6 Phase

Induction

Motor & Inverter

Gradution Project

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Introduction

Power electronics circuits convert electric power from on form to other using electronic devices. Power electronics circuits function by using in or current. Applications of power electronics range from high-power conversion equipment such as dc power transmission to everyday appliances, such as cordless screwdrivers, power supplies for computers, cell phone chargers, and hybrid automobiles. Power electronics includes applications in which circuits process milliwatts or megawatts. Typical applications of power electronics include conversion of ac to dc, conversion of dc to ac, conversion of an unregulated dc voltage to a regulated dc voltage, and conversion of an ac power source from one amplitude and frequency to another amplitude and frequency. The design of power conversion equipment includes many disciplines from electrical engineering.

Advances in semiconductor switching capability combined with the desire to improve the efficiency and performance of electrical devices have made power electronics an important and fast-growing area in electrical engineering.

We will focus on DC to AC converters or Inverters as important application of power electronics. An Inverter is basically a converter that converts DC-AC power. The word "inverter" in the context of power electronics denotes a class of power conversion circuits that operates from a dc voltage source or a dc current source and converts it into ac voltage or current. Even though input to an inverter circuit is a dc source, it not uncommon to have this dc derived from an ac source such as utility ac supply.

The inverters can be classified as voltage source inverters or current source inverters. When input DC voltage remains constant, then it is called voltage source inverter (VSI) or Voltage Fed Inverter (VFI). When input supply current is maintained constant, then it is called current source inverter (CSI) or Current Fed Inverter (CFI). Sometimes the DC input voltage to the inverter is controlled to adjust the output. Such inverters are called variable DC link inverters. The inverters output can be single phase, three phase or polyphase specifically, six phase inverter.

The inverter circuit’s output voltage waveform can be square wave, quasi-square wave or low distorted sine wave. Also, To control the output voltage of inverters, the pulse width modulation (PWM) techniques are generally used. Such inverters are known as PWM inverters.

There are some of the industrial applications of the inverter circuits like Standby aircraft power supplies, High voltage DC Transmission(HVDC), Variable frequency AC drives, Induction heating and Uninterruptible power supplies(UPS) for computers.

The use of six-phase induction motor, inverter for industrial drives presents several advantages over the conventional three-phase drive such as improved reliability magnetic flux harmonic reduction, torque pulsations minimization, and reduction on the power ratings for the static converter. For these reasons, six-phase induction motors are beginning to be a widely acceptable alternative in high power applications. A typical construction of such drives includes an induction machine with a dual three-phase connection, where two three-phase groups are spatially shifted 30 electrical degrees, a six-leg inverter, and a control circuit. By controlling the machine's phase currents, harmonic elimination and torque-ripple reduction techniques could be implemented. So we use six phase inverter in our project to fed six phase motor which which will be represented in this book.

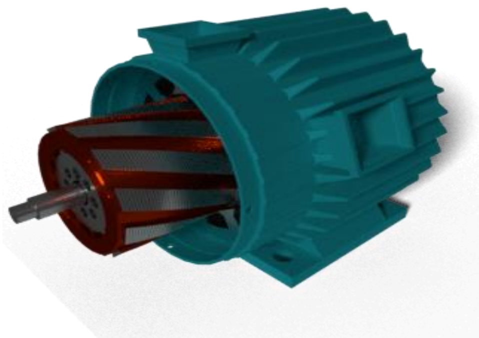
In this book, we have five chapters. First chapter covers induction motor, in this chapter we will talk generally about induction motor principle, construction, types and comparison between them after that we talk about rotating magnetic field, next we talk about single phase motor, next the relations between slip, torque and power stages, then we discuss speed control of induction motor, finally we will make clear comparison between (single, three, six) phase motor.

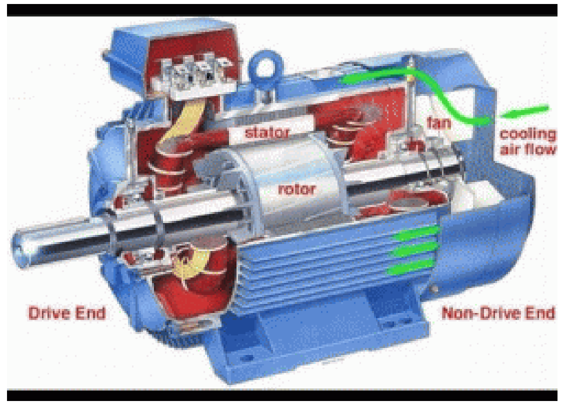
Second chapter covers winding, in this chapter we will illustrate some important steps and data which are necessary for everyone who is interested in winding of all its types, starting with types of winding and ending by the problems which may be found during the work and we will show and expose practical data and pictures taken from real work so you will feel like if you are really at lap, so pay attention to this chapter as it the bass rock for upcoming chapters.

Introduction to Arduino and microcontroller in the third chapter, in this chapter we will describe what is microcontroller ,types, we focus on Arduino ,and how to build up project with arduino, next we move to describe Avr, then we talk about Atmega, finally we built small project with Arduino to control of small motor.

Fourth chapter, Operating Principles of Inverter and Implementation of Single and Three Phase Inverter, This chapter overview the concept of DC/AC power conversion the classifications of inverters, the technologies and techniques used in designing them. Also the operating principles of some components used in designing inverter circuits are briefly discussed and some Experimental projects in the lab. Finally, we have finished this book with the fifth chapter which talks about six phase inverter.

Chapter.1: induction motor





Introduction: in this chapter we will talk generally about induction motor principle, construction, types and comparison between them after that we talk about rotating magnetic field, next we talk about single phase motor, next the relations between slip, torque and power stages, then we discuss speed control of induction motor, finally we will make clear comparison between (single ,three, six) phase motor.

Content of this chapter

1-1-Induction motor general principle:

As a general rule conversion of electrical power to mechanical power takes place in rotating part of an electrical motor.

In dc motors the electric power is conducted directly to the armature through brushes and commutator.

Hence in this sense a dc motor can be called conduction motor.

However in ac motors the rotor does not receive electric power by conduction but by induction in exactly the same way as the secondary of 2-winding transformer receives its power from primary.

In fact an induction motor as shown in Fig: 1-1 and Fig: 1-2 can be treated as a rotating transformer one in which primary winding is stationary but the secondary is free to rotate.

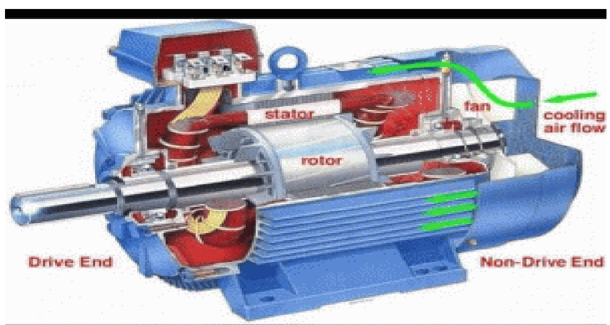


Fig: 1-1

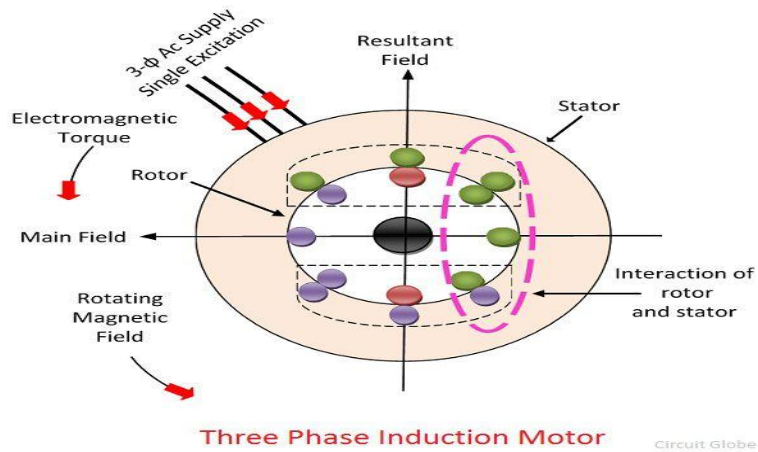


Fig: 1-2

Of all ac motors the poly phase induction motor is the one which is extensively used for various kinds of industrial drives; it has the following advantages and disadvantages.

1-1-1-Advantages:

1-it has very simple and extremely rugged

2-low cost compare to dc

3-it is very reliable

4-it has high efficiency at normal running condition

5-it requires minimum maintenance

6-good power factor

7-starting from rest (3 or more), not need to be synchronized

1-1-2-Disadvantages:

1- During light load conditions, the power factor of the motor drops to a very low value.

2-single phase does not have self-starting torque

3-not use in applications needs high starting torque

4-speed control is difficult

1-1-3-Uses:

1-domonstic loads like fans, wash machine

2-industrial filed need large power

3-some commercial devices

4-used in factories

1-2-Construction of induction motor:

Like any other electrical motor induction motor also have two main parts namely rotor and stator.

1. *Stator*: As its name indicates stator is a stationary part of induction motor. A stator winding is placed in the stator of induction motor and the three phase supply is given to it.
2. *Rotor*: The rotor is a rotating part of induction motor. The rotor is connected to the mechanical load through the shaft.

1-2-1-Stator of Three Phase Induction Motor

The stator of the three-phase induction motor consists of three main parts:

1. Stator frame
2. Stator core
3. Stator winding or field winding.

-Stator Frame

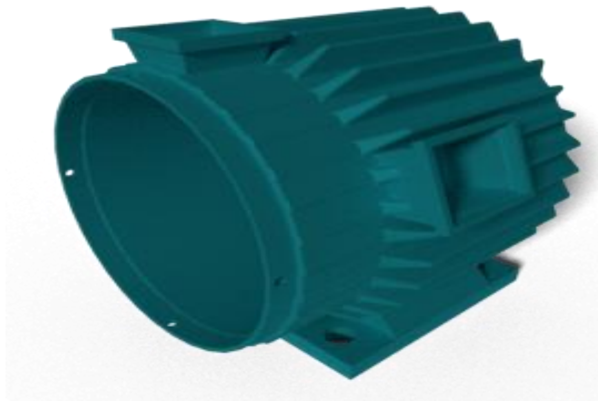


Fig: 1-3

It is the outer part of the three phase induction motor. Its main function is to support the stator core and the field winding. It acts as a covering, and it provides protection and mechanical strength to all the inner parts of the induction motor as shown in Fig:1-3 .

-Stator Core

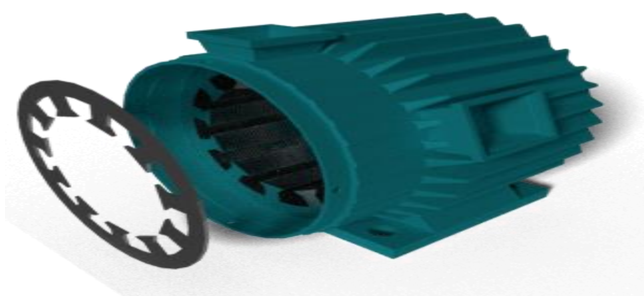


Fig: 1-4

The main function of the stator core shown in Fig1:-4 is to carry the alternating flux. In order to reduce the eddy current loss, the stator core is laminated.

-Stator Winding or Field Winding

The slots on the periphery of the stator core of the three-phase induction motor carry three phase windings shown in Fig: 1-5. We apply three phase ac supply to this three-phase winding. The three phases of the winding are connected either in star or delta depending upon which type of starting method we use.

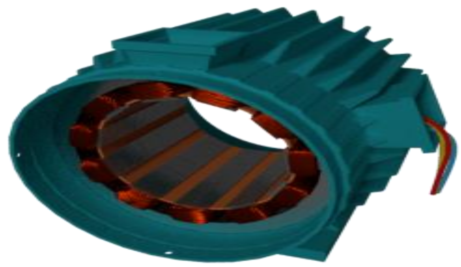


Fig: 1-5

1-2-2-Rotor of three phase induction motor:

1-squirrel cage

2-slip ring or wound rotor.

And we describe the both of the next part

1-3-Squirrel Cage Three Phase Induction Motor

The rotor of the squirrel cage three phase induction motor is cylindrical and have slots on its periphery. The slots are not made parallel to each other but are bit skewed (skewing is not shown in the fig:1-6 as the skewing prevents magnetic locking of stator and rotor teeth and makes the working of the motor more smooth and quieter. To provide mechanical strength, these rotor conductors are braced to the end ring and hence form a complete closed circuit resembling like a cage and hence got its name as squirrel cage induction motor.

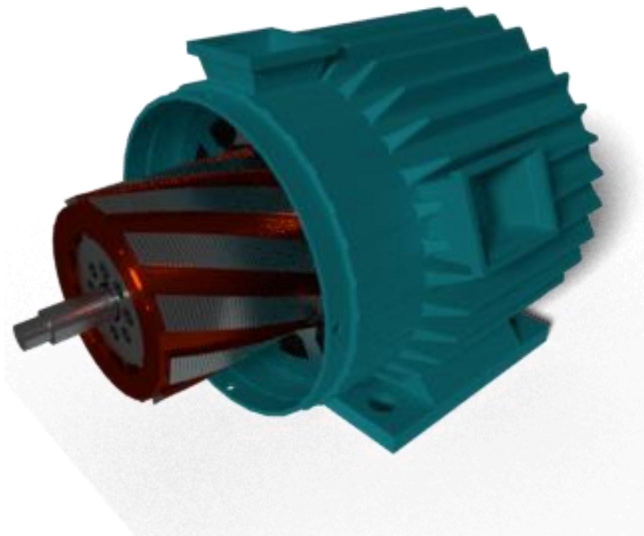


Fig: 1-6

1-3-1-Advantages of Squirrel Cage Induction Rotor

1. Its construction is very simple and rugged.
2. As there are no brushes and slip ring, these motors requires less maintenance.

1-3-2-Applications of Squirrel Cage Induction Rotor

We use the squirrel cage induction motors in lathes, drilling machine, fan, blower printing machines, etc.

1-4-Slip Ring or Wound Rotor Three Phase Induction Motor

In this type of three phase induction motor the rotor is wound for the same number of poles as that of the stator, but it has less number of slots and has fewer turns per phase of a heavier conductor. The rotor also carries star or delta winding similar to that of the stator winding.

Fig: 1-7

The rotor consists of numbers of slots and rotor winding are placed inside these slots. The three end terminals are connected together to form a star connection. As its name indicates, three phase slip ring induction motor as shown in Fig:1-7 consists of slip rings connected on the same shaft as that of the rotor.

The three ends of three-phase windings are permanently connected to these slip rings. The external resistance can be easily connected through the brushes and slip rings and hence used for speed controlling and improving the starting torque of three phase induction motor.

At starting, the resistance is connected to the rotor circuit and is gradually cut out as the rotor pick up its speed. When the motor is running the slip ring are shorted by connecting a metal collar, which connects all slip ring together as shown in Fig:1-8.

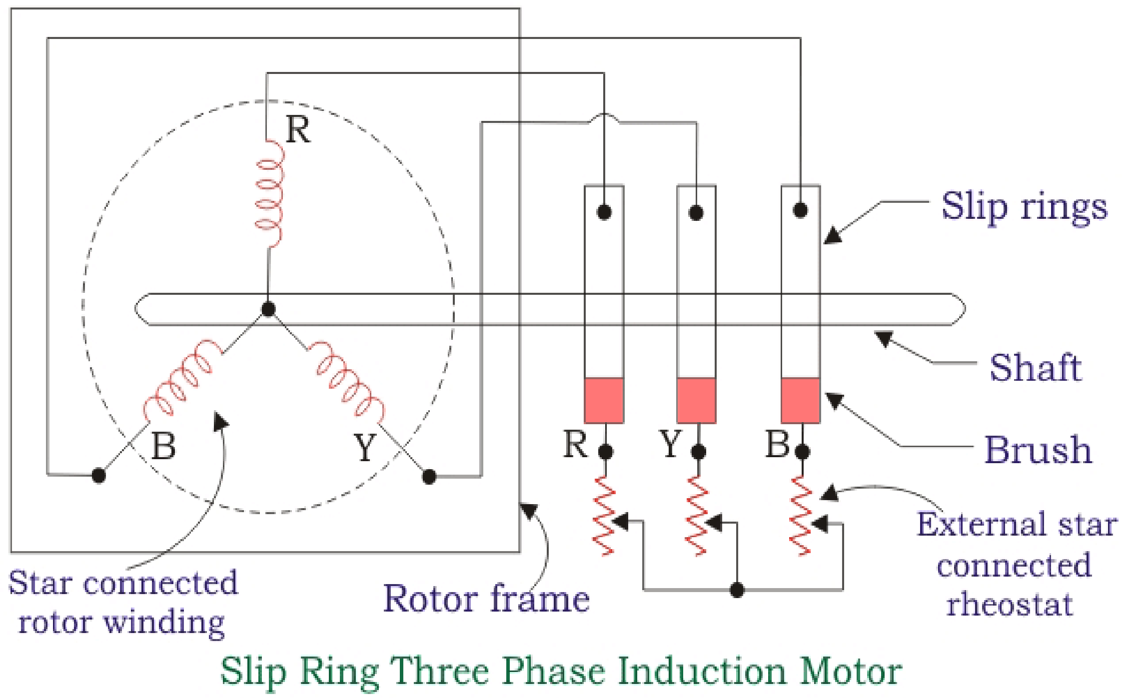


Fig:1-8

1-4-1-Advantages of Slip Ring Induction Motor

1. It has high starting torque and low starting current.
2. Possibility of adding additional resistance to control speed.

1-4-2-Application of Slip Ring Induction Motor

Slip ring induction motors are used where high starting torque is required i.e. in hoists, cranes, elevator etc.

1-5-Difference between Slip Ring and Squirrel Cage Induction Motor:

Slip ring or phase wound Induction motor	Squirrel cage induction motor
Construction is complicated due to presence of slip ring and brushes	Construction is very simple
The rotor winding is similar to the stator winding	The rotor consists of rotor bars which are permanently shorted with the help of end rings
We can easily add rotor resistance by using slip ring and brushes	Since the rotor bars are permanently shorted, its not possible to add external resistance
Due to presence of external resistance high starting torque can be obtained	Staring torque is low and cannot be improved
Slip ring and brushes are present	Slip ring and brushes are absent
Frequent maintenance is required due to presence of brushes	Less maintenance is required
The construction is complicated and the presence of brushes and slip ring makes the motor more costly	The construction is simple and robust and it is cheap as compared to slip ring induction motor
This motor is rarely used only 10% industry uses slip ring induction motor	Due to its simple construction and low cost. The squirrel cage induction motor is widely used
Rotor copper losses are high and hence less efficiency	Less rotor copper losses and hence high efficiency
Speed control by rotor resistance method is possible	Speed control by rotor resistance method is not possible

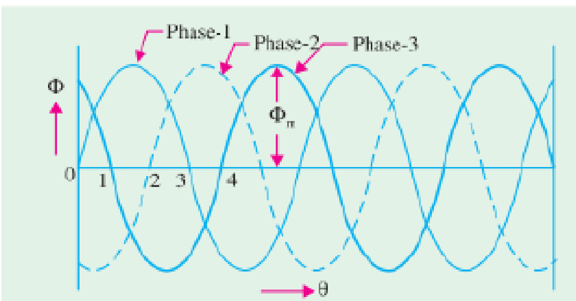
Slip ring induction motor are used where high starting torque is required in hoists, cranes, elevator etc	Squirrel cage induction motor is used in lathes, drilling machine, fan, blower printing machines etc

1-6-Production of rotating field:

1-6-1-Three phase supply

When we have three phase winding displaced by 120^o fed from three phase supply displaced in time by 120^o,they produce rotating magnetic flux.

The principle of three phase two pole stator having 3 identical winding placed 120^o space and the flux produce is is shown in Fig:1-9



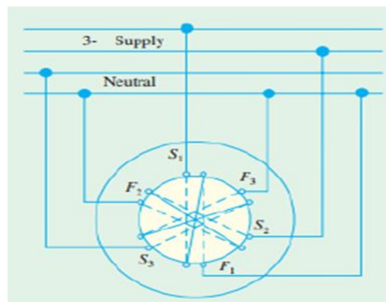


Fig:1-9

Hence, we conclude that:

1-The resultant flux is constant value=1.5Øm

2- The resultant flux rotates around the stator at NS

And we easily show this in Fig: 1-10

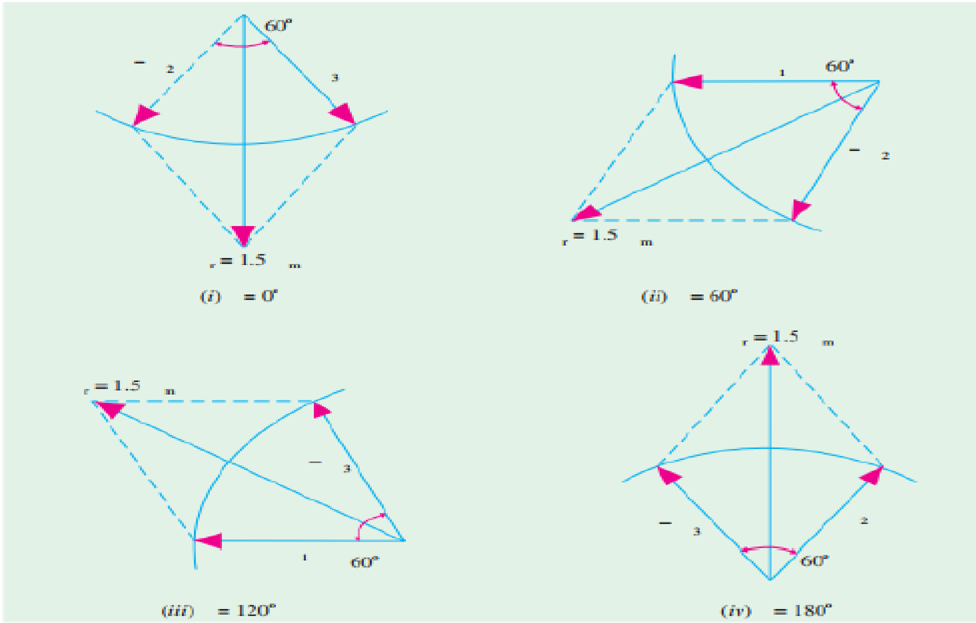


Fig: 1-10

1-7-single phase induction motor:-

This motor is similar to a poly phase as shown Fig:1-11 IM except:-

1-its stator is provided with a single phase winding.

2-a centrifugal switch is used in some types of motors, used only for starting purposes.


Single-phase induction motor

Fig: 1-11

-why single phase motor can't start?

when fed from a single phase supply its stator winding produces a flux which is only alternating.one which alternates along one space axis only ,but in 2 or 3 phase supply the flux produced is rotating .so that single phase motor is not self-starting.

1-7-1-Double field revolving theory:

This theory makes use of the idea that an alternating uni-axial quantity can be represented by two oppositely-rotating vectors of half magnitude.so alternating sinusoidal flux can be represented by two revolving fluxes show in Fig:1-12.each equal to half the value of the alternating flux and each rotating synchronously (Ns=120 f/p) in opposite direction ,A &B: components of maximum flux (A=B=.5 MAXØ).

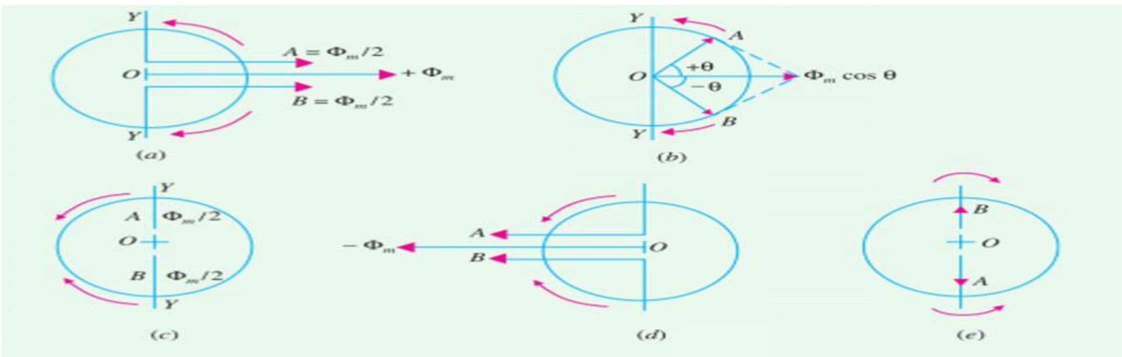


Fig :1-12

1-7-2Total torque:

T=Tf +Tb where Tf :forward torque & Tb: backward torque

Fig;1-13 shows both torques and the resultant torque for slips between (0&+2).at standstill, s=1 and (2-s)=1

hence ,Tf &Tb are numerically equal but in opposite direction ,produce no resultant torque ,that explains why there is no starting torque in single phase IM.

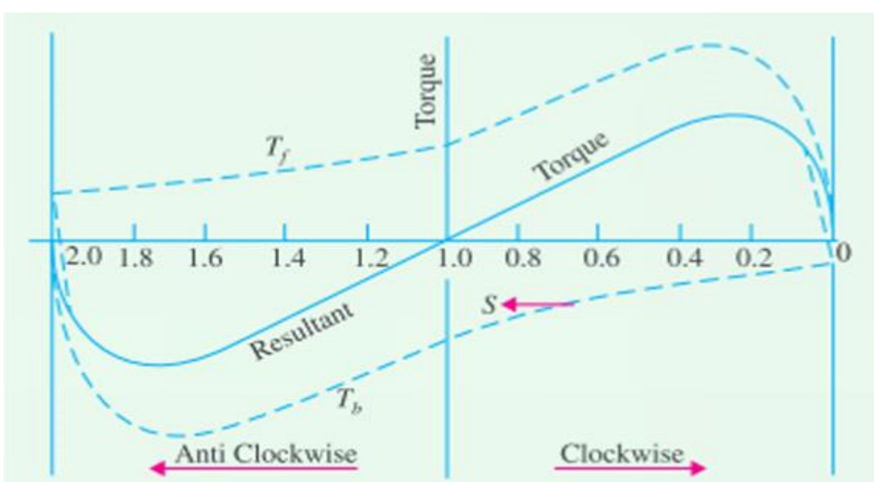


Fig:1-13

1-7-3-methods of starting of single phase IM :-

1-split phase starting

2-capacitor starting

3-shaded-pole starting

4- Capacitor start capacitor run

1-8-Slip

It is the difference between the synchronous speed (Ns) and the actual speed of rotor.

-Why rotor can't catching up with speed of stator field?

Because the e.m.f in rotor equal (dØ \dt) and if the two speeds are equal then e.m.f equal zero also current and torque equal zero.

So it is nature to see the slip speed and it is equal (Ns-N).

Now we can evaluate the %slip:

%S=Ns-N/Ns

And slip effect on the rotor frequency……who?--

Let at any slip-speed the frequency of rotor is(f')

Slip speed=Ns-N=120f'/p

Also Ns=120f/p

Now divide both side of slip speed by Ns

Ns-N/Ns=120f'p/120fp

Now solving this equation

F'/F=Ns-N/Ns=s

F'=Sf

-To ensure of the calculation:

Relative speed =sNs   & actual speed = (1-S)Ns

Relative speed +actual speed
=sNs+(1-s)Ns=Ns

1-9-Torque under running condition:

T=K*Er*Ir*cos(Ø)

Where Er=sE2 , Ir=Er/Zr , Zr=√(R2^2+(SX2)^2)

cos(Ø)=R2/Zr ,we can easily obtained the P.F from this triangle Fig:1-14

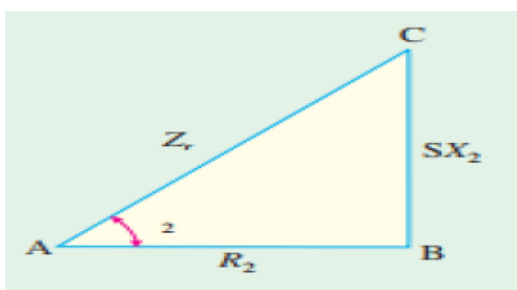


Fig:1-14

K=3/Wms , Wms=2πNs

By substitution

T=3*(SE2)^2*R2/2πNs*(R2^2+(Sx2)^2)

If we put "s=1" this called starting torque and equal

T=3*E2^2*R2/2πNs*(R2^2+x2^2)

1-10-Condition of maximum Torque under running condition:

The condition can be obtained by differentiating equation of torque with respect to slip "s" and then put it equal zero to make it simple put j=1/T

J=$(R2^2+(sX2)\hat{}2)/KØsE2$

Where Ø proportional to E2   now dj/ds=

$\frac{-R2}{KØs\hat{}2E2}+\frac{X2\hat{}2}{KØR2E2}=0$ $\quad$ $\frac{R2}{KØs\hat{}2E2}=\frac{X2\hat{}2}{KØR2E2}$ $\quad$ $\therefore\ R2=\ sX2$

By substitution in torque equation we find

Tmax= T=3*E2^2 /2πNs*2x2

1-11-Relation between torque and slip:

$$T=\frac{k\ Ø\ sE2R2}{R2^2+(SX2)^2}$$

It is clear if s=0 $\rightarrow$T=0

-At normal speed the term (sx2)is small and we can neglected it

So T $\propto \frac{S}{R2}$ or T$\propto$ s as shown in Fig:1-15

-for low values of slip the torque/slip curve approximate a straight line

_as slip increases the torque also increase and becomes max when s=$\frac{R2}{X2}$

-as the slip further increases (motor speed falls), then R2can we neglect as compared to (sx2), therefore for large value of slip T$\propto \frac{S}{(sx2)\hat{}2}$ $\propto$ T $\propto \frac{1}{S}$

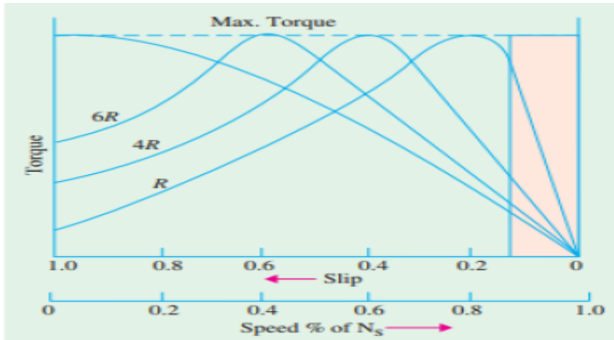


Fig:1-15

1-12-Effect of change in power supply voltage on torque and speed:

$$T = \frac{k\ Ø\ E2R2}{R2^2 + (SX2)^2}$$

As E2 ∝ Ø ∝ V Where V is supply voltage ∴ T ∝ V^2

Torque at any speed is proportional to square of the applied voltage

Let v change to v' and slip to s'

$$\frac{T}{T'} = \frac{SV\text{^}2}{S'V'^2}$$

1-13-Full load torque and maximum torque:

Tf ∝ $\frac{SfR2}{R2^2+(SfX2)\text{^}2}$ Tmax ∝ $\frac{1}{2X2}$

$$\frac{\text{Tf}}{Tmax} = \frac{2SfX2R2}{R2^2 + (SfX2)\text{^}2}$$

Dividing both numerator and denominator by $X2\text{^}2$

$$\frac{\text{Tf}}{Tmax} = \frac{2Sf * R2/X2}{(R2/X2)^2 + Sf\text{^}2} = \frac{2asf}{a^2 + sf\text{^}2} \text{ where a} = \text{R2/X2}$$

1-14-Starting torque and maximum torque:

$Tst \propto \frac{R2}{R2^2+X2^2}$ Tmax ∝ $\frac{1}{2X2}$

$$\frac{\mathrm{Tf}}{Tst} = \frac{2X2R2}{R2^2 + X2\hat{}2}$$

Dividing both numerator and denominator by $X2\hat{}2$

$$\frac{\mathrm{Tf}}{Tst} = \frac{2R2/X2}{(R2/X2)^2 + 1} = \frac{2a}{a^2 + 1} \quad where\ a = R2/X2$$

1-15-Torque speed curve:

The relation between slip and torque can't be represented by simple equation ,it easier to show it from Fig:1-16.

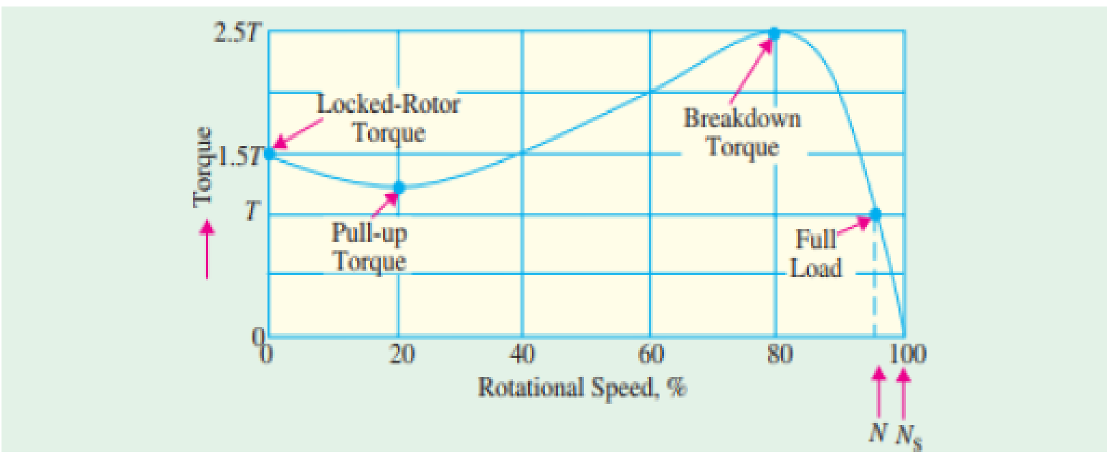


Fig:1-16

1-16-Complete torque /speed curve of three phase machine:

-induction machine can run as a motor when it takes electrical power and supplies mechanical power.

_the same machine can be used a generator when speed is more than Ns,as shown in Fig:1-17

_the same machine can be used a brake during plugging period.

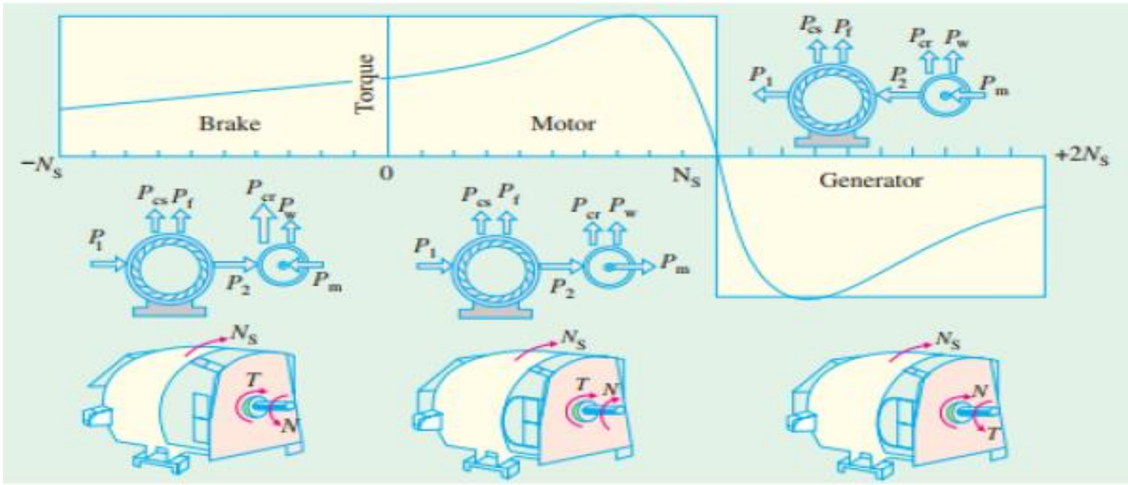
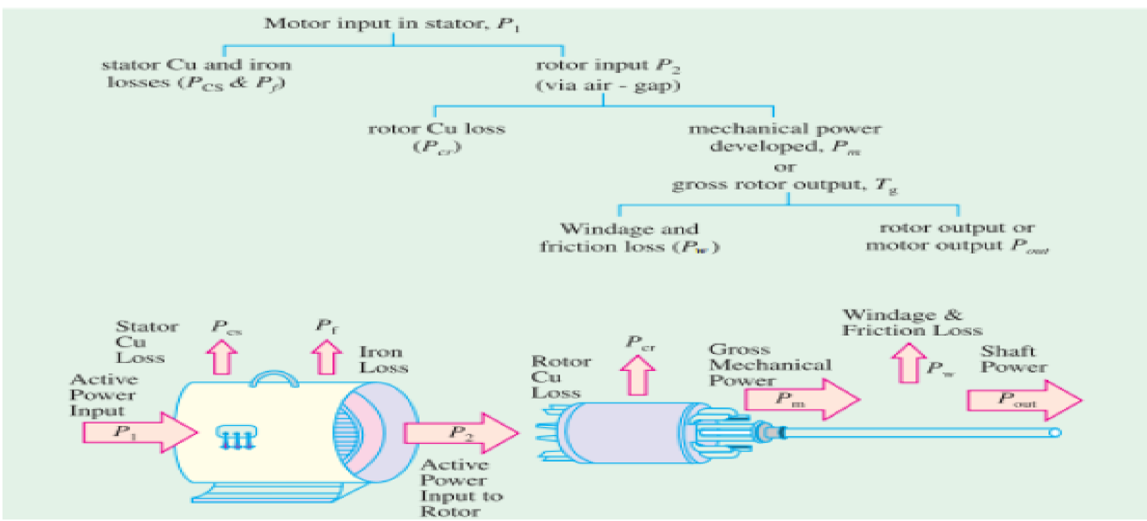


Fig:1-17

1-17-Power stages in induction motor:

Briefly



1-18-Speed control of induction motor:

The Speed of Induction Motor is changed from Both Stator and Rotor Side**.**

1-18-1-The speed control of three phase induction motor from stator side is further classified as:

a) V / f control or frequency control.
b) Changing the number of stator poles.
c) Controlling supply voltage.
d) Adding rheostat in the stator circuit.

1-18-2-The speed controls of three phase induction motor from rotor side are further classified as:

a) Adding external resistance on rotor side.
b) Cascade control method.
c) Injecting slip frequency e.m.f into rotor side.

1-18-1-a-V / f Control or Frequency Control

In three phase induction motor e.m.f is induced by induction similar to that of transformer which is given by

$$v=4.44\ K.\text{Ø}.T.F$$

Where, K is the winding constant, T is the number of turns per phase , f is frequency and speed given by Ns=120f/p, . Now if we change frequency synchronous speed changes but with decrease in frequency flux will increase and this change in value of flux causes saturation of rotor and stator cores which will further cause increase in no load current of the motor . So, its important to maintain flux , ϕ constant and it is only possible if we change voltage. i.e if we decrease frequency flux increases but at the same time if we decrease voltage flux. change in flux and hence it. So, here we are keeping the ratio of V/f as constant. Hence its name is V/ f method. For controlling the speed of three phase induction motor by V/f method we have to supply variable voltage and frequency which is easily obtained by using converter and inverter set.

1-18-1-b-Changing the number of stator poles:

The stator poles can be changed by two methods

-Multiple stator winding method.

-Pole amplitude modulation method (PAM)

-***Multiple Stator Winding Method***

In this method of speed control of three phase induction motor, we provide two separate windings in the stator. These two stator windings are electrically isolated from each other and are wound for two different numbers of poles. Using a switching arrangement, at a time, supply is given to one winding only and hence speed control is possible. Disadvantages of this method are that the smooth speed control is not possible. This method is more costly and less efficient as two different stator windings are required. This method of speed control can only be applied to squirrel cage motor.

-***Pole Amplitude Modulation Method (PAM)***

In this method of speed control of three phase induction motor the original sinusoidal mmf wave is modulated by another sinusoidal mmf wave having the different number of poles.

1-18-1-c-Controlling Supply Voltage

As we describe in "slip "part

1-18-1-d-Adding Rheostat in Stator Circuit

In this method of speed control of three phase induction motor rheostat is added in the stator circuit due to this voltage gets dropped .In case of three phase induction motor torque produced is given by $T \propto sV_2^2$. If we decrease supply voltage torque will also decrease. But for supplying the same load, the torque must remain the same and it is only possible if we increase the slip and if the slip increase motor will run reduced speed.

1-18-2-Speed Control from Rotor Side

1-18-2-a-Adding External Resistance on Rotor Side

In this method of speed control of three phase induction motor external resistance are added on rotor side. The equation of torque for three phase induction motor is

$$T = \frac{k\,\emptyset\, sE2R2}{R2^2 + (SX2)^2}$$

The three-phase induction motor operates in a low slip region.
In low slip region term $(sX)^2$ becomes very very small as compared to R_2. So, it can be neglected. and also E_2 is constant. So the equation of torque after simplification becomes $T \propto S/R2$.

Now if we increase rotor resistance, R_2 torque decreases but to supply the same load torque must remain constant. So, we increase slip, which will further result in the decrease in rotor speed. Thus by adding additional resistance in the rotor circuit, we can decrease the speed of the three-phase induction motor. The main advantage of this method is that with an addition of external resistance starting torque increases but this method of speed control of three phase induction motor also suffers from some

-disadvantages :

a) The speed above the normal value is not possible.
b) Large speed change requires a large value of resistance
c) large copper loss and hence reduction in efficiency.
d) This method cannot be used for squirrel cage induction motor.

1-18-2-b-Cascade Control Method

In this method of speed control of three phase induction motor, the two three-phase induction motors are connected on a common shaft and hence called cascaded motor. One motor is the called the main motor, and another motor is called the auxiliary motor. The three-phase supply is given to the stator of the main motor while the auxiliary motor is derived at a slip frequency from the slip ring of the main motor.

1-18-2-c-Injecting Slip Frequency EMF into Rotor Side

When the speed control of three phase induction motor is done by adding resistance in rotor circuit, some part of power called, the slip power is lost as I^2R losses. Therefore the efficiency of three phase induction motor is reduced by this method of speed control. This slip power loss can be recovered and supplied back to improve the overall efficiency of the three-phase induction motor, and this scheme of recovering the power is called slip power recovery scheme and this is done by connecting an external source of e.m.f of slip frequency to the rotor circuit.

1-19-Compare between single, three and six phase induction motor:

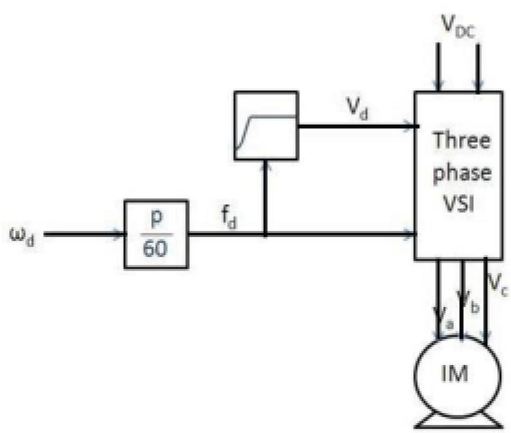
characteristics	**single**	**three**	**Six**
Power source	Single phase source	Require more than single phase(three phase)	Six phase source
Starting mechanism	Not self-start	Self-start	Self-start
efficiency	Low as only one winding has to carry total current	High because three winding are available to carry current	Higher than three because six winding available
types	Shaded pole ,spilt phase, capacitor start inductor run, Capacitor start capacitor run	Squirrel cage, Wound rotor(slip ring)	Squirrel cage, Wound rotor(slip ring)

slip	There are two slip forward(s), Backward(2-s)	It has only forward slip	It has only forward slip
Size for same power rating	large	Smaller in size	Smaller than three phase
Power factor	low	high	Higher than 3 phase
Repair and maintenance	Easier repair	Difficult to repair	Difficult to repair
Starting torque	low	High	Higher than 3phase
noise	high	quiet	More quiet
Starting current	high	low	Lower than 3 phase
Motor rotation	There is no mechanism to change rotation	Can be change easily by change the phase sequence	Can be change by change the phase sequence
uses	They are mostly used in domestic applications such as mixer, grinder, fans, compressors, washing machine.	Mostly used in industries some commercial drives	We can use it in industrial field when we have efficient six phase supply

Control Methods of Induction Motor

1. Scalar Control (V/F)

The Scalar Control method is an open loop control scheme, in which no feedback system is required. Synchronous speed can be control by varying the supply frequency f. The voltage induced in the stator is directly proportional to ϕ, where ϕ is the air-gap flux. As we can neglect the stator voltage, we obtain terminal voltage directly proportional to ϕ. Thus reducing the frequency without changing the supply voltage will cause an increase in the air-gap flux, which is considerable. Hence, whenever frequency is varied, the terminal voltage is also varied in order to maintain the V/F ratio constant. Thus by maintaining a constant V/F ratio, the maximum torque of the motor can keep constant for changing speed



2. Vector control

Vector control is controlling of an ac motor similar to a dc motor by the use of feedback control. It is compulsory to perform d-q transformation [9,10,11,12]. By this method, fast torque response can be achieved.

Steps followed in vector control:

1. d-q transformation

2. Speed estimation

3. Generating error signal from reference and measure speed

4. The error signal is fed to the controller to generate a torque reference signal

5. Calculation of current for d and q axis, the position of rotor flux and transformation into a real model

6. Generation of PWM signal for an inverter.

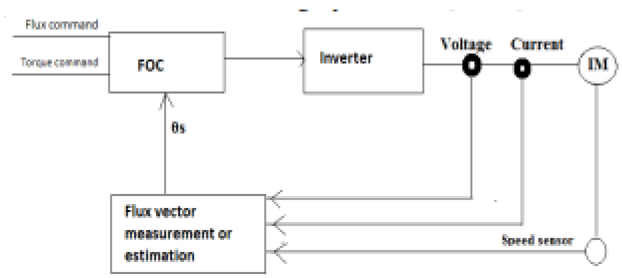
There are two methods to detect rotor flux position:

i) Direct vector method

ii) Indirect vector method

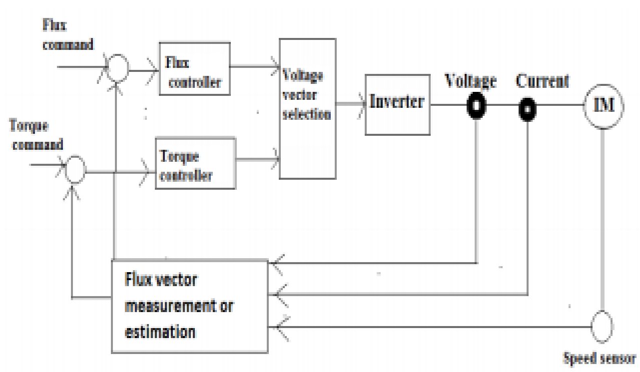
i) Direct vector method

In this method, flux sensing coils or the Hall devices are used to measure the flux. It adds extra cost, also the result is not highly accurate



ii) Indirect Vector method

In this method, flux angle is not measured directly; instead, it is estimated from the equivalent circuit diagram, measurement of rotor speed, stator current and voltage



3. Direct Torque Control (DTL)
The DTC scheme is no need for d-q transformation. In this case, torque and the stator flux are estimated and directly controlled by applying the appropriate stator voltage vector [15,16].

Advantages:

1. Fastest response time
2. Eliminating the need for a rotor speed sensor
3. Elimination of feedback devices
4. Reduce mechanical failure.

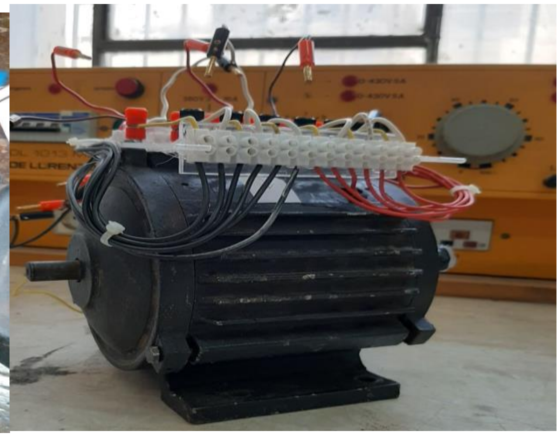
Disadvantages:

1 Inherent hysteresis of the comparator
2. Higher torque
3. Flux ripple exists.

Steps followed in DTL:
1. Speed and torque are estimated
2. Estimated speed is compared with the desired value
3. Error signal acts on PI controller to generate reference torque signal.
4. Estimated speed generates a reference signal for the stator flux linkage.
5. Error in torque and stator flux, combined with the angular position of the stator linkage space vector, determines the stator voltage space vector.

Application: Variable speed control.

Chapter 2: winding:

Introduction: In this chapter we will illustrate how to rewind a malfunctioned motor in detailed steps, making a comprehension -vision about the techniques used for winding purposes.

Content of this chapter:

1- Winding Design

1.1- Types of winding

2-Mathmatical calculation for three phase motor

3- Preparation of the malfunctioned motor

4-Preparation the new coils and insert them into the motor

5-Motor test (3 phase)

6-performane of mathematical calculation for 6 phases

7-Connection of ends and the ways of connection (Star –Delta)

8-Motor test using a transformer with specific design

9- The problems that popped up and how we resolved them

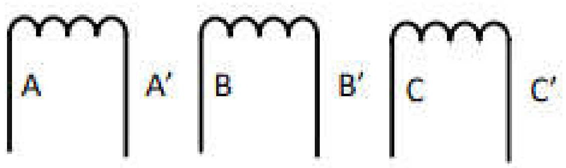
Introduction

The Induction motors are usually used in many sectors, especially in industrial and home applications, because this motor is simple and robust construction. At present, there are two types of induction motor in application, three phase and single-phase motor. The three-phase motor is usually supplied by a 3-phase system, whereas a single phase motor with a 1-phase system
phase motor with a 1-phase system .
The 3-phase motors usually operate on a three-phase system. The motors are usually produced in high power ratings. They operate normally by using Three-phase power supply. The motors have 3 identical windings separated by 120 electrical degrees. The number of turns of each winding is equal, so that the motor can operate with a balanced current on each winding when the 3-phase balanced source is used in the motor.
In the development of operating system, the 3-phase motor had been operated on 1-phase power system
The motor was operated on 1-phase power supply by installing some capacitors to the windings of the motor.
The modification technique was developed by adopting 2 windings principle of single-phase capacitor motor. Some evaluation methods had been developed by some research to find a simple method for analyzing the characteristics of the motor.
Single-phase induction motor is a motor that is usually produced at low power rating. The motor is operated on a single-phase supply and usually used in some home applications, such as fans, etc. The motor usually has 2 windings, auxiliary and main windings.
will operate with better performance when capacitors are installed on the motor. These capacitors serve to produce the phase difference between the two windings (auxiliary and main windings) of the motor which aims to produce a large torque to the motor.
This method is called the conventional method because the motor only has 2 windings. Although the performance of the motor had been developed.
the construction design of the winding of the motor still has the same with the conventional methods.

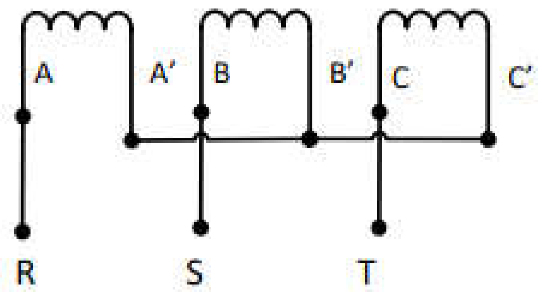
Winding Design of Induction Motor

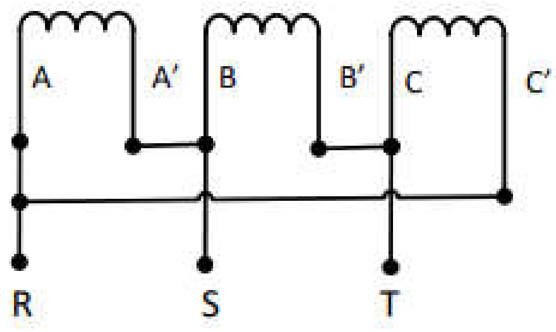
Three Phases Winding Design

Three-phase induction motor has three identical windings that are separated from each other by 120 degrees. The design of the motor windings can be modeled as shown in



The windings of a three-phase motor can be connected in two variation standards, Wye (Y) and delta (Δ)





the 3-phase motor has three identical windings, A (A to A’), B (B to B’) and C (C to C’). The letters R, S and T in Figs. 2 and 3 are the spots for which a three-phase source is connected to supply the motor.

Conventional 1-phase Capacitor Motor

Single-phase capacitor motor usually has 2 windings. The windings are called main and auxiliary windings respectively. Both windings are usually used for starting. A 1-phase capacitor motor usually used capacitors that installed in series with one of the windings

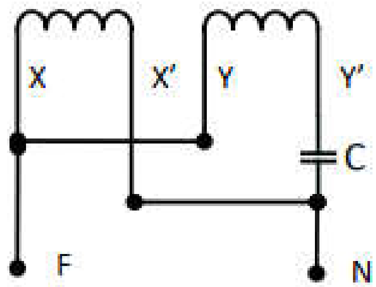


Fig. 4. Windings of a 1-phase capacitor motor

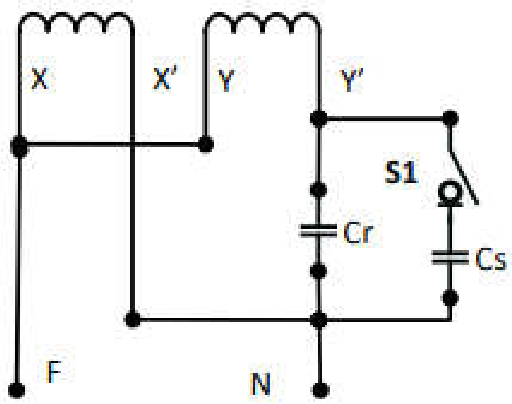


Fig. 5. Two windings of a conventional single-phase capacitor motor

From the data shown in Fig. 4 and Fig. 5 can be explained that the letter X to X' is main winding and Y to Y’ is auxiliary winding. C is capacitor installed at auxiliary winding in Fig. 4. Cs and Cr in Fig. 5 are the start capacitor and the run capacitor respectively. Letter ‘F’ and ‘N’ in Fig. 4 and Fig. 5 are line power and Neutral of the single-phase supply system respectively.

Four Phases Windings design

Four phases windings design of the motor has four identical windings that are separated from each other by 90 degrees. The model of the windings design

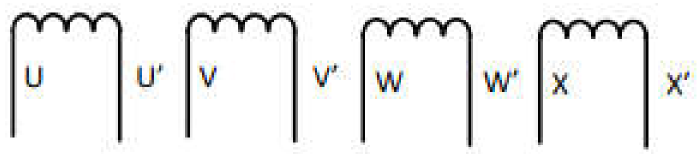


Fig. 6. Four phases windings design of the motor

2-1-Types of Winding:

2-1-1-Closed coil type:

In this type of winding, a closed path is formed around the armature. The starting point of the winding is reached again after passing through all the turns. The current passing through closed type of winding is through brushes placed on commutator. The commutator segments are connected to various armature coils.

The armature current gets divided into different parallel paths. The current flowing through the coil changes continuously but from brush side the winding view remains same and polarity is maintained which is in effect due to use of commutator segments.

The closed type of winding is normally used in A.C and D.C commutator machines. This type of winding is usually double layer.

2-1-2-Open coil type:

In case of A.C machines, commutator is not used and hence closed winding is not required to be used. In such cases open type winding is used. The armature is left open at one or more points.

The ends of each section of the winding can be brought at the terminals to do the required type of interconnection externally. The open type of winding is preferred over closed type as it gives better flexibility in design and freedom of connections, These type of windings are either single layer type or double layer type and are mainly used in induction machines and synchronous machines.

Open coil winding converts into Lap and Wave as follows in Fig: 2-1

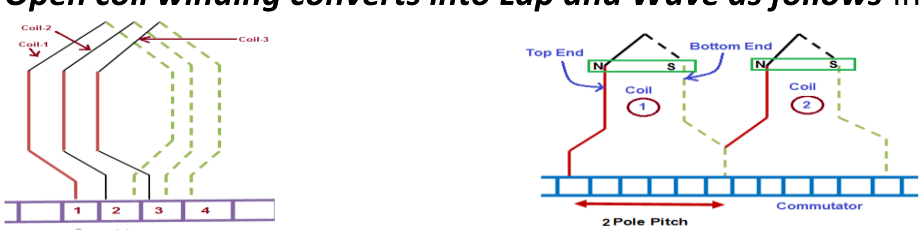


Fig:2-1

The main difference between lap and wave winding is the manner of connecting the armature winding coil end to the commutator segment, in lap winding, the top and bottom coil ends are connected to adjacent commutator segment whereas in wave winding, they are bent in opposite direction and connected to commutator segments which are approximately two pole pitches apart.

-There are different types of winding used in alternators. The windings can be classified as

1. Single phase and poly phase armature winding.
2. Concentrated winding and distributed winding.
3. Half coiled and whole coiled winding.
4. Single layer and double layer winding.
5. Lap, wave and concentrated or spiral winding and
6. Full pitched coil winding and fractional pitched coil winding

We describe (a) lap, (b) wave and (c) concentrated or spiral winding *for EX*. (4 poles, 12 slots, 12 conductors)

A-Lap Winding of Alternator

Full pitched lap winding of 4 poles, 12 slots, 12 conductors (one conductor per slot) alternator is shown below, The back pitch of the winding is equal to the number of conductors per pole, i.e., = 3 and the front pitch is equal to the back pitch minus one. The winding is completed per pair of the pole and then connected in series as shown in Fig: 2-2

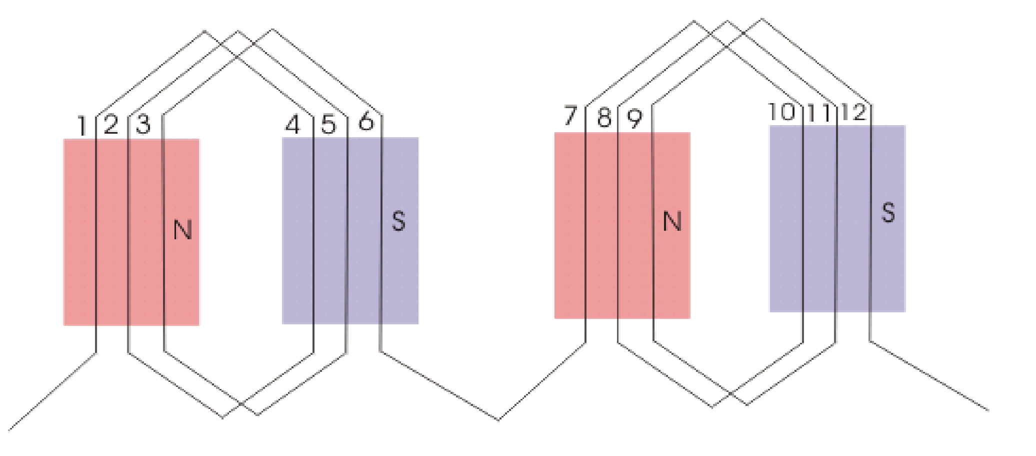


Fig: 2-2

B-Wave Winding Of Alternator

Wave winding of the same machine, i.e., 4 poles, 12 slots, 12 conductors as shown in Fig: 2-3. Here, back pitch and front pitch both equal to the same conductor per poles.

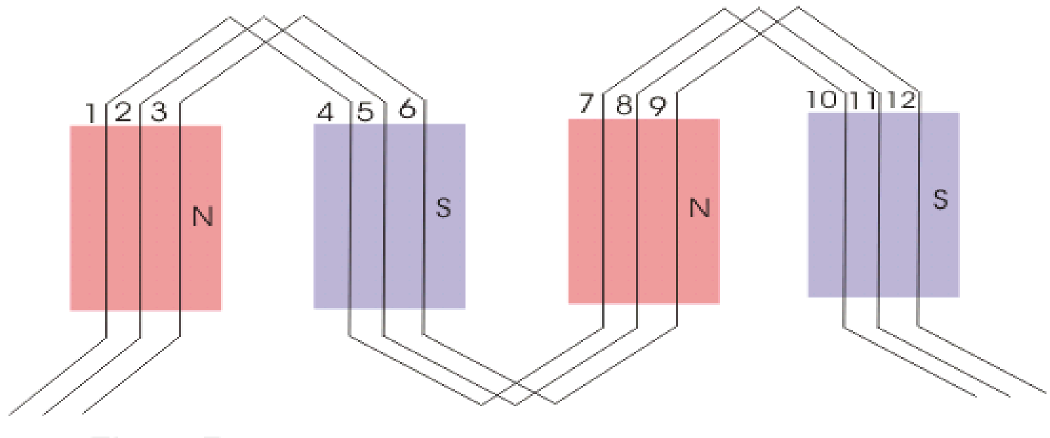


Fig: 2-3

C-Concentrated or Spiral Winding

This winding for the same machine, i.e., 4 poles 12 slots 12 conductors alternator is shown in Fig:2-4 below. In this winding, the coils are of different pitches. The outer coil pitch is 5, the middle coil pitch is 3, and inner coil pitch is one.

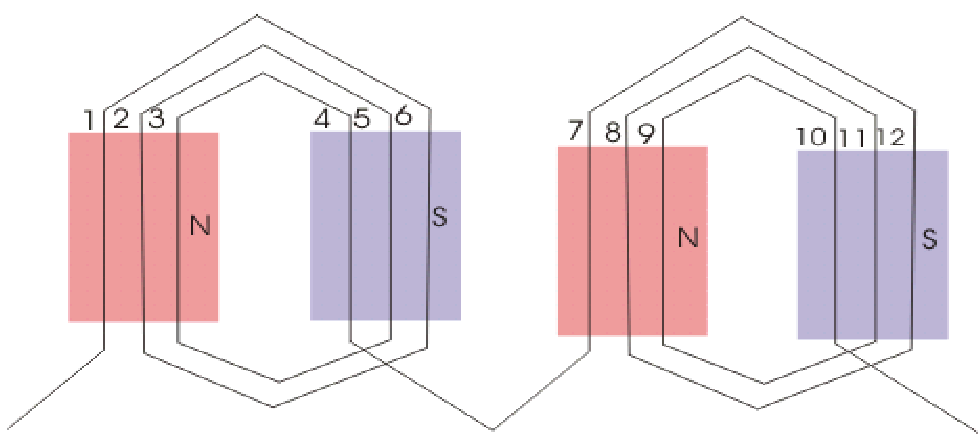


Fig: 2-4

We have chosen "Lap type "as it is practically easier.

2-2- Mathematical Calculation:

We bought an old malfunctioned motor and reused it.

We replaced the old burned coils by new active coils, using electrical calculations

N= 120f/p= (120*50)/6=3000 rpm

Pole pitch=no. of slots/no. of poles=24/2=12 slot / pole

Total no. of coils=0.5 no. of slots=0.5*24=12 coil

No. of coils/phase=12/3=4 coils/phase

No. of coils/phase/pole=4/2=2

Using Lap winding, where the 1st coil begin from slot 1 up to slot 13, and the 2nd coil from slot 2 to slot 14 and so on…… the distribution of slots shown in Fig:2-5

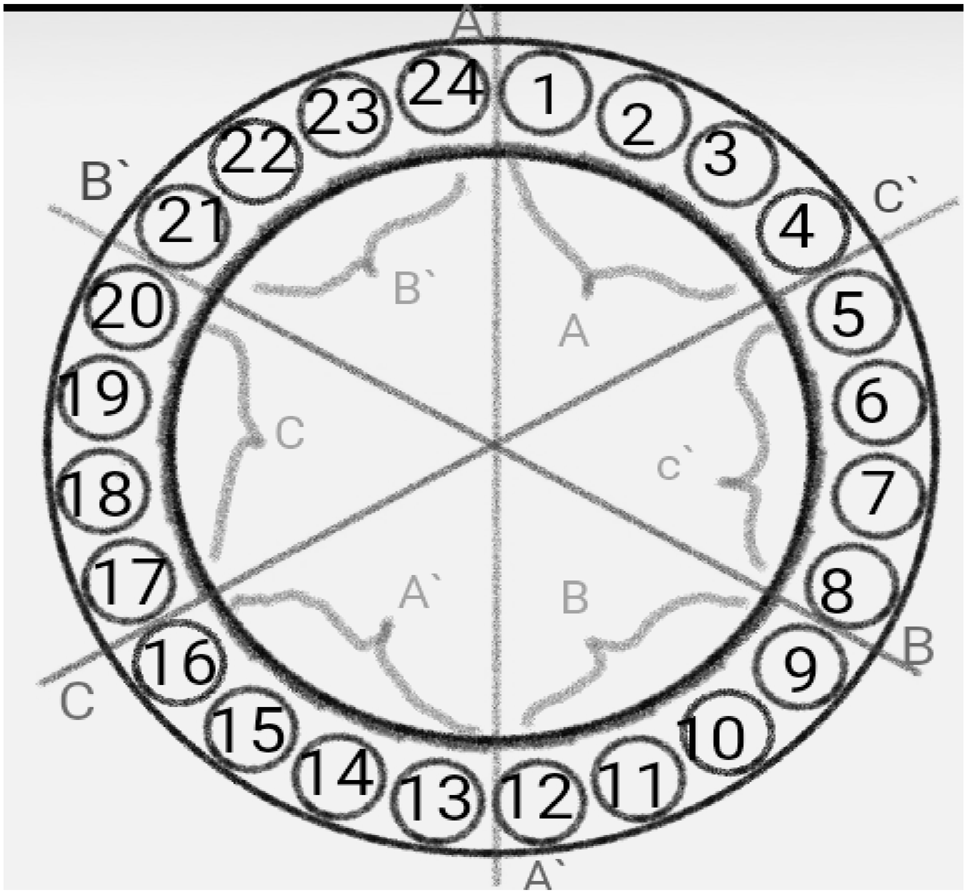


Fig: 2-5

-The coils of each phase is connected in series as shown in Fig: 2-6

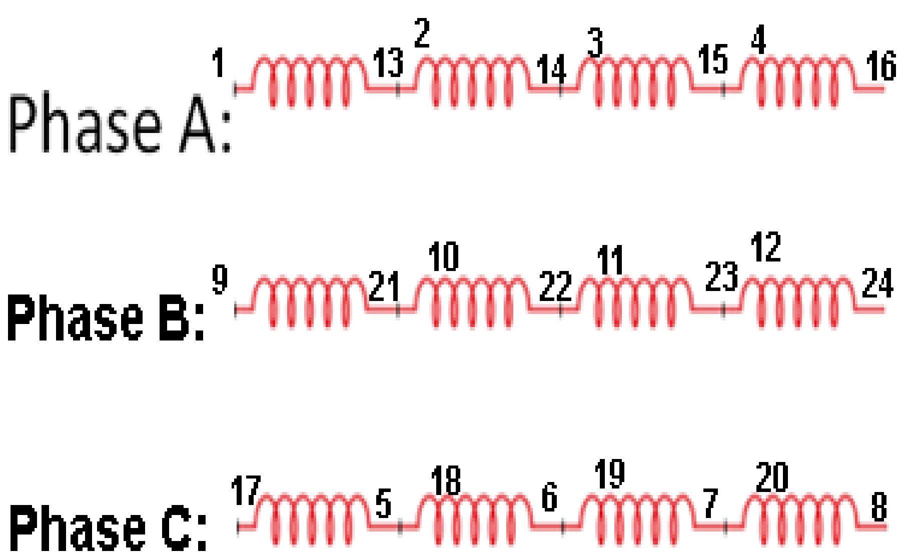


Fig: 2-6

- (1,9,17) where the power cables feed our motor

- (8,12,24) gathered at one point

-And the angles among the 3 phases are 120 ^{o} as shown in Fig:2-7

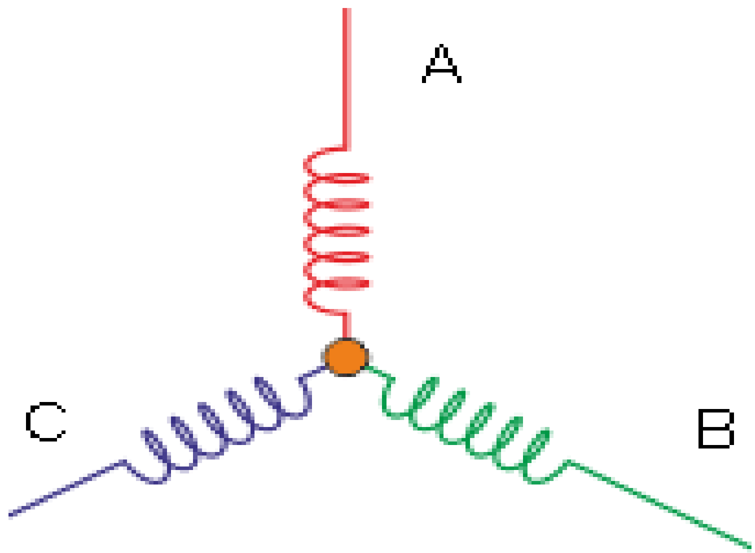


Fig: 2-7

2-3.Preparation of the broken motor:

A-Technical information extraction:

- (Single phase -24 slot -concentric Winding - 4 poles)

B-We have prepared and have bought some tools and instruments as shown in Fig: 2-8

- Dead blow hammer or rubber mallet
- Brush
- Pliers
- Cutter pliers

- Chisels
- Screwdriver

Fig:2-8

C – We have extracted the old copper out of the motor with some considerations*:*

1- We have cut the old copper off one side, with a certain angle to avoid scratching the slots
2- cutting is a common parallel process for all coils
3 After cutting off one end, we pull the copper out of the slots from the other side.

-Here are some pictures of the old burnt coils shown in Fig: 2-9

Fig: 2-9

D-We checked the coils, then we have found two types of coils one for strarting, and one for operation

- there were 4 coils, 3 for operation, and 1 for starting, after counting them all, we found the avearge of turns per slot=66 turn

E- We brushed the slots to get any impurities out

This is the motor after removing the old copper out as shown in Fig: 2-10 and ready for winding.

Fig: 2-10

2-4 Preparation of the new coils:

We discussed in the previous section how we prepared the broken motor, whereas here we will illustrate how the preparation of the new coils will be for three phase winding. **a-First** of all, we had to know two important things to start winding the new coils:-

1. The number of turns in each coil.

2. The diameter of the coil.

Well, when we want to know the no of turns of each coil, we notice that we have two different windings in the broken motor, and we figured out that type of coils was responsible for the starting of the motor when it was a single phase motor which needs some extra winding to help it for starting up and the other winding was the one which responsible for building the magnetic field, and that will be the coil which we will focus on.

So we used micrometer as shown in Fig: 2-10 to measure the diameter of both windings and we found that the starting coil was (**.4mm**) in diameter while the other winding was (**.7mm**) in diameter, so the new coil will be (**.7mm**) in diameter, because we will not need another coil for starting the (3 or 6) phase motor.

Fig: 2-10

Then we counted the no of turns in each coil and it was **66** turn each, But we had to reduce the no of turns to **33** turns for some problems we faced when we tried to enter the coil into the slots, and this problem will be discussed in details at the end of this chapter.

B-After that we had to measure the length and the width to make some handmade tool called "Stamba" or model as shown in Fig: 2-11, which will help us to wrap the coils, as you can see it in the following picture.

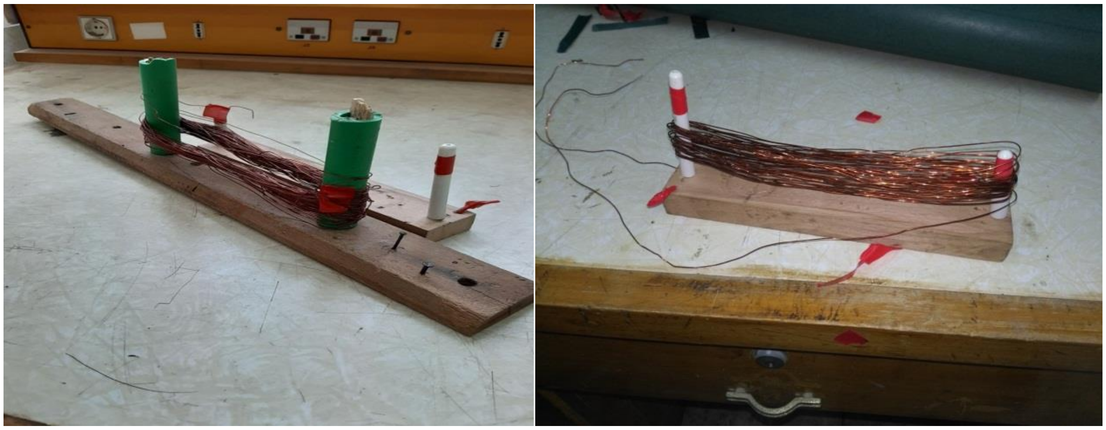


Fig: 2-11

As you see the new coil (the **.7mm** coil) is wrapping up, and after the coil reaches 33 turn we remove it gently and start to wrap another one, and the number of coils we need is **12** coils as we have **24** slots and every two slots should contain one coil.

C-then, after wrapping the required no of coils we have to prepare the empty slots for setting the coils down, so we use insulating fish paper as shown in Fig: 2-12

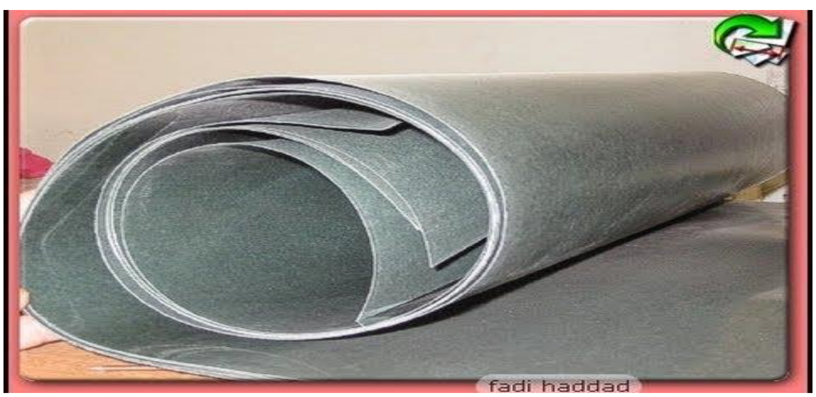


Fig: 2-12

We cut this insulating fish paper into small sizes according to the dimensions of the slots, and then we put these insulating fish paper and lay it down in the bottom of each slot ***to provide***:-

1. Good insulation between the slots and the coils.

2. Facilitate the process of setting the coils out in the slots.

3. The shape of insulating fish paper will be as Fig: 2-13

Fig: 2-13

-Now we will lay these insulating fish paper into the slots, as shown in Fig: 2-14

Fig:2-14

D-After finishing laying the insulating fish paper, now we will start to lay the coils down into the slots, as shown in Fig: 2-15

Fig: 2-15

But laying the coils into the slots needs some calculations such as: what is the pole pitch? , no of poles, how many phases do we have? …………. Etc. and this had been illustrated in section no **2** in this chapter.

2-4-1-Some considerations during inserting the coils

1-Insert the coils carefully and watch-out the slot order and the pole pitch.

2-Insert the first coil of each phase at the beginning, then the second of each phase, then the third of each phase to avoid any tangle.

3- After entering the coil put a piece of insulating fish paper before moving to another slot and making sure the fish paper encapsulates the coil.

4-You have to order the coils you finished by giving them a number from 1: 24.

2-5- Testing the 3 phase motor:

A-As soon as we put all the coils in their slots, we had to do an important test, called continuity test, in this test we checked if there were any faults or distortions happened in each coil while we were laying the coils down into the slots, using Avometer as shown in Fig:2-16

Fig: 2-16

<u>B-</u> After doing the test, and making sure that there weren't any faults at any coil, we started to tie the outer parts of the coils with each other using thin rope to gather it tightly in a bunch, and to create suitable space to the rotor and to avoid any noisy rattle sound as shown in Fig: 2-17

Fig:2-17

<u>C-After</u> that we used some varnish to increase the level of insulation among the turns of the coils and among the coils themselves.

D-Then we have taken out the ends of the coils, we did that before tighten as shown in Fig: 2-18 and we made and prepared small plate made of acrylic as shown in Fig: 2-19.

Fig: 2-18

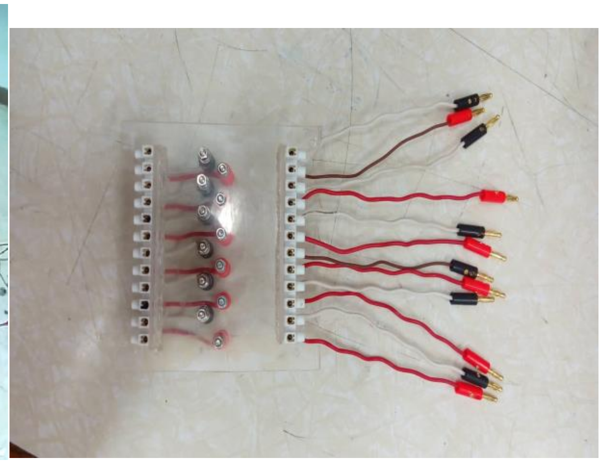


Fig: 2-19

E-Then we put the rotor inside the vacuum of the stator, and tighten the screws of the motor then; we commenced the electricity to operate the motor, as shown in Fig: 2-20

Fig:2-20

-When the motor begins to start, its speed increases slightly, draws a high starting current up to **5.5** ampere, then its speed increases until the motor reaches the steady state, the speed fixed at **3000** rpm and the final current would be **1.5** to **2** Ampere.

We changed the sequence of three phase and we have seen that the motor opposite the direction of rotation.

We didn't have to do more detailed test on the motor as it wasn't the main purpose of the project. Only the two things we wanted to know:

- **First**: Did we re-wind the motor correctly or not?

-**Second**: Are the inverter acts properly or not?

And here the final appearance of the motor Fig: 2-21

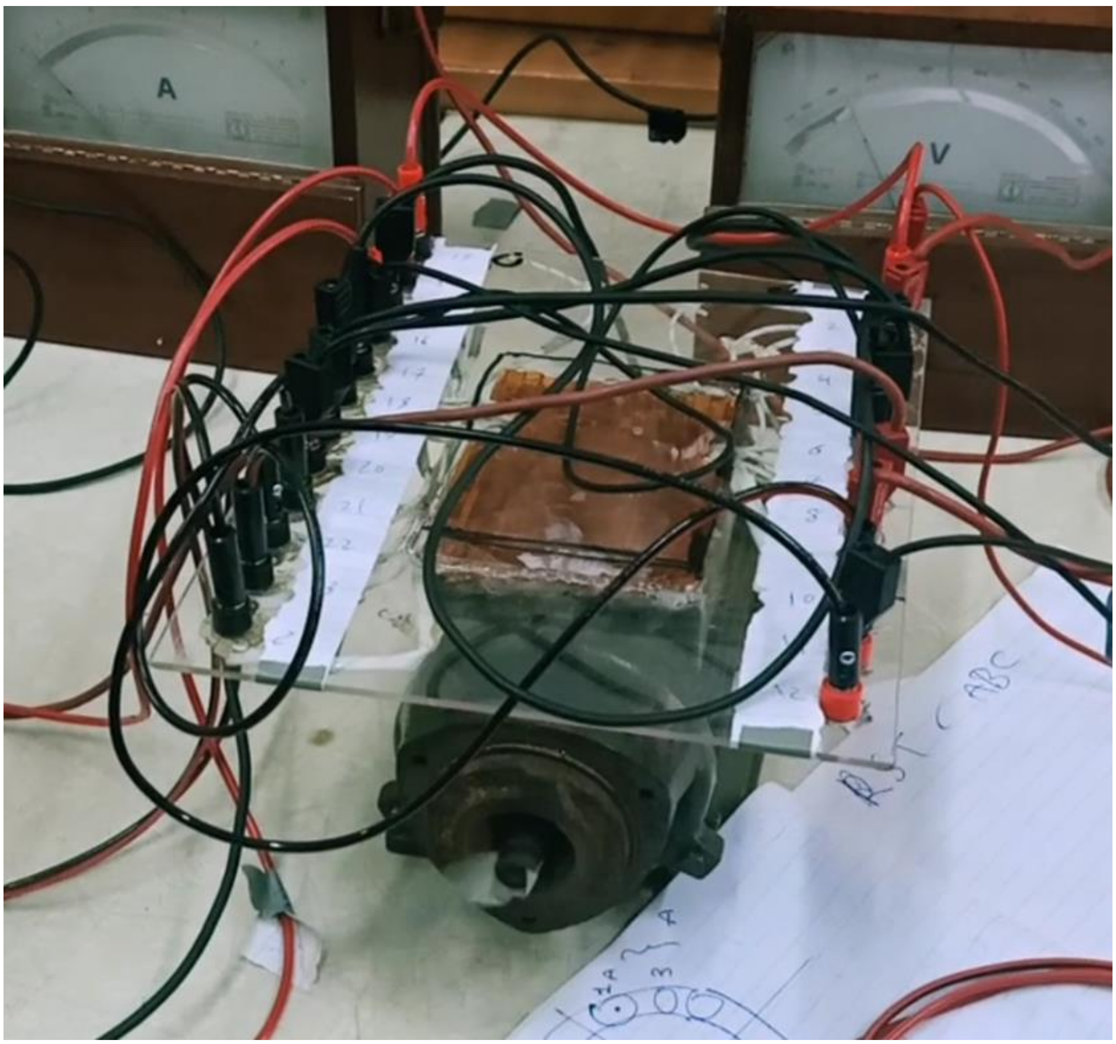


Fig: 2-21

6- Mathematical calculations for 6 phase winding.

Data we have: - **24** slots

Required: - winding a 6 phase motor, lap winding, **2** poles

Calculations:-

Speed= (**120*f**)/**p** = (120*50)/2= 3000 **rpm**

No of coils= **no of slots/2**= 24/2= 12 **coil**

Coil per phase= **no of coil**/**no of phases**

Coil per phase= 12/6= 2coil

So each phase has two coils and occupies 4 slots.

Theta = (**360/no of poles) (theta electrical=theta mechanical)"2pole".**

Theta= 360/2= 180 **degree**

Pole pitch= (180/360)*24= 12 slot

And as we know, in **6** phases there is **60** degree phase shift among phases, so the coils distribution over the slots as shown in Fig: 2-22

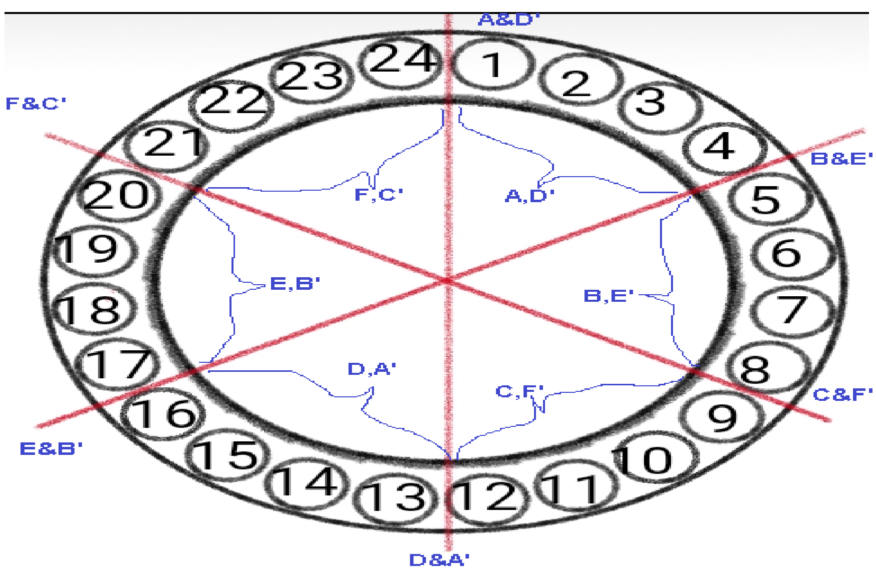
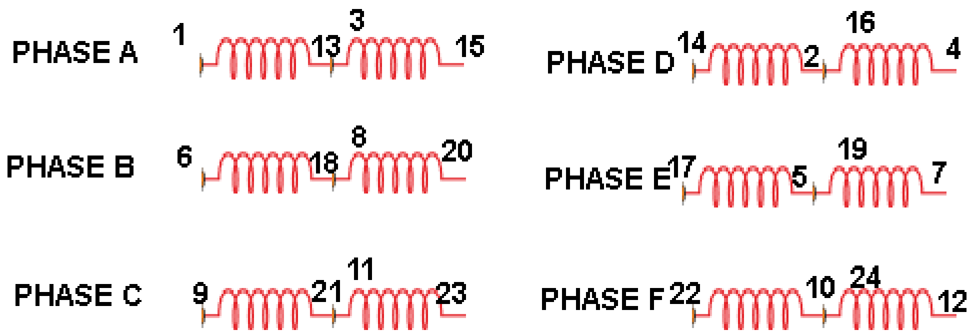


Fig:2-22

The coils in each phase connected in series



Starting points (1,9,17),(6,14,22) and ending points (15,20,23,4,7,12) connected together.

2-7- connection of ends (star –delta):

Motor can behave as 3-Φ or 6-Φ, according to the way of wiring at the connections plate. The motor contains 24 slots each 2 slots have a one coil buried inside, so 12 coils appears out. When it comes to 3-Φ configuration the coils number per phase would be 4 coils.

$$N_c = \frac{coils\ number}{phases\ number} = \frac{12}{3} = 4\ coil/phase$$

-star and delta configuration………. As shown in Fig:2-23

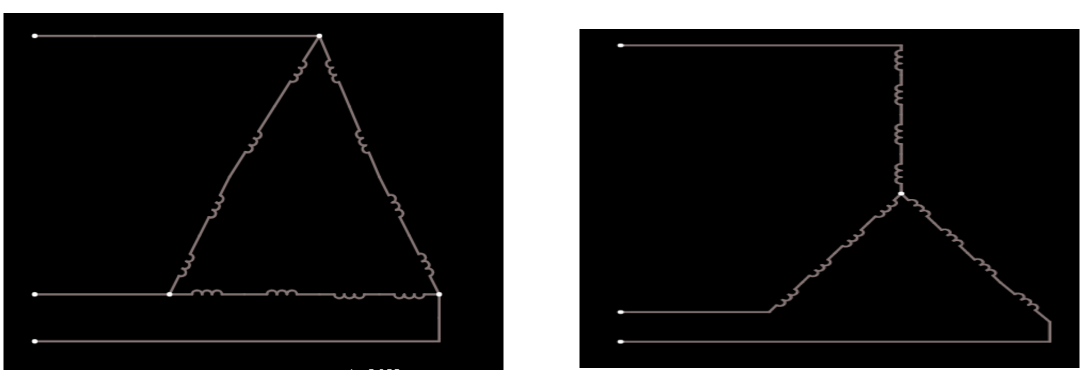


Fig:2-23

Each of both configurations has a different behavior than the other as shown next page.

Star	Delta
Line current = phase current.	Line voltage = phase voltage.
Line voltage = $\sqrt{3}$ times of phase voltage.	Line current = $\sqrt{3}$ times of phase current.
Smaller starting torque by $\frac{1}{3}$	Higher starting torque by $\frac{1}{3}$
Lower speed	Higher speed
$starting\ current\ per\ phase = \frac{V_l}{\sqrt{3} \times Ze}$	$Starting\ current\ per\ phase = \frac{V_l}{Ze}$
	$Line\ starting\ current = \frac{\sqrt{3} \times V_L}{Z_e}$

** Z_e The standstill equivalent impedance per phase referred to stator.*

They have taken the advantage of star-connection in providing lower current, lower voltage, and exploit it in order to achieve motor starting method (Star – Delta).This method to avoid starting at full voltage causing a mechanical shock to the load. Coils begin as a Star then are switched to Delta and the following equation clarifies the reason.

$$\boldsymbol{\frac{I_{stY,line}}{I_{st\Delta,line}} = \frac{V_l/(\sqrt{3}\times Ze)}{(\sqrt{3}\times V_l)/Z_e}} \qquad \boldsymbol{\frac{T_{st,Y}}{T_{st,\Delta}} = \frac{\left(V_l/\sqrt{3}\right)^2}{{V_l}^2} = \frac{1}{3}}$$

- When it comes to 6-Φ configuration we need to get 60̊ phase difference among phases derived by an inverter or we can make 30̊ phase difference feeding by two supplies Star and Delta, so three ends are connected to Star- Supply and the other three coils are connected to Delta -Supply to exploit the 30̊ phase difference between Delta and Star connections as shown in the following Fig: 2-24

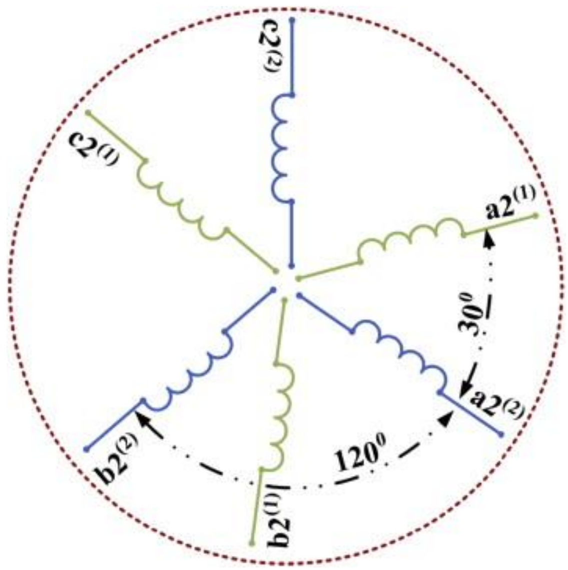


Fig:2-28

-But the Coils number per phase would be $\frac{12}{6} = 2\ coils$, and the following figure Fig: 2-29 shows Phases distribution over the slots.

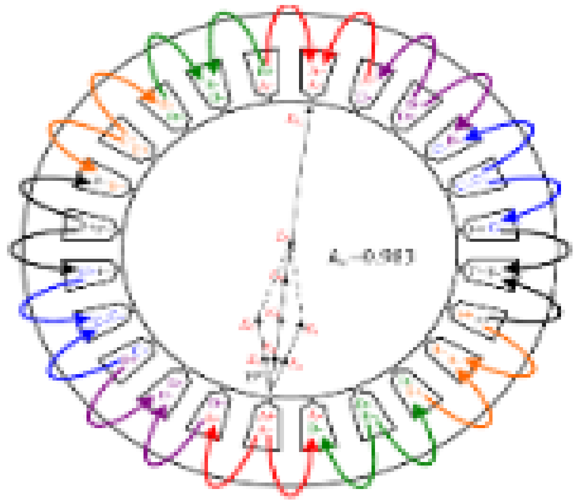


Fig:2-29

2-8-Testing the motor by transformer

Powering of the 6-Φ motor depending on transformer with six outlets, three connected as a Star and three connected as a Delta in order to create 30° phase shift the transformer shown in Fig: 2-30.

Fig:2-30

-**Inner connections of the transformer**…… as shown in Fig:2-31

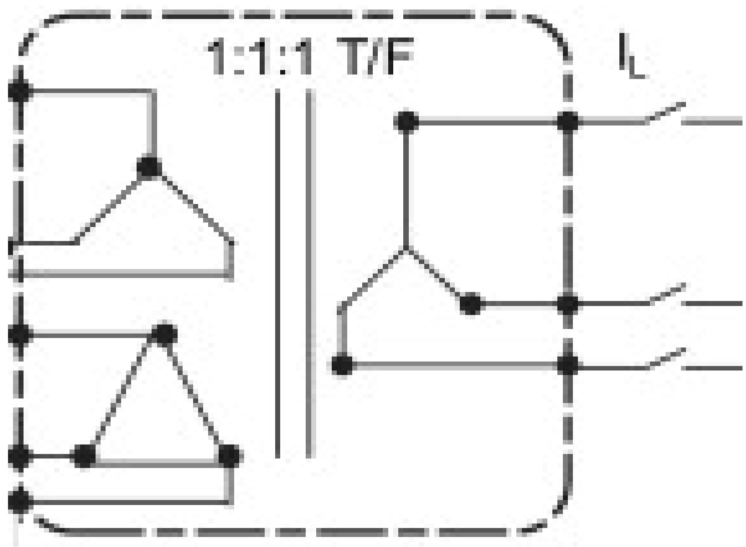


Fig:2-31

-We connected the motor to a transformer with Star source connected to(1,9,17) and Delta source connected to (6,14,22).

-When the motor begins to start, its speed increases slightly , draws starting current up to 2 Ampere, then its speed increases until the motor reaches the steady state, the speed fixed at 3000 rpm and the final current would be less than 1 ampere.

-when we remove one phase from star source or delta source motor continue running but speed decreases.

_when we compare the results with 3 phase we find lower starting current, higherstarting torque and lower noise .

2-9-Some problems and how to solve it

1-Size of winding is larg

-we couldnt't complete the insertion process of the coils at the first time because the size of coils was large ,and the winding type of the old burnt coil was Spiral Winding and had winded automatically by manufacturing line.

To solve it:

We taken out the coils and reduced the number of turns from 66

to 33

2-Motor can't run:

After we inserted the coils and taken the motor to test ,we found that motor can't start

To solve it :

We opened the motor again and ensured that ends are connected properly.

-Then we tested all the coils

-Testing of coils:

By measuring the resistance of each coil separately, then measuring the total phase resistance, then measuring the X_l of each single coil by AC feeding and getting Z_l value,

$X_l = \sqrt{Z_l{}^2 - R_l{}^2}$, and the values of each single coil must be equal, and the values of each single phase must me equal as well, and we made this examination practically and the results are attached at the following tables named by coil's number.

(1-13)			
I	2.55	3.75	5
V	6	10.7	14
Z	2.41	2.85	2.8

(2-14)			
I	.875	3.6	7.45
V	1.8	9.4	14.6
Z	2.075	2.6	3.07

(3-15)			
I	1.5	2.5	5
V	3.4	6	13.8

(4-16)			
I	1.25	2.35	4.5
V	2.9	5.8	12.4

Z	2.27	2.4	2.76

(5-17)			
I	1.5	2.5	4.95
V	3.3	6	13.3
Z	2.2	2.4	2.7

(7-19)			
I	1.7	2.75	4.9
V	3.8	6.6	13.4
Z	2.23	2.4	2.7

Z	2.38	2.86	2.75

(6-18)			
I	1.4	2.5	4.95
V	3.4	6.3	13.2
Z	2.26	2.37	2.72

(9-21)			
I	1.75	2.3	1.85
V	4	5.6	11.6
Z	2.2	2.4	2.6

(10-22)			
I	2.1	2.85	4.4
V	4.8	7	12.2
Z	2.3	2.4	2.56

(11-23)			
I	1.9	2.7	4.1
V	4.3	6.6	10.9
Z	2.2	2.4	2.65

(22-24)			
I	2.2	3	4.2
V	5.2	7.5	11.9
Z	2.3	2.5	2.8

-We found the resistances average= 1.1 Ώ, the impedance average=2.4 Ώ, hence all coils are perfect.

(8-20)			
I	1.5	2.65	4.85
V	3.4	6.5	13.2

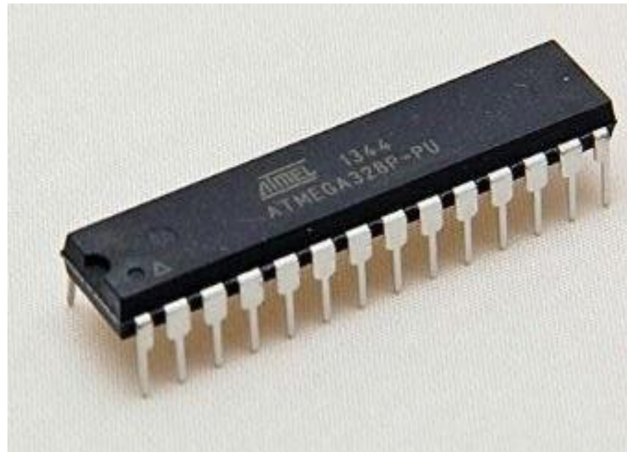
Z	2.26	2.37	2.72

-Finally we found a short circuit in the connections plate,

We solved it and the motor ran flawlessly.

" Now after giving enough area to winding of motors ,we are moving to drivers and control section to be able to build our project correctly ,In the next chapter we will discuss an introduction about Arduino and Micro Controller "

Ch.3:Introduction to Arduino and microcontroller



introduction: in this chapter we will describe what is microcontroller ,types, we focus on Arduino ,and how to build up project with arduino,
next we move to describe Avr, then we talk about Atmega, finally we built small project with Arduino to control of small motor.

Contents of chapter.

1-introduction microcontroller

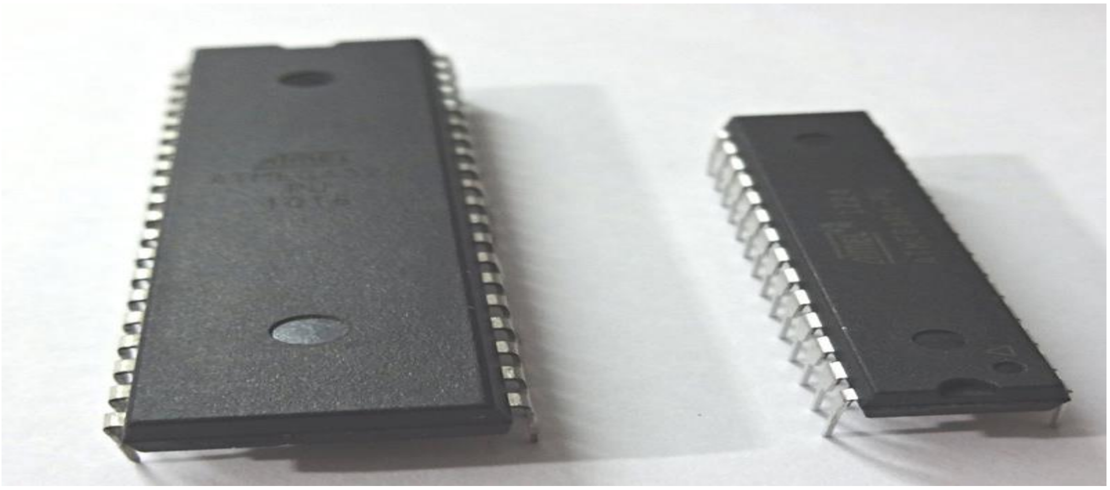


Fig:3_1

A microcontroller (MCU for microcontroller unit, or UC for μ-controller) (Fig3-1) is a small computer on a single integrated circuit. In modern terminology, it is similar to, but less sophisticated than, a system on a chip (SoC); an SoC may include a microcontroller as one of its components. A microcontroller contains one or more CPUs (along with memory and programmable input/output peripherals, Program memory in the form of ferroelectric RAM, NOR flash or OTP ROM is also often included on chip, as well as a small amount of RAM. Microcontrollers are designed for embedded applications, in contrast to the microprocessors used in personal computers or other general purpose applications consisting of various discrete chips.

Microcontrollers are used in automatically controlled products and devices, such as automobile engine control systems, implantable medical devices, remote controls, office machines, appliances, power tools, toys and other embedded systems. By reducing the size and cost compared to a design that uses a separate microprocessor, memory, and input/output

3-2 -The difference between Arduino and others controllers

-What is Arduino?

Arduino is a small computer that can interact and control the environment around it better than a desktop computer. Technically, it is an open source platform consisting of a micro-controller and an integrated development environment for software writing.

-**The power of Arduino**

Is reflected in its great ability to communicate with other electronic components such as switches or sensors, and to use them to obtain various data such as temperature or light intensity, as well as its great efficiency in motor control, LEDs and many other electronic parts.

Arduino projects can be run by connecting to a computer and dealing with one of the programs on the device or it can be run independently.

-Features of Arduino

What distinguishes Arduino is a set of things that make the difference between it and other important ones:

1- Simplicity

The Arduino Arduino piece is designed to suit the needs of everyone, professionals, professors, students

2-price

The Arduino is less expensive compared to other panels of the same type. The most expensive Arduino does not exceed $ 50.

3-Self-Assembly

You can download the Arduino Datasheet free of charge

4-Multi-Platform:

The program has the ability to work on Windows, Mac OS Mac and Linux Linux and most other electronic controls running only on Windows only.

5-Easy and simple programming environment:

The programming environment is designed to be easy for beginners, stable and powerful for professionals.

6-open Source Software:

Written in C ++. It is available for everyone to download and programmers can modify it according to their need

7-OPen Source Hardware:

Arduino Arduino is made mainly of ATMEGA8 and ATMEGA168 controllers. The schemas are published under the Creative Commons license, allowing electronic circuit designers to design their own circuits.

3-3-Basics component and types of Arduino:

3-3-1-Basics component

In this chapter, we will learn about the different components on the Arduino board as shown in (Fig:3-2) . We will study the Arduino UNO board because it is the most popular board in the Arduino board family. In addition, it is the best board to get started with electronics and coding.

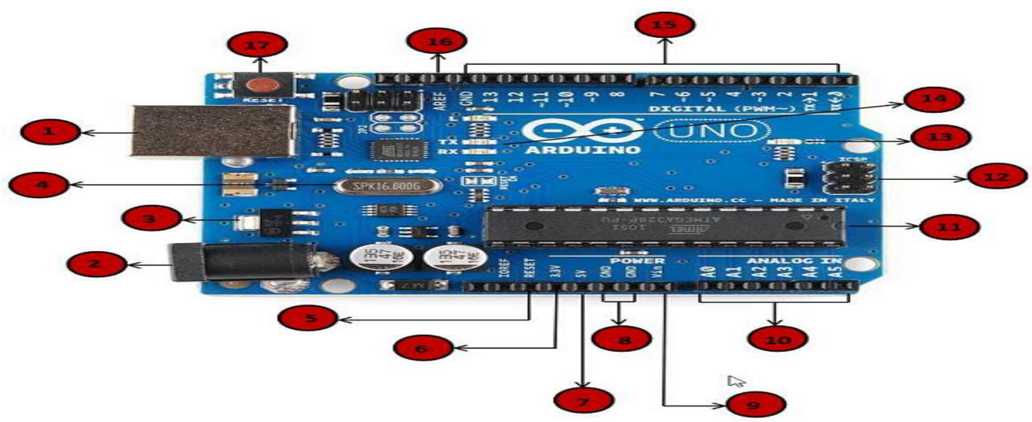


Fig:3-2

1	Power USB Arduino board can be powered by using the USB cable from your computer. All you need to do is connect the USB cable to the USB connection (1).
2	Power (Barrel Jack) Arduino boards can be powered directly from the AC mains power supply by connecting it to the Barrel Jack (2).
3	Voltage Regulator The function of the voltage regulator is to control the voltage given to the Arduino board and stabilize the DC voltages used by the processor and other elements.
4	Crystal Oscillator The crystal oscillator helps Arduino in dealing with time issues. How does Arduino calculate time? The answer is, by using the crystal oscillator. The number printed on top of the Arduino crystal is 16.000H9H. It tells us that the frequency is 16,000,000 Hertz or 16 MHz.
5,17	Arduino Reset You can reset your Arduino board, i.e., start your program from the beginning. You can reset the UNO board in two ways. First, by using the reset button (17) on the board. Second, you can connect an external reset button to the Arduino pin labelled RESET (5).
6,7 8,9	Pins (3.3, 5, GND, Vin) • 3.3V (6) − Supply 3.3 output volt • 5V (7) − Supply 5 output volt

	• Most of the components used with Arduino board works fine with 3.3 volt and 5 volt. • GND (8)(Ground) − There are several GND pins on the Arduino, any of which can be used to ground your circuit. • Vin (9) − This pin also can be used to power the Arduino board from an external power source, like AC mains power supply.
10	Analog pins The Arduino UNO board has six analog input pins A0 through A5. These pins can read the signal from an analog sensor like the humidity sensor or temperature sensor and convert it into a digital value that can be read by the microprocessor.
11	Main microcontroller Each Arduino board has its own microcontroller (11). You can assume it as the brain of your board. The main IC (integrated circuit) on the Arduino is slightly different from board to board. The microcontrollers are usually of the ATMEL Company. You must know what IC your board has before loading up a new program from the Arduino IDE. This information is available on the top of the IC. For more details about the IC construction and functions, you can refer to the data sheet.
12	ICSP pin Mostly, ICSP (12) is an AVR, a tiny programming header for the Arduino consisting of MOSI, MISO, SCK, RESET, VCC, and GND. It is often referred to as an SPI (Serial Peripheral Interface), which could be considered as an "expansion" of the output. Actually, you are slaving the output device to the master of the SPI bus.
13	Power LED indicator

	This LED should light up when you plug your Arduino into a power source to indicate that your board is powered up correctly. If this light does not turn on, then there is something wrong with the connection.
14	TX and RX LEDs On your board, you will find two labels: TX (transmit) and RX (receive). They appear in two places on the Arduino UNO board. First, at the digital pins 0 and 1, to indicate the pins responsible for serial communication. Second, the TX and RX led (13). The TX led flashes with different speed while sending the serial data. The speed of flashing depends on the baud rate used by the board. RX flashes during the receiving process.
15	Digital I/O The Arduino UNO board has 14 digital I/O pins (15) (of which 6 provide PWM (Pulse Width Modulation) output. These pins can be configured to work as input digital pins to read logic values (0 or 1) or as digital output pins to drive different modules like LEDs, relays, etc. The pins labeled "~" can be used to generate PWM.
16	AREF AREF stands for Analog Reference. It is sometimes, used to set an external reference voltage (between 0 and 5 Volts) as the upper limit for the analog input pins.

3-3-2-Types of Arduino Boards

There are different Arduino boards which are following

- Arduino UNO (R3)
- Lilypad Arduino
- Red Board
- Arduino Mega (R3)
- Arduino Leonardo
- Nano

There is no clear difference between the types of arduino except the number of in pins and out pins and some secondary tasks such as timer. And the micro-user according to each application.

We note that the families of the Arduino are similar to the component and the method of programming them.

3-4- How to build project with Arduino

You need both hard and soft ware

3-4-1-hard ware

_Arduino board

_Usb printer cable

_Breadboard

_Resistors

_Leds, wires

_Avometer

3-4-2-soft ware

You will need to learn programming principles on the Arduino Environment and also the Arduino palette to apply what you have learned. There are some things you have to know to program arduino .

-**Arduino Integrated Development Environment**

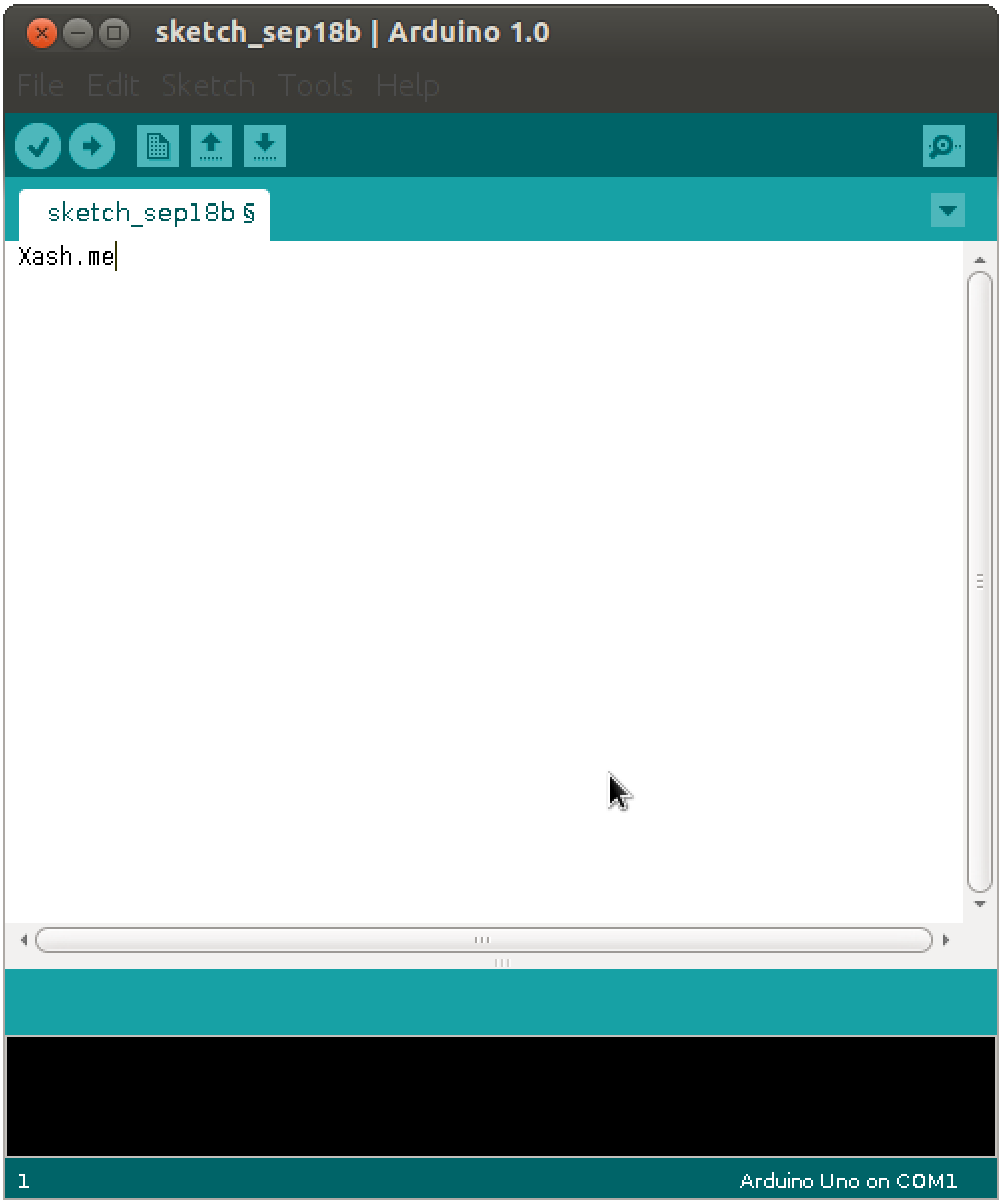


Fig:3-3

It is a multi-tasking program, containing a text editor for writing code, a space for error warning and a toolbar to control the settings. The compiler is also a compiler that converts the code into a language that Arduino understands and passes to it, The main window of IDE as shown (Fig:3-3).

-How to program arduino

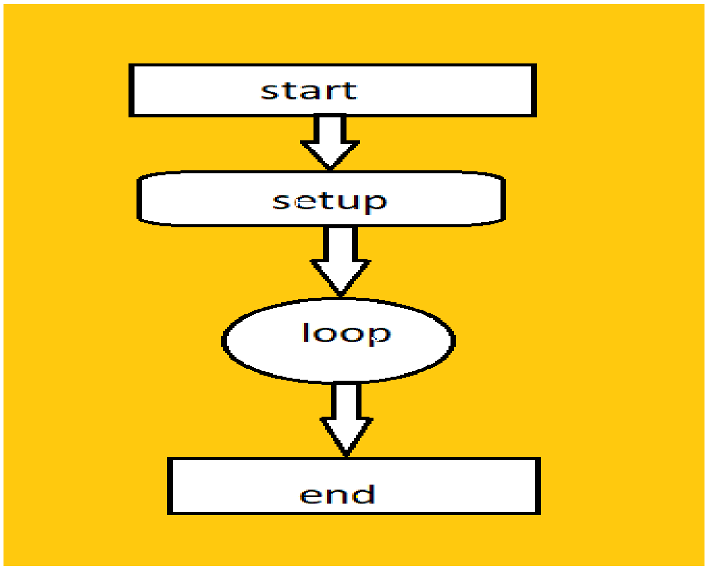


Fig:3-4

A sketch (Fig:3-4)can be divided in three parts.

1. ***Name variable*** in the first part elements of the program are named This part is not absolutely necessary.

2. ***setup***: It is called only when the Arduino is powered on or reset. It is used to initialize variables and pin modes

3. ***loop*** : The loop functions runs continuously till the device is powered off. The main logic of the code goes here.

3.5 : ATmega and component of control circuit

3.5.1:Brief history of AVR microcontrollers

AVR derives its name from its developers and stands for Alf-Egil Bogen Vegard Wollan RISC microcontroller, also known as Advanced Virtual RISC. The AT90S8515 was the first microcontroller which was based on AVR architecture however the first microcontroller to hit the commercial market was AT90S1200 in the year 1997

3.5.2: AVR microcontroller categories:

1. **TinyAVR** – Less memory, small size, suitable only for simpler applications

2. **MegaAVR** – These are the most popular ones having good amount of memory (upto 256 KB), higher number of inbuilt peripherals and suitable for moderate to complex applications.

3. **XmegaAVR** – Used commercially for complex applications, which require large program memory and high speed.

The following table compares the above mentioned AVR series of microcontrollers:

Series Name	**Pins**	**Flash Memory**	**Special Feature**
TinyAVR	6-32	0.5-8 KB	Small in size
MegaAVR	28-100	4-256KB	Extended peripherals
XmegaAVR	44-100	16-384KB	DMA , Event System included

3.5.3: What’s special about AVR?

They are fast: AVR microcontroller executes most of the instructions in single execution cycle. AVRs are about 4 times faster than PICs, they consume less power and can be operated in different power saving modes. Let's do the comparison between the three most commonly used families of microcontrollers.

	8051	**PIC**	**AVR**
SPEED	Slow	Moderate	Fast
MEMORY	Small	Large	Large
ARCHITECTURE	CISC	RISC	RISC
ADC	Not Present	Inbuilt	Inbuilt
Timers	Inbuilt	Inbuilt	Inbuilt
PWM Channels	Not Present	Inbuilt	Inbuilt

AVR is an 8-bit microcontroller belonging to the family of Reduced Instruction Set Computer (RISC). In RISC architecture the instruction set of the computer are not only fewer in number but also simpler and faster in operation. The other type of categorization is CISC (Complex Instruction Set Computers). Click to find out differences between RISC and CISC. We will explore more on this when we will learn about the architecture of AVR microcontrollers in following section.

3.5.4: Architecture of AVR :

The AVR microcontrollers are based on the advanced RISC architecture and consist of 32 x 8-bit general purpose working registers. Within one single clock cycle, AVR can take inputs from two general purpose registers and put them to ALU for carrying out the requested operation, and transfer back the result to an arbitrary register. The ALU can perform arithmetic as well as logical operations.

over the inputs from the register or between the register and a constant. Single register operations like taking a complement can also be executed in ALU. We can see that AVR does not have any register like accumulator as in 8051 family of microcontrollers; the operations can be performed between any of the registers and can be stored in either of them.

AVR follows Harvard Architecture format in which the processor is equipped with separate memories and buses for Program and the Data information. Here while an instruction is being executed, the next instruction is pre-fetched from the program memory as shown in **Fig:3-5.**

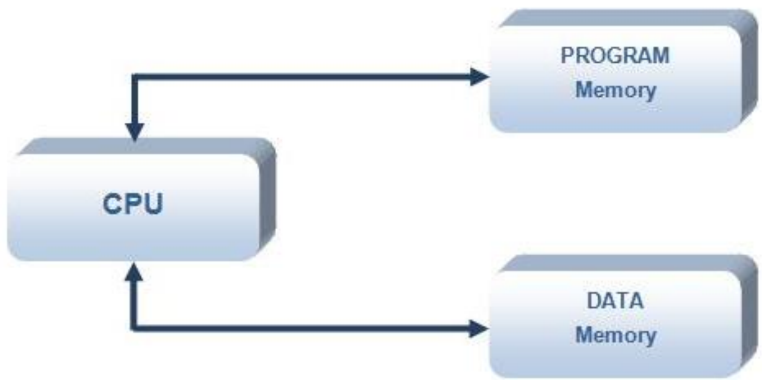


Fig:3-5

Block Diagram Of memory architecture In AVR

Since AVR can perform single cycle execution, it means that AVR can execute 1 million instructions per second if cycle frequency is 1MHz. The higher is the operating frequency of the controller, the higher will be its processing speed. We need to optimize the power consumption with processing speed and hence need to select the operating frequency accordingly.

There are two flavors for Atmega16 microcontroller:

1. Atmega16:- Operating frequency range is 0 – 16 MHz.

2. Atmega16L:- Operating frequency range is 0 – 8 MHz.

If we are using a crystal of 8 MHz = 8 x 106 Hertz = 8 Million cycles, then

AVR can execute 8 million instructions.

3.5.5: Naming Convention.! :

Naming Convention Of AVR Microcontroller

3.5.6: Various microcontrollers of Mega AVR series:

ATmega8 and Atmega32 are other members of MegaAVR series controllers. They are quite similar to ATmega16 in architecture. Low power version MegaAVR controllers are also available in markets. The following table shows the comparison between different members of MegaAVR family:

Part Name	ROM	RAM	EEPROM	I/0 Pins	Timer	Interrupts	Operation Voltage	Operating frequency	Packaging
ATmega8	8KB	1KB	512B	23	3	19	4.5-5.5 V	0-16 MHz	28
ATmega8L	8KB	1KB	512B	23	3	19	2.7-5.5 V	0-8 MHz	28
ATmega16	16KB	1KB	512B	32	3	21	4.5-5.5 V	0-16 MHz	40
ATmega16L	16KB	1KB	512B	32	3	21	2.7-5.5 V	0-8 MHz	40
ATmega32	32KB	2KB	1KB	32	3	21	4.5-5.5 V	0-16 MHz	40
ATmega32L	32KB	2KB	1KB	32	3	21	2.7-5.5 V	0-8 MHz	40

3.5.7: Why we Use ATMEGA328P

ATMEGA328P is high performance, low power controller from Microchip. ATMEGA328P is an 8-bit microcontroller based on AVR RISC architecture. It is the most popular of all AVR controllers as it is used in ARDUINO boards.

Fig:3-6

So it is used in our project. Although we have many controllers ATMEGA328P is most popular of all because of its features and cost. ARDUINO boards are also developed on this controller because of its features.

- With program memory of 32 Kbytes ATMEGA328P applications are many.
- With various POWER SAVING modes it can work on MOBILE EMBEDDED SYSTEMS.
- With Watchdog timer to reset under error it can be used on systems with minimal human interference.
- With advanced RISC architecture, the controller executes programs quickly.
- Also with in chip temperature sensor the controller can be used at extreme temperatures.

These all features add together promoting ATMEGA328P further.

3.5.8: How to Use ATMEGA328P

ATMEGA328 is used similar to any other controller. All there to do is programming. Controller simply executes the program provided by us at any instant. Without programming controller simply stays put without doing anything.

As said, first we need to program the controller and that is done by writing the appropriate program file in the ATMEGA328P FLASH memory. After dumping this program code, the controller executes this code and provides appropriate response.

Entire process of using an ATMEGA328P goes like this:

1. List the functions to be executed by controller.
2. Write the functions in programming language in IDE programs.
3. ATMEGA328P programming can also be done in ARDUINO IDE.
4. After writing the program, compile it to eliminate errors.
5. Make the IDE generate HEX file for the written program after compiling.
6. This HEX file contains the machine code which should be written in controller flash memory.
7. Choose the programming device (usually SPI programmer made for AVR controllers) which establishes communication between PC and ATMEGA328P. You can also program ATMEGA328P using ARDUINO UNO board AS shown in **Fig:3-7**
8. Run the programmer software and choose the appropriate hex file.
9. Burn the HEX file of written program in ATMEGA328P flash memory using this program.
10. Disconnect the programmer, connect the appropriate peripherals for the controller and get the system started.

3.5.9: How to Use ATMega328P using Arduino

Since ATmega328P is used in Arduino Uno and Arduino Nano boards, you can directly replace the arduino board with ATmega328 chip. For that first you need to install the Arduino boot loader into the chip (Or you can also buy a chip with boot loader – ATMega328P-PU). This IC with boot loader can be placed on Arduino Uno board and burn the program into it. Once Arduino program is burnt into the IC, it can be removed and used in place of Arduino board, along with a Crystal oscillator and other components as required for the project. Below is the pin mapping between Arduino Uno and ATmega328P chip as shown **Fig:3-8**.


ATmega328 & Arduino

Fig:3-7

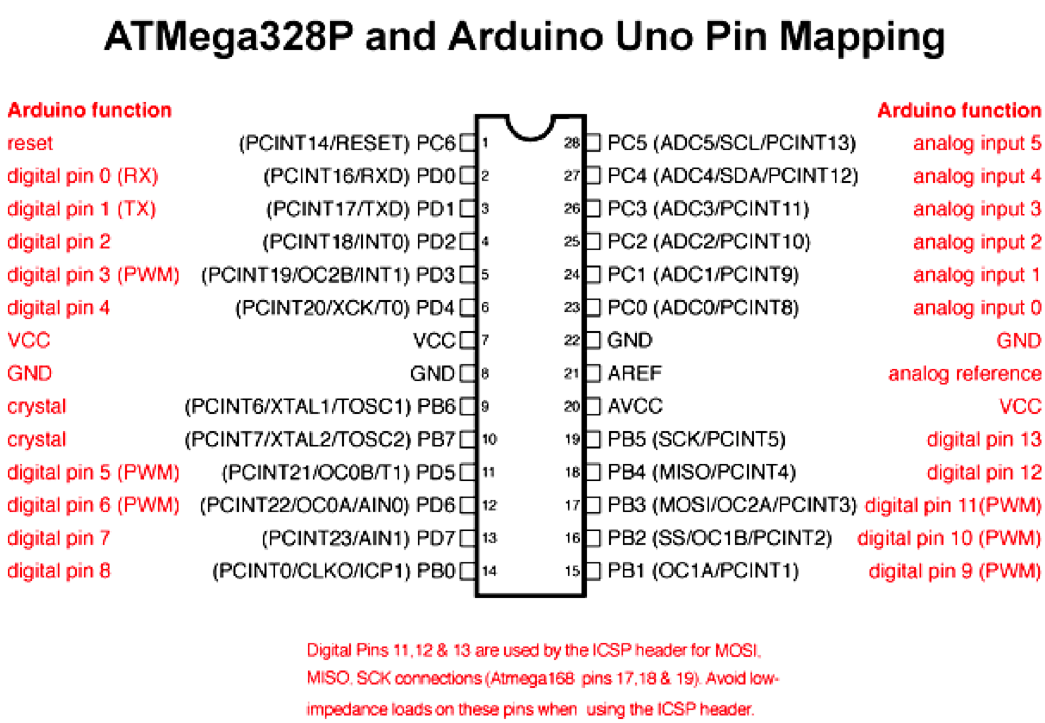
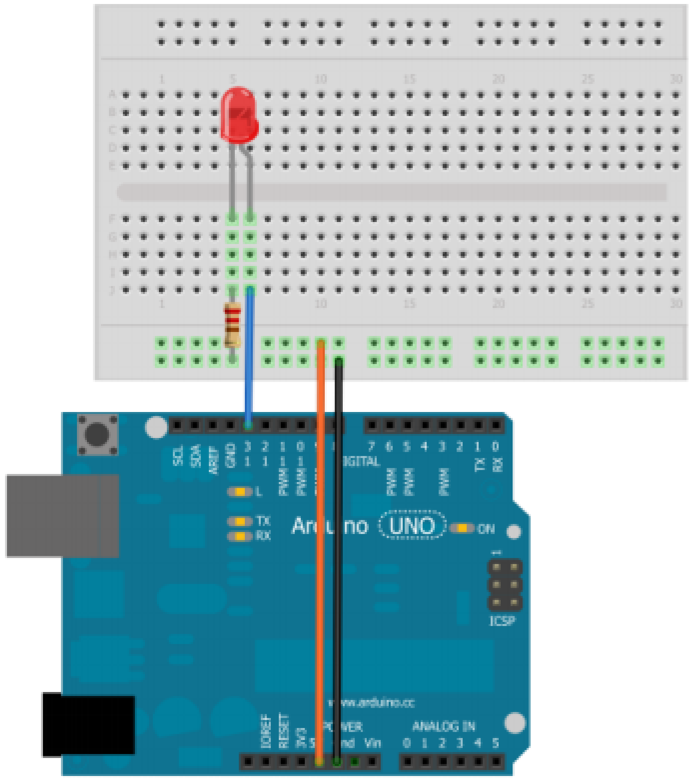

ATMega328P and Arduino Uno Pin Mapping
Arduino function
Arduino function
reset (PCINT14/RESET) PC6 1
28 PC5 (ADC5/SCL/PCINT13) analog input 5
digital pin 0 (RX) (PCINT16/RXD) PD0 2
27 PC4 (ADC4/SDA/PCINT12) analog input 4
digital pin 1 (TX) (PCINT17/TXD) PD1 3
26 PC3 (ADC3/PCINT11) analog input 3
digital pin 2 (PCINT18/INT0) PD2 4
25 PC2 (ADC2/PCINT10) analog input 2
digital pin 3 (PWM) (PCINT19/OC2B/INT1) PD3 5
24 PC1 (ADC1/PCINT9) analog input 1
digital pin 4 (PCINT20/XCK/T0) PD4 6
23 PC0 (ADC0/PCINT8) analog input 0
VCC VCC 7
22 GND GND
GND GND 8
21 AREF analog reference
crystal (PCINT6/XTAL1/TOSC1) PB6 9
20 AVCC VCC
crystal (PCINT7/XTAL2/TOSC2) PB7 10
19 PB5 (SCK/PCINT5) digital pin 13
digital pin 5 (PWM) (PCINT21/OC0B/T1) PD5 11
18 PB4 (MISO/PCINT4) digital pin 12
digital pin 6 (PWM) (PCINT22/OC0A/AIN0) PD6 12
17 PB3 (MOSI/OC2A/PCINT3) digital pin 11(PWM)
digital pin 7 (PCINT23/AIN1) PD7 13
16 PB2 (SS/OC1B/PCINT2) digital pin 10 (PWM)
digital pin 8 (PCINT0/CLKO/ICP1) PB0 14
15 PB1 (OC1A/PCINT1) digital pin 9 (PWM)
Digital Pins 11,12 & 13 are used by the ICSP header for MOSI, MISO, SCK connections (Atmega168 pins 17,18 & 19). Avoid low-impedance loads on these pins when using the ICSP header.

Fig:3-8

Example 1: Blinking led المثال الأول: تشغيل دايود ضوئي

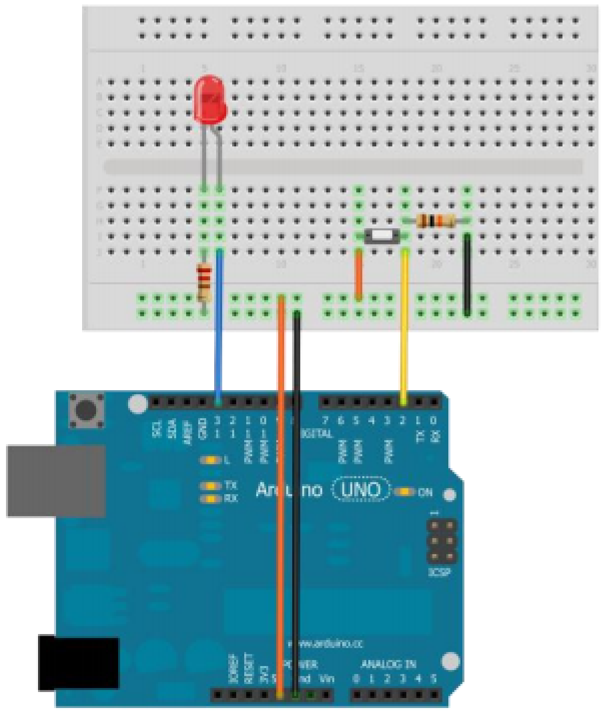


Arduino code

```
const int LED = 13;
void setup (){
pinMode(LED,OUTPUT);
}
void loop(){
digitalWrite(LED,HIGH);
delay(1000);
digitalWrite(LED,LOW);
delay(1000);
}
```

المثال الثاني: تطوير للمثال السابق ليعمل فقط عند ضغط مفتاح (سويتش) من نوع Push button

في هذا المثال سنقوم بتطوير الفكره السابقه و سنجعل الليد يعمل في حاله اذا ضغط المستخدم على زر من نوع push button و هو اشهر انواع السويتشات المستخدمة في الأجهزة الإلكترونية.



Arduino code

```
const int ledPin = 13;
const int buttonPin = 2;
int val;

void setup(){
pinMode(ledPin, OUTPUT);
pinMode(buttonPin, INPUT)
}

void loop() {
val = digitalRead(buttonPin);
```

```
if (val == HIGH) {
 digitalWrite(ledPin, HIGH);
 delay(1000);
digitalWrite(ledPin, LOW);
delay(1000);
}
else {digitalWrite(ledPin, LOW);
}
}
```

3.6:How to control a small DC motor using an Arduino and a transistor.

Components:

1-Small 6V DC Motor

2-PN2222 Transistor

3-1N4001 diode

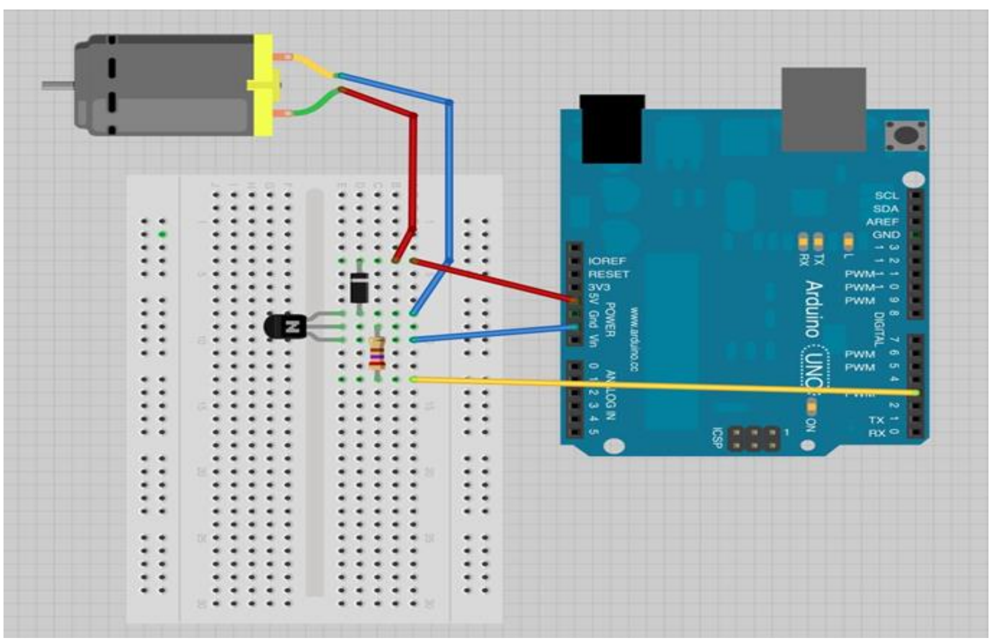
4-270 Ω Resistor (red, purple, brown stripes)

5-Half-size Breadboard

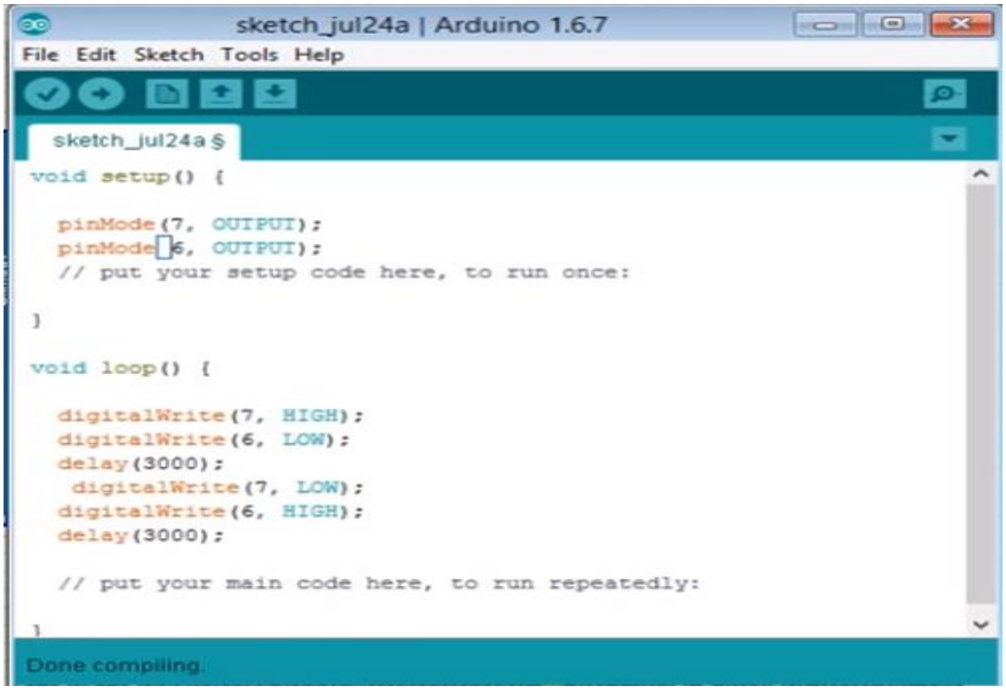
6-Arduino Uno R3

7-Jumper wire pack

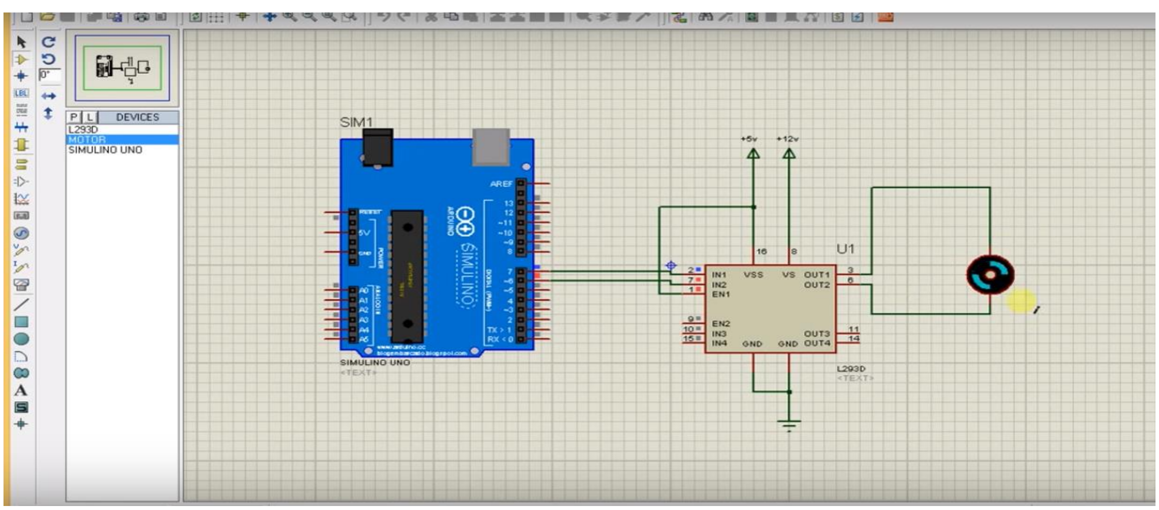
Breadboard Layout by fritzing:



Arduino code:



Simulation by proteus:



"Now after we know how to build small project with arduino ,in the next chapter we will talk about inverters, and how to build inverter ,component of inverter, and some projects to the main project"

Ch.4:Operating Principles of Inverter and Implementation of Single and Three Phase Inverter:

Introduction: This chapter overviews the concept of DC/AC power conversion the classifications of inverters, the technologies and techniques used in designing them. Also the operating principles of some components used in designing inverter circuits are briefly discussedand some Experimentalprojects in the lab

4-1-Inverters:

- Inverters are circuits that convert DC to AC.
- More precisely, inverters transfer power from a DC source to an ACload.
- In other applications, the objective is to create an AC voltage when only a DC voltage source is available.
- The focus of this chapter is on inverters that produce an ACoutput from a DC input.
- Inverters are used in applications such as Adjustable-Speed AC Motor Drives, Uninterruptible Power Supplies (UPS), and Running AC appliances from an automobile battery.

The Block Diagram of the Inverter

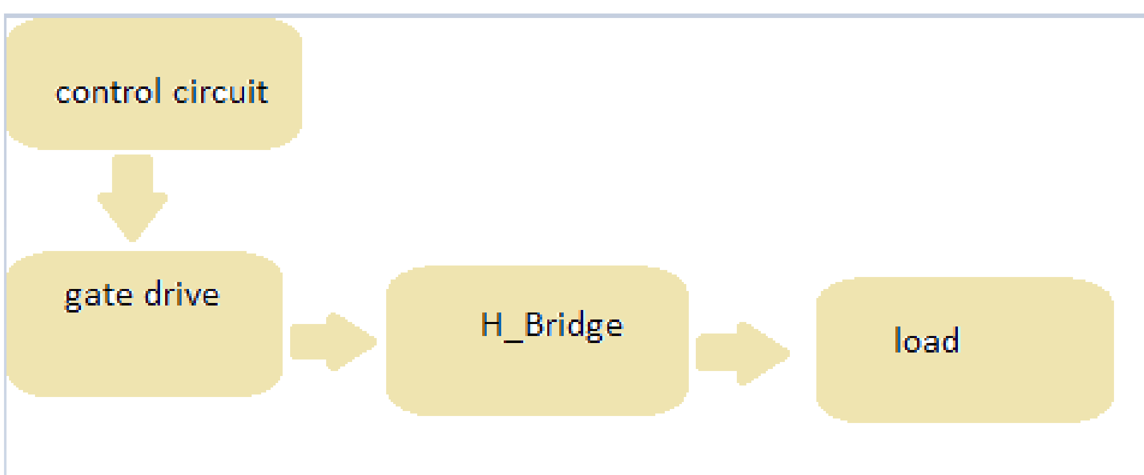


Fig:4-1

4.1.1 Classification of Inverters

There are different basis for classification of inverters.

Inverters are broadly classified as current-source inverters and voltage-source inverters.

Moreover, it can be classified on the basis of devices used (SCR or gate-commutation devices), circuit configuration (half-bridge or full-bridge), nature of output voltage (square, quasi-square or sine-wave) and type of circuit (switch-mode PWM or resonant converters), etc.

- **Current-Source Inverters CSI**

  This type of inverter is fed by a 'current source' with a high-internal impedance (using currentlimiting chokes or inductor in serried with a DC source). Therefore, supply current does not change quickly. The load current is varied by controlling the input dc voltage to the current-source inverter CSI are used in a high-power ACDrives.

- **Voltage-Source Inverters VSI**

  This type of inverter is fed by a dc source of small internal impedance. Looking from the ac side, the terminal voltage remains almost constant irrespective of the load current drawn. Depending onthe circuit configurations, the voltage source inverter may be classified as half-bridge and full-bridge inverters. Voltage-source inverters may further be classified as square-wave inverter and pulse-width modulated inverter.

- **Square-Wave Inverters**

  A square-wave inverter produces a square-wave AC voltage of a constant magnitude. The output voltage of this type of inverter can only be varied by controlling the input DC voltage.

- **Pulse-Width Modulated Inverters**

In a PWM inverter, the output has one or more pulses in each half-cycle. Varying the width of these pulses, the output maybe controlled.

The magnitude of input DC voltage is essentially constant in this inverter. . There are several different PWM techniques, differing in their methods of implementation.

However in all these techniques the aim is to generate an output voltage, which after some filtering, would result in a good quality sinusoidal voltage waveform of desired fundamental frequency and magnitude.

But we used the square wave (Although we succeeded in getting this technique out of the Microcontroller's circuit but the switches didn't succeed)

4.2 Power Switch:

A metal oxide semiconductor field effect transistor, MOSFET is a voltage controlled semiconductor device whose function is to control the flow of current. Depending on different dopingtechniques, MOSFETs can be either N-channel or P-channel.
We used the N-channel in this project.

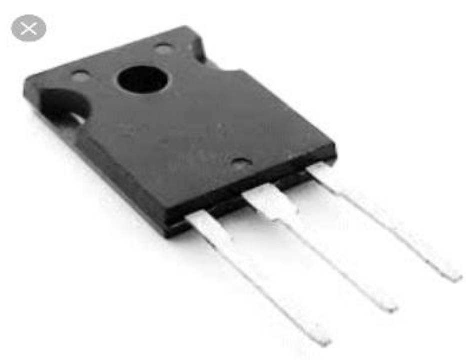


Fig 4-2

The N-channel MOSFET

-Consider the N-channel (enhancement mode) MOSFET as shown in Figure 4-3.
-If 0V is applied between gate and source (VGS= 0v) the MOSFET switch is open.
- If a sufficient positive voltage is applied between gate and source
- (e.g. VGS = 10V), theMOSFET switch is closed.

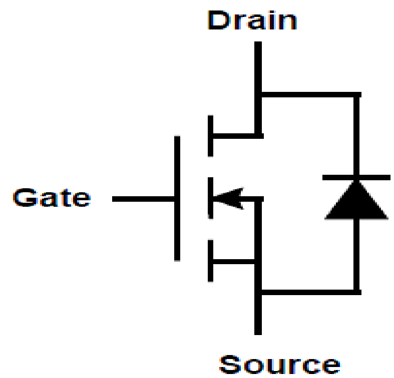


Fig 4-3

4.3 Gate driver :-

Is a power amplifier that accepts a low-power input from a controller IC and produces a high-voltage drive input for the gate of a high-power transistor such as an IGBTor Power MOSFET.

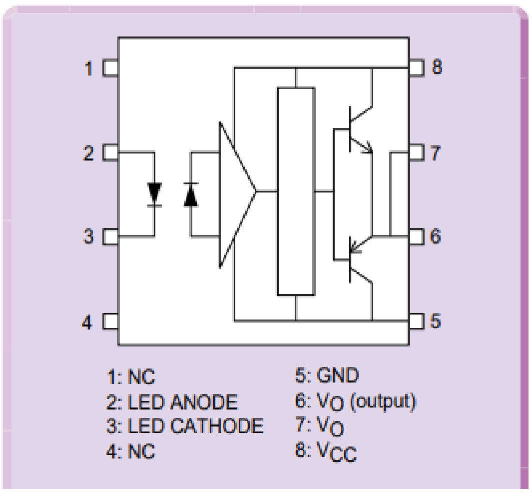
-There are lot of Gate Drives available, but most frequently used one is:

- **TLP250**

Fig; 4-4

- MOSFET driver TL250 like other MOSFET drivers have input stage and output stage, it also have power supply configuration, TLP250 is more suitable for MOSFET and IGBT.

- The main difference between TLP250 and other MOSFET drivers is that TLP250 MOSFET Driver is optically isolated;
It means that input and output of TLP250 MOSFET Driver are isolated from each other-Its works likeOptocoupler-as shown inFigure 4-5(Input stage have a light emitting diode and output stage have photo diode) whenever input stage LED light falls on output stage photo detector diode, output becomes high as shown table 4.1



		Tr1	Tr2
LED INPUT	ON	ON	OFF
	OFF	OFF	ON

Fig:4-5table:4-1

pin configuration of isolated MOSFET driver TLP250Truth Table

- ***Features***

  -Input threshold current: IF = 5 mA (max)
  - Supply voltage: 10 V ~ 35 V
  - Output peak current: 2.0 A (max)
  - Response speed: 0.5 µs (max)
  - Isolation voltage: 2500 Vrms (min)

  A Picture showing the TLP250MOSFET Gate Drive in AC-Motor Speed control application.

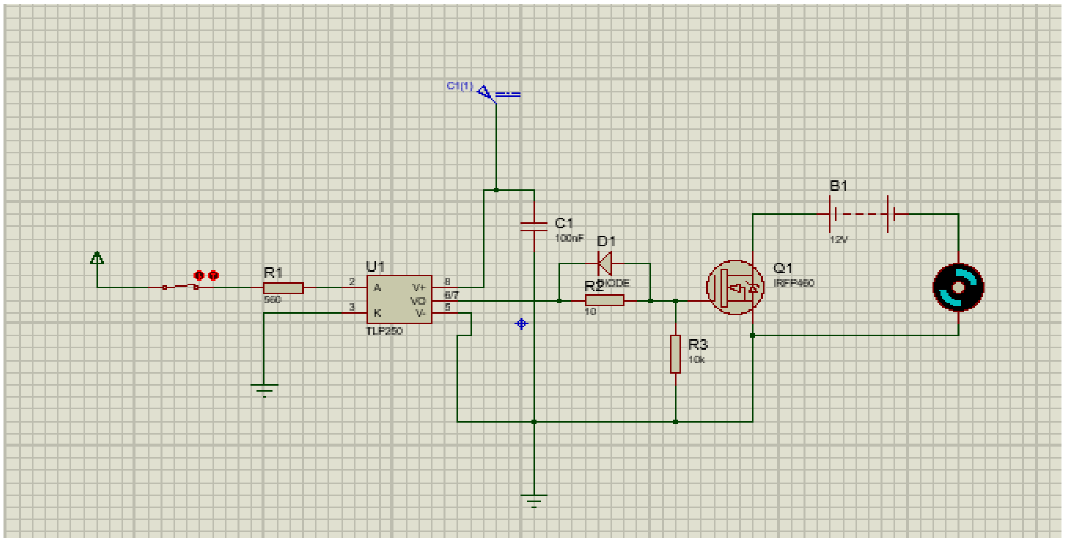


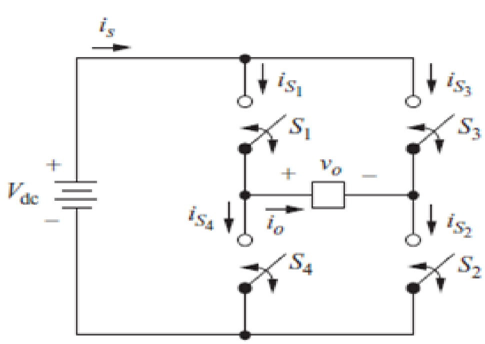
Fig: 4-6

4.4 principles operating single Phase square Inverter

The schematic of inverter system is as shown in Figure 4-7, in which the battery or rectifier provides the DC supply to the inverter.

The inverter is used to control the fundamental voltage magnitude and the frequency of the AC output voltage.

AC loads may require constant or adjustable voltage at their input terminals, when such loads are fed by inverters, it is essential that the output voltage of the inverters is so controlled as to fulfill the requirement of the loads.



(a)

Fig:4-7

The circuit diagram of full bridge inverter is as shown in table 2.4

In this application, an AC output is synthesized from a DC input by closing and opening switches in an appropriate sequence.

The output voltage *Vo* can be _*V*dc, _*V*dc, or zero, depending on which switches are closed.

Figure 4-8shows the equivalent circuits for switching combinations.

***S*1 and *S*2**	+*V*dc
***S*3 and *S*4**	-*V*dc
***S*1 and *S*3**	0
***S*2 and *S*4**	0

Table 2.4

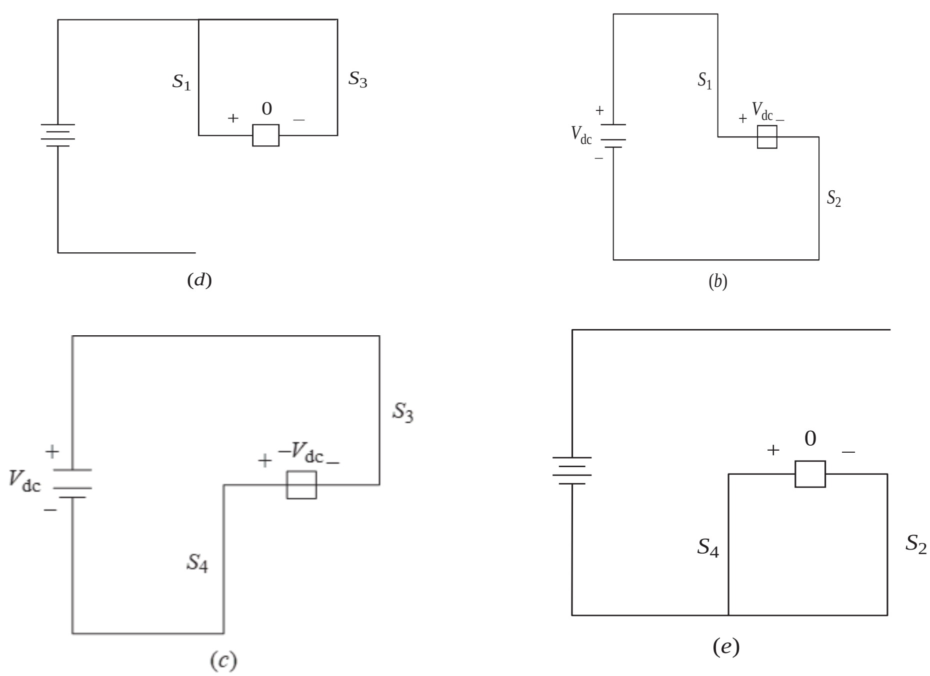


Fig: 4-8

(*a*) Full-bridge converter; (*b*) *S*1 and *S*2 closed; (*c*) *S*3 and *S*4

Closed; (*d*) *S*1 and *S*3 closed; (*e*) *S*2 and *S*4 closed

Note that:

- S1 and S4 should not be closed at the same time, nor should S2 and S3. Otherwise, a short circuit would exist across the DC source.
- Real switches do not turn on or off instantaneously. Therefore, switching transition times must be accommodated in the control of the switches. Overlap of switch “on” times will result in a short circuit, sometimes called a shoot-through fault, across the dc voltage source
- The time allowed for switching is called blanking time to prevent short-circuit across the source.

What is MATLAB?

MATLAB (an abbreviation of "matrix laboratory") is a proprietary multi-paradigm programming language and numeric computing environment developed by MathWorks. MATLAB allows matrix manipulations, plotting of functions and data, implementation of algorithms, creation of user interfaces, and interfacing with programs written in other languages

Although MATLAB is intended primarily for numeric computing, an optional toolbox uses the MuPAD symbolic engine allowing access to symbolic computing abilities. An additional package, Simulink, adds graphical multi-domain simulation and model-based design for dynamic and embedded systems.

Some especially large changes to the software were made with version 8 in 2012.The user interface was reworked and Simulink's functionality was expanded.By 2016, MATLAB had introduced several technical and user interface improvements, including the MATLAB Live Editor notebook, and other feature.

Fun Story:
In 2020, Chinese state media reported that MATLAB had withdrawn services from two Chinese universities as a result of US sanctions, and said this will be responded to by increased use of open-source alternatives and by developing domestic alternatives.

What is Simulink?

Simulink is a MATLAB-based graphical programming environment for modeling, simulating and analyzing multi domain dynamical systems. Its primary interface is a graphical block diagramming tool and a customizable set of block libraries. It offers tight integration with the rest of the MATLAB environment and can either drive MATLAB or be scripted from it. Simulink is widely used in automatic control and digital signal processing for multidomain simulation and model-based design.

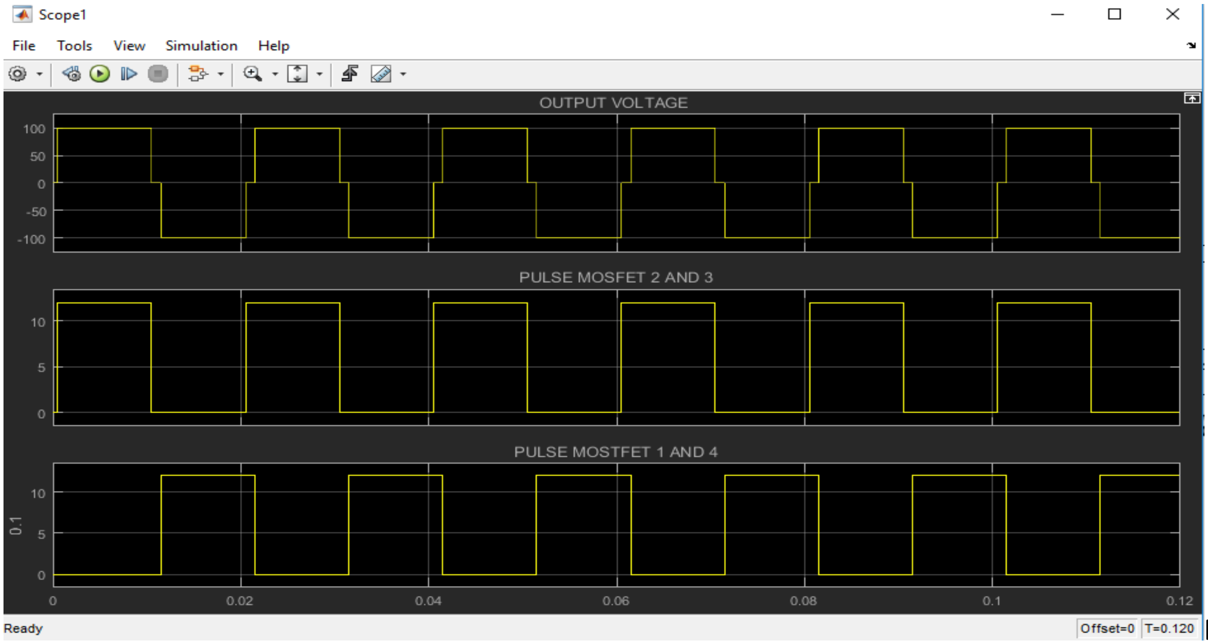


Fig: 4-10

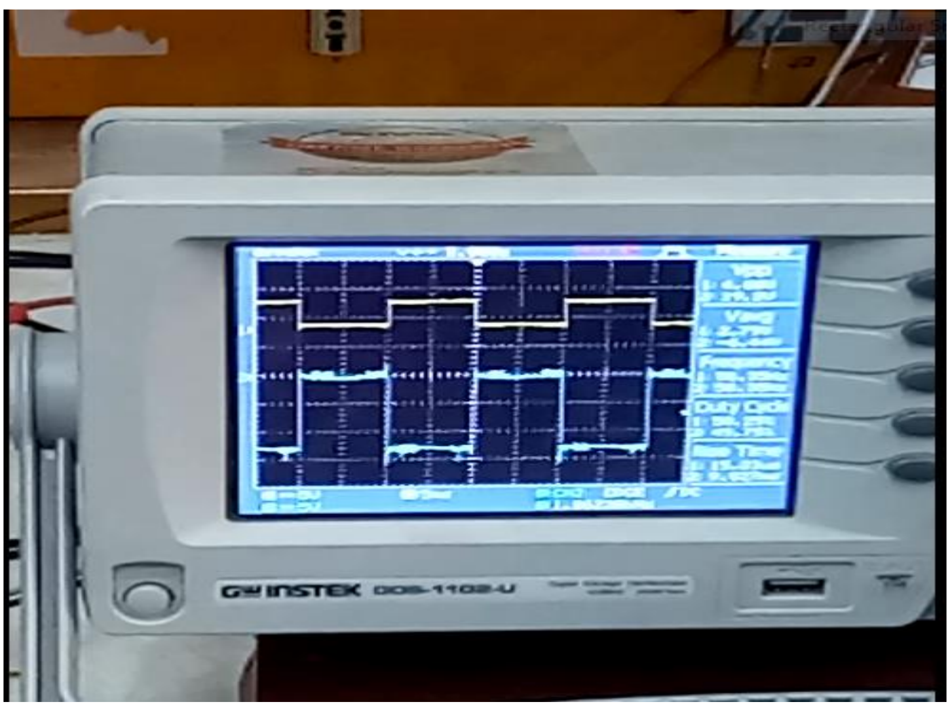


Fig: 4-13

4.5 Three Phase Inverter

4.5.1 Principles operatingof Three Phase Inverter (six step _VSI).

Figure 4-14 shows a circuit that produces a three phase AC output from a DC input using Six-step square-wave inverter;
In this case, each switch is turned ON for 180the switches are closed and opened in the sequenceas shown in **Figure4-15**

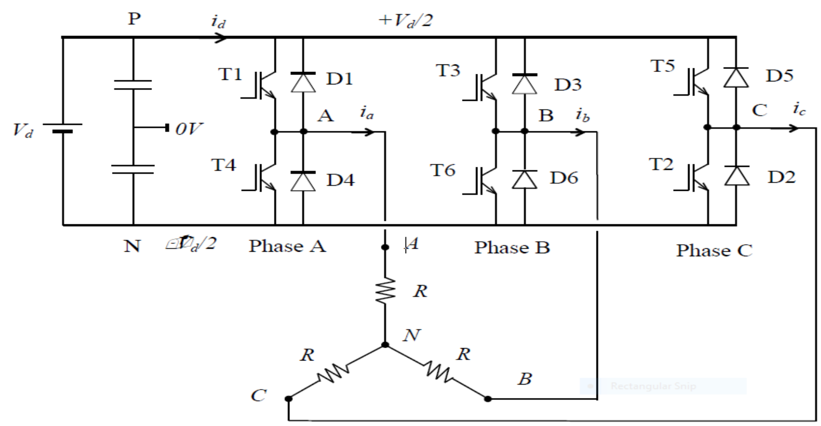


Fig.4-14

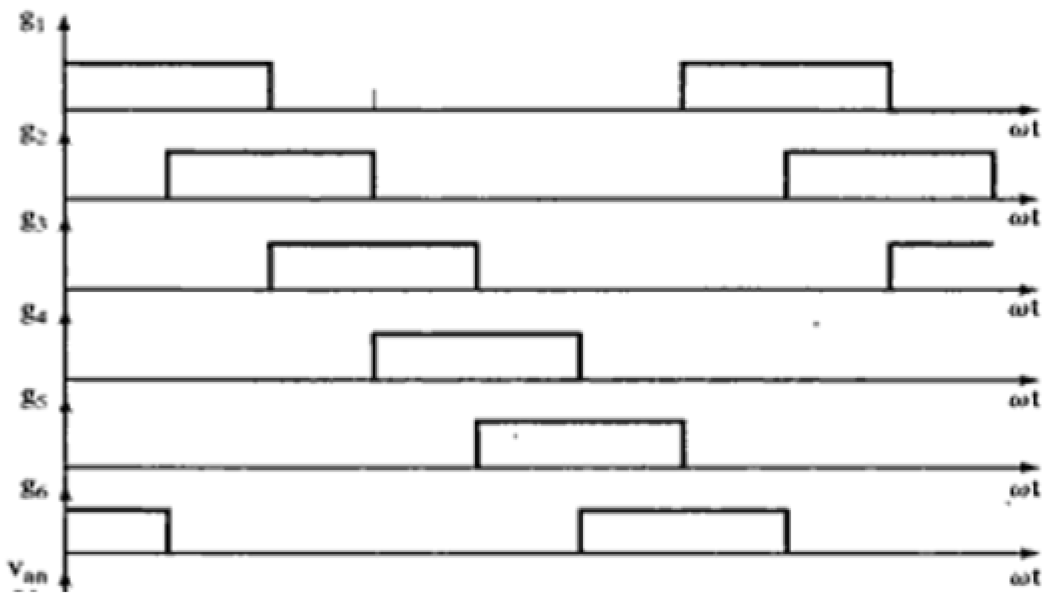


Fig:4.15

Where: each switch has a duty ratio of 50 percent, and switching action takes place every T/6 time interval, or 60 angle interval.

Note that:

SwitchG1 andG4 are closed and opened in the opposite of each other as do switch (G2 and G5)&(G3 and G6).

TheseSwitch pairs must coordinate so they are not closed at the same time, which would results in a short circuit across the source.

4.5.1.1Line-line voltage waveforms.

The line-line voltages, *vAB*, *vBC* and *vCA* are determined from the switching states at the poles) and the DC source voltage, (*Vd*). Thus, when switches T1 and T3 are ON, *vAB* = 0V, when T1 and T6 are ON, *vAB* = +*Vd*, and so on. The line-line voltages *vAB*, *vBC* and *vCA* (for the +ve or ABC phase sequence) aretherefore quasi-square waveforms of 120 of ON and 60 of OFF durations, as shown in Figure 4-16 Each phase is displaced from its adjacent ones by 120.

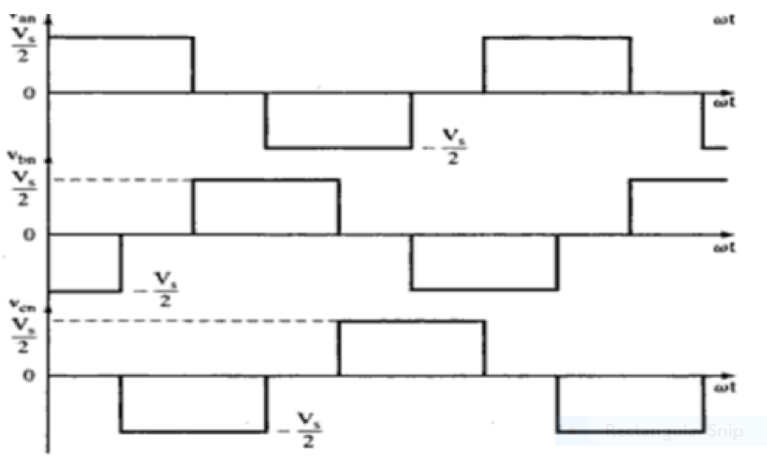


Fig:4-16

4.5.1.2 Line-neutral voltage waveforms

Line-neutral voltages are determined from the switching states and the neutral point voltage of the load which can be found by assuming that the load consists of a balanced three-phase resistor bank. For instance, if T1, T3 and T2 are ON, the potential of the neutral point of the load is 2/3Vd as shown inFigure4-17.

and therefore V_{AN} and V_{BN} will each be at potentials $\frac{1}{3}V_d$ while v_{CN} will be at $-\frac{2}{3}V_d$. Similarly, when T4, T2 and T3 are ON, the potential of the neutral point becomes $\frac{1}{3}V_d$, As a result, the potential v_{BN} will become $\frac{2}{3}V_d$ and v_{AN} and v_{CN} will each be at $-\frac{1}{3}V_d$.

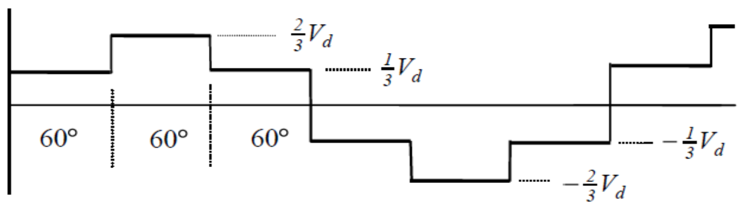


Fig:4-17

4.5.2 Implementation of three phase inverter resistive load.

The following subsections show the computer simulation and hardware implementation of asimple inverter circuit intended to drive a 30 ohm load star connected using 100 volts DC.

4.5.2.1 Software Implementation

Simulate the design of the simple inverter as shown in **Figure 4-18**below.

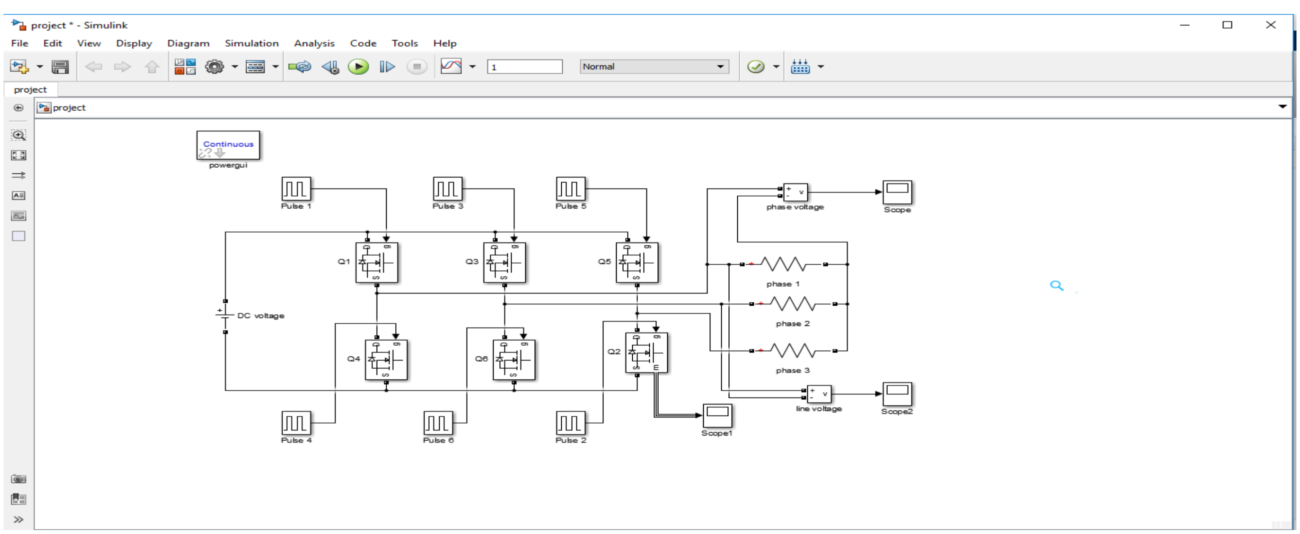


Fig:4-18

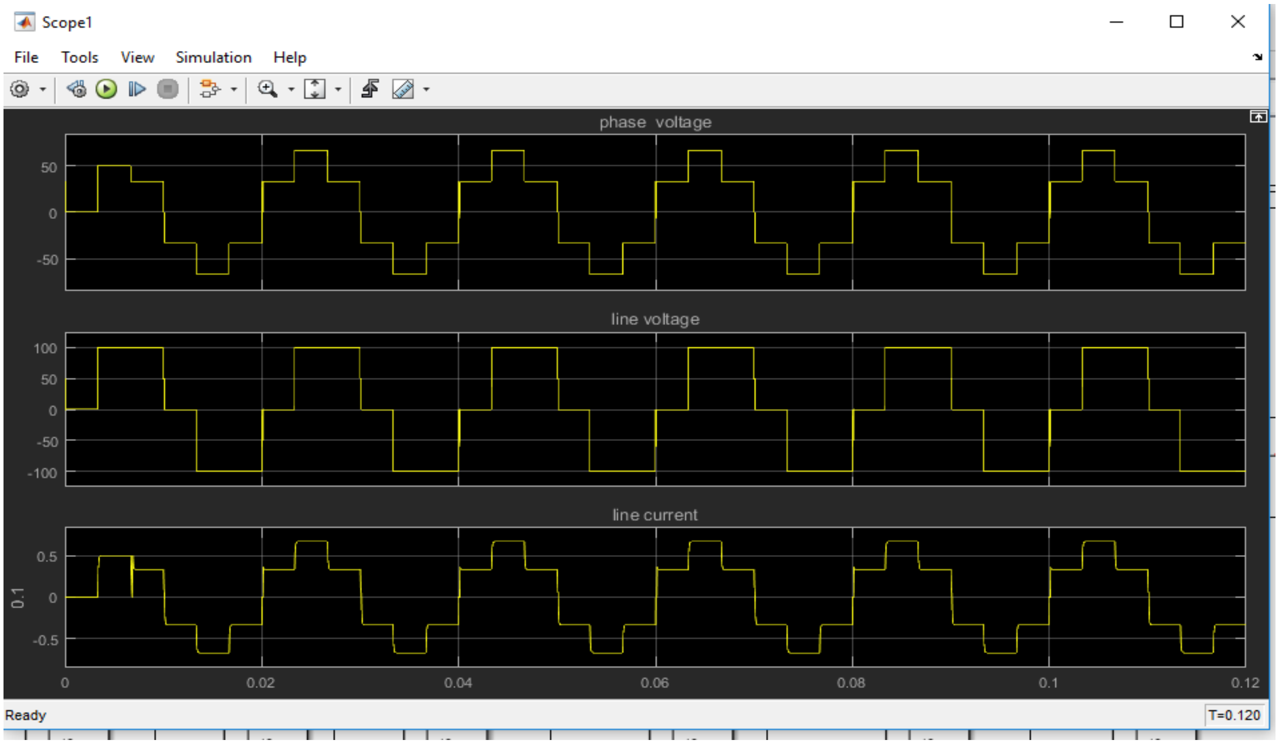


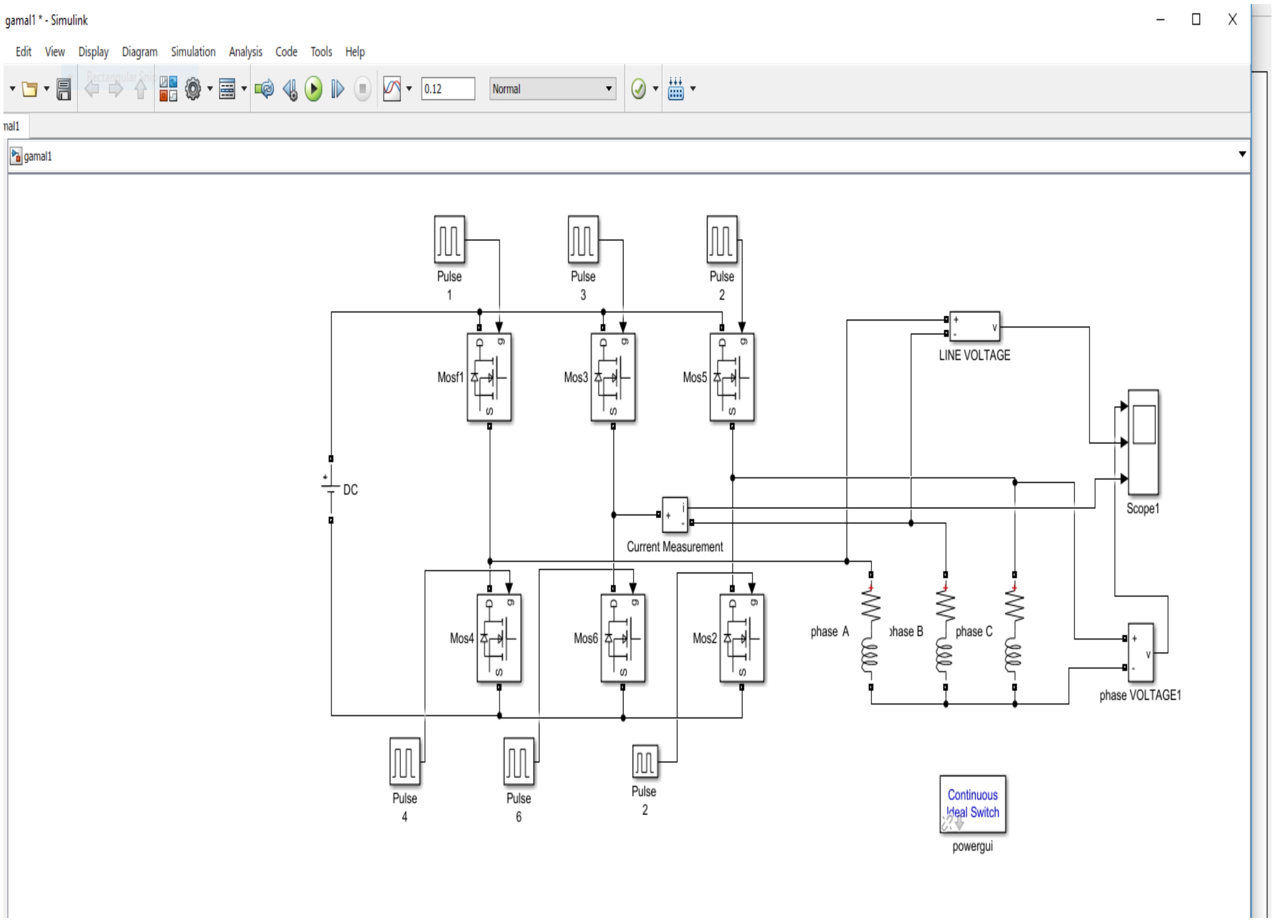
Fig:4-19

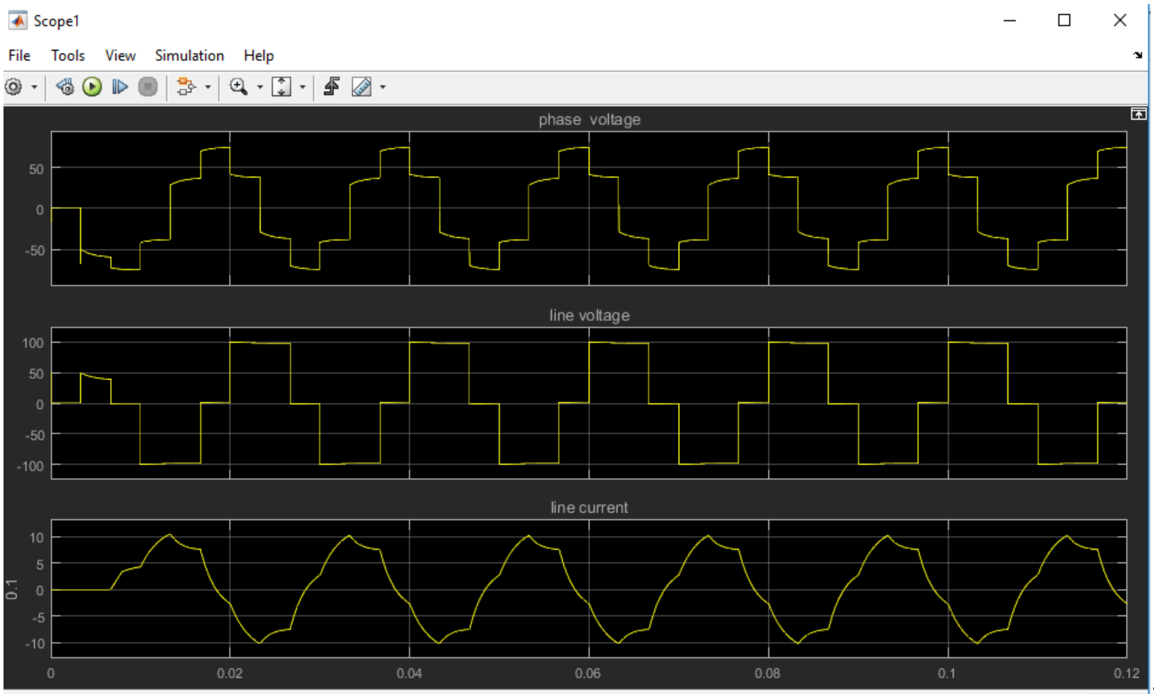
4.5.3 Implementation of three phase inverter with inductive load.

The following subsections show the computer simulation and hardware implementation of a three phase inverter circuit intended to drive aninductive load star connected using 100 volts DC.

4.5.3.1 Software Implementation

Simulate the design of the simple inverter as shown in **Figure 4-21**below:


gamal1 * - Simulink
Edit View Display Diagram Simulation Analysis Code Tools Help
0.12
Normal
gamal1
Pulse 1
Pulse 3
Pulse 2
Mosf1
Mos3
Mos5
DC
LINE VOLTAGE
Scope1
Current Measurement
Mos4
Mos6
Mos2
phase A
phase B
phase C
phase VOLTAGE1
Pulse 4
Pulse 6
Pulse 2
Continuous
Ideal Switch
powergui



Scope1
File Tools View Simulation Help
phase voltage
50
0
-50
line voltage
100
50
0
-50
-100
line current
10
5
0
-5
-10
0.1
0
0.02
0.04
0.06
0.08
0.1
0.12

Fig:4-21

4.4 .1 Implementation of the Simple Inverter

The following subsections show the computer simulation and hardware implementation of asimple inverter circuit intended to drive a 30 ohmsload using 100 volts DC.

4.4.1.1 Software Implementation

Matlab was used to simulate the design of the simple inverter as shown in Figure 4-9below:

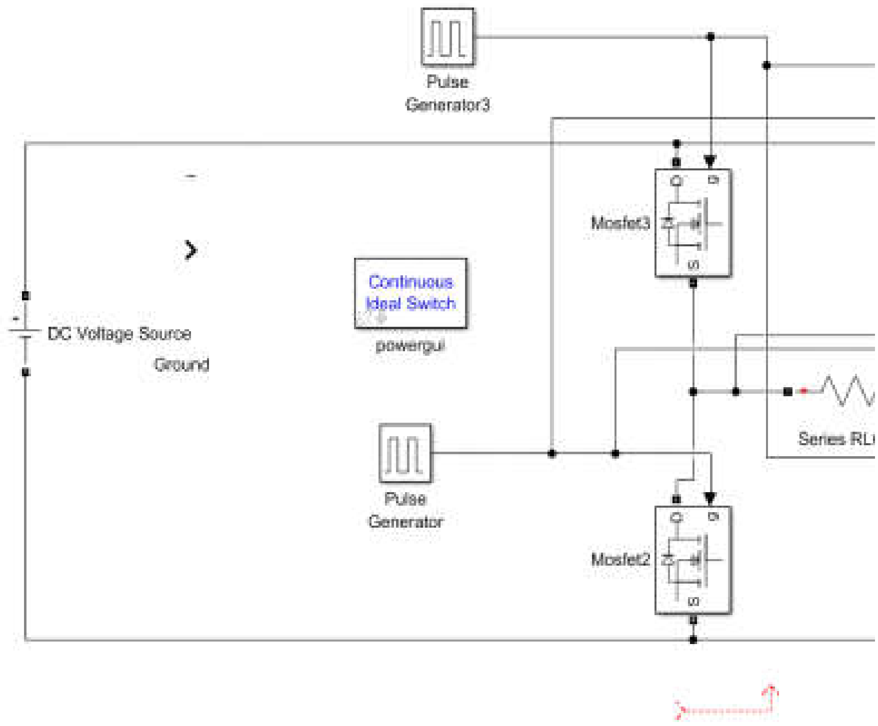


Fig: 9-4

Note that the shape of the output voltage wave and pulses of all switchesare as shown in Figure 4-10

Summary:

The main objective of this project which is the design of microcontrollerbased Power-electronics single and three phase inverters using six step technology was achieved in means of software simulation without the hardware implementation for both of them. The stages that have been completed in the project are stated as follows:

-The simple inverter circuit design was accomplished successfully and theconcept of inversion was clearly demonstrated.

-For the single-phase inverter, the generation of six step signals that correspond to variable frequency sine waves was successfully done. The program waswritten using Bascom AVR and the simulation results for the full inverter.
Designs were obtained using (Proteus \ Matlab) as obtained in the previous chapter.
TheDesign here was partially fulfilled hence the hardware implementation wasAchieved only to generate a six step signal that corresponds to 50Hz sine waveOut of the microcontroller.

-For the three-phase inverter circuit, the design was restricted to be software Simulated.
The six step signals that corresponding to three square waves shifted by120 degree from each other were generated successfully from the Microcontroller, however the voltage across the load connected to the three phaseinverter was not as expected.