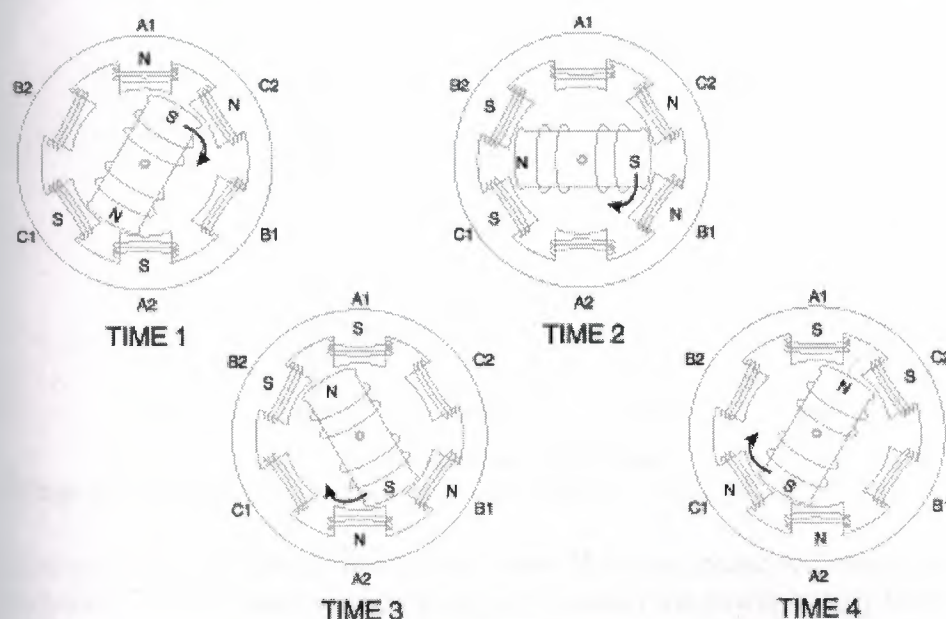
An AC motor has two basic electrical parts: a "stator" and a "rotor" as shown in Figure 2.10. The stator is the stationary electrical component. It consists of a group of individual electro-magnets arranged in such a way that they form a hollow cylinder, with one pole of each magnet facing toward the 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 2.10** - Basic electrical components of an AC motor.



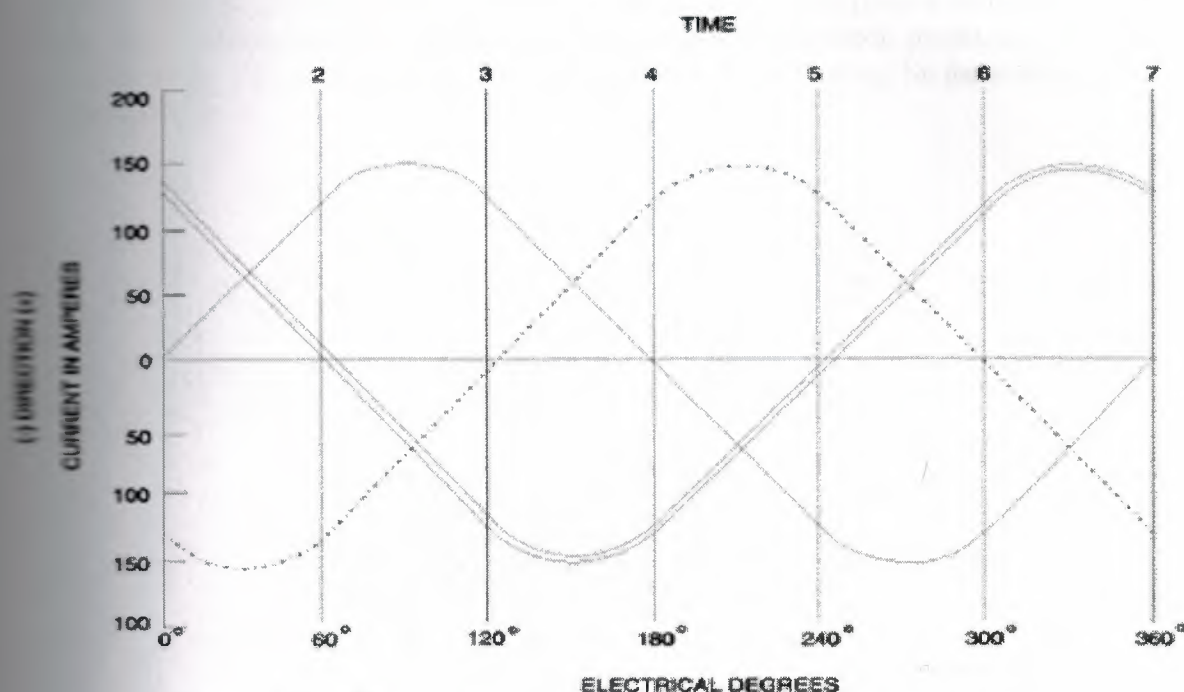
This "rotating magnetic fields of the stator can be better understood by examining Figure 2.11. As shown, the stator has six magnetic poles and the rotor has two poles. At time 1, stator poles A-1 and C-2 are north poles and the opposite poles, A-2 and C-1, are south poles. The S-pole of the rotor is 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 are 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 2.11** - The rotating magnetic field of an AC motor.

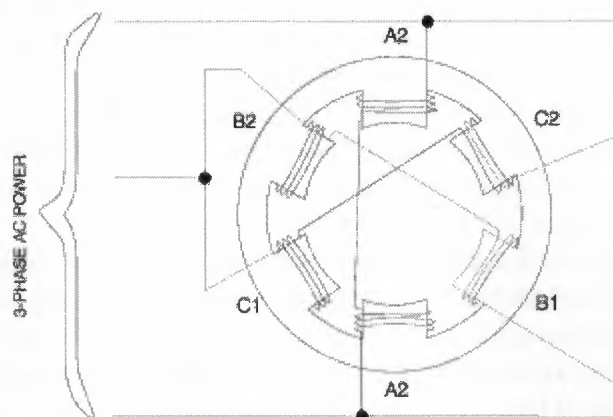
One way to produce a rotating magnetic field in the stator of an AC motor is to use a three-phase power supply for the stator coils. What, you may ask, is three-phase power? The answer to that question can be better understood if we first examine single-phase power. Figure 1.7 is the visualization of 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 Figure 10. 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

2.12, 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 2.12** - The pattern of the separate phases of three-phase power.

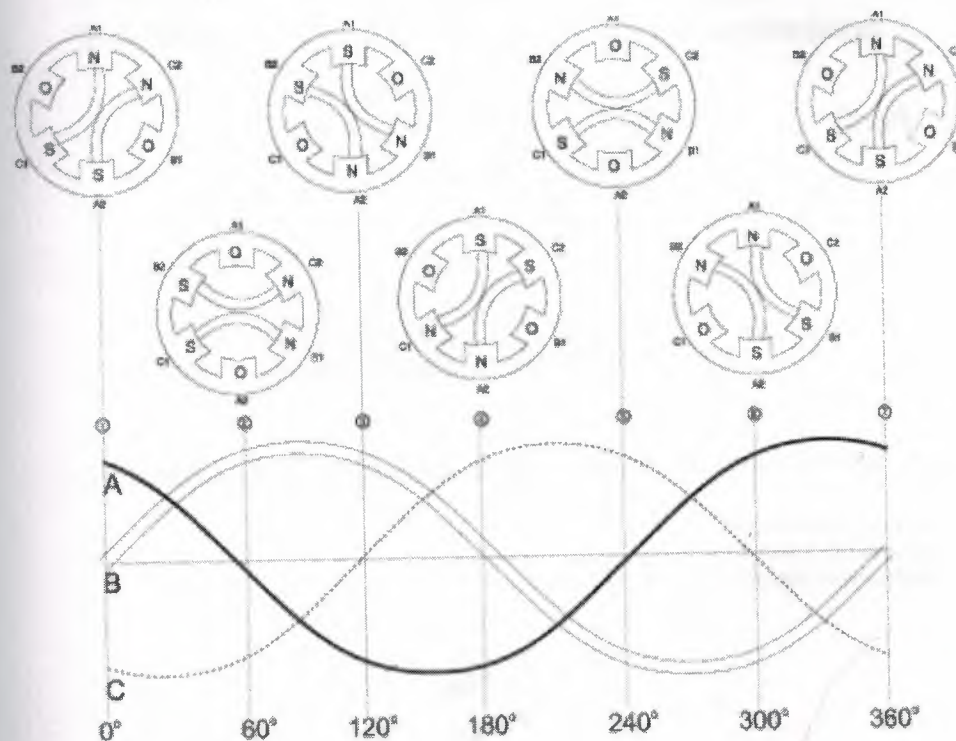
To produce a rotating magnetic field in the stator of a three-phase AC motor, all that needs to be done is wind the stator coils properly and connect the power supply leads correctly. The connection for a 6 pole stator is shown in Figure 2.13. Each phase of the three-phase power supply is connected to 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 2.13** - Method of connecting three-phase power to a six-pole stator.



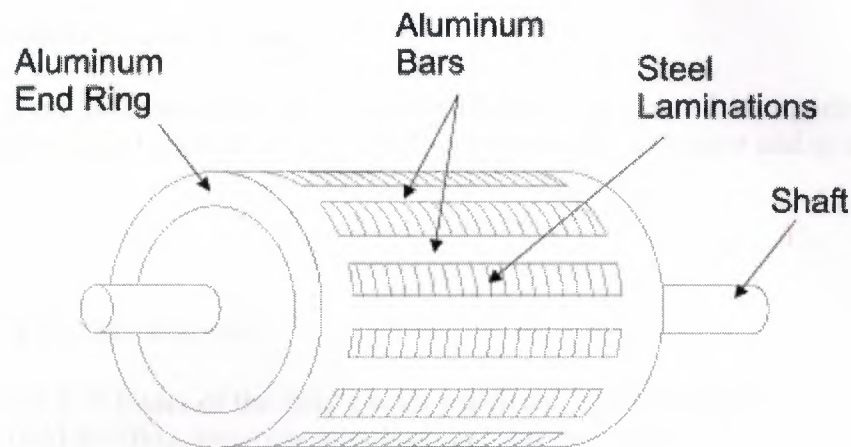
Figure 2.14 shows how the rotating magnetic field is produced. At time 1, the current flow in the phase "A" poles is positive and pole A-1 is N. The current flow in the phase "C" poles is negative, making C-2 a N-pole and C-1 is S. There is no current flow in phase "B", so these poles are not magnetized. 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.



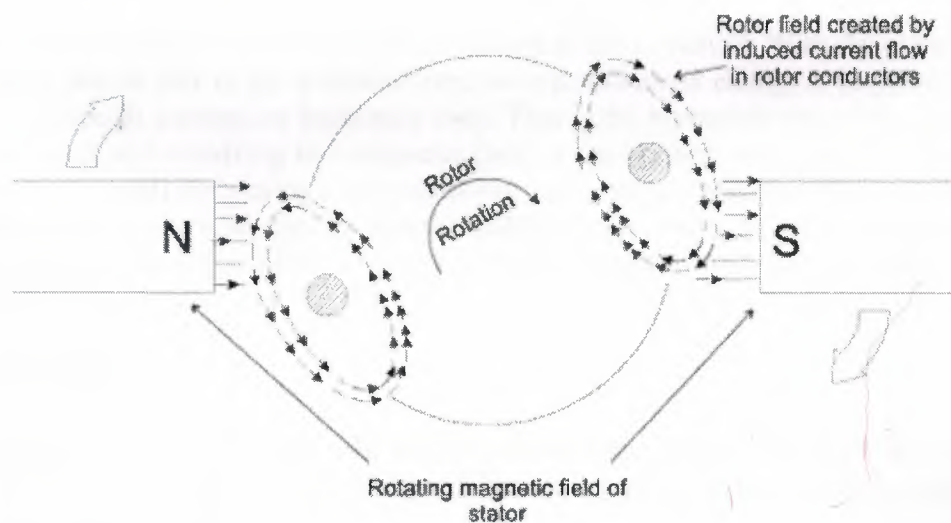
**Figure 2.14 - How three-phase power produces a rotating magnetic field.**

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 2.15) 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 2.16. This magnetic field around each rotor conductor will cause each rotor conductor to act like the permanent magnet in the Figure 2.11 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 2.15** - Construction of an AC induction motor's rotor.



**Figure 2.16** - 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 generators 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:

$$\text{Motor Efficiency} = (\text{Input} - \text{Losses}) / \text{Input}$$

$$\text{Generator Efficiency} = \text{Output} / (\text{Output} + \text{Losses})$$



## 3 Chapter

### Rewinding the Three-Phase Motor

Many separate steps are involved in rewinding a three-phase motor, as follows:

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

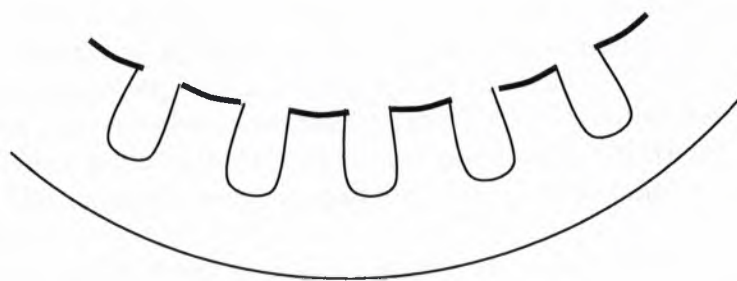
All these data must be recorded adequately enough to enable the repairman to rewind the motor without loss of time.

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.

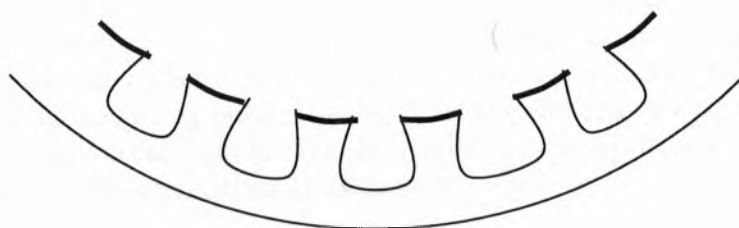
#### 3.2 Stripping the Winding

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 be recorded. This can 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 coils 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. Many 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 called 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 following 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 through 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 first 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=poleXphase.

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

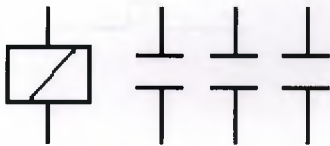
The there-phase motors should be given tests for the following defects after a repair or winding job: grounds, opens, shorts and reverses.

## 4 Chapter

### Alternating-current motor control

#### 4.1.1 Contactors

Contactors are 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 and photograph (AEG)

The holding coil on an a-c magnetic is excited 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.

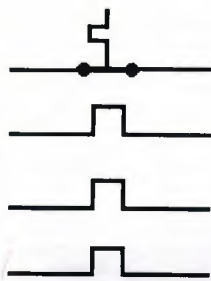
#### 4.1.2 Overload Relays

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 consists 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 depends 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 of 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



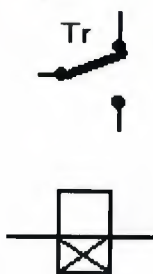
overload relay is usually designed with a feature, which permits automatic resetting, although it is also designed for manual resetting. Some overload relays are ambient-compensated to provide maximum protection where the temperature surrounding the relay differs from the temperature surrounding the 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 (AEG)

#### 4.1.3 Time Relays

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

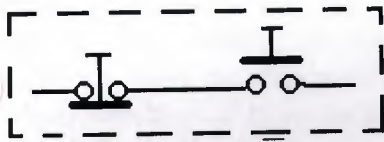


**Figure 4.3**  
Time relay symbol and photograph (INTER)



#### 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**

Pushbutton station, START and STOP symbol and photograph (EMAS)



**Figure 4.4**

START and STOP symbol and photograph (EMAS)

#### 4.1.5 Limit Switch

For automation, one is often faced with the need to deal with moving mechanisms, to control the correct sequence of operations and to detect the maintained or attained position, in every instance, of various parts in motion or to simply stop them. All this is very obvious for industrial machinery where in addition to the previously specified operations, it is essential to monitor mobile protections and warrant total safety to machinery as well as personnel who operate them. Position limit switches can be used in all of these cases, working together with moving parts of machines and signalling when well defined positions are reached. In this relation, the control of the grinding machine saddle, the correct position of packages on a conveyor belt, the stopping of a platform or fork lift at the end of travel or, again, the disconnection of supply when a mobile protection of a press is opened can cross one's mind. Limit switches are illustrated in figure 4.5.

An assortment of position limit switches exists in trade and each can differ per operational or design features; one typically finds electromechanical, electronic, inductive, magnetic or optical position switches. However, not all of these are suitable for every application since some may not correctly operate in particular circumstances, for instance, in dirty or dusty ambient, common to the industrial field. In other cases, like safety applications, there are standards like EN 60204-1, which tend to mainly take into account the electromechanical types only since indeed it does assure the disconnection of supply by means of physically opening an electrical contact.

Within the family of electromechanical position switches, diverse types can be found as well, basically related to the evolution of standards over the years, which have laid down rules for dimensional standardisation. It is many years now that all manufacturers and users of limit switches prefer types complying with EN 50047 standards, which dictate the fundamental dimensions of the device.

The EN 50047 define the characteristics of compact limit switches, generally used in modern industrial machinery. Before this, the EN 50041 standards had been considered and, although still valid, prescribe larger dimensions and thereby formulate bigger products.

Other even more compact position switches are prevalent in trade, typically called microswitches, which however cannot guarantee direct opening operation of the NC contacts.



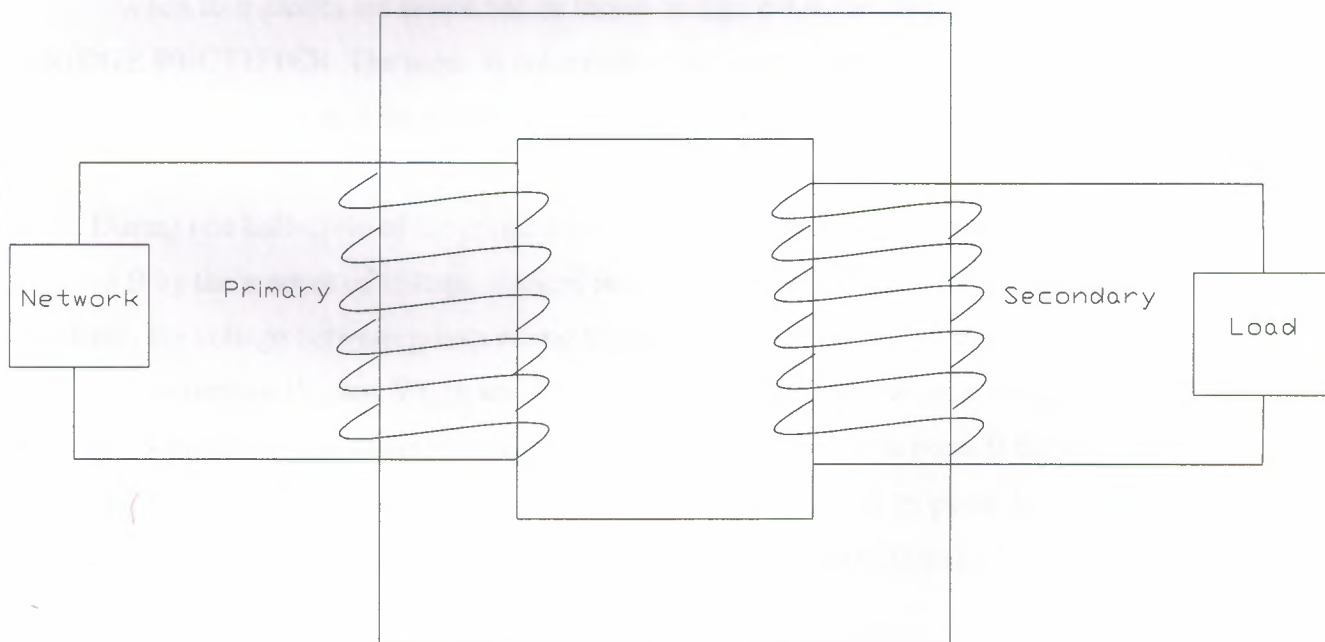
Figure 4.5 Limit switches

#### 4.1.6 Transformer

Basically the transformer is a device for transferring electrical energy from one circuit to another without a change in frequency. This transfer of energy may occur at any voltage level. (Lower-Same-Higher voltage levels) Thus for the domestic households uses, the distributed 240V ac is changed or stepped-down to 12V, on other hand for efficient power transmission the generated voltage is stepped-up to certain Mvolts.

The transformers have very high efficiency in electrical energy conversion. (Up-to 98-99%) Also the maintenance is simpler and cheaper.

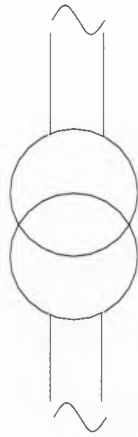
The changing flux can be obtained by impressing alternating current on a coil, which will vary in magnitude and time, and therefore the flux produced by this current will also vary in magnitude with time. If we now place this coil on a magnetic core together with another coil as shown in figure 4.6. We have the simple transformer. Assuming that all the magnetic flux is confined to the iron core; since there is change of flux linking the second coil there will also be a voltage induced in that coil.



**Figure 4.6 Transformer**

The coil or winding which receives energy is called primary and the winding which delivers energy to a load is called secondary. A transformer is illustrated in figure 4.7.





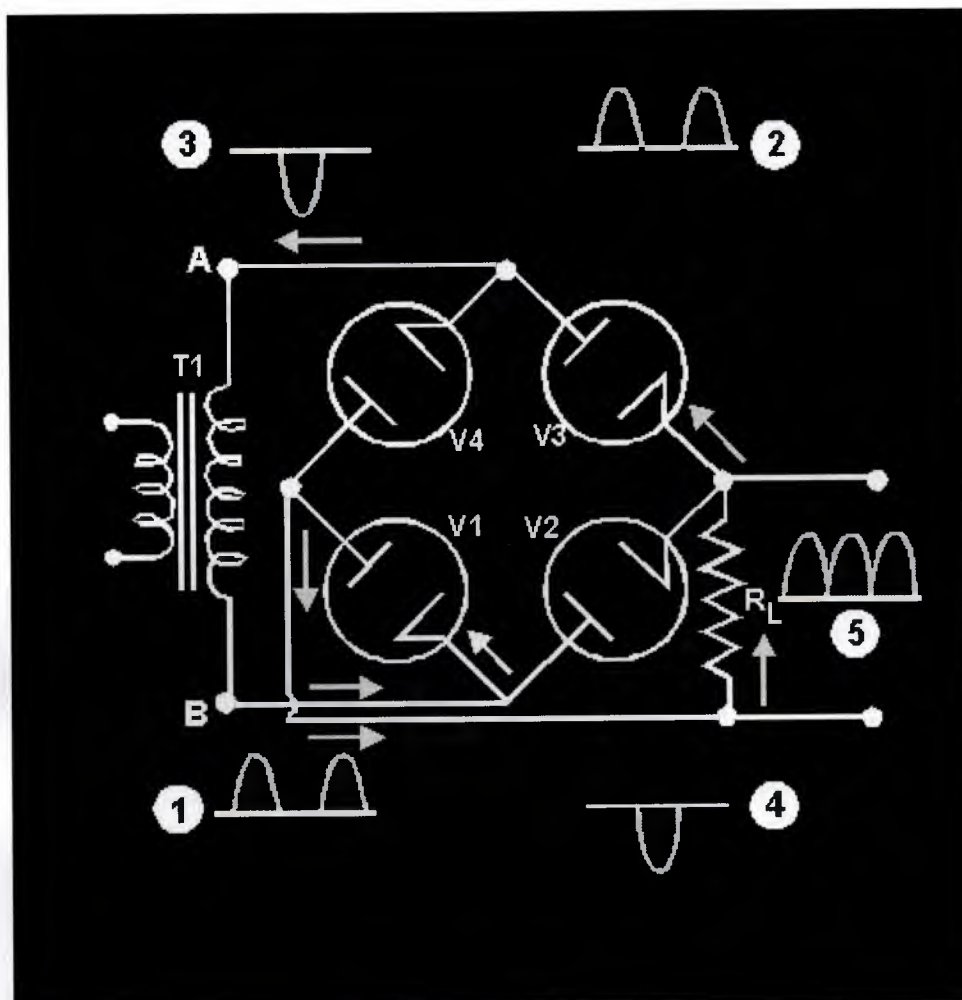
**Figure 4.7** Transformer

#### **4.1.7 The Bridge Rectifier**

When four diodes are connected as shown in figure 4.8, the circuit is called a **BRIDGE RECTIFIER**. The input to the circuit is applied to the diagonally opposite corners of the network, and the output is taken from the remaining two corners.

During one half-cycle of the applied voltage, point A becomes positive with respect to point B by the amount of voltage induced into the secondary of the transformer. During this time, the voltage between points A and B may be considered to be impressed across V1, the load resistor  $R_L$ , and V3, in series. The voltage applied across these tubes makes their plates more positive than their cathodes, and current flows from point B through tube V1 in an upward direction across the load resistor, through tube V3, to point A. This path is indicated by the solid arrows. The waveform is shown as numbers (1) and (2).

One half-cycle later, the polarity across the secondary reverses, making the plates of V1 and V3 negative with respect to their cathodes. At the same time, the plates of V2 and V4 become positive with respect to their cathodes, and current flows in the direction indicated by the dashed arrows. The current through  $R_L$  is always in the same direction. This current, in flowing through  $R_L$ , develops a voltage corresponding to that shown in waveform (5) of the figure. The bridge rectifier is a full-wave rectifier since current flows through the load during both half cycles of the applied alternating voltage.

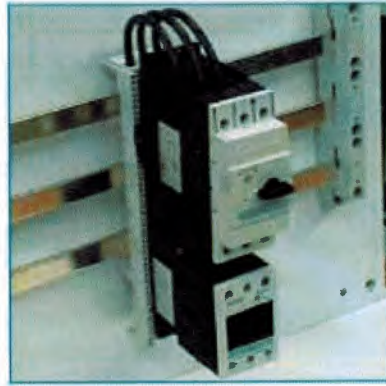


**Figure 4.8 - Bridge rectifier circuit**

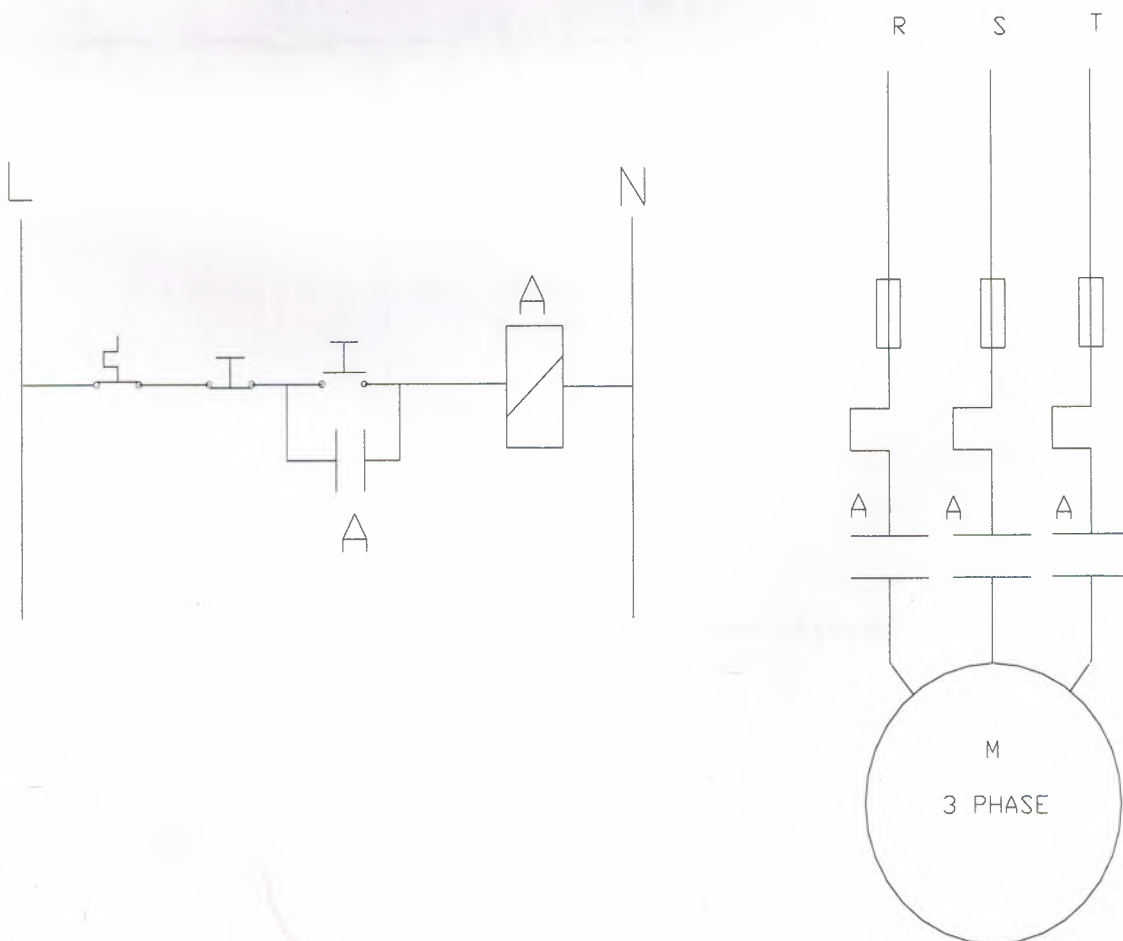
## 4.2 Starters

### 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 4.9 . 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 4.9**  
Dol starter photograph



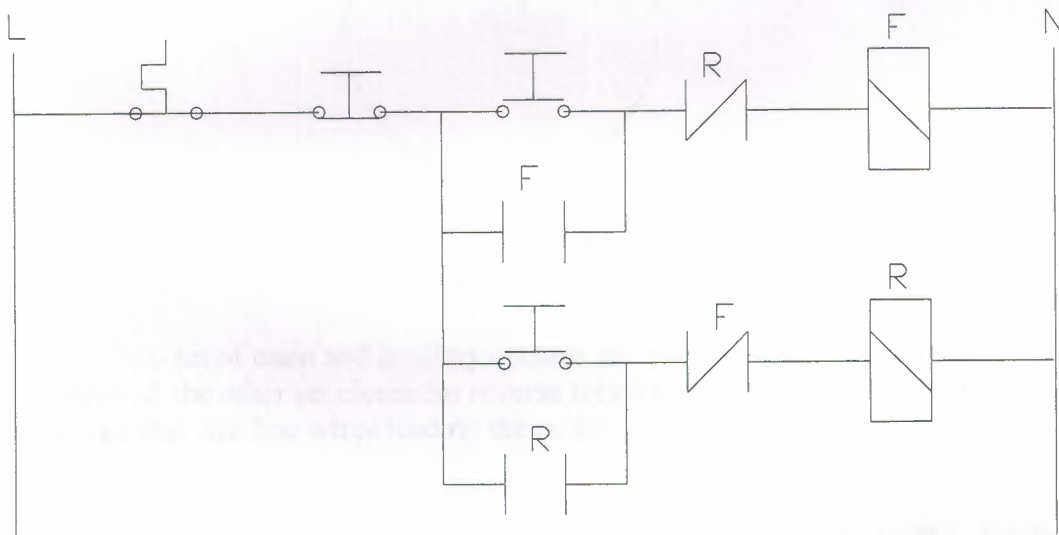
**Figure 4.9**  
Dol starter control, power circuit



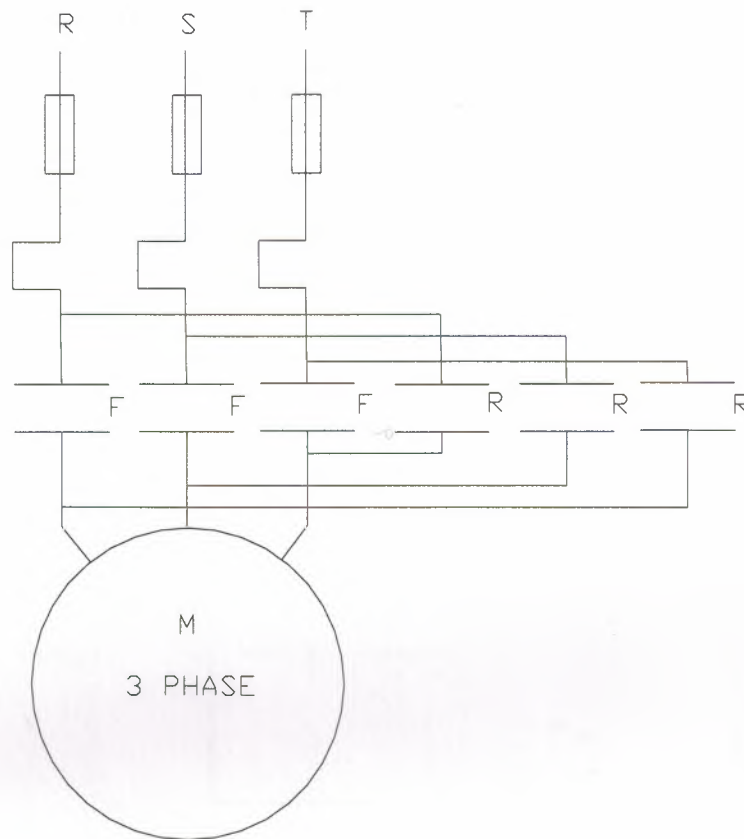
### 4.2.2 Full-Voltage Reversing Starter

The starter shown thus far are designed to operate the motor in one direction, either clockwise or counterclockwise. 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 button is pressed. Thus, two of the line leads can be interchanged to reverse a three-phase motor by means of a magnetic reversing switch. The circuit is given in figure 4.10. Note that it is necessary to use a stop-forward-reverse station, with three buttons, and that two operating coils are used, one for forward rotation and the other for reverse rotation.



**Figure 4.10**  
Full-Voltage Reversing Starter control circuit



**Figure 4.10**  
Full-Voltage Reversing Starter power circuit

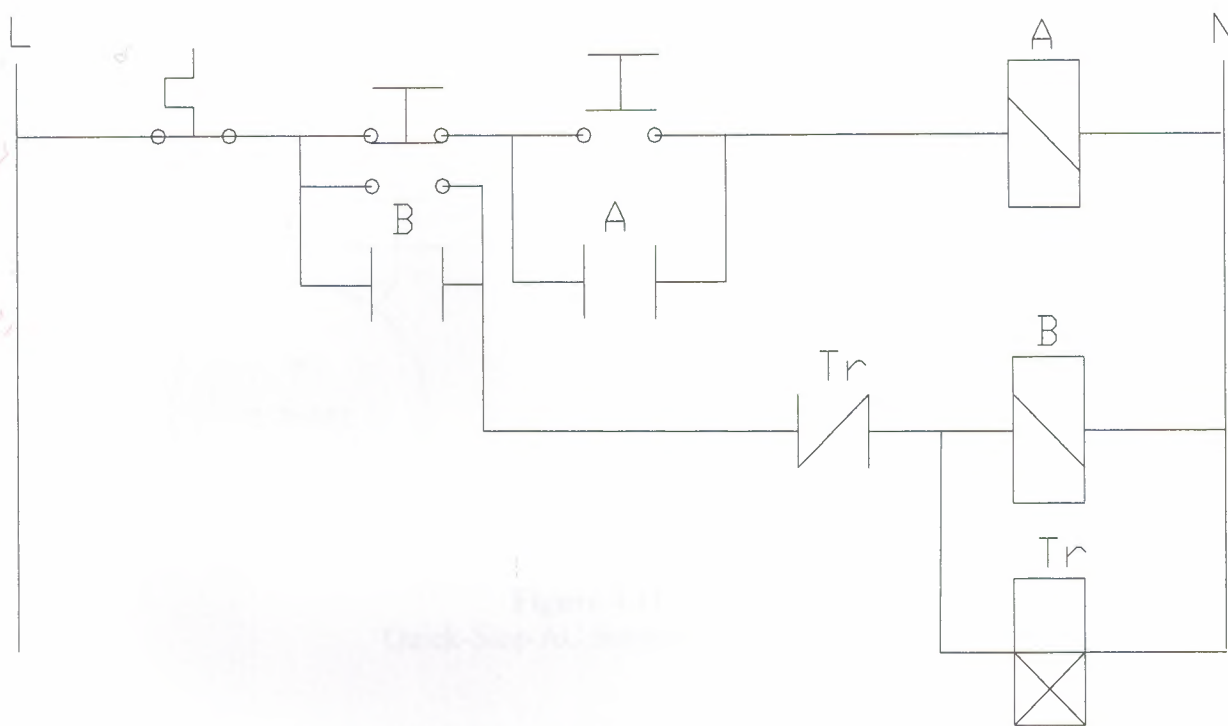
Two set of main and auxiliary contacts are used. One set closes when forward operation is desired; the other set closes for reverse rotation. These contacts are connected in such a manner that two line wires feeding the motor are interchanged when reverse the contact close.

In operation, pressing the forward button completes a circuit from L, the stop button, the forward button, the forward coil to N. This energizes the coil, which closes the contacts for forward operation of the motor, and also F NC contact locks R coil. Auxiliary F NO contact also closes, maintaining the current through coil F when the button is released. Pressing stop button opens the circuit through the forward coil which releases 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 Quick-Stop AC Starters

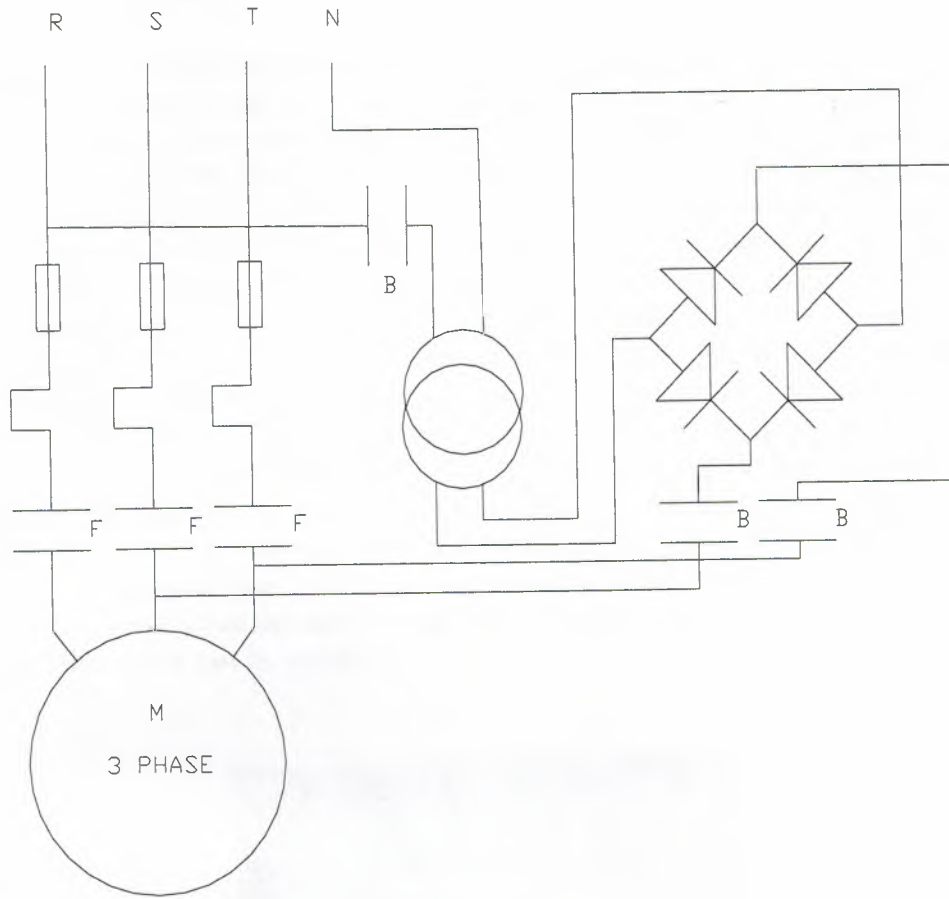
In many motor application, it is necessary to have a method of quick stopping or braking the motor to ensure safe operation and to save time

There are several methods that can be used for quick stopping a polyphase motor. One of these is the application of low-voltage direct current to one phase immediately after the line switch to the motor is opened. Quick-stop AC starter is shown in figure 4.11.



**Figure 4.11**  
Quick-Stop AC Starters control circuit



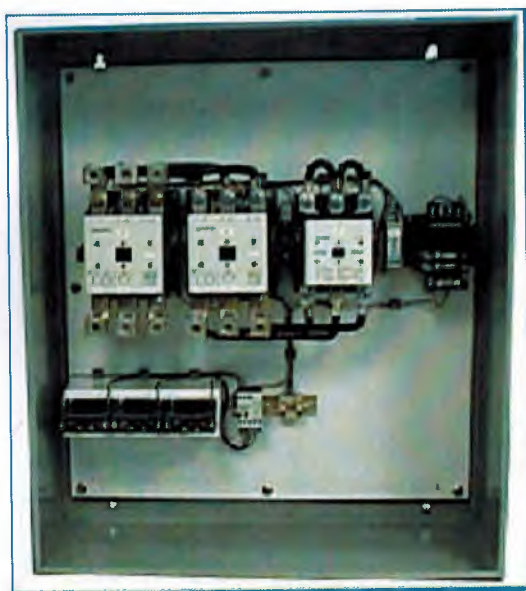


**Figure 4.11**  
Quick-Stop AC Starters power circuit

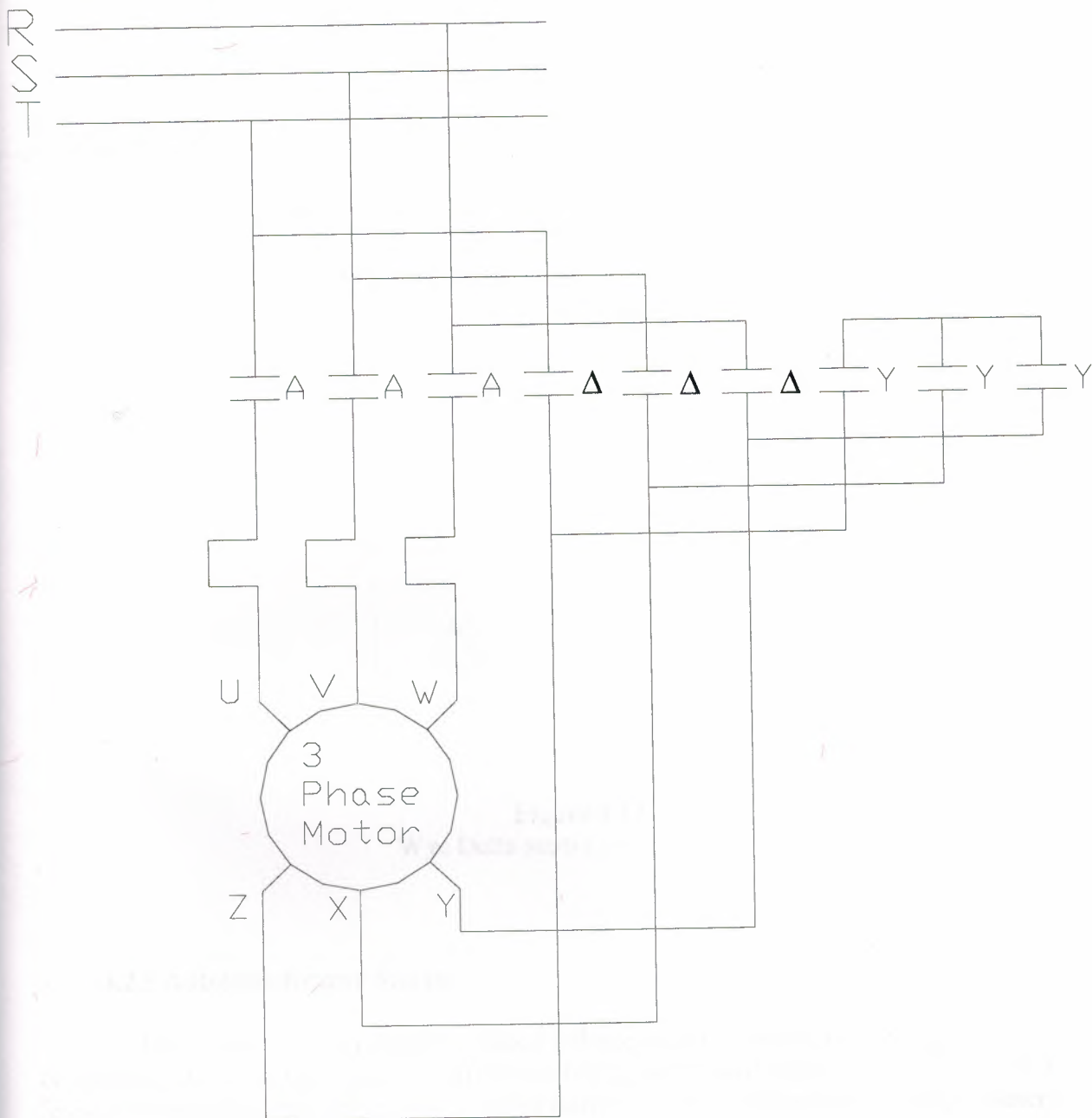
There are one stop button which has two contacts one NC other NO, and one normal start button. When the start button is pressed it completes the circuit from L normally closed contact of the overload relays to the normally closed contact of the stop button through the holding coil A to N. Thus the coil 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. When stop button pressed coil de-energized coil and stop button NO contact will be close. B coil is energized, and transformer will be energized, motor breaking by low DC voltage. After some second timer contact will be change and all system will be de-energized.

#### 4.2.4 Wye Delta Starter

Figure 4.12 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  $\Delta$ . The  $\Delta$  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  $\Delta$  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.

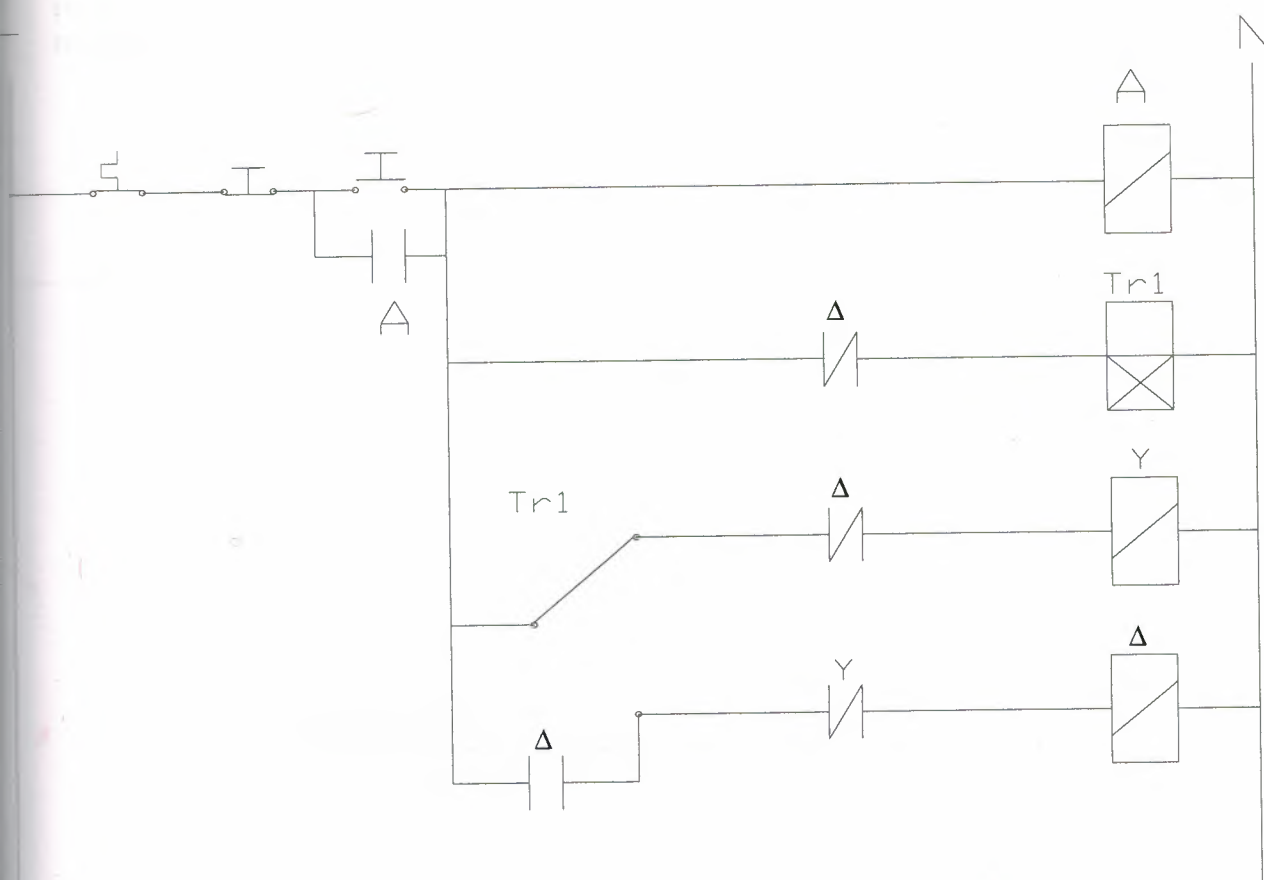


**Figure 4.12** Wye Delta starter photograph



**Figure 4.12**  
Wye Delta starter power circuit





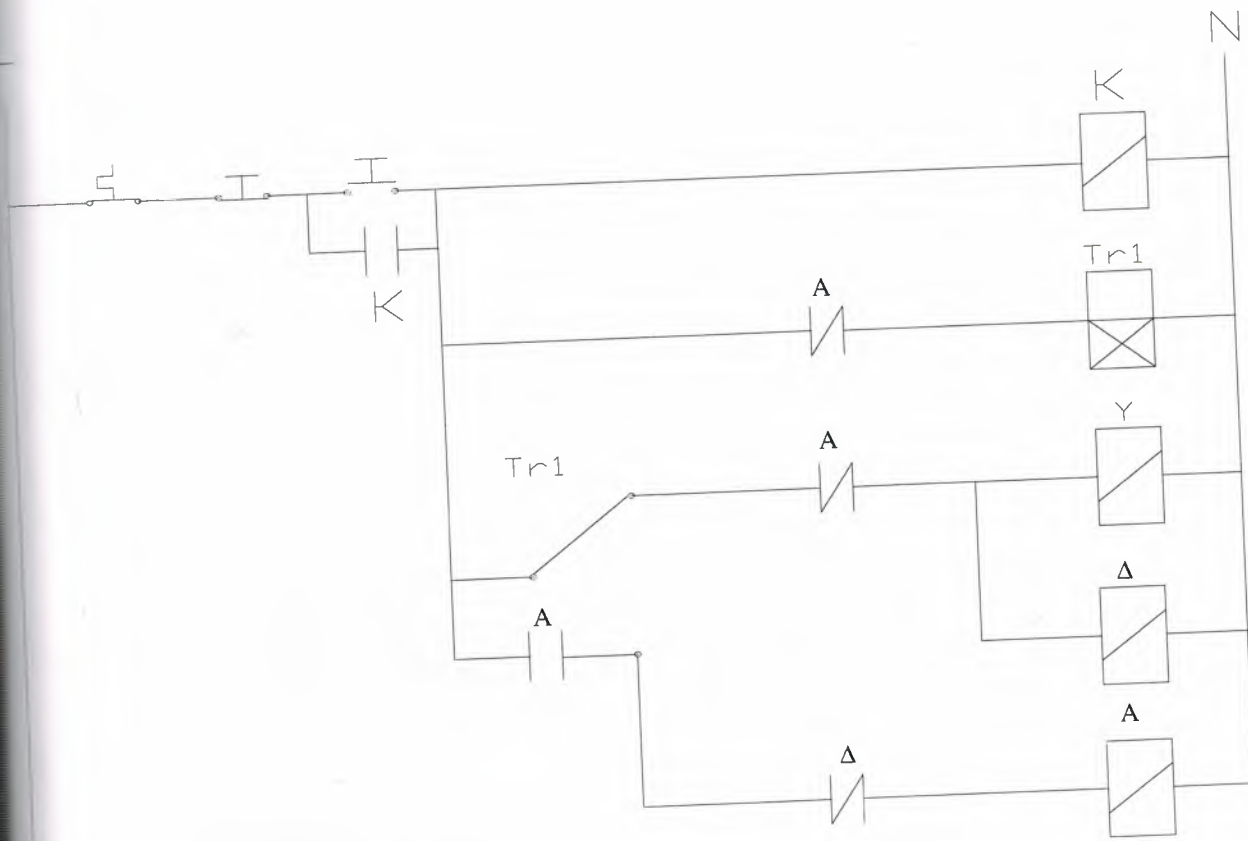
**Figure 4.12**  
Wye Delta starter control circuit

#### 4.2.5 Autotransformer Starter

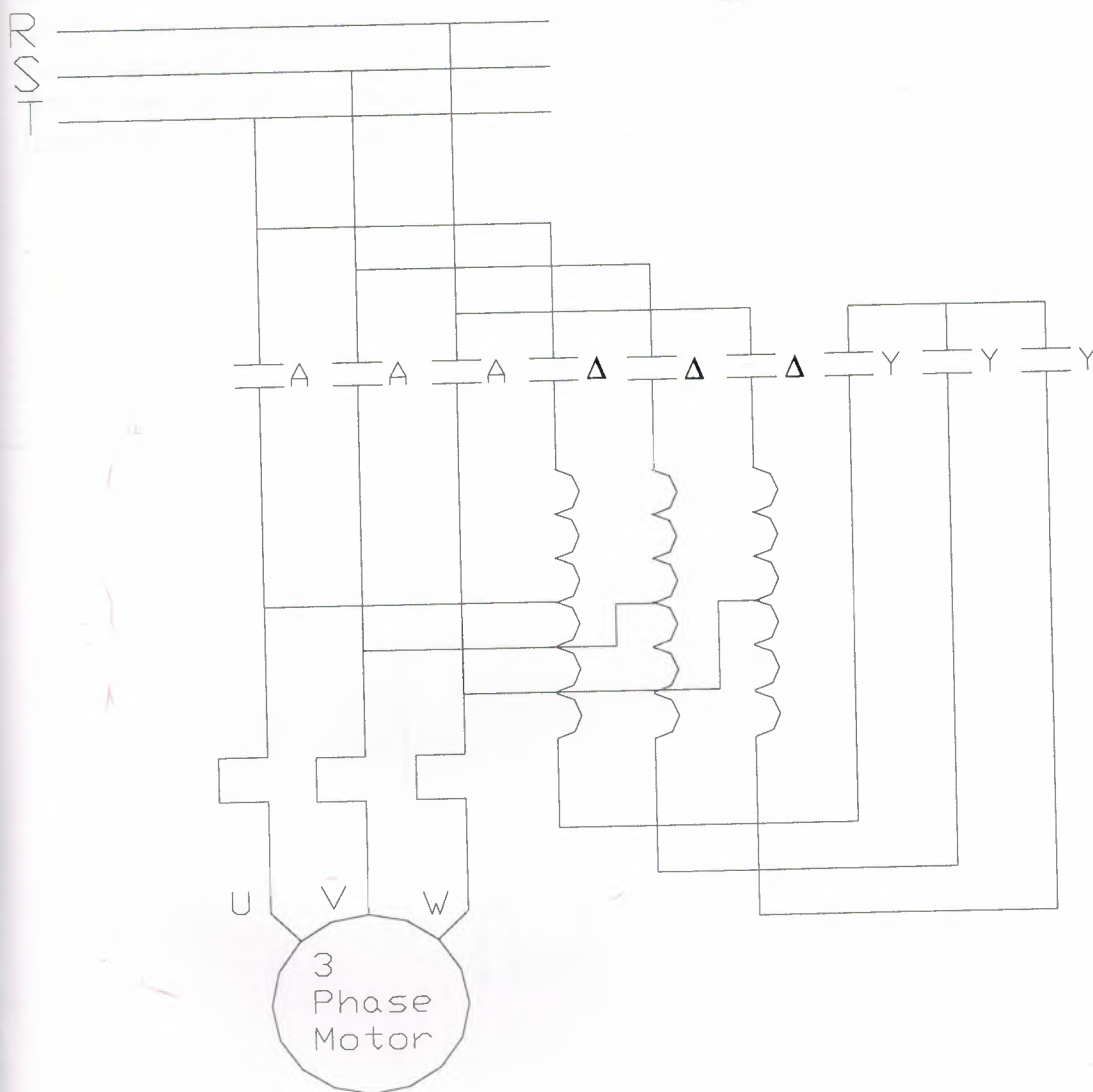
The autotransformer type of reduced-voltage starter is much the same in principle of operation as the resistor type, the difference being that a transformer is used in place of a resistor for reducing line voltage to the motor during starting. This reducing-voltage starter has a three-coil autotransformer, 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 4.13 ) is as follow; Pressing the start button energizes the K,  $\Delta$  and Y contactor coils. The contactors for  $\Delta$  and Y close, placing the motor on reduced voltage. The Y contactors connect the three coil ends of the autotransformers together to from the star point. After a present time interval, the pneumatic timing relay opens the  $\Delta$  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 4.13**  
Autotransformer starter control circuit



**Figure 4.13** Autotransformer starter power circuit

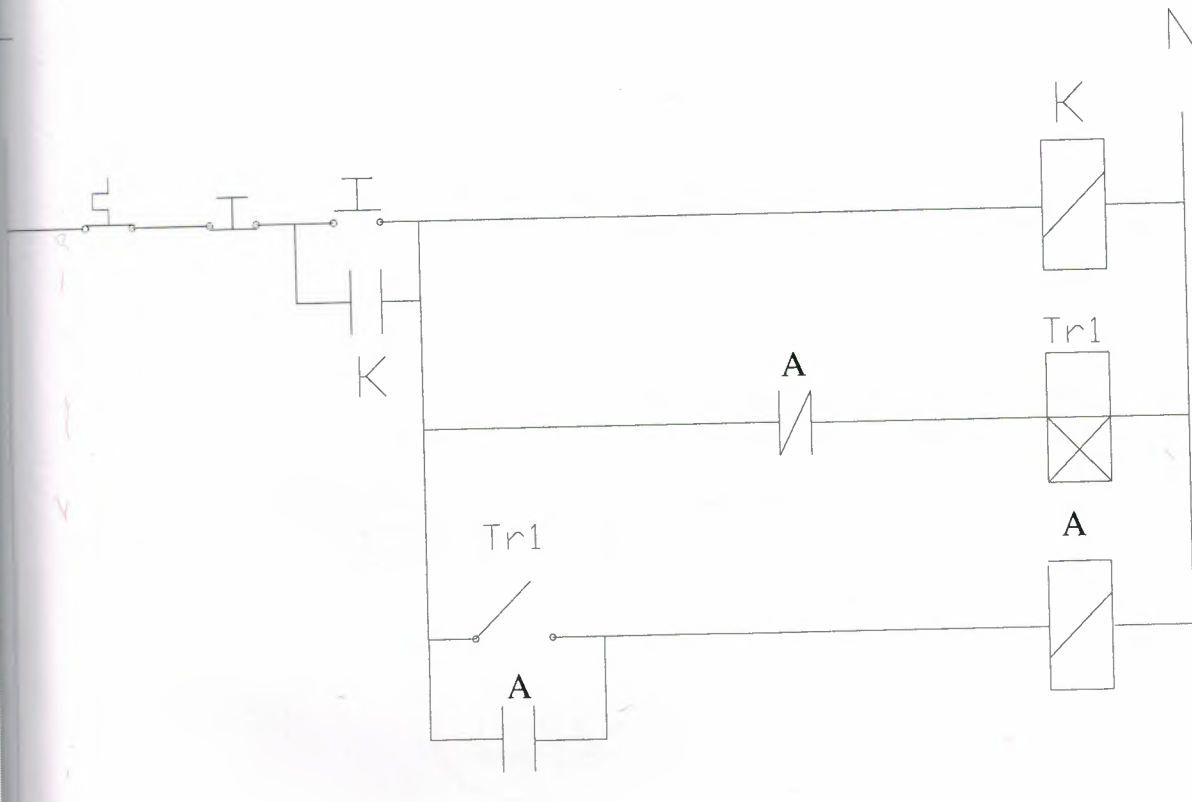
#### 4.2.6 Resistance Starter.

Figure 4.14 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  $\Delta$  are closed, a resistance unit is placed in series with 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;

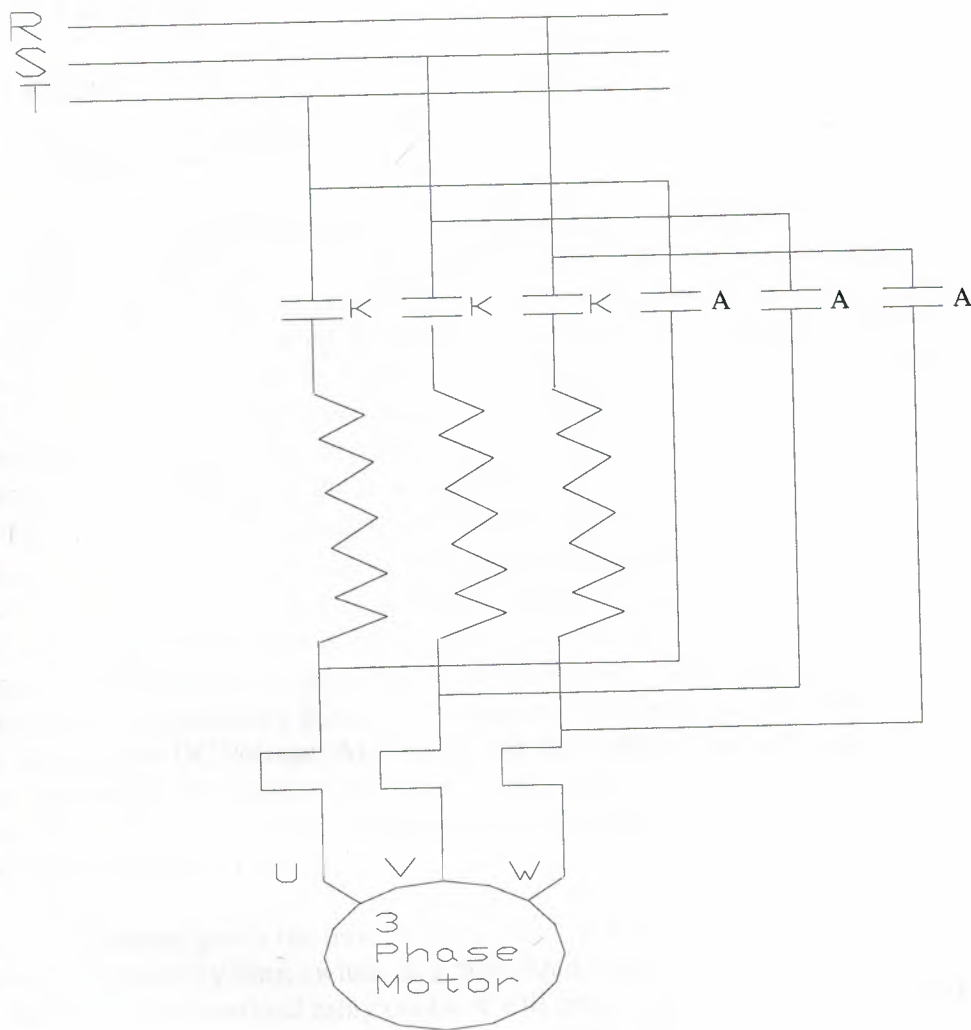
When the start button is pressed, the circuit is completed from L through coil  $\Delta$  to N, coil  $\Delta$  is energized, closing  $\Delta$  contacts, and the motor starts slowly. When the  $\Delta$  contacts close, the auxiliary interlock contacts also close to maintain a circuit through coil  $\Delta$ . 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, a three-pole run contactor, a pneumatic timing relay, single step resistor, and bimetallic overload relays.



**Figure 4.14** Resistance starter control circuit



**Figure 4.14**  
Resistance starter power circuit

Pressing the start button energizes the start contactor coil. The  $\Delta$  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 and, 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-energizes all contactors and stops 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.

## 5 Chapter

### Project

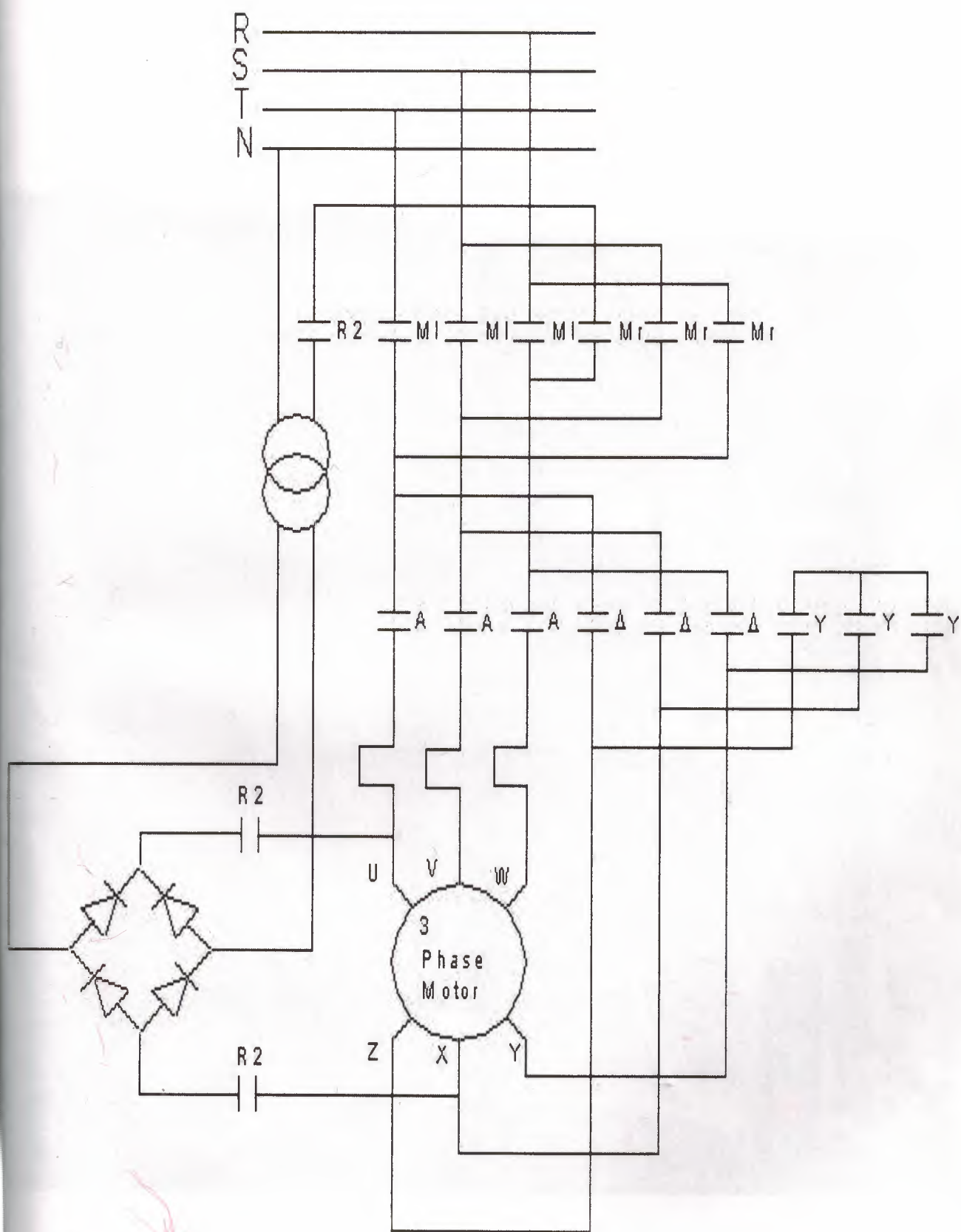
#### 5.1 Operation of circuit

In operation, pressing the left button completes a circuit from L, the stop button, the left button, the M1 coil to N. This energizes the coil, which closes the contacts for left operation of the motor, and also M1 NC contact its locked Mr coil. Auxiliary M1 NO contact also close, maintaining the current through coil M1. When the M1 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  $\Delta$  and G1 green lamp light. The  $\Delta$  contactor, upon energizing, applies the line wires to terminals Z, X, and Y causing the motor to run at full voltage. Contactors Y and  $\Delta$  are mechanically and electrically interlocked. R1 is energized by  $\Delta$ . Pressing the stop button drops all contactors, stopping the motor. M1 NC contact become normal situation, R2 is energized. Transformer energized by R2 and AC voltage is converted DC by bridge rectifier. Motor broken by low DC voltage. After some seconds TR2 active and breaking system stop. Pressure on the right button energizes the Mr coil which closes the reverse contacts. Terminals R and T are now interchanged and the motor reverses. Figure 5.1 shows control and power circuit of project.

If container pushes the limit switch (Ls2), limit switch NC contact will be open, and motor is stopped by limit switch. If a prolonged overload should occur during the operation of the motor, the overload relay contacts will open and de-energize the holding coil, R red lamp light. 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 5.1** Photograph of project



**Figure 5.1** Photograph 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- $\Delta$  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.

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