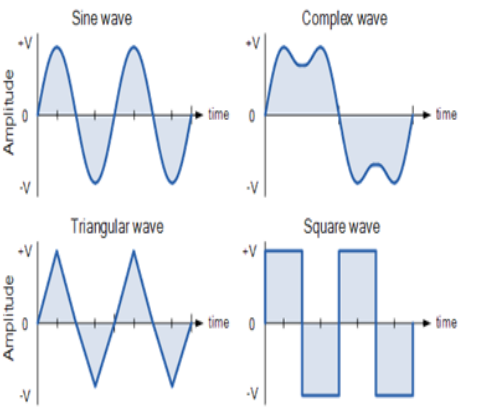
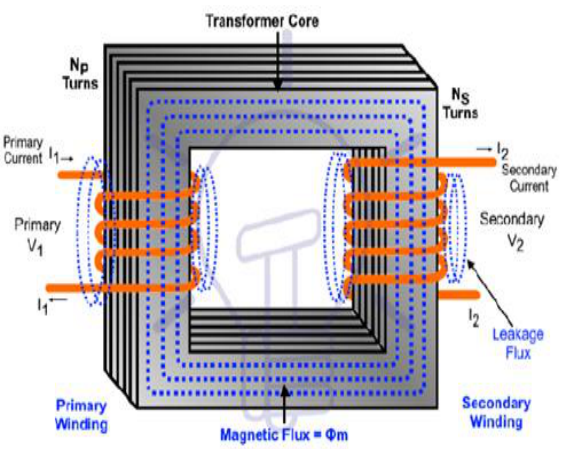
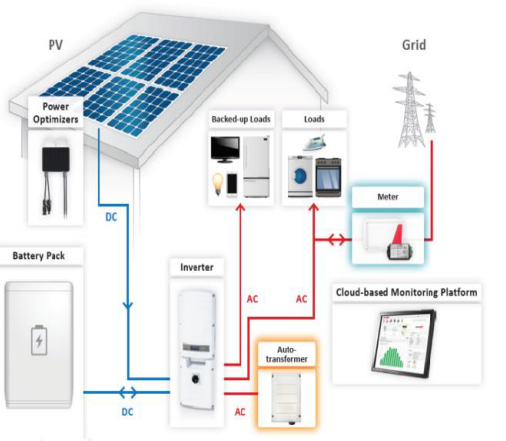
Textbook of

Applied Electrician

Class-X







LEARN RISE SHINE

NAVTTC

National Vocational & Technical Training Commission (NAVTTC)

Textbook of

Applied Electrician

Grade – X

National Vocational and Technical Training Commission

H-9, Islamabad

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PREFACE

This book has been written to cater the needs of Matric-Tech to teach & train the students for the subject of Applied Electrician. Matric-Tech is a new initiative of NAVTTC and Applied Electrician trade is highly suitable for present day needs. Key attempt has been made to make the book interesting and useful. The chapters cover the basic details understandable to the students of Matric Tech. All chapters includes assessment in form of MCQs, Short Questions & Long Questions.

This book has been written to cover most of the topics to train the students in the field of electrician trade focusing the electronics topics of power backup system, Safety & Security and Communication Systems for domestic and industrial applications. All the topics pertaining to theory & practical have been explained in a simple and convenient style. Some topics for personal and professional development including CV writing, use of Emails and registering and searching on various job portals have also been covered.

The book is written to add the skills rather to learn theory only. It should be read conceptually. Perform all the activities and tasks to acquire hands on experience of the trade of Industrial electrician.

I am really thankful to NAVTTC and review team for their cooperation & guidance. Any suggestions for improvement of this book will be highly acknowledged.

Executive Director
National Vocational & Technical Training Commission
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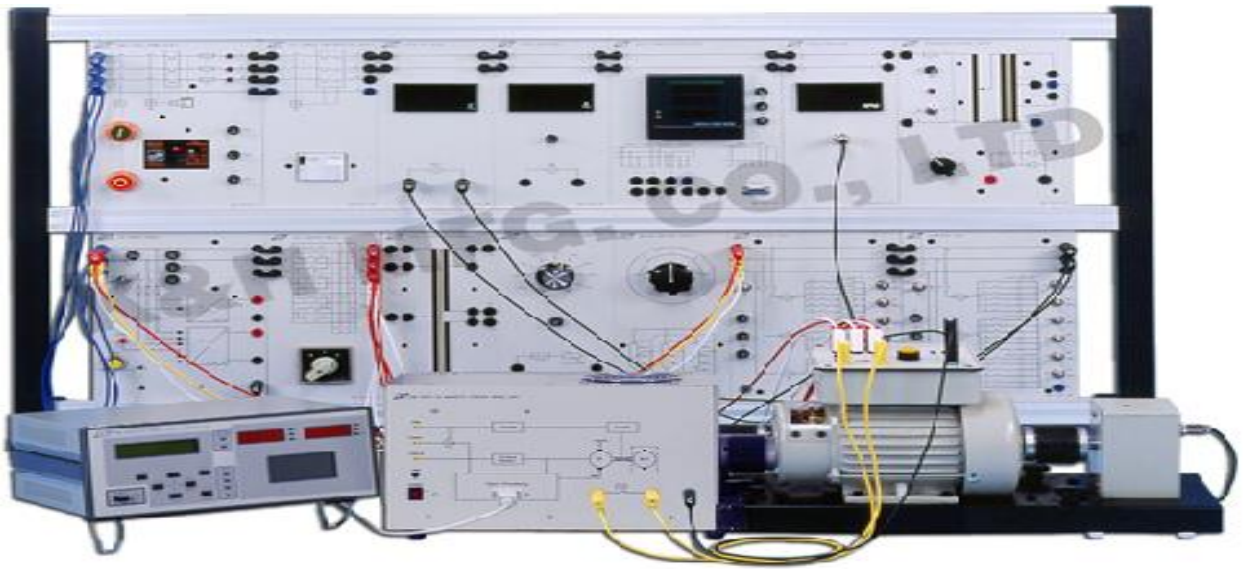
Chapter 1: Motors and Generators



Students Learning Outcomes

After completion of this chapter you will be able to:

- define Motor.
- explain Types of DC Motor (Series, Shunt & Compound).
- explain types of AC motors (Single/3-Phase Induction Motors).
- describe parts of DC Motor.
- describe parts of AC Motor.
- describe the working principle of AC/DC Motors.
- explain types of motor connections (Star, Delta).
- explain visual inspection of mechanical defects such as, tight bearings, bent shaft, noisy running.
- explain the connection techniques of motors.
- define Generator.
- describe Types of Generators.
- describe Parts of Generator.
- describe the working principles of Generators.
- explain Generator Connections.
- describe the procedure for checking of generators by using specified test instruments to detect electrical defects such as loose/or burnt electrical connections, burnt windings, low insulation resistance etc.
- explain the importance of service and maintenance of electrical machines.
- eomprehend importance of preventive maintenance of motors, generators etc.
- explain tagging procedure (maintenance card) of motors, generators etc.

1.1 Electric Motor

Electric motor is a machine that converts electrical energy to mechanical energy. Any DC machine can be used as DC motor. From construction point of view there is no difference between a DC Motor and a Generator. The only difference lies in the direction of flow of power. If a DC machine is run by giving power then it is termed as a motor and if the same machine is run from an external source e.g. prime mover and DC supply is taken from the machine, then it is termed as the DC generator.

An electric motor operated by DC (direct current) is known as a DC motor. A DC motor converts DC electrical energy into mechanical energy.

1.2

Based on input supply to a motor, it can be classified as AC & DC Motors.

Direct Current (DC) motors are classified according to the connection of the field winding to the armature.

There are 3 main types of DC Motors:

1. DC Shunt Motor
2. DC Series Motor
3. DC Compound Motor

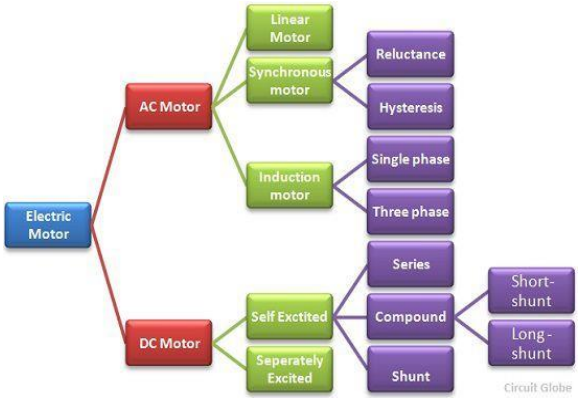


Fig 1.1 Types of Electric Motors

DC Shunt Motor

It is a type of DC motor in which field windings are connected in parallel to the armature winding. Since they are connected in parallel, the armature and field windings are connected to the same supply voltage.

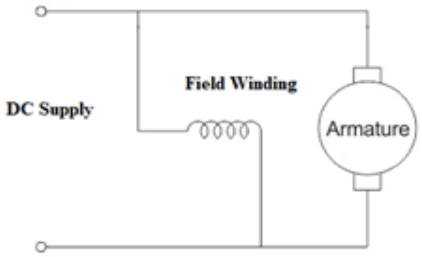


Fig 1.2 DC Shunt Motor

1. In DC motors the torque is proportional to the armature current so the armature winding must be exposed to an amount of current that's much higher than the field winding current.
2. The field winding must be wound with many turns to increase the flux linkage, as flux linkage between the field and armature winding is also proportional to the torque.

3. Keeping in view these two points a **DC shunt motor** is designed in such a way, that the field winding possess much higher number of turns to increase net flux linkage and are lesser in diameter of conductor to increase resistance (reduce current flow) compared to the armature winding of the DC motor.
4. A very important and interesting fact about the DC shunt motor, is in its ability to self-regulate its speed on the application of the load to the shaft of the rotor terminals. This essentially means that when switching a motor in running condition from no load to loaded, there is no considerable change in speed of running, as would be expected in the absence of any speed regulating modifications from outside.

DC Series Motor

In a series DC motor the armature and field windings are connected in series. So the field winding is exposed to the same armature current unlike in the case of a shunt motor.

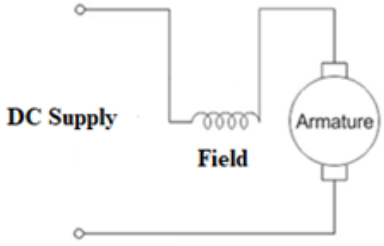


Fig1.3 DC Series Motor

1. The field coils of DC series motor are wound with relatively fewer turns as the current through the field is its armature current and hence for required MMF less numbers of turns are required. The wire selected is thick to provide minimum electrical resistance to the flow of full armature current.

2. In spite of the above mentioned differences, about having fewer coil turns the running of this DC motor remains unaffected, as the current through the field is reasonably high to produce a field strong enough for generating the required amount of torque. To understand that better let us look into the voltage and current equation of DC series motor.

DC Compound Motor

A DC compound motor is a type of DC motor in which both series and shunt field coils are connected to the armature winding as shown in the Fig. 1.4.

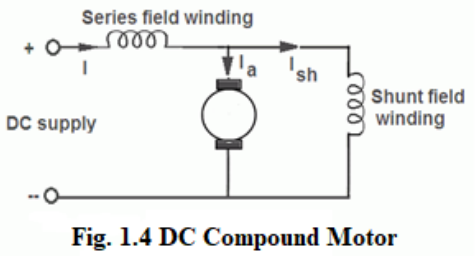


Fig. 1.4 DC Compound Motor

Both the field coils provide for the required amount of magnetic flux that links with the armature coil and brings about the torque necessary to facilitate rotation at the desired speed. As we can understand, a

compound wound DC motor is basically formed by combining a shunt wound DC motor and series wound DC motor to achieve the better off properties of both these types.

1. A DC shunt motor is having an extremely efficient speed regulation characteristic, whereas the DC series motor has high starting torque.
2. The compound DC motor reaches a compromise in terms of both these features and has a good combination of proper speed regulation and high starting torque.
3. Though its starting torque is not as high as in case of DC motor, nor is its speed regulation as good as a shunt DC motor. Overall characteristics of DC shunt motor falls somewhere in between these two extreme limits.

1.3 AC Motors

A motor which converts the alternating current into mechanical power by using an electromagnetic induction phenomenon is called an AC Motor. This motor is driven by an alternating current. The stator and the rotor are the two most important parts of the AC motors. The stator is the stationary part of the motor, and the rotor is the rotating part of the motor. The AC motor may be single phase or three phase.

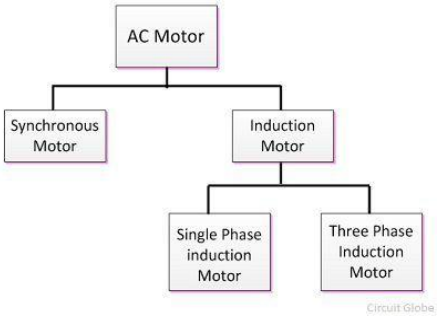


Fig 1.5 AC Motors

Types of AC Motors

The AC motor is mainly classified into two types. They are the synchronous motor and the induction motor.

Synchronous Motor

A Synchronous Motor is an AC motor where the rotation of the rotor (or shaft) is synchronized with the frequency of the supply current. That is, the rotation period of the rotor is equal to the rotating field of the machine it is inside of.

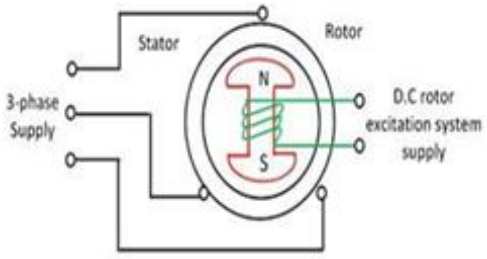


Fig 1.6 AC Synchronous Motor

It is a motor that converts the AC electrical power into mechanical power and is operated only at the synchronous speed is known as a synchronous motor. When supply is given to synchronous motor, a revolving field is set up. This field tries to drag the rotor with it, but could not do so

because of rotor inertia. Hence, no starting torque is produced. Thus, inherently synchronous motor is not a self-starting the motor.

Induction Motor or Asynchronous Motor

An induction motor (also known as an asynchronous motor) is a commonly used AC electric motor. In an induction motor, the electric current in the rotor needed to produce torque is obtained via electromagnetic induction from the rotating magnetic field of the stator winding. The rotor of an induction motor can be a squirrel cage rotor or wound type rotor.

Induction motors are referred to as 'asynchronous motors' because they operate at a speed less than their synchronous speed. So the first thing to understand is – what is synchronous speed? Synchronous speed is the speed of rotation of the magnetic field in a rotary machine, and it depends upon the frequency and number poles of the machine. The induction motor always runs at speed less than its synchronous speed.

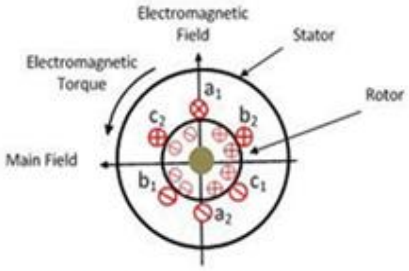


Fig. 1.7 Induction Motor

The induction motor is mainly classified into two types, i.e., the single phase induction motor and the three phase induction motors.

In an induction machine the armature winding serve as both the armature winding and field winding. When the stator windings are connected to an AC supply flux is produced in the air gap. The flux rotates at a fixed speed called synchronous speed. This rotating flux induces voltages in the stator and rotor winding.

If the rotor circuit is closed, the current flows through the rotor winding and react with the rotating flux and a torque is produced. In the steady state, the rotor rotates at speed very close to synchronous speed.

1.4 Parts of DC Motors

A DC motor contains different parts that understanding each one can assist to know deeply these parts cooperate with each other and in the end how DCs work. These components are: a stator, a rotor, a yoke, poles, armature windings, field

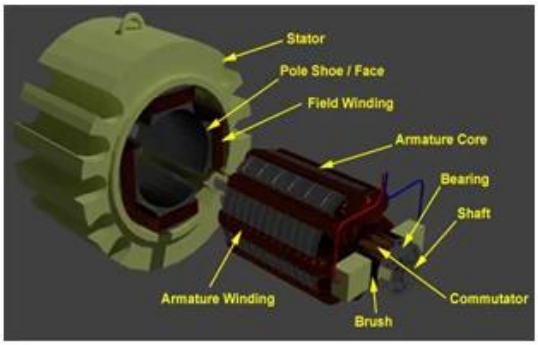


Fig. 1.8 Parts of DC Motor

windings, commutator, and brushes. Many of its parts are the same as parts of AC motor, but with a little change.

Stator

A stator is the stationary part of the DC motor containing the field windings.

Rotor

The moving or dynamic part of a DC motor is the rotor that creates the mechanical rotations of the unit.

Yoke

Another unit of the DC motor parts is the Yoke. A Yoke is a magnetic frame made of cast iron or sometimes steel, which works as a protector. This protective cover keeps the inner parts of the motor safe and sound and also supports the armature. Yoke also houses the magnetic poles and field windings of a DC motor to help supporting the field system.

Poles

DC motor has magnetic poles that fit into the inner wall of the Yoke with the help of screws to tighten them up. Poles have two parts: The Pole Core and the Pole Shoe. These two parts are fixed together by hydraulic pressure and are attached to the Yoke. Each part of the Poles has a specific task based on its design. The core holds the Pole Shoe over the Yoke while the Pole Shoe is structured to both carry slots for the field winding and spread the produced flux by the field windings into the air gap between the rotor and stator. It helps to reduce the loss caused by reluctance.

Field Windings

A field winding is an insulated current carrying coils on a field magnet that produce the magnetic field needed to excite a generator or motor. The field windings form an electromagnet capable of producing field flux. Field windings are generally made with Copper wire and circle around the slots carried by the Pole Shoes. The rotor armature rotates inside the field flux, resulting in the effective flux cutting.

Armature Windings

The armature winding is defined as the conductors which are housed and protected within the armature slots and are connected properly. The helpful EMF will be encouraged in this winding which is received across the brushes. These windings have two constructions: Lap Winding and Wave Winding. Their

difference is in the number of parallel paths. Armature Winding is attached to the rotor and alters the magnetic field in the path that it rotates. The result of this procedure is magnetic losses.

Commutator

A commutator is a rotary electrical switch in certain types of electric motors and electrical generators that periodically reverses the current direction between the rotor and the external circuit. It consists of a cylinder composed of multiple metal contact segments on the rotating armature of the machine.

Brushes

Brushes are made of Carbon or Graphite structures with the commutator, working as a bridge to connect the static electrical circuit to the rotor. Brushes are in contact with the commutator and relay the produced current to the commutator from an external circuit. The current then moves into the armature winding.

1.5 Parts of AC Motor

AC motors are capable to convert electrical energy into mechanical energy, which is used to rotate fan, blower, or pump impeller, lift materials and to drive compressors. These motors are run by AC Supply. This motor is capable to distribute alternating current over a long-range.

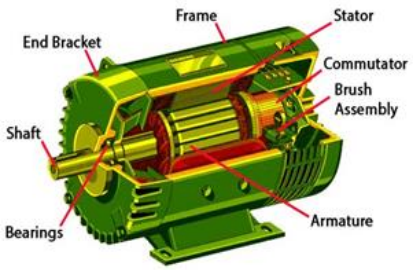


Fig.1.9 Parts of AC Motor

The three-phase AC induction motor is used for many industrial applications and it has two major parts they are stator and rotor. A stator is the stationary part of the induction motor and this part has windings. The second major part is the rotor and it is the rotating section and this part has the conductor. The stator would look like a cylinder and it has coils that are insulated and it is in the slots, so the coils and the steel core together make an electromagnet. The rotor of the motor is of two types and they are wound rotor and squirrel cage. In the wound rotor type, it has coils of wire wound in its rotor slot. While in the case of squirrel cage type it has copper or aluminum bars that will be electrically connected at each end of the conducting rings.

1. Enclosure – it is the outer part of the motor, it can hold parts together and can help with heat dissipation, and can protect the internal components from hazards

2. Stator – it is the stationary part also called windings it is basically an iron core which is wounded with copper wire
3. Rotor – it is the rotating part of the motor
4. Bearings – This part is to support the shaft
5. Terminal box – It is the part where electrical power is connected to the motor
6. Fan
7. Eyebolt

Compared with DC motors, there is no commutator and the structure is simple and strong that is easy to manufacture, as a result, high-speed, high voltage, high current, high-capacity motors can be produced easily.

What are the advantages of an AC motor?

- It has a simple design
- Economical
- Good power to weight ratio
- Less maintenance
- It can be directly connected to an AC source
- Better power factor

What are the disadvantages of an AC motor?

- It won't be able to operate at low speeds
- Positioning control is really poor
- Speed is limited by the supply frequency
- It has very low starting torque

Activity 1.1 Enlist the parts of motor.
Components/Instruments AC & DC Motors , Electric Tool Box
Step 1: Issue the materials from the store as per the list provided by instructor. Step 2: Identify various parts of the AC & DC Motors and make separate lists. Step 3: Record the observations and detail of the motor parameter found.

1.6 Working Principle of AC/ DC Motor

DC Motor works on the principle that when a current-carrying conductor is placed in a magnetic field, it experiences a force and has a tendency to move. In other words, when a magnetic field and an electric field interact, a mechanical force is produced. This is known as motoring action.

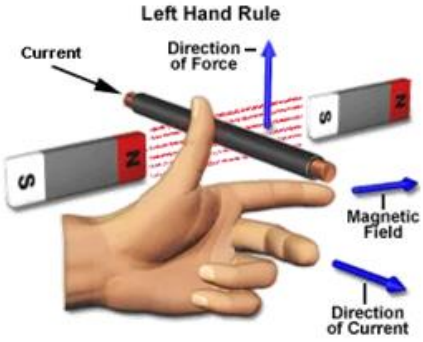
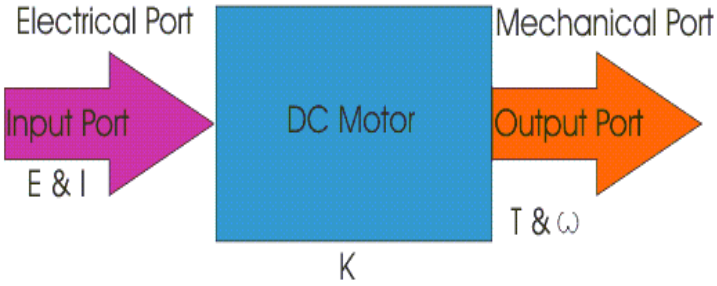


Fig. 1.10 Working Principle of AC/DC Motors

The direction of rotation of this motor is given by Fleming's left hand rule, which states that if the index finger, middle finger, and thumb of your left hand are extended mutually perpendicular to each other and if the index finger represents the direction of the magnetic field, middle finger indicates the direction of the current, then the thumb points in the direction in which force is experienced by the shaft of the DC motor.



Structurally and construction wise a direct current motor is exactly similar to a DC generator, but electrically it is just the opposite. Here we unlike a generator we supply electrical energy to the input port and derive mechanical energy from the output port. We can represent it by the block diagram shown above.

1.7 Motor Connection Techniques

Star Connection

The configuration of voltage sources is characterized by a common connection point joining one side of each source is commonly known as the "Y" (or "star") configuration is shown in Fig.1.11. If we draw a circuit showing each voltage

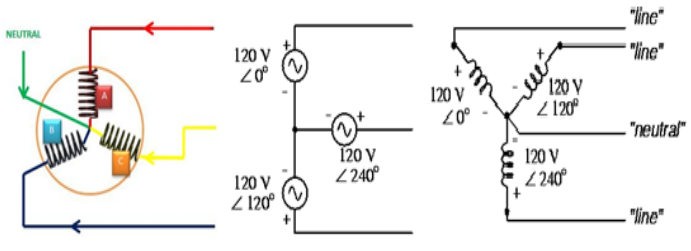


Fig. 1.11 AC Motor Star Connection

source to be a coil of wire (alternator or transformer winding) and do some slight rearranging, the "Y" configuration becomes more obvious in figure below. Three-phase, four-wire *"Y"* connection uses a "common" fourth wire.

The three conductors leading away from the voltage sources (windings) toward a load are typically called lines, while the windings themselves are typically called phases. In a Y-connected system, there may or may not be a neutral wire attached at the junction point in the middle, although it certainly helps alleviate potential problems.

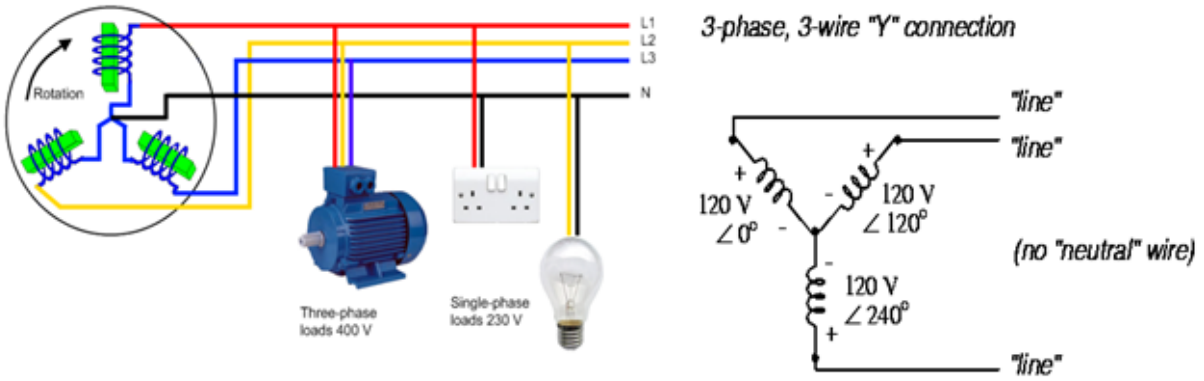


Fig. 1.12 AC Motor Star/ Y Connection

Relationship between Phase and Line Current

In star connection, line current equal to phase currents (As line and phase is being in series). If I_L represents value of line current and I_{ph} represents the value of phase current then, $I_L = I_{ph}$

Relation between Phase & Line Voltages in Star Connection

Y-connected sources and loads always have line voltages greater than phase voltages. The potential difference between lines 1 & 2 is

$V_{RY} = E_R - E_Y$ (Vector difference)

Hence, V_{RY} is found by compounding E_R and E_Y reversed and its value is given by the diagonal of the parallelogram of figure as shown below. The angle between E_R and E_Y reversed (i.e. $-E_Y$) is 60º.

Hence if $E_R = E_Y = E_B = E_{ph}$

$V_{RY} = 2\ E_{ph} \cos (60º / 2)$

$= 2\ E_{ph} \cos 30º$

$= 2\ E_{ph} \frac{\sqrt{3}}{2}$

$= \sqrt{3}\ E_{ph}$

Similarly, $V_{YB} = E_Y - E_B$ (Vector difference)

$= \sqrt{3}\, E_{ph}$

And $V_{BR} = E_B - E_R$

$= \sqrt{3}\, E_{ph}$

Now $V_{RY} = V_{YB} = V_{BR}$ = Line Voltage, say, V_L

Hence, in star connection $V_L = \sqrt{3}\, E_{ph}$

Delta Connection

Another possible configuration for connection is known as the "Delta," for its geometric resemblance to the Greek letter of the same name (Δ).

Take close notice of the polarity for each winding in Fig.1.13 below. Three-phase, three-wire Δ connection has no common

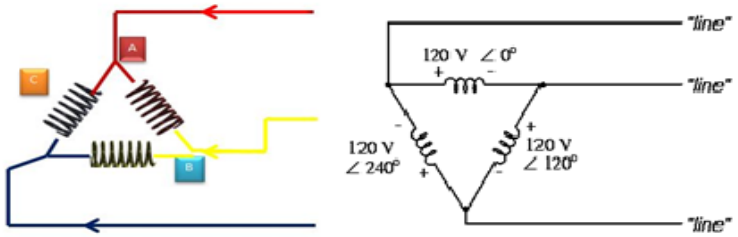


Fig 1.13 AC Motor Delta Connection

Relation between Line and Phase Voltage in Delta Connection

Because each pair of line conductors is connected directly across a single winding in a Δ circuit, the line voltage will be equal to the phase voltage. If V_L represents value of line Voltage and V_{ph} represents the value of phase Voltages then,

$V_L = V_{ph}$

Relation between Phase & Line Currents

Because each line conductor attaches at a node between two windings, the line current will be the vector difference of the two joining phase currents.

The Line current of line 1 is

$I_1 = I_R - I_B$ (Vector difference)

Hence, I_1 is found by compounding I_R and I_B reversed and its value is given by the diagonal of the parallelogram of figure as shown below. The angle between I_R and I_B reversed (i.e. $-I_B$) is 60°. Hence if $I_R = I_Y = I_B = I_{ph}$

$I_1 = 2\ I_{ph} \text{ Cos } (60^o / 2)$

$= 2\ I_{ph} \text{ Cos } 30^o$

$= 2\ I_{ph} \frac{\sqrt{3}}{2}$

$= \sqrt{3}\ I_{ph}$

Similarly, $I_2 = I_Y - I_R$ (Vector difference)

$= \sqrt{3}\ I_{ph}$

and $I_3 = I_B - I_Y$

$= \sqrt{3} I_{ph}$

Now $I_1 = I_2 = I_3$ = Line Current, say, I_L

Hence, in delta connection $I_L = \sqrt{3} I_{ph}$

Did You Know?

When the windings of a 3-phase motor are connected in STAR, the voltage applied to each winding is reduced to only $(1/\sqrt{3})$ of the voltage applied to the winding when it is connected directly across two incoming power service lines. In DELTA, the current per winding is reduced to only $(1 / \sqrt{3}$ of the normal running current taken when it is connected in DELTA. so, because of the Power Law V [in volts] x I [in amps] = P [in watts], The voltages across the impedances and the currents in the impedances are 120° out of phase.

Activity 1.2

Perform the connection of motor.

Components/Instruments

AC & DC Motors , Multimeter, Connecting Leads, Electric Tool Box

Step 1: Issue the materials from the store as per the list provided by instructor.

Step 2: Make the connection of the motors as per the instruction provided and run the motors and use the clamp meter to measure the current.

Step 3: Record the observations as per the instructions of the instructor.

1.8 Visual Inspection of Mechanical Defects

When we think of the inspection of electric motors, it's not just the electrical components that are important. The mechanical aspects of a motor are extremely important to its performance. It is

therefore mechanical inspection of electric motors is also very important. There is also a visual inspection aspect of performing mechanical inspections. For example, consider sleeve bearings: they often have oil ring keepers or oil rings that require a quick look to evaluate their condition, or a visual check to see if the material is still securely bonded to the interior of the bearing. Technicians also look for signs of surface wear on mechanical components, including gauges, abrasions, and pitting. For insulated bearings, a visual check of the insulation is also key. Following important inspections must be carried out.

i. Inspecting Critical Fits for Electric Motors

As the motor is carefully dismantled, critical fits needs to be measured. These critical fits include. For an electric motor to run efficiently and productively, attention must be paid to the mechanical fits and tolerances. When the dimensions of these fits are not within the correct manufacturer tolerances, things will go wrong with the motor and can cause:

- Bearings fits
- Journal fits
- Housings
- Seal fits
- Keyway
- Shaft extension size

ii. Inspecting & Measuring Specific Parameters of Bearings

The mechanical inspection of a motor includes measuring specific parameters of bearings, shafts, and seals, such as:

- Bearing OD (Outer Diameter) to Housing ID (Inner Diameter)
- Bearing ID to Shaft OD
- Mechanical Seal Fit Clearance
- Coupling ID to Shaft OD
- Run outs

Instruments Used in Mechanical Inspections

Key instruments for performing these types of measurements include:

- Digital calipers (which are especially useful for measuring lengths but can also be used for inside and outside diameters if necessary)
- Outside Micrometers (for measuring external dimensions)

- Inside Micrometers (for measuring internal dimensions)
- Dial bore gauge (often used for measuring smaller bearings that have been spun cast and finished)
- Lathe (used for measuring run out when combined with a dial indicator)

Activity 1.3 Develop a data sheet of Electric motor with Reading name plate & manufacturer manuals power supply.
Components/Instruments AC & DC Motors , Electric Tool Box
Step 1: Issue the materials from the store as per the list provided by instructor. Step 2: Inspect the AC & DC Motors minutely and read name plate and motor manual carefully. Step 3: Tabulate the following information from the data collected: 1. Motor Type 2. Power Capacity (Watt) 3. Single Phase/Three Phase 4. Input Supply Voltage 5. Rated Speed (RPM) Step 4: Make the connection of the motors as per the instruction provided and run the motors and use the clamp meter to measure the current.

Activity 1.4 Checking Bearing Status, Shaft Status, Winding Status, Capacitor Status, Armature Status and Commutator Status.
Components/Instruments AC & DC Motors , Multimeter, Connecting Leads, Electric Tool Box
Step 1: Issue the materials from the store as per the list provided by instructor. Step 2: Inspect the various parts of the AC & DC Motors. Step 3: Check the status of the motor Bearing, Shafts, Windings, Capacitors, armature and commutator individually for both types of machines. Step 3: Record the observations and detail found during observations.

1.9 Generator

Generator is a machine/device which converts mechanical energy into the electrical energy. The energy is produced due to the dynamically induced EMF. When a conductor is linked with the

magnetic flux, it causes a change in flux and EMF is induced according to the Faraday's laws of electromagnetic induction. The direction of the magnetic field can be found by using Fleming's right hand rule.

It is to be noted that only AC voltage is produced in every generator. It is further converted in DC with the help of commutator mounted on the end of armature. It is provided to outer circuit with the help of slip sings. If the commutator is not used and only the slip rings are used, then the AC can be obtained at the outer circuit. This is the basic difference between an AC and DC generator.

1.10 Types of Generator

Types of DC Generator:

DC generator are generally classified according to following two ways:

1. Field Excitation
2. Connections

1. Field Excitation

There are two types of generators according to the field excitation classification.

i. Separately excited

ii. Self-excited

These two types have been discussed below:

i. Separately-Excited

The field magnets of separately excited generators are energized by independent external source e.g. battery excites or amplifier. The separately excited ac generator cannot excite its field itself rather it needs external source for of power to excite its field. Such soft of generators are of law voltage and high current generators. These generators are generally used in sea ships, electroplating works, automatic control of motors and in electro refining of motors. The circuit of separately excited generator has been shown in Fig.1.14. These are two circuits in these generators, one is field circuit which is connected with external source and the other circuit is armature circuit which is composed of armature coils and load resistance. These generators can have controlled output.

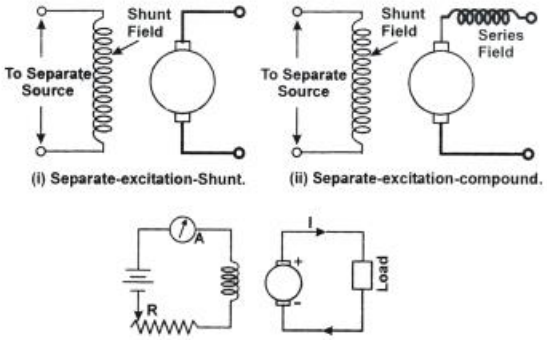


Fig.1.14 Separayely Excited DC Generator

ii. Self-Excited DC Generator

Self-excited generators are such generators which energize field magnets with their own generated current. Due to residual magnetism, some flux always exists in the poles. When the armature rotates then the EMF some EMF and current is induced due to the magnetism existing in the poles which strengthens the magnetism or flux partially or completely by flowing through field coils. In this way the remaining pole flux becomes strong. With the increase in generator speed, its magnetism also increased and consequently, generator, begins to induce load current according to its rated capacity. These generators are used to get power and light. The circuit of self-excited generator has been shown in the Fig1.15.

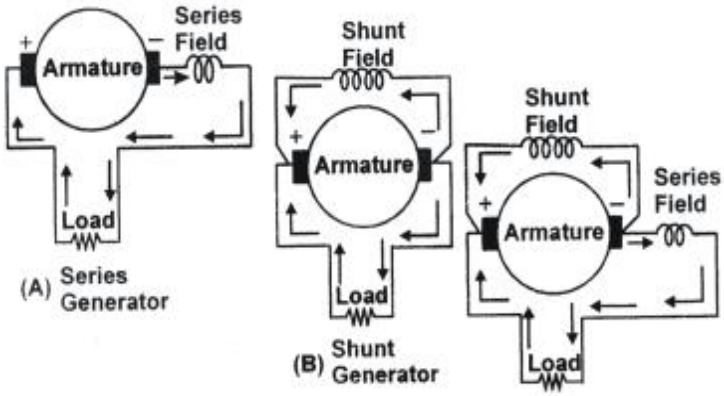


Fig.1.15: Self-excited DC Generator

2. Types of Generator w.r.t Connections:

With respect to connection arrangement, the self-excited generator has the following types:

i. Shunt Generators
ii. Series generators
iii. Compound Generators

i. Shunt Generators:

If the field winding of the self-excited generator is connected in parallel with the armature circuit, then the generator is known as shunt generator. As there are full voltage across the generator field winding, therefore, the field winding of such generator is made from several turns of thin copper wire. These types of generators are frequently used. Shunt generator is shown in Fig.1.16

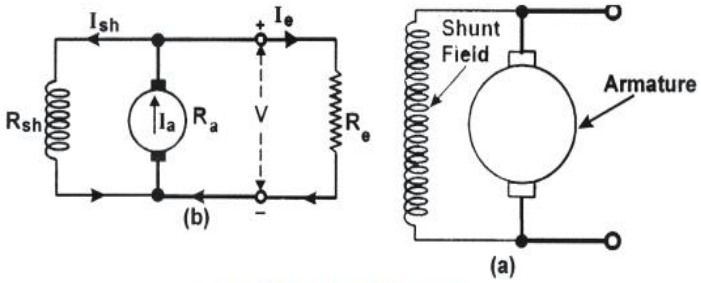


Fig. 1.16 DC Shunt Generator

ii. Series Generators

In DC Series generators the field winding is in series with the armature winding. In this generator, the full load current flows through the series field, therefore its field winding is composed of some turns of thick copper wire. These types of generators are rarely used except for specific tasks. It is shown in Fig.1.17

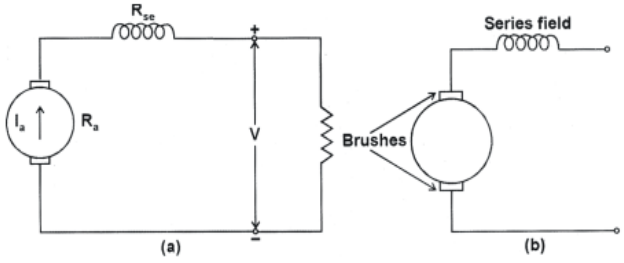


Fig.1.17 DC Series Generator

iii. Compound Generators:

A generator which is combination of series and shunt windings is known as compound generator. To excite the compound generator, series and shunt coils are used partially. If a series field is added to shunt generator, it will become the compound generator. Its field poles are made of dual windings. One is composed of several turns of thin wire and the other is composed of some turns of thick wire. These are shunt and series field windings respectively. Shunt winding is connected parallel with armature and the series is connected in series with the armature. The direction of flow of current in both the coils is same in order to have stronger field poles. In order to avoid decrease in terminal voltage in shunt generator, compound generator is made therefore it is used where the constant output voltages are required.

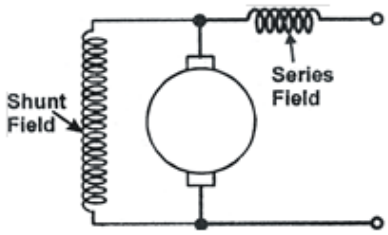


Fig.1.18 DC Compund Generator

1.11 Parts/Construction of Generator

The DC motor and generator have the same general construction. In fact, when the machine is being assembled, the workmen usually do not know whether it is a DC generator or motor. Any DC generator can be run as a DC motor and vice versa. All DC machines have the following principal parts.

a. Magnetic frame or yoke

b. Pole core and Pole shoes

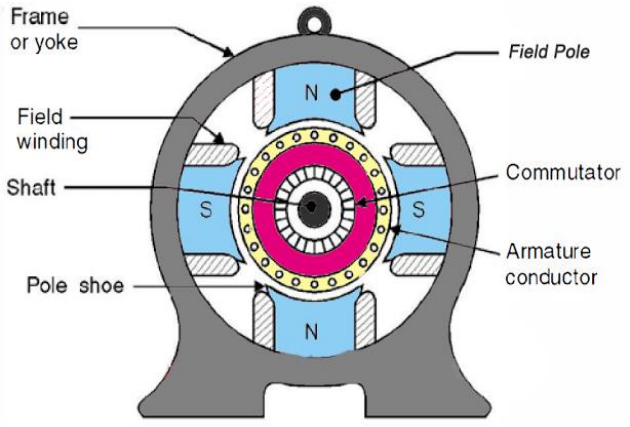


Fig.1.19 Parts of DC Generator

c. Field coils or Field Winding

d. Inter poles or commutating poles.

e. Armature and armature winding

f. Commutator

g. Carbon brush and brush holder

h. Rocker

i. Side covers or end housing

j. Shaft

k. Bearings

The yoke, pole cores, armature core and air gaps between the poles and the armature core form the magnetic field. The rest form the electrical circuit. Fig. 1.19 shows the construction of a DC machine.

a. Magnetic Frame or Yoke

The magnetic frame or yoke gives mechanical support for poles as well as protects the whole machine as a protecting cover. It also carries the magnetic flux produced with the help of the poles. In small generator yokes are made of cast iron whereas in large machines cast steel is used for yoke construction.

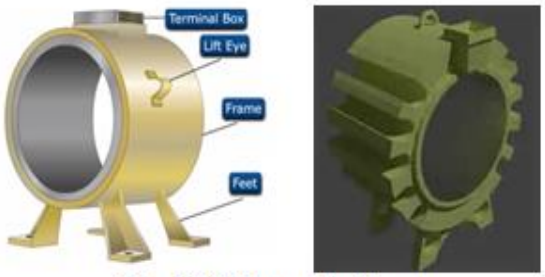


Fig.1.20 Magnetic Frame

b. Pole Core and Pole Shoes

The field magnet has two parts such as pole cores and pole shoes. Pole shoes spread out the flux in the air gap and reduce the reluctance of the magnetic path due to its large cross section. Pole shoes support the exciting coils. Pole core may be a solid piece and is made out of either cast iron or cast steel whereas the pole shoes is laminated and fastened to the pole face by counter sunk screws. In modern design, the pole cores and pole shoes are made of thin laminations of annealed steel where the

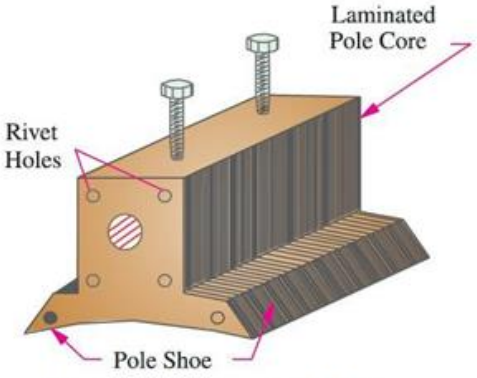


Fig.1.21 Pole Core & Pole Shoe

thickness of lamination varies from 1mm to 0.25mm. To secure the laminated poles to yoke, any one of the following two methods can be used:

i. The holding screws may be bolted into the steel bar. It passes through the pole across the plane of laminations.

ii. The pole is secured to the yoke by means of screw & bolted through the yoke and into the pole body.

c. Field Coils or Field Windings

The field coils or pole coils consist of copper core or strip. These are former wound for correct dimension. After the correct dimension is obtained, the former is removed. Now the wound coil is placed over the core. To get the necessary flux, a current is passed through these coils. When the current is passed through these coils, then the poles become the electromagnets and the necessary flux is produced which is cut by armature conductors. The field coils are wounded in two ways either shunt or series. Series winding is made of thick wire which comprises of some turns and shunt field is made of thin wire which comprises of more turns compared to series field. Fig.1.22 illustrates the field coils.

d. Inter Poles or Commutating Poles

In the modern DC machines, additional poles are placed between the main poles, interior to yoke. These poles are known as inter poles or commutating poles.These are rectangular in construction and small in size. Winding of these poles is composed of some turns of thick wire. This winding is connected in series with armature. The purpose is to eliminate the spikes induced on commutator. Interpoles are made either solid or laminated and constructed with wrought iron or mild steel.

e. Armature and Armature Winding

The cylindrical part rotating between the field poles inside the DC machine is known as armature. The armature core is usually made of circular sheet steel discs or laminations. The thickness of laminations are of the order of 0.5mm. These are slots existing in the stampings and the insulated coils are inserted into these slots. These coils are known as armature windings. Armature core is keyed to the shaft.

Fig.1.22 ArmatureWinding

f. Commutator

We know that AC is induced in the generator. To convert AC into DC, a device known as commutator is used. It rectifies AC into DC and provides to the external load circuitry. Each armature coil is connected with commutator. It is cylindrical in shape and made by highly conductive hard drawn copper wedges or segments.

Fig.1.23 Commutator

g. Carbon Brush and Brush Holder

The function of the brushes which are housed in a brush holder is to collect current from the commutator. The brushes are usually made of carbon or graphite and are in the shape of a rectangular block. As the carbon is soft therefore it itself worn out and eliminates the damage to commutator. There is a spring mounted on it which compresses it on the commutator. In this way there are no spikes produced on commutator. Brush holder is insulated from the parts of machine.

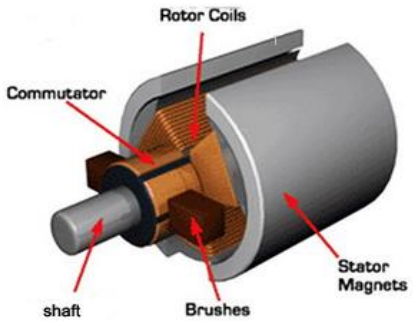


Fig.1.24 Carbon Brushes

h. Rocker

If the carbon brushes are not placed at the proper place on the commutator, then there are spikes produced, these spikes can be eliminated by using rocker. Rocker is like a handle by which the brushes are moved towards the proper place, Rocker is installed only on the large machines.

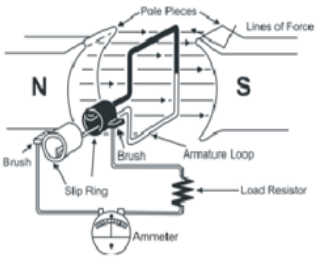


Fig.1.25 Working Principle of Generator

i. Side Covers or End Housing

There are two caps on each side of the frame which are called side covers. These are connected with the ends of main frame. These covers have the bearings through which the armature shaft is rotated. These are holes made in the covers for ventilation purposes. The backside housing is generally supports the bearings and the front side housing is used to support the brushes.

j. Shaft

The solid iron bar which passes through the armature is called the shaft. The ends of shaft rotate in the bearings of end covers. The shaft supports the whole armature assembly.

k. Bearings

In order to reduce the friction losses, the bearings are mounted. Armature rotates with ease with the help of bearings. Bearings are mounted in the end covers.

Activity 1.5 Enlist the parts of generator.
Components/Instruments AC & DC Generator , Electric Tool Box
Step 1: Issue the materials from the store as per the list provided by instructor. Step 2: Identify various parts of the AC & DC Generator and make separate lists. Step 3: Record the observations and detail of the motor parameter found.

1.12 Working Principle of Generator

An electrical generator is a device that converts mechanical energy to electrical, generally using electromagnetic induction. Therefore, the essential components of generator are:

a. A Magnetic Field

b. Conductor or Group of Conductors

c. Motion of Conductor with respect to Magnetic Field.

When a conductor or coil is rotated in a uniform magnetic field then an EMF is induced in the conductor due to flux linkage. The magnitude of induced EMF is directly proportional to the rate of change of flux. If circuit of loop or conductor is closed, then there will be flow of current in the conductor.

Construction of Simple Loop Generator

A simple generator has been shown in Fig.1.25 which comprises of only one turn rectangular copper coil or loop. This coil is rotating between north and south poles of a magnet. Both ends of the coil has been joined with two slip rings. Both the slip rings are

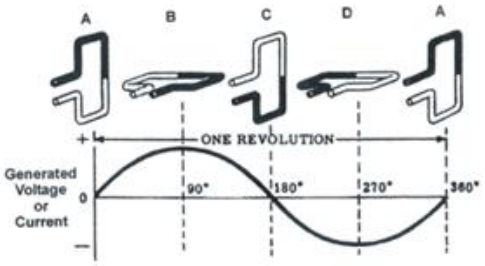


Fig.1.26

insulated from each other and the shaft as well. There exist two carbon brushes on the slip rings. These brushes are used to carry out the current induced in the coil to the outer load resistor. The rotating coil or loop in the magnetic field is known as armature and the magnetic poles are known as field magnets.

Working Principle:

The working of a simple loop generator can be understood by considering a coil rotating in clockwise direction in a magnetic field. When the sides/arms of coil are reached at a specific point then they cut the magnetic lines of forces and hence emf is induced. The magnitude of this induced emf is dependent upon the rate of change of flux. When the coil cuts the magnetic lines of forces, the current begins to flow through the loop, slip rings, carbon brushes, and the ampere meter. It is because all these are connected in series. The magnitude of the induced current depends upon the rotating position of coil in the magnetic field. When the coil is at right angle with the magnetic lines of forces being stationary at this position, then there is maximum flux linkage with the coils but the rate of change of flux is minimum. Hence, the coil moves parallel along with the magnetic lines of forces and does not cut the magnetic lines of forces. Hence there is no emf induced. This phenomenon has been explained in Fig.1.26 position A.

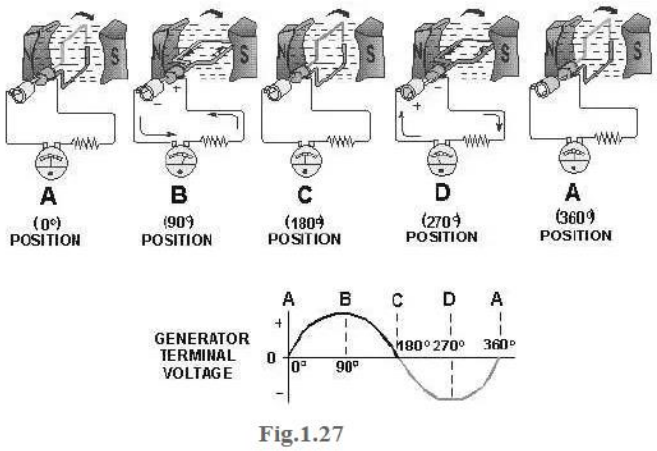


Fig.1.27

As soon as the coil turns towards the position B from A as shown in Fig 1.26, the conductor/coil begins to cut the lines of forces. For the purpose of understanding the one side of the coil is kept black and one is white. From 0° to 90° black conductor cuts magnetic field from top to bottom and the white conductor cuts from bottom to top (Position B). The emfs induced in both the conductors are being added up in series and the resultant voltages are equal to the sum of individual voltages of both the conductors.

The change in the magnitude of current is according to the change in the emf induced. At 0° the current is 0 ampere and at 90° it is maximum. The polarity of the induced emf depends upon the magnetic field and the direction of rotating armature. The wave form shown in figure 1.6 depicts the change in the position of terminal voltage.

When the loop is rotated from position B(90°) to position C(180°) then those conductors which were cutting maximum magnetic lines of forces, cuts only a few. At last at position C, these are parallel along with the lines of forces. In this state, this conductor does not cut any lines of forces. So the emf induced at 90° to 180° is reduced in a similar way as were increased from 0° to 90°. Similarly, the current is also decreased and at 180° (position C) it becomes 0 ampere. In figure 1.6 the generator action is shown between position B and C. As the direction of voltage and current from 0° to 180° is totally opposite to the direction of voltage and current from 180° to 360°. Therefore, the direction of current is changed after every half cycle. It is shown in figure 1.7. Due to this reason, the induced current is known as alternating current. Both the half cycles are termed as positive and negative half cycles respectively.

1.13 Generator Connections

Connecting a portable emergency generator to the home power supply system by using manual or automatic changeover switches (Auto transfer Switch (ATS) is the safest and recommended method.

To connect a portable generator to the home electric supply system by manual changeover switch, following steps are followed.

1. Install a Changeover switch (about 63-100A depends on the load) near main distribution board.
2. Connect the main power supply (Line and Neutral) as incoming to the first upper slots of Changeover Switch as shown in figure.
3. Connect a 6 AWG (7/064″ or 16mm^2)" cable wire to the lower two slots of changeover switch.
4. Now connect a 3-pin power socket to the 6AVG wire and install onto the wall (near to the generator) and put the generator 3-pin power plug into the power socket which have been installed before.
5. You have done and ready to supply emergency electric power to the home appliances in case of emergency power blackout.

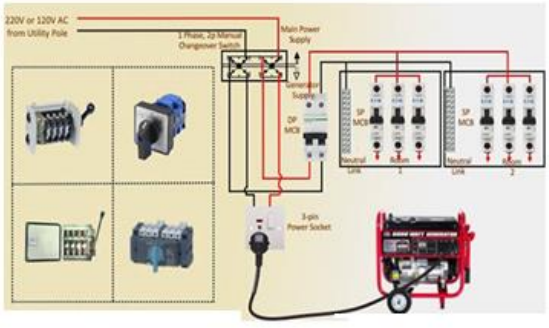


Fig.1.28 Generator Connection

Activity 1.6 Perform the connection of generator with load.
Components/Instruments AC & DC Generator , Multimeter, Connecting Leads, Electric Tool Box
Step 1: Issue the materials from the store as per the list provided by instructor. Step 2: Make the connection of the generator as per the instruction provided and run the generator and use the clamp meter to measure the current. Step 3: Record the observations as per the instructions of the instructor.

1.14 Generators Tests /Checking

A gas or diesel / petrol generator is not a "Set it and forget it" type of device. It pays to conduct a visual inspection of the generator before every use, and create a maintenance schedule that includes weekly, monthly, and annual checkups.

A regular maintenance schedule is crucial to avoid breakdowns and prolong the life of your gas or diesel generator.

A generator maintenance checklist helps you prioritize which parts to check and when to do preventive maintenance, a backup generator set can last for 20 years or more. Of course, that depends in part on how often you use it. You might need one for as little as 26 hours a year if you don't have any outages and conduct a half-hour's worth of weekly exercise. Power generators have a lot of moving parts, from the control panel (the brains of the generator) to the battery and cables. Here are a few tasks you'll want to consider for a preventive generator maintenance checklist.

Maintenance with Each Use

- General inspection
- Test batteries
- Check intake and exhaust
- Manual start
- Engine exercise
- Adjustments
- Check for leaks

Maintenance as Needed

- Repairs
- Replace filters
- Lubrication
- Cleaning
- Cooling system servicing
- Fuel system servicing

1.15 Importance of Service and Maintenance of Electrical Machines

Electrical systems over age with the time, just like office buildings, appliances, and equipment and malfunctions can occur. Small issues, if left unaddressed, can grow to become bigger problems over time. With electricity playing an integral part in so many important tasks at work, it's essential for businesses to establish an electrical service & maintenance program for their operations.

Electrical maintenance is an essential component of maintaining workplace safety, but it can also lead to benefits like energy efficiency and reduced power costs. Let's take a look at the potential benefits that businesses can get from scheduled electrical maintenance:

1. Minimizes Downtime

Scheduled maintenance helps reduce the potential for downtime. A small malfunction can quickly become a bigger problem if left unaddressed, and can even result in critical situations. Scheduled electrical maintenance is critical for successful businesses since it can help you avoid problems with your electrical system and electricity-powered equipment. Electricity is needed for everything from your security cameras and protection systems to your smart lighting and computer servers.

2. Avoids Expensive Repairs

Regular maintenance helps to detect any electrical issues before they become serious difficulties that damage equipment and in turn, this will help you avoid emergency power losses after hours which comes with a higher price to be spent on repair.

3. Saves Time and Money

Properly scheduled commercial electrical maintenance can help you save time and money in the long run. With a licensed electrician carrying out your plans, you can minimize interruptions, reduce or even eliminate energy wastage by making sure that your equipment is running without hitches.

4. Optimizes the Lifecycle of Your Equipment

Well-maintained equipment which is powered by a carefully designed electrical system can have a longer life expectancy, which helps you save money on both component and repair expenditures.

5. Better Productivity

Optimized equipment and machinery, along with improved efficiency in your teams, aid in higher productivity. Downtime is an unpleasant experience for your employees, and it can also have a

detrimental impact on their moods and productivity. Eliminating downtime can boost your employees' morale and improve their productivity.

6. Improved Energy Efficiency

It's possible to address energy drains due to outdated or faulty equipment with basic electrical maintenance. Your business may become more energy-efficient and cut costs by replacing outdated components and tuning equipment.

1.16 Preventive Maintenance of Electrical Machines (Motors & Generators)

With preventive maintenance, a backup generator set can last for 20 years or more. Of course, that depends in part on how often you use it. You might need one for as little as 26 hours a year if you don't have any outages and conduct a half-hour's worth of weekly exercise. Without preventive maintenance, generators are susceptible to fuel problems, which can cause breakdowns and even ruin a generator eventually. Running a gas or diesel generator regularly is an important part of maintenance, just as it's important to take your car for a spin at least once a week. By keeping your generator properly maintained, you will be able to keep it running smoothly for much longer than if you ignore maintenance tasks.

Preventive Generator Maintenance Checklist

Power generators have a lot of moving parts, from the control panel (the brains of the generator) to the battery and cables. Here are a few tasks you'll want to consider for a preventive generator maintenance checklist.

Maintenance with each use:

- General inspection
- Test batteries
- Check intake and exhaust
- Manual start
- Engine exercise
- Adjustments
- Check for leaks

Maintenance as needed:

- Repairs
- Replace filters
- Lubrication
- Cleaning
- Cooling system servicing
- Fuel system servicing

Weekly Generator Maintenance Checklist

During any inspection, whether weekly, monthly, or annually, begin by looking for oil leaks or other signs of wear. It's also important to keep your generator clean by removing dirt and debris, and making sure no rodents, birds, or harmful insects have infiltrated the enclosed unit (if there is one).

During weekly maintenance, you should:

- Do a visual inspection
- Run the generator
- Check fluid levels
- Check for leaks
- Check auto mode

To exercise the generator, check the fuel level and start the motor, then leave it running for 30 minutes or so to make sure it's working properly. Once you've started the generator, check the exhaust system. Examine the muffler, manifold, and exhaust pipe for leaks, and be sure the pipes aren't overheating any nearby components. Be sure the engine is purring; look and listen for signs of a misfire, such as vibrations, smoke, or power fluctuations.

Monthly Generator Maintenance Checklist

Inspect battery cables and electrolyte levels monthly. Remove the plastic tops from the cell ports and use a toothbrush and baking soda to clean away corrosion or dirt. Check engine coolant and oil levels (the oil should be close to full without overflowing), and look for signs of leaks in the oil or coolant lines. Also check the coolant concentration: It should be roughly half purified water and half antifreeze. If you live where freezing is a risk, the antifreeze level can be as high as 60% (but no higher).

Use a load bank to conduct a load test monthly for at least 1 hour to make sure everything is in running order. You should also do an electrolyte specific gravity test or electrical conductance test at this time. How often you use a generator matters, and for how long. If you use the generator more often, you'll likely have to adjust how often you perform certain maintenance tasks to account for wear and tear.

Here's a list of other steps to take on a monthly basis:

- Clean Generator

- Clean Surrounding Area
- Check Engine Coolant Levels
- Check Battery Charger
- Check Engine Oil Levels

You should change the oil after 100 hours of use, and sooner the first time. It's recommended that you do the first oil change after 30 hours. Also, switch out plugs and the air filter every 200 hours. But if, on the other hand, you keep your generator in storage and don't use it often, you should drain it of fuel.

Annual Generator Maintenance Checklist

In once a year, we should at least focus on the generator's electrical system. Turn off all power sources to conduct an internal inspection. Examine the AC wiring and alternator, making sure it's free of dirt. Inspect the air intake system and replace the air filter. Check the air induction piping while you're at it. You'll also want to make sure the crankcase breather is in good shape: that's the generator's source of fresh air, which allows it to sweep fumes out of the crankcase.

Steps to take annually include:

- Change oil
- Change oil filter, fuel filter, and air filter
- Flush cooling system
- Inspect wiring/electrical system
- Change spark plugs
- Test transfer switch

Activity 1.7

Identify the required tools for preventive maintenance of generators.

Components/Instruments

AC & DC Generator , Electric Tool Box

Step 1: Issue the materials from the store as per the list provided by instructor.

Step 2: Identify the tools as per following list.

i. Straight Screw Driver 4" x 1/4"
ii. Straight Screw Driver 6" x 3/16"
iii. Straight Screw Driver 6" x 3/8"

iv. Phillips Screw Driver
v. Wire Strippers
vi. Voltage Tester
vii. Measuring Tape, minimum 1” wide
viii. Hacksaw
ix. Hammer
x. Pencil & Knife
xi. Torpedo Level
xii. Cold Chisel ¾”
xiii. Flashlight
xiv. Wire Stripper

Voltage OHM Meter (multi-meter)

xv. Pliers (Cutting, Nose, Side Cutter, Wire Cutter)

Step 3: Understand their use.

Activity 1.8
Identify the required materials for preventive maintenance of generators.

Components/Instruments
AC & DC Generator , Electric Tool Box

Step 1: Issue the materials from the store as per the list provided by instructor.

Step 2: Identify the materials as per following list.

i. Engine Oil
ii. Fuel Level Gauges
iii. Electric Breakers
iv. Plugs and Sockets
v. Wires
vi. Battery Chargers
vii. Filters

Step 3: Understand their use.

1.17 Tagging Procedure/Maintenance of Motors & Generators

Lock out, Tag out (**LOTO**) is a safety procedure used in industry and research settings to ensure that dangerous machines are properly shut off and not able to be started up again prior to the completion of maintenance or repair work. It requires that hazardous energy sources be "isolated and rendered inoperative" before work is started on the equipment in question. The isolated power sources are then locked and a tag is placed on the lock identifying the worker who placed it. The worker then holds the key for the lock, ensuring that only he or she can remove the lock and start the machine. This prevents accidental startup of a machine while it is in a hazardous state or while a worker is in direct contact with it. Lockout–Tag out is used across industries as a safe method of working on hazardous equipment and is mandated by law in some countries.

Key points

1. Electric motor is a machine that converts electrical energy to mechanical energy. Any DC machine can be used as DC Motor. From construction point of view there is no difference between a dc motor and generator.
2. Based on input supply to a motor, it can be classified as AC & DC Motors.
3. DC Motors are of three types i.e. Series Motor, Shunt Motor & Compound Motor.
4. A motor which converts the alternating current into mechanical power by using an electromagnetic induction phenomenon is called an AC motor.
5. AC Motors are classified as Synchronous and Asynchronous or Induction Motors.
6. A stator is the stationary part of the DC motor containing the field windings.
7. The moving or dynamic part of a DC motor is the rotor that creates the mechanical rotations of the unit.
8. A field winding is the insulated current-carrying coils on a field magnet that produce the magnetic field needed to excite a generator or motor.
9. The armature winding is defined as the conductors which are housed and protected within the armature slots and are connected properly. The helpful EMF will be encouraged in this winding which is received across the brushes.
10. A commutator is a rotary electrical switch in certain types of electric motors and electrical generators that periodically reverses the current direction between the rotor and the external

circuit. It consists of a cylinder composed of multiple metal contact segments on the rotating armature of the machine.

11. DC Motor works on the principle that when a current-carrying conductor is placed in a magnetic field, it experiences a force and has a tendency to move.
12. AC Motors can be connected to load as Star and Delta Connection.
13. Generators can be Series, Shunt & Compound.
14. If the carbon brushes are not placed at the proper place on the commutator, then there are spikes produced, these spikes can be eliminated by using rocker.

Exercise

Select the most appropriate option (✓).

1. A motor converts electrical energy to _____ energy.

   a. Electrical b. Mechanical c. Chemical d. Any of above

2. There is _____ difference between motor and generator regarding construction.

   a. No b. Huge c. Partial d. None of above

3. DC motor can be run as _____

   a. Induction motor b. Servo motor c. DC generator d. Stepper motor

4. DC motors have _____ types.

   a. Two b. Three
   c. Four d. Five

5. Which Motor has both series and shunt field windings?

   a. Series b. Shunt c. Induction d. Compound

6. Faraday introduced the laws of _____.

   a. Inertia b. Gravitation
   c. Electromagnetic Induction d. Motion

7. When a conductor cuts a magnetic field _____ is induced.

   a. EMF b. Current c. Vibration d. Capacitance

8. A simple loop generator consists of _____

   a. Two magnetic poles b. Conductor
   c. Slip rings d. All

9. The purpose of a brush in a DC machine is to _____

   a. Collect current from the commutator
   b. Collect voltage from the commutator

c. To provide interaction between the segments of commutator

d. Clean the commutator

10. The yoke is _____ of dc machine.

a. Base b. Frame c. Structure d. All

11. The rotating cylindrical part inside the dc machine is _____

a. Commutator b. Carbon brush c. Armature d. Stator

12. There are _____ inside the armature stampings.

a. Slots b. Field poles c. Field coils d. All

Answer Key

1.b	2.a	3. c	4.b
5.d	6.c	7.a	8.d
9.a	10.c	11.c	12.a

Give Short answer to the following questions

1. What is a DC motor?
2. Define the principle of DC motor.
3. State the Fleming's left hand rule.
4. Enlist the types of DC motor.
5. Define series motor.
6. What is a shunt motor?
7. Define the principal of operation of a generator.
8. Define DC generator.
9. Enlist the elementary parts of DC generator.
10. What is an armature?
11. Define shunt generator.
12. Define compound generator.

Answer the following questions in detail.

1. Describe the working principle of AC/DC motors with suitable diagram.
2. Describe the Star & Delta Connections of motor in detail.

3. Describe the types of generator.
4. Explain the generator connection for a domestic generator with manual changeover.
5. Enlist various parts of a generator and explain briefly.

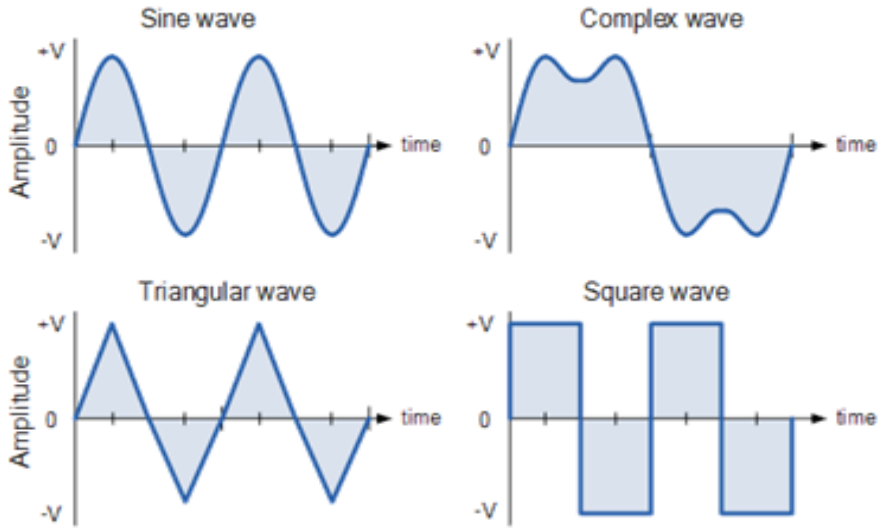
Practical Activities

1. Perform service and maintenance of electric motor and generator.
2. Maintain service and maintenance chart (cleaning/ lubrication) of electrical machines (Motors and generators).

Instructions for the Teachers

1. Adopt Health and Safety measures in the Lab.
2. Divide the students in group and properly monitor the activity and ensure the record of observations.
3. Use all the available ICT resources for better delivery of the content.
4. Ensure proper functioning of lab equipment

Chapter 2: Introduction to Alternating Current (AC)



Students Learning Outcomes

After completion of this chapter you will be able to:

- define AC and DC.
- describe the term time period and frequency.
- describe the maximum value of Current and Voltage
- describe RMS value of sine wave.
- describe the impedance of AC Circuit.
- describe the power in AC.
- describe Effective, Reactive and Apparent power.
- explain Power Factor.
- explain the procedure for measurement of effective and apparent power.

2.1 AC & DC

AC (Alternating Current)

The AC current changes its polarity and magnitude periodically and continuously with respect to time. The AC current can be produced with a device named alternator that produces the alternating current.

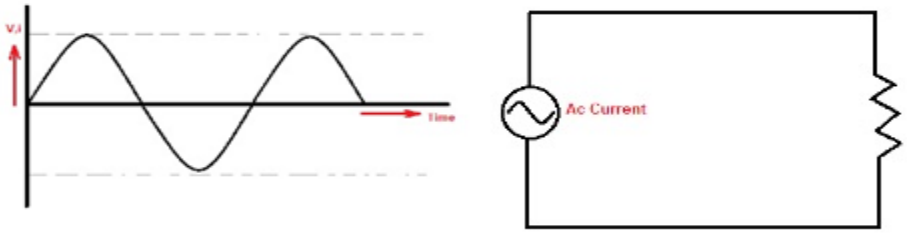


Fig. 2.1 AC Signal Waveform & Circuit Symbol

Every AC Waveforms have a divider line or called the zero voltage line that divides the waveform two halves as the AC Current Changes the magnitude and direction periodically so on every one complete cycle it reaches zero volts.

Applications of AC

- AC is used for long-distance transmission for Offices and Homes
- Energy Loss in AC is less so widely used in transmission
- The AC current can be converted into a high voltage to low voltage and low to high voltage efficiently using the transformer
- AC power is used in larger applications and appliances like Freezers, AC. Dishwashers, washing machines, Fans, Bulbs.

DC (Direct Current)

The DC (Current / Voltage) is a unidirectional flow of current or electric charge. Unlike AC it does not change the magnitude and polarity with time.

Since the DC current has constant magnitude and direction so the frequency of DC current is zero.

The electrons in DC current flow from high electron density to low electron density.

We can get DC from AC current using the process called **Rectification** and the device that does this is called a **Rectifier**.

Application of DC

- DC current is widely used in small electronic devices and applications.

- DC current is not good for long-distance transmission but storage of dc current is easy in form of Battery.
- DC power is used in Cell phones, laptops, radio, Flashlights, EV and Hybrid Cars and other electronic gadgets.

Difference between AC and DC

- AC current changes its direction during flow while the DC current does not change its direction during flow and remains constant.
- The AC current has a frequency that shows how many times the direction of current flow changes during flow while the frequency of the direct current is zero as it does not change the direction of flow.
- The power factor of AC is 0 to 1 while for DC it is 0.
- The AC current is generated by the alternator while DC current is generated by Photovoltaic cells, generators and batteries. The AC load can be capacitive, inductive or resistive but the load on DC is always resistive.
- The DC current graph has a constant line showing magnitude and direction is constant while the AC current can be a sinusoidal wave, square wave or triangular wave.
- The AC converted into DC using a device named rectifier while the DC converted into AC named inverter.
- AC is widely used in industrial equipment and consumer electronics like AC, Freezer, Cooler, washing machine, lights, fans While DC is used in electronic gadgets and small devices like clocks, laptops, cell phones, Sensors.
- AC can be transmitted over long distance with some loss while DC can be transmitted very long distance with very low loss using High Voltage DC (HVDC).

Standard AC Waveforms

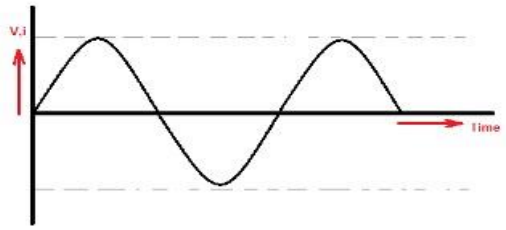


Figure 2.2

Sine Wave

Square Wave

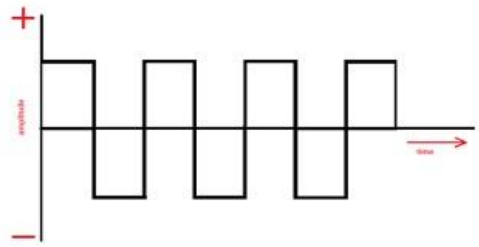


Figure 2.3

Triangle Wave

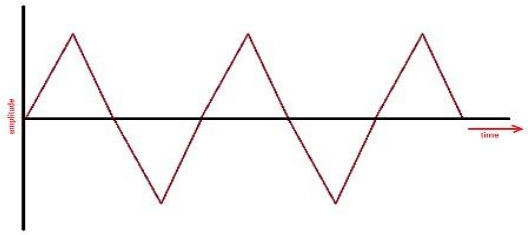


Figure 2.4

2.2 Terms Related to AC Waveforms

Time Period

Time Period is the time taken by a wave to complete one cycle. It is represented by T.

Mathematically it is written as

$$T=\frac{1}{f}$$

Where f is the frequency of the wave in Hertz (Hz)

Higher the frequency, shorter will be the time period and vice versa. Unit of period is second and smaller units are mille seconds and micro seconds etc.

Frequency

Number of cycles per second is called as the frequency. If number of cycles completed is more, frequency will be more and if cycles completed are less than frequency will be less. It is measured in Hz (Hertz).

f=1/T

Amplitude

The magnitude of the signal is called amplitude.

Cycle

A cycle is one complete set of positive and negative value of the alternating current or voltage. It is measured in cycles.

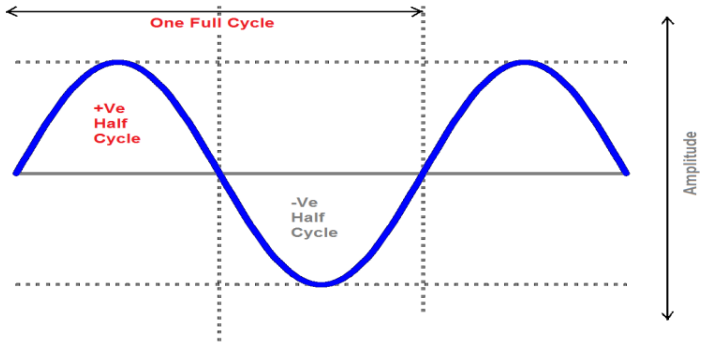


Fig 2.5 Representation of cycle

Wave Length

The distance covered by one cycle is called as wavelength. It is represented by λ.

Mathematically,

$$V = f\ \lambda$$

Or $$\lambda = \frac{V}{f} = \frac{\text{Velocity of Wave}}{\text{Frequecy of Wave}}$$

For Radio Waves f = 3×10^{10} cm/sec

$$\therefore \quad \lambda = \frac{3\times10^{10}\ \text{cm/sec}}{\text{f(Hz)}}$$

For Sound Waves f=1130 ft/sec

$$\lambda = \frac{1130\ \text{ft/sec}}{\text{f(Hz)}}$$

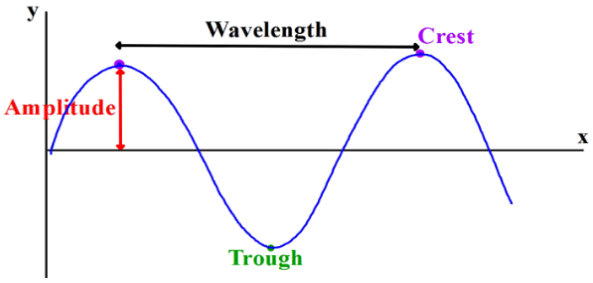


Fig.2.6 Wavelength

Peak Values / Maximum Value

Peak value is called as amplitude. The peak value of an alternating current or voltage is the highest value during the cycle.

It is represented by V_p or V_m. It is shown below:

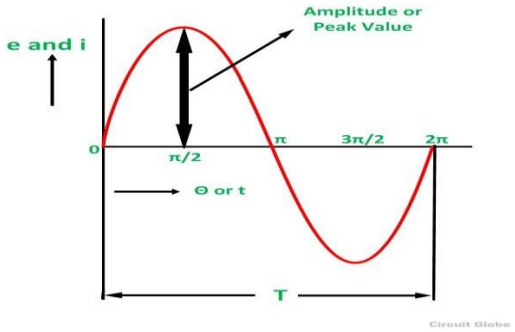


Fig.2.7 Peak Value

Peak to Peak Value

The peak to peak value of AC Waveform is the value between positive peak to negative peak. It is represented by V_{pp} or I_{pp}.

If $V_P = V_m = 5$ Volts

Then $V_{pp} = V_{mm} = 10$ Volts

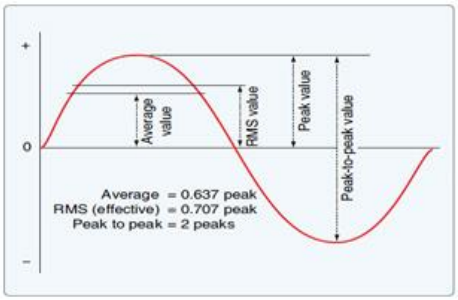


Fig.2.8 Peak to Peak Value

Average Value

The average value of an alternating current or voltage is calculated for half cycle. The average value of an alternating current or voltage is an arithmetic average of all the values for half cycle. It is represented by V_{avg} or I_{avg}.

The maximum value V_m and V_{avg} are related by the relation:

$$V_{avg} = 0.637\ V_{max}$$

and

$$I_{avg} = 0.637\ I_{max}$$

The average value of complete ac cycle is zero.

Effective Value (Root Mean Square)

The RMS value of an AC signal is equal to the dc value that products the same amount of heat as produced by the ac signal.

Mathematically,

$$V_{rms} = \sqrt{\text{Average value of } v^2}$$

And

$$I_{rms} = \sqrt{\text{Average value of } i^2}$$

That is the RMS or effective value of an ac signal is the square root of the average of the square values of the ac signal.

Mathematically we can find

$V_{rms} = 0.707\ V_{max}$

And $I_{rms} = 0.707\ I_{max}$

AC Through Resistors

Consider a pure resistor R and AC supply of voltage V and frequency *f* is connected to the resistor as shown in Fig.2.9.

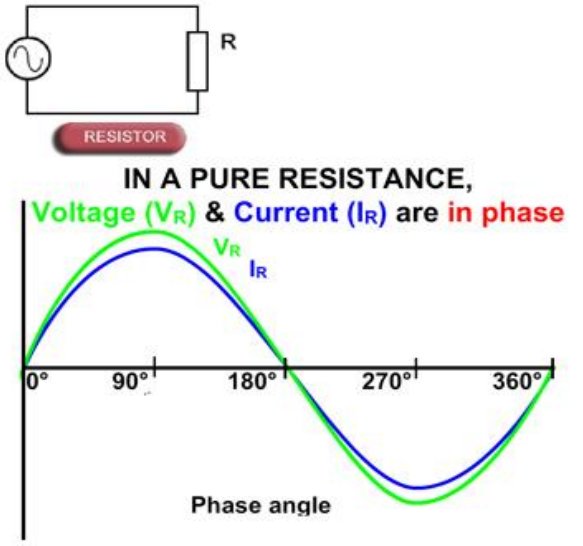


Fig.2.9 AC through pure resistor

In purely resistive circuits, the current and voltage both change in the same way, and at the same time. This relationship is true, whether the applied voltage is direct or alternating. The main difference in AC circuits is that the voltage continues to change in a way that depends on the shape of the input wave. When a sine wave voltage is applied to a purely resistive circuit, it produces a sine wave (sinusoidal) current. Both waveforms attain their peak values at the same time, and pass through zero at the same time. Voltage and current in a purely resistive circuit are therefore said to be "IN PHASE" with each other.

Activity 2.1 Measure the peak value of current and voltage.
Components/Instruments Oscilloscope, Function Generator, Resistors, Multimeter , Connecting Leads
Step 1: Issue the materials from the store as per the list provided by instructor. Step 2: Connect the ac source to the resistor and connect the output to oscilloscope. Step 3: Measure the readings and record the results.

AC Through Inductor

In a purely inductive circuit the voltage and current waveforms are not in phase. Inductance opposes change in current due to the back emf effect. This causes the current to reach its peak value sometime after the voltage. So in an inductive circuit, current "LAGS" voltage.

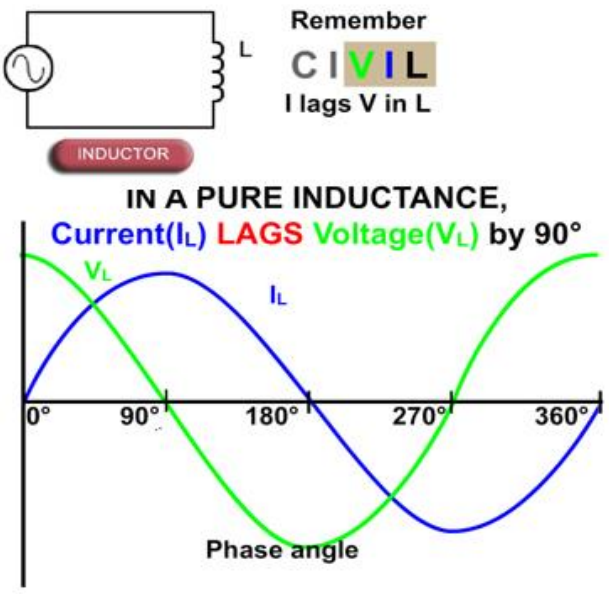


Fig.2.9 AC through pure Inductor

In DC circuits the current eventually settles to a steady state value, and the period of change prior to steady state depends on the time constant (i.e. the component values) of the circuit. In an AC circuit however, as the voltage is continually changing, the current also continues to change, and in a purely inductive circuit, the peak values of current occur a quarter of a cycle (90°) after those of the voltage.

Inductive Reactance

The opposition to the flow of the current offered of an inductor is called as Inductive Reactance (X_L). The inductive reactance (X_L) of the inductor depends upon its value of the inductance (L) and its frequency (f). If frequency is zero i.e. DC is applied to inductor its inductive reactance will be zero. If the frequency of the AC signal is increased its inductive reactance increases and vice versa.

Mathematically we can say:

$X_L \propto f$

$X_L \propto L$

$X_L \propto f \times L$

X_L = Constant (f L)

$X_L = 2 \pi f L$ (Where 2π is Constant.)

AC through Pure Capacitor

Capacitance has the property of delaying changes in voltage as i.e. the applied voltage reaches steady state only after a time determined by the time constant. In AC circuits, voltage and current are changing continuously, and in a purely capacitive AC circuit the peak value of the voltage waveform occurs a quarter of a cycle after the peak value of the current. Therefore, a phase shift is occurring in the capacitor, the amount of phase shift between voltage and current is +90° for a purely capacitive circuit, with the current LEADING the voltage. The opposite phase shift to an inductive circuit.

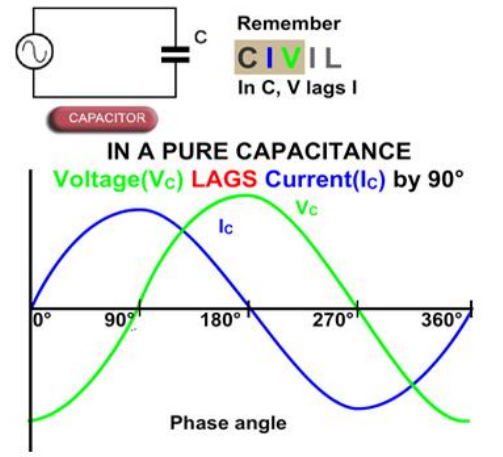


Fig.2.11 AC through pure Capacitor

A CIVIL Relationship

One way to memories these current/voltage (I/V) relationships in capacitors(C) and inductors (L) is to consider the positions of letters in the word CIVIL. The first three letters CIV indicate that in a capacitor (C), V lags (comes after) I, and the last three letters VIL indicate that I lags (comes after) V in an inductor (L).

Capacitive Reactance X_c

The opposition to the flow of current offered by a capacitor is known as capacitor reactance X_C. It is verified that Xc is inversely proportional to the value of the capacitance C and also inversely proportional to the supply frequency f.

So

$$X_C \propto \frac{1}{C}$$

$$X_C \propto \frac{1}{f}$$

Combining these two relations

$$X_C \propto \frac{1}{fc}$$

$$X_C \propto \frac{1}{2\pi fC}$$

$X_C = \frac{1}{2\pi fC}$ where $\frac{1}{2\pi}$ is constant of proportionality.

This relation determines the value of the capacitive reactance.

Activity 2.2 Measure the RMS Value.
Components/Instruments Oscilloscope, Function Generator, Resistors, Multimeter , Connecting Leads
Step 1: Issue the materials from the store as per the list provided by instructor. Step 2: Connect the ac source to the resistor and connect the output to oscilloscope. Step 3: Measure the readings and record the results.

2.3 Impedance

Impedance is the opposition to alternating current presented by the combined effect of resistance and reactance in a circuit.

Impedance extends the concept of resistance to alternating current (AC) circuits. Impedance possesses both magnitude and phase, unlike resistance, which has only magnitude.

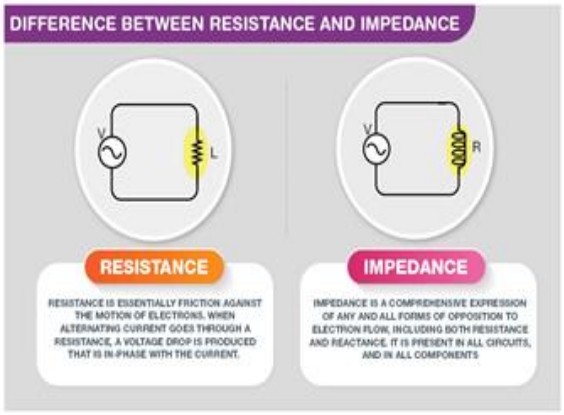


Fig.2.12 Difference between resistance & inductor

Unlike electrical resistance, electrical impedance's opposition to current depends on the frequency of the circuit. Resistance can be thought of as impedance with a phase angle of zero. The **impedance** is normally denoted by English letter **Z.** The unit of impedance, like that of resistance, is the ohm.

2.4 Power in AC

The rate of doing work is called as Power. In other words, we can say the rate at which energy is used is called as Power. Electric Power is the rate (per unit time) at which electrical energy is transferred by an electric circuit. It is represented by P (Symbol of Electric Power).

Mathematically,

$$\text{Power} = \frac{\text{Energy}}{\text{Time}}$$

$$P = \frac{W}{t}$$

$$= \frac{V \times Q}{t}$$

$$= \frac{V \times I \times t}{t} \text{ (As Q= I×t)}$$

$$P = V\ I$$

Another formula for electric power is:

$$P = I^2\ R$$

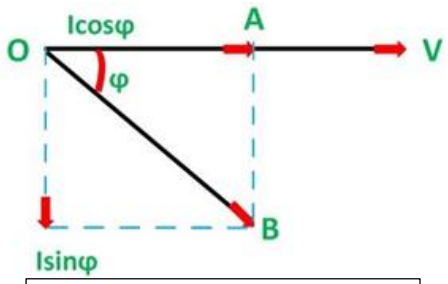


Fig.2.13 Phasor Diagram for inductive Circuit

Active, Reactive and Apparent Power

Active Power/Effective

The power which is actually consumed or utilized in an AC Circuit is called True power or Active power or Real power. It is measured in kilowatt (kW) or MW. It is the actual outcomes of the electrical system which runs the electric circuits or load.

Reactive Power

The power which flows back and forth that means it moves in both the directions in the circuit or reacts upon itself, is called **Reactive Power**. The reactive power is measured in kilo volt-ampere reactive (kVAR) or MVAR.

Apparent Power

The product of root mean square (RMS) value of voltage and current is known as **Apparent Power**. This power is measured in kVA or MVA.

Fig.2.14 Power & Power Factor

It has been seen that power is consumed only in resistance. A pure inductor and a pure capacitor do not consume any power since in a half cycle whatever power is received from the source by these components, the same power is returned to the source. This power which returns and flows in both the direction in the circuit, is called Reactive power. This reactive power does not perform any useful work in the circuit.

In a purely resistive circuit, the current is in phase with the applied voltage, whereas in a purely inductive and capacitive circuit the current is 90 degrees out of phase, i.e., if the inductive load is connected in the circuit the current lags voltage by 90 degrees and if the capacitive load is connected the current leads the voltage by 90 degrees.

Hence, from all the above discussion, it is concluded that the current in phase with the voltage produces true or active power, whereas, the current 90 degrees out of phase with the voltage contributes to reactive power in the circuit. Therefore,

- True power = voltage x current in phase with the voltage
- Reactive power = voltage x current out of phase with the voltage

The phasor diagram for an inductive circuit is shown in Fig.2.13.

Taking voltage V as reference, the current I lags behind the voltage V by an angle ϕ. The current I is divided into two components:

- I Cos ϕ in phase with the voltage V
- I Sin ϕ which is 90 degrees out of phase with the voltage V

Therefore, the following expression shown below gives the active, reactive and apparent power respectively.

Active Power (Real Power) $P = V \times I \cos\phi = V I \cos\phi$

Reactive Power P_r or $Q = V \times I \sin\phi = V I \sin\phi$

Apparent Power P_a or $S = V \times I = VI$

2.5 Power Factor

Power Factor is defined as the ratio of the Real Power to the Apparent Power in a circuit.

$$\textbf{Power Factor} = \frac{\textbf{Real Power}}{\textbf{Apparent Power}}$$

Essentially, real (or active) power is the amount of power that is actually usable, while reactive power is waste or unusable power. Apparent power is the vector sum of real power and unusable reactive.

The phenomenon of real power and reactive power occurs due to the phase difference between voltage and current. It's an inherent result of inductance and capacitance in any AC circuit. This frequent lag causes results in only some of the power being useful. Correcting the power factor reduces the power that is wasted.

An ideal power factor would be 1.0, as the range is from 0 to 1. Because inductance is always changing with the load, maintaining a perfect power factor of 1.0 is impractical and often impossible. However, Power Factor Correction (PFC) procedures can keep the power factor within an acceptable range. For some applications, correcting the power factor in an

AC circuit can be as simple as adding a capacitor in parallel with the electrical load. For others, it can be more complex.

2.6 Measurement of Effective & Apparent Power

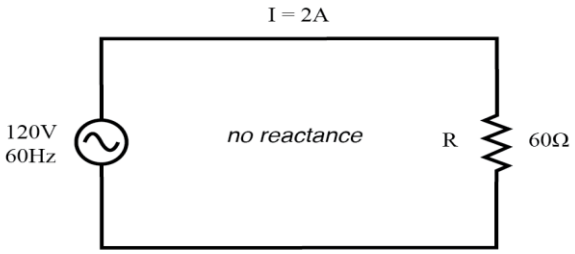
In order to measure the power following mathematical equations are used:

Active Power	$P = V \times I \cos\phi = V I \cos\phi$
	(Measured in Volt Ampere (VA))
Reactive Power	P_r or $Q = V \times I \sin\phi = V I \sin\phi$
	(Measured in Volt Ampere Reactive (VAR))
Apparent Power	P_a or $S = V \times I = VI$ (Measured in Watts)

Examine the given circuits and see how these three types of power interrelate for: a purely resistive load, a purely reactive load, and a resistive/reactive load.

Resistive Load Only

True power, reactive power, and apparent power for a purely resistive load.



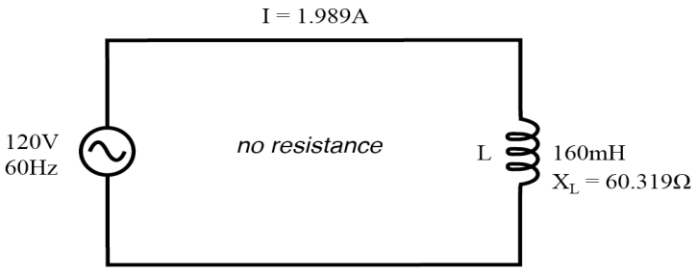
P = true power = I^2R = 240W

Q = reactive power = I^2X = 0 VAR

S = apparent power = I^2Z = 240VA

Reactive Load Only

True power, reactive power, and apparent power for a purely reactive load.



P = true power = I^2R = 0W

Q = reactive power = I^2X = 238.73VAR

S = apparent power = I^2Z = 238.73VA

These three types of power are trigonometrically related to one another. In a right triangle, P = adjacent length, Q = opposite length, and S = hypotenuse length. The opposite angle is equal to the circuit's impedance (Z) phase angle.

Activity 2.3 Identify the tools/equipment used for measurement of Effective and Apparent power.
Components/Instruments Oscilloscope, Function Generator, Resistors, Multimeter , Connecting Leads
Step 1: Issue the materials from the store as per the list provided by instructor. Step 2: Connect the ac source to the resistor and connect the output to oscilloscope. Step 3: Measure readings and record the results.

Activity 2.4 Measure Effective and Apparent power.
Components/Instruments Oscilloscope, Function Generator, Resistors, Multimeter , Connecting Leads
Step 1: Issue the materials from the store as per the list provided by instructor. Step 2: Connect the ac source to the resistor and connect the output to oscilloscope. Step 3: Measure the readings and record the results.

Key points

1. The **AC** (Alternating Current /Voltage) changes its polarity and magnitude periodically and continuously with respect to time. The AC current can be produced with a device named alternator that produces the alternating current.
2. The **DC** (Direct Current / Voltage) is a unidirectional flow of current or electric charge. Unlike AC it does not change the magnitude and polarity with time.
3. We can get DC from AC current using the process called Rectification and the device that does this is called a Rectifier.
4. Time Period is the time taken by a wave to complete one cycle. It is represented by Mathematically;

$$T=\frac{1}{f}$$

5. Number of cycles per second is called as the frequency. If number of cycles completed is more, frequency will be more and if cycles completed are less than frequency will be less. It is measured in Hz (Hertz). Mathematically;

$$f = \frac{1}{T}$$

6. A **Cycle** is one complete set of positive and negative value of the alternating current or voltage.

7. The distance covered by one cycle is called as **Wavelength**. It is represented by λ. Mathematically,

$$\mathbf{V = f \lambda}$$

8. **Peak Value** is called as amplitude. The peak value of an alternating current or voltage is the highest value during the cycle.

9. The average value of an alternating current or voltage is calculated for half cycle. The average value of an alternating current or voltage is an arithmetic average of all the values for half cycle. It is represented by Vav or Iav.
   The maximum value V_m and V_{avg} are related by the relation:

$$V_{avg} = 0.637\ V_{max}$$

10. In purely Resistive Circuits, the current and voltage both change in the same way, and at the same time. This relationship is true, whether the applied voltage is direct or alternating.
11. In a purely inductive circuit the voltage and current waveforms are not in phase. Inductance opposes change in current due to the back emf effect. This causes the current to reach its peak value sometime after the voltage. So in an inductive circuit, current "LAGS" Voltage.
12. Capacitance has the property of delaying changes in voltage as i.e. the applied voltage reaches steady state only after a time determined by the time constant. In AC circuits voltage and current are changing continuously, and in a purely capacitive AC circuit the peak value of the voltage waveform occurs a quarter of a cycle after the peak value of the current.
13. Impedance is the opposition to alternating current presented by the combined effect of resistance and reactance in a circuit.

14. The rate of doing work is called as Power. In other words, we can say the rate at which energy is used is called as Power. Electric Power is the rate (per unit time) at which electrical energy is transferred by an electric circuit. It is represented by P (Symbol of Electric Power). Mathematically,

$$\text{Power} = \frac{\text{Energy}}{\text{Time}}$$

$$P = \frac{W}{t}$$

15. The power which is actually consumed or utilized in an AC Circuit is called **True Power or Active Power or Real Power**. It is measured in kilowatt (kW) or MW. It is the actual outcomes of the electrical system which runs the electric circuits or load.

16. The power which flows back and forth that means it moves in both the directions in the circuit or reacts upon itself, is called **Reactive Power**.

17. The product of root mean square (RMS) value of voltage and current is known as **Apparent Power**. This power is measured in kVA or MVA.

18. **Power Factor** is defined as the ratio of the real power to the apparent power in a circuit.

$$\textbf{Power Factor} = \frac{\textbf{Real Power}}{\textbf{Apparent Power}}$$

Exercise

Select the most appropriate option (✓)

1. A sinusoidal ac voltage which undergoes 100 reversals of polarity per second has a frequency of _____ Hz.

a. 50 b. 60 c. 70 d. 100

2. The polarity of an ac waveform reverses every _____ cycle.

a. One b. Half c. Three d. Four

3. The difference between AC and DC is

a. AC changes value DC does not b. AC changes direction DC does not

c. Both a and b d. Neither a nor b

4. During each cycle, a sine wave reaches its peak value _____.

a. One time b. Two time

c. Three time c. Depending on the frequency.

5. The average half cycle value of a sine wave over one complete cycle is

   a. 0 V b. 6.37 V

   c. 12.74 V d. 14.14 V

6. A power factor of 1 indicates that the circuit phase angle is _____

   a. 90° b. 45° c. 180° d. 0°

7. The power in an AC circuit is given by _____

   a. VI Cos φ b. VI Sin φ c. VI d. V^2/R

Answer Key

1.a	2.b	3.b	4.b	5.a
6.d	7.a			

Answer the following questions briefly

1. Define AC (alternating current).
2. What do you mean by time period?
3. Define frequency of an AC wave.
4. Calculate the frequency of an AC wave having time period of 1 KHz.
5. Define RMS value.
6. What do you understand by Maximum or Peak Value of an AC Signal?
7. Define impedance.
8. Define effective power.
9. Define apparent power.
10. Define power factor.

Answer the following question in detail.

1. Describe the AC & DC. Differentiate AC & DC.
2. Explain Impedance and compare Resistance and Impedance.
3. Prove the following relations

   i. $X_L = 2 \pi f L$

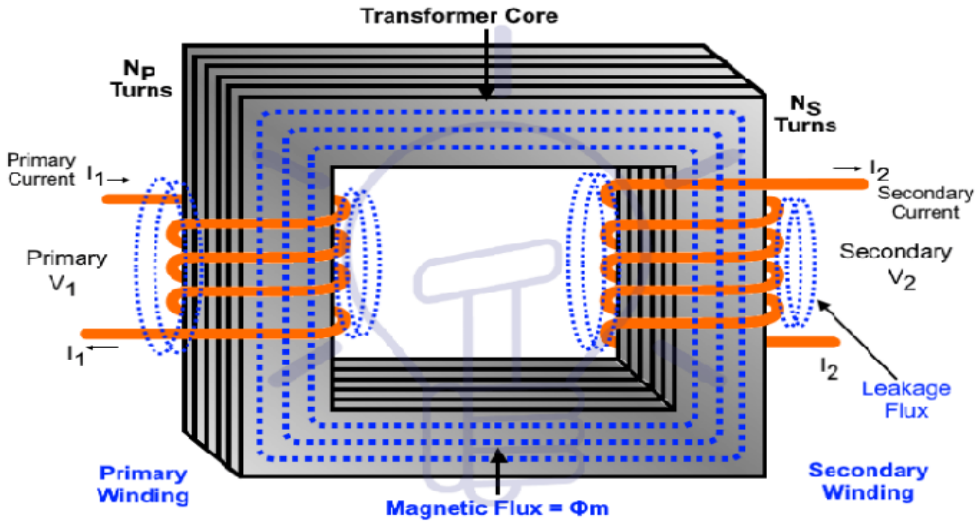
   ii. $Xc = \frac{1}{2\pi fC}$

4. What is difference between real power and apparent power? How can you find the power factor using real power and apparent power?

Instructions for the Teachers

1. Adopt Health and Safety measures in the Lab.
2. Divide the students in group and properly monitor the activity and ensure the record of observations.
3. Use all the available ICT resources for better delivery of the content.
4. Ensure proper functioning of lab equipment

Chapter 3: Transformers



Students Learning Outcomes

After completion of this chapter you will be able to:

- define Transformer
- describe Self-inductance.
- describe the Principal of Transformer.
- understand the function of transformer
- describe types of transformer (step up, step down)
- define eddy current loss.

3.1 Transformer

A transformer is a passive electrical device that transfers electrical energy from one circuit to another through the process of electromagnetic induction. It is most commonly used to increase (‘step up’) or decrease (‘step down’) voltage levels between circuits.

3.2 Self-Inductance

The property of self-inductance is a particular form of electromagnetic induction. Self-inductance is defined as the induction of a voltage in a current-carrying wire when the current in the wire itself is changing. In the case of self-inductance, the magnetic field created by a changing current in the circuit itself induces a voltage in the same circuit. Therefore, the voltage is self-induced.

The term inductor is used to describe a circuit element possessing the property of inductance and a coil of wire is a very common inductor. In circuit diagrams, a coil or wire is usually used to indicate an inductive component. Taking a closer look at a coil will help understand the reason that a voltage is induced in a wire carrying a changing current. The alternating current running through the coil creates a magnetic field in and around the coil that is increasing and decreasing as the current changes. The magnetic field forms concentric loops that surround the wire and join to form larger loops that surround the coil as shown in the image below. When the current increases in one loop the expanding magnetic field will cut across some or all of the neighboring loops of wire, inducing a voltage in these loops. This causes a voltage to be induced in the coil when the current is changing. By studying this image of a coil, it can be seen that the number of turns in the coil will have an effect on the amount of voltage that is induced into the circuit. Increasing the number of turns or the rate of change of magnetic flux increases the amount of induced voltage. Therefore, Faraday's Law must be modified for a coil of wire and becomes the following.

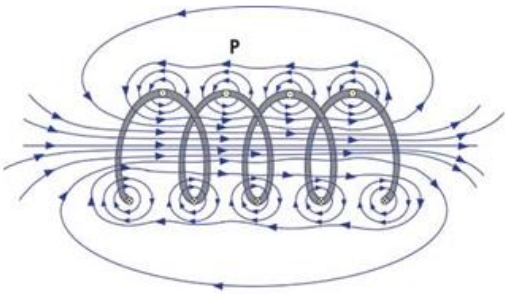


Fig.3.1 Self Inductance

$$V_L = L\frac{di}{dt}$$

Where:

V_L = induced voltage in volts

N = number of turns in the coil

di/dt = rate of change of magnetic flux in Weber /second

3.3 Principle of Transformer

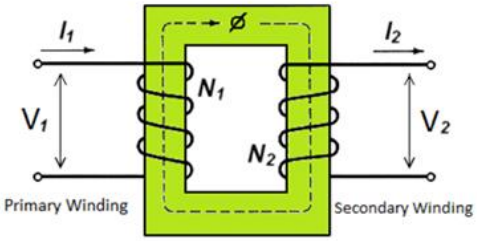


Fig.3.2 Basic Transformer

It works on the principle of mutual induction. A basic single phase transformer having two windings wound on a common magnetic core is shown in Fig.3.2. From the principle of mutual induction, when two coils are inductively coupled and if the current in one coil is changed uniformly, an EMF (electro-magnetic force) is induced in the other coil. If a closed path is provided at the secondary circuit, this induced EMF at the secondary drives a current. As shown in Fig. 3.3, the transformer has two coils which are electrically separated and magnetically linked through a common path. The basic principle of the transformer is same as the principle of mutual induction. The coils of the transformer have high mutual inductance.

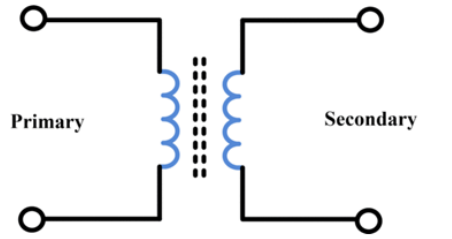


Fig 3.3 Symbolic representation of Transformer

Activity 3.1 Identify input/output of Transformers.
Components/Instruments Transformers , Electrical Tool Kit
Step 1: Issue the materials from the store as per the list provided by instructor. Step 2: Observe the transformer and get check its rated input and output ratings and input and output terminals. Step 3: Tag the input and output sides.

3.4 Function of Transformer

Transformer is a static device which is used for:

- Transfers electric power from one circuit to another.
- During transfer of power, there is no change of frequency.
- It uses electromagnetic induction to transfer electric power from one circuit to another circuit.
- The two electric circuits are in mutual inductive influence of each other.

TURN RATIO

Turn ratio is a very important parameter of a transformer. It is defined as the ratio of the secondary turns to the primary turns of a transformer. Following figure shows a transformer with Np turns on the primary an NS turns on the secondary winding. The voltage applied at primary is Vp and the voltage at secondary is Vs as shown in Fig. 3.4.

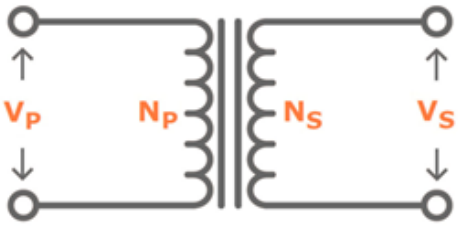


Fig. 3.4 Turn Ratio of Transformer

Turn ratio N is given by;

$$N = \frac{Ns}{Np} = \frac{Vs}{Vp} = \frac{Ip}{Is}$$

Application of Transformer in Electronics

i. Step Down Transformer

A step down transformer is one in which output voltage is less than the input voltage. The main uses of step down transformers have been given below:

- To step down the 14KV voltage to 440V for industry applications.
- To step down 440V for house hold and other uses.
- To isolate the high primary current from the secondary current.
- To isolate the primary and secondary windings in order to avoid shorts.

ii. Step Up Transformer

A step up transformer is one in which output voltage is greater than the input voltage. The main uses of step up transformer are where the voltage needs to be stepped up from low value to high value.

iii. Impedance Matching

For maximum transfer of power from one circuit to another, the both of two should have equal impedances. If they do not have equal impedances, a transformer with suitable turn ratio can be used to achieve this impedance match. A certain circuit working at a high voltage but low current (hence high impedance) has some times to be coupled to another circuit which requires low voltage but high current (hence low impedance). If two such circuits are coupled directly, energy transfers will not maximum. In such cases, a transformer is used as impedance matching devices because it can do the job of increasing or decreasing the voltages and currents very efficiently.

$$T = \frac{V_S}{V_P} = \frac{I_P}{I_S}$$

$$T^2 = \frac{V_S}{V_P} \times \frac{I_P}{I_S}$$

Consider,

$$T^2 = \frac{I_S Z_S}{I_P Z_P} \times \frac{I_P}{I_S}$$

$$T^2 = \frac{Z_S}{Z_P}$$

Where Z_P=Impedance of primary
Zs = Impedance of Secondary
T = Turn Ratio
Suppose a circuit of output impedance 200Ω is to be coupled to a circuit of input impedance 2π. The turn ratio Ns/Np should be such that the impedances match to each other. From the formula:

$$Z_P = \frac{Z_S}{T^2}$$

$$200 = \frac{2}{T^2}$$

$$T^2 = \frac{2}{200}$$

$$T^2 = \frac{1}{100}$$

$$T = \sqrt{\frac{1}{100}}$$

$$\frac{N_S}{N_P} = \frac{1}{10}$$

This means that the secondary turns should be one-tenth the primary turns. Often, auto transformer is also sued for impedance matching purpose.

iv. Coupling

Two AC circuits are said to be coupled when they are linked in such a way that energy is transferred from one circuit to another.

When there is an existence between the coils that are in separate circuits, then they are inductively coupled. Mutual inductance makes possible the transfer of energy from one circuit to the other by transformer action. It means that the alternating current established in the first or primary circuit produces magnetic flux which is linked with, and induces a voltage in the coupled or secondary

circuit. This does not of course; apply to PC circuits since the flux must be changing for electromagnetic induction to occur.

Activity 3.2 Connect the transformer with the supply.
Components/Instruments Transformers , Electrical Tool Kit ,Connecting Leads
Step 1: Issue the materials from the store as per the list provided by instructor. Step 2: Set the ac Voltage as per the rated input of the transformer and get the output at the Oscilloscope or through multimeter. Step 3: Measure the readings and record the results.

Activity 3.3 Check the voltage of input/output.
Components/Instruments Transformers , Electrical Tool Kit ,Connecting Leads
Step 1: Issue the materials from the store as per the list provided by instructor. Step 2: Fix a particular value of the voltage at the input and observe through multimeter or oscilloscope and measure the transformer output. Step 3: Measure and Record the readings and record the results for various input ac voltage settings.

3.5 Types of a Transformer

There are two main types of transformer are given below.

i. Step up transformer

ii. Step down transformer

Step Up Transformer

If the number of turns of secondary winding are more than the number of turns of the primary winding then such a transformer is called the step up transformer. The induced voltage in the secondary coil always depends upon the turn ratio of transformer. The ratio of secondary voltage of a transformer to the primary voltage is always equal to the ratio of secondary turns to the primary turns, i.e.

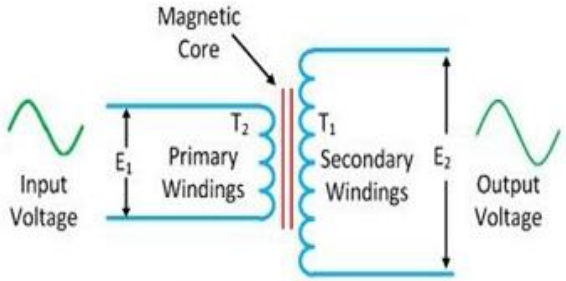


Fig. 3.5 Step Up Transformer

$$\frac{VS}{VP} = \frac{Ns}{NP}$$

$$V_S = \frac{Ns}{NP} \times V_P$$

The turn ratio of step up transformer is always more than 1.

Step Down Transformer

If the numbers of turns in the secondary winding are less than the number of turns of the primary winding then the transformer in known as the step down transformer, the step down transformer is shown in the Fig.3.6.

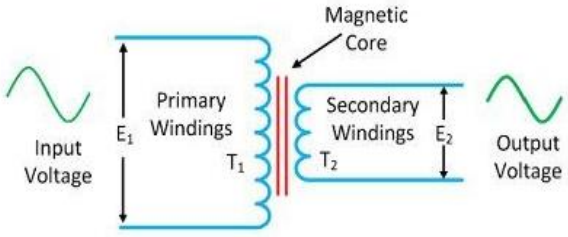


Fig.3.6 Step Down Transformer

Activity 3.4 Identify step-up and step-down transformers and check their functions.
Components/Instruments Transformers , Electrical Tool Kit ,Connecting Leads
Step 1: Issue the materials from the store as per the list provided by instructor. Step 2: Connect the ac source to the input of the transformer and get on digital meter or oscilloscope. Step 3: For large value of the output, it will be Step Up and for less output it will be Step down transformer.

3.6 Transformer Losses

There are various types of losses in the transformer such as iron loss, copper loss, hysteresis loss, eddy current loss, stray loss, and dielectric loss. The hysteresis losses occur because of the variation of the magnetization in the core of the transformer and the copper loss occurs because of the transformer winding resistance.

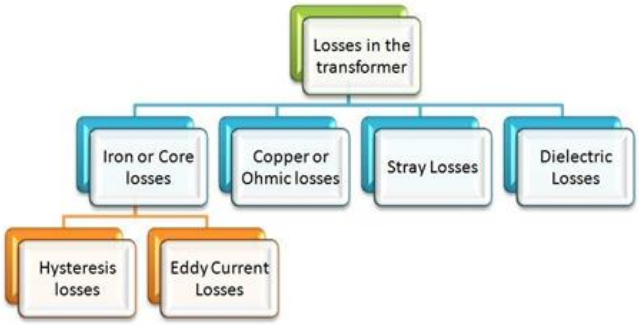


Fig.3.7 Transformer Losses

The various types of losses are explained below in detail.

- Iron Losses
- Hysteresis Loss
- Eddy Current Loss
- Copper Loss Or Ohmic Loss
- Stray Loss
- Dielectric Loss

Iron Losses

Iron losses are caused by the alternating flux in the core of the transformer as this loss occurs in the core it is also known as **Core loss**. Iron loss is further divided into hysteresis and eddy current loss.

Hysteresis Loss

The core of the transformer is subjected to an alternating magnetizing force, and for each cycle of EMF a hysteresis loop is traced out. Power is dissipated in the form of heat known as hysteresis loss. The iron or core losses can be minimized by using silicon steel material for the construction of the core of the transformer.

Eddy Current Loss

When the flux links with a closed circuit, an emf is induced in the circuit and the current flows, the value of the current depends upon the amount of emf around the circuit and the resistance of the circuit. Since the core is made of conducting material, these EMFs circulate currents within the body of the material. These circulating currents are called **Eddy Current**. They will occur when the conductor experiences a changing magnetic field. As these currents are not responsible for doing any useful work, and it produces a loss (I^2R loss) in the magnetic material known as

an **Eddy Current Loss**. The eddy current loss is minimized by making the core with thin laminations.

Copper Loss or Ohmic Loss

These losses occur due to Ohmic Resistance of the transformer windings. If I_1 and I_2 are the primary and the secondary current. R_1 and R_2 are the resistance of primary and secondary winding then the copper losses occurring in the primary and secondary winding will be $I_1^2R_1$ and $I_2^2R_2$ respectively.

$$P_c = I_1^2R_1 + I_2^2R_2$$

These losses varied according to the load and known hence it is also known as variable losses. Copper losses vary as the square of the load current.

Stray Loss

The occurrence of these stray losses is due to the presence of leakage field. The percentage of these losses are very small as compared to the iron and copper losses so they can be neglected.

Dielectric Loss

Dielectric loss occurs in the insulating material of the transformer that is in the oil of the transformer, or in the solid insulations. When the oil gets deteriorated or the solid insulation gets damaged, or its quality decreases, and because of this, the efficiency of the transformer gets affected.

Key points

1. A Transformer is defined as a passive electrical device that transfers electrical energy from one circuit to another through the process of electromagnetic induction. It is most commonly used to increase (‘step up’) or decrease (‘step down’) voltage levels between circuits.
2. Self-Inductance is defined as the induction of a voltage in a current-carrying wire when the current in the wire itself is changing. In the case of self-inductance, the magnetic field created by a changing current in the circuit itself induces a voltage in the same circuit. We can get DC from AC current using the process called Rectification and the device that does this is called a Rectifier.
3. Transformer works on the Principle of Mutual Induction.

4. The turn ratio of a transformer is defined as the ratio of the secondary turns to the primary turns.

5. Various applications of transformer in electronics are:

i. Step down transformer
ii. Step up transformer
iii. Impedance Matching
iv. Coupling

6. There are two main types of transformer are given below.

i. Step up transformer
ii. Step down transformer

7. There are various types of losses in the transformer such as iron loss, copper loss, hysteresis loss, eddy current loss, stray loss, and dielectric loss.

Exercise

Select the most appropriate option (✓)

1. Induction of voltage in a coil itself due to changing current is called _____

a. Mutual Induction b. Self-Induction
c. Remittance d. Permeability

2. A transformer can operate with _____

a. DC b. AC
c. Both AC & DC d. Sine wave Only

3. A ____ function with the principle of mutual inductance.

a. Transformer b. Capacitor
c. Conductor d. Insulator

4. Transformer coils are _____ coupled.

a. Electrically b. Magnetically
c. Horizontally d. Vertically

5. A _____ transformer has more than 1 turn ratio.

a. Step-Up b. Step-down
c. Auto d. Tapped

6. A _____ transformer has less than 1 turn ratio.

a. Step-up b. Step-Down

c. Auto d. Tapped

7. _____ cannot be increased by transform.

a. Current b. Power

c. Resistance d. Inductance

8. Step-up transformer steps up _____.

a. Voltage b. Current

c. Power c. Capacitance

9. A step up transformer always decreases the _____

a. Voltage b. Resistance

c. Power d. Current

10. The purpose of laminating is _____

a. To decrease resistance b. To decrease eddy current loss

c. To increase resistance d. To increase power

Answer Key

1.b	2.b	3.a	4.b	5.a
6.b	7.b	8.a	9.d	10.b

Give short answer to the following questions

1. Define transformer
2. Define self-inductance.
3. What do you understand by mutual inductance?
4. What is meant by turn ratio of transformer?
5. Enlist the types of transformer.
6. Define step down transformer.
7. Define step up transformer.
8. Enlist the transformer losses.

Answer the following questions in detail

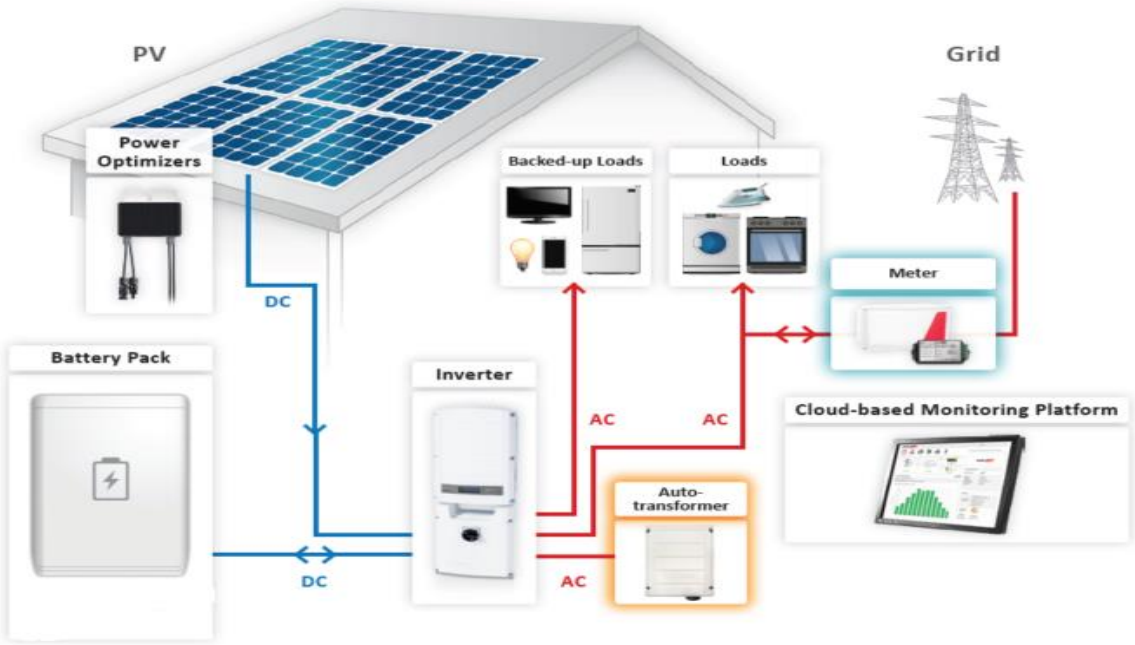
1. What is meant by transformer? Write down its working principle.
2. Describe the function of transformer.
3. Describe the types of transformer.

4. Explain eddy current losses.

Instructions for the Teachers

1. Adopt Health and Safety measures in the Lab.
2. Divide the students in group and properly monitor the activity and ensure the record of observations.
3. Use all the available ICT resources for better delivery of the content.
4. Ensure proper functioning of lab equipment

Chapter 04: Power Backup Systems



Learning Outcomes

After completion of this chapter you will be able to:

- define Power Backup Systems.
- explain the importance of power backup system.
- various types of power backup systems.
- select appropriate power backup systems as per requirements.
- calculate Load for the desired power backup systems.
- explain importance of load calculation for power backup system.
- explain nature of load (Single/ Three phase).
- describe Sources of Power Backup System.
- explain the functions of various components of power backup system.
- describe the appropriate tools/materials for installation of power backup system.
- explain installation techniques of the desired power backup system.
- explain procedure for maintaining PV Solar System.

4.1 Power Backup Systems

Power Backup system is defined as any device or system that provides instantaneous, uninterruptible power. The term UPS (uninterruptible power supply) is an often used term, that supply power for not more than 30 to 60 minutes.

Fig.4.1 UPS & Generator Back Up

Many businesses suffer economic losses due to failure of electric power supply during a natural disaster. For businesses with highly sensitive loads such as data centers and financial institutions, medical center and research organizations the risk of economic losses from downtime is high.

Commonly used power back up systems include:

i. Uninterruptable Power Supplies (UPS)
ii. Solar Systems
iii. Generators
iv. Battery Backup Systems

4.2 Importance of Power Backup Systems

A backup power system is used to provide energy when the primary source fails. This system is very important since an uninterruptible power supply is crucial for any operation. Typical applications for backup power include:

i. Telecommunications Systems
ii. Information technology & Computer Systems
iii. Manufacturing Processes
iv. Security Systems / Emergency Lights
v. Utility Substations
vi. Medical Services

In hospitals patient lives could be at risk if power is not available for operating rooms, medicine refrigeration, and life support systems. The backup power needed to sustain life in hospital is more

than 3 days which is typically needed for certain types of critical equipment after a disaster. The use generators is one way of providing backup power.

4.3 Various Types of Power Backup Systems

Various Power back up systems include the following:

Generators

Backup Generators are of following types:

i. Portable Generator

Perhaps the most popular option for suburban homes, a portable generator can be easily stored and utilized at various locations. Portable generators require a constant source of fuel, most often diesel or gasoline. This fuel must be stored properly and does produce emissions during use. Portable generators also tend to be loud and need to be set up outside your home while in use.

Fig.4.2 Portable Generator

Permanent or Fixed Generator

When space and budget permits, a permanent or fixed generator is used as a backup source for many organizations. Permanent generators are widely used by commercial establishments and must be installed by a professional. A fixed generator can handle all the same loads as a portable generator, along with some appliances. This system requires a transfer switch and inverter. A charger is required for generators with a battery bank.

Fig.4.3 Fixed Generator

ii. Solar Generator

A single panel or multiple panel PV (photovoltaic) solar generator mounts directly to your roof or ground-mount framing. Portable systems are available, although with only limited generation. Solar panels produce DC electricity, and should be used to power up

Fig.4.4 Solar Generator

DC appliances and lighting. Some homeowners also add an AC inverter to expand the function of this backup power system. A twin panel or multiple panel system is required to power appliances like microwaves.

Battery banks make these systems more practical, but must be maintained and replaced every eight to ten years. This backup system is permanently installed in a secure, dry location with conduits and wires connecting the inverter, panels and a separate panel board.

ii. Wind Generator

These are suitable only for rural areas with proper zoning and weather patterns. Installing a wind turbine in an area with little wind exposure does not make economic sense, wind speed is essential. Find out the wind speed on your property from a local weather source or through testing. If the average annual speed exceeds 4 miles/second, a wind turbine can be used for backup power. Remember that wind does not blow at a constant speed, and therefore power generation must be transferred to a battery bank via an inverter. A separate breaker panel should be installed and in certain circumstances, the power can be fed back into the grid through a reverse meter.

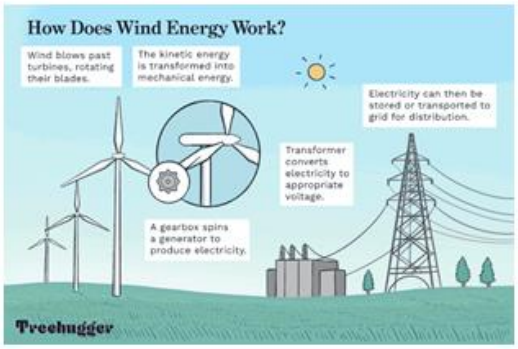


Fig.4.5 Wind Generator

Use a wind turbine to power well pumps, heating units, emergency lights and other essential power. This system does require regular maintenance and must be designed and installed by some professional & skilled person.

Battery Backup System

A traditional type of backup power still used by many, a battery backup system can handle both AC and DC loads, depending on the design. Single battery systems work well for power outages lasting only a few hours, while larger battery bank systems or those that utilize a vehicle battery can provide steady power for one to two days. Battery backup systems require an inverter and some require a charger. Quality systems also provide protection against overheating, a common problem with this type of generator.

Fig.4.6 Battery Back Up System

Activity 4.1 Enlist types of power backup system
Components/Instruments Generator, UPS, Solar System / Study carefully Theory Part of Course.
Step 1: Get the information collected from the theory or physical availability of the equipment. Step 2: Enlist the Equipment. Step 3: Consult the teacher for further guidance.

4.4 Selection of Appropriate Power Backup System as per Requirement

The selection of power backup system depends upon the types of load & size of load. It may vary from Uninterruptable power supply to generator, solar system or battery backup system.

Activity 4.2 Select appropriate power backup systems as per requirements**.**
Components/Instruments Generator, UPS, Solar System.
Step 1: Get the information of the total load to be backed up and also identify the nature of the load. Step 2: Propose the suitable option. Step 3: Consult the teacher for further guidance.

4.5 Load Calculation for the Desired Power Backup Systems

The backup power requirements of my facility depends what loads to backup and what are their power requirements. One should also have understood how different types of loads affect the backup power source, how to manage the connection of loads.

With different types of backup power supplies, we will focus on the most common backup power supply, a standby generator set.

Loads can be defined in terms of real power and apparent power. Real power, measured in kilowatts (kW), is electrical energy provided by the source and consumed in the load; it can be thought of as power that produces useful work like pumping fluid against pressure or raising an elevator against the force of gravity. Apparent power, measured in kilo-volt-amperes (kVA), is the arithmetic product of voltage and current and represents the total current capacity that the source

must have. The difference between these, reactive power (kVAR), creates the magnetic fields necessary for machines like motors and transformers to operate but is not converted to work or dissipated in the system. Power factor (PF), defined as the ratio of kW to kVA, is then a measure of how "efficiently" the system uses current-carrying capacity to provide useful power to the load. In a generator set, the engine produces real power, and must provide mechanical power output at least equal to the maximum load kW plus the losses in the alternator. The alternator converts mechanical power to electrical kW, but also supplies the reactive power component and must therefore have current-carrying capacity at least equal to the maximum kVA. In battery-based systems the battery stores energy and must be sized for the kW requirement and discharge duration, but the power electronics equipment (inverter) is rated on current-carrying capacity and must be able to provide the required kVA.

Another important distinction is between average and peak load. Average load determines the required energy storage capacity of a backup power source, such as fuel consumption for a generator set or discharge time of a battery bank. Peak load, on the other hand, determines equipment ratings: an engine must provide mechanical power output to supply the peak kW even if the average kW is only half that value. Likewise, an inverter must carry the peak kVA without overheating or shutting down regardless of the average value of the load.

If planning to back up the entire load of an existing facility, you may be able to obtain the average load data from your electric utility. Utility bills report energy consumption in kilowatt hours (kWH) and average kW can be determined by dividing kWH usage over time by the time period. Beware, however, of using kW demand reported on utility bills as equivalent to peak kW for sizing the backup power source. Many utilities calculate kW demand by summing kWH over a set period, the demand interval, and dividing by that period. Thus reported peak demand is actually the highest average kW recorded over any demand interval, which may be as long as 15 minutes. If loads in your facility cycle on for periods of less than twice the demand interval, peak kW seen by your backup power source may exceed the utility's reported peak demand.

4.6 Importance of Load Calculation for Power Backup Systems

In all types of the facilities under consideration we are managing (manufacturing plant, data center, telecom packaging plant, agricultural operation, processing facility, commercial building, etc.) we should have a thorough plan in place to deal with power outages of all types from short term to extended.

If you have not done any planning now is the time to take a close look at your infrastructure and current environment, here are a few key points to note:

1. At the most basic level, you should have a backup power generator of some type (natural gas or diesel) that is large enough to power up your critical systems. A commercial electrician can help test your load and also review future requirements. Depending on how your account is set up and your separate facility is reported on, you can also typically get usage data and averages from your local power company to see what type of load you have historically used.
2. On top of simply having the above, you may also want to consider a UPS for short-lived outage coverage as well, so you don't lose power to front line systems like servers and computers before the generator takes over.
3. Generator Maintenance & System Testing – many people get the basics above but forget to make sure everything stays operational and will perform when it's needed most. This was painfully obvious in a number of blackouts when even hospitals had issues with generators that had not been properly maintained and they had to divert patients to other facilities. If nothing else, make sure you occasionally run your generator, there is no type of mechanical equipment with an engine that does well when it sits idle for a long period of time.
4. Fuel Management Planning - in the event of an outage from severe weather, knowing how long your current fuel storage will allow you to run is the first step. Refueling and knowing how you are going to get fuel during an extended outage is also critical. What is your plan if natural gas lines are down or a fuel delivery truck can't get into your area? Is your generator properly installed to operate in a flooded environment as well? These are just a few examples of the types of questions you need to run through to be fully prepared.

4.7 Nature of Load (Single / Three Phase)

The AC power (alternating current) is a kind of electricity where there is frequent change in the current flow direction. At the beginning of the 1900 year, AC power supply is used for businesses as well as homes and now it got expanded to. The system of the power supply is categorized into two type's namely single phase power supply, as well as 3 phase power supply. For most industrial and business settings, three-phase supply is used to run the high loads, whereas homes are generally supplied by a single phase power supply, because home appliances require less power.

In electricity, the phase refers to the distribution of a load. Residential homes are usually served by a single-phase power supply, while commercial and industrial facilities usually use a three-phase supply

There is a limit to the load that a single phase can handle and typically that number is set to 7.5 kW (or 7500 watts or 10 Horse Power) (but varies from state to state). So if the sum of wattage of all the appliances that you are running at a time is more than 7.5 kW, then you need a three-phase connection.

Activity 4.3 Enlist the appliances with specifications required for load calculation to be connected with power backup system
Components/Instruments Generator, UPS, Solar System.
Step 1: Get the information of the total load to be backed up and also identify the nature of the load. Step 2: Propose the suitable option. Step 3: Consult the teacher for further guidance.

4.8 Sources of Power Backup System

There are various kinds of emergency backup devices depending on the type of energy source they are using to produce electricity. When you are choosing your system, the main things you get to decide are: the amount of electrical power you may need during a blackout, the length of time you want to produce it, and of course your budget.

BACKUP POWER SOURCE	MAIN FEATURES	PRO's	CON's	NOTES
PORTABLE GENERATOR	Runs on gasoline, diesel, propane, or natural gas (depending on the model) Power range: 500-17,500 W	Can be moved from place to place No professional installation is needed [unless you want to connect it to the	Limited run time (less than a day before refueling) unless hooked up to an external fuel source	Must be run outdoors only Potential fire and carbon monoxide hazard if used improperly

	Gasoline models are good mainly for short-term outages Multi-fuel models running on LPG or NG may provide long-term power	house wiring via a manual transfer panel and/or to an external fuel source]	Very noisy No auto start Requires maintenance Burns fuel even when it idles	
STATIONARY STANDBY SYSTEM (WHOLE HOUSE GENERATOR)	Connects to the home wiring via a transfer switch Runs on diesel, propane or natural gas (Depending on model) Highest power range (6kW - 100's kW) The best type during long blackouts and as the whole house generator Typical transfer time with auto transfer switch: 10-30 seconds	Auto start option on many models Practically infinite run time when connected to natural gas line	Expensive Requires professionally installed transfer switch and fuel line Older homes may require a new higher volume natural gas meter Requires maintenance	Installed outdoors on a cement pad and connected via a transfer switch
BATTERY BACKUP WITH DC-AC POWER INVERTER / CHARGER	Powers critical appliances via extension cords. May be permanently	No maintenance required Quiet	Limited run time (typically 2 to 12 hours) depending on	Look for a sealed deep cycle battery and a temperature compensated charger with a

	connected to the house wiring via a transfer switch Typical power for residential use: 5-10 kW Auto start systems have response time 16-36 ms	May be installed indoor Low power consumption at no load (consumes power according to the actual load demand)	the battery tank capacity	trickle mode to avoid battery overheating
BACKUP HOME GENERATOR VIA VEHICLE	Good for short outages and to power only essential loads Typical power 300 W- 5000W depending on the battery capacity and inverter	Lowest cost No professional installation required	Engine must be ON all the time to avoid car battery discharge Power is limited by the rating of vehicle parts Limited run time	Exhaust fumes present potential hazard Hybrid and electric cars batteries have the highest capacity, but you need a special inverter rated for high input DC voltage; dealing with high voltage poses electrocution hazard
SOLAR PANELS WITH A BATTERY SYSTEM AND DC-AC INVERTER/ CHARGER	Photovoltaic (PV) panels charge battery bank Produces electricity only on bright days Can power stand-alone AC loads or can be connected to the house wiring (in which case it	Utilizes renewable energy quiet No maintenance required Defrays energy cost or even let you sell electricity back to utility Federal and state incentives	The most expensive type Limited run time [depending on the battery tank's capacity] Requires professional installation	In off-grid installations it's worth to supplement the system by a diesel or a propane genset

	requires a grid-interactive type of inverter with a transfer relay)			
WIND GENERATORS WITH BATTERY AND DC-AC INVERTER	A wind turbine converts wind energy into electric energy. Includes a battery bank, charger and grid tie DC-AC inverter with auto transfer switch May be used primarily in rural areas	Uses renewable energy Federal and state incentives Defrays energy cost or even let you sell electricity back to utility	The second most expensive type after solar Limited run time [depending on the battery tank's capacity] Requires a tall tower	In off-grid installations it's worth to supplement the system by a diesel or propane Genset

Activity 4.4 Operate the power back up system.
Components/Instruments Generator, UPS, Solar System.
Step 1: Get the information of the total load to be backed up and also identify the nature of the load. Step 2: Operate the selected power backup system. Step 3: Consult the teacher for further guidance.

4.9 Function of Various Components of Power Backup System

There are five main components in any online double conversion uninterruptible power supply (UPS) system:

- **i.** Rectifier
- **ii.** Batteries
- **iii.** Inverter
- **iv.** Filter
- **v.** Static Bypass Switch.

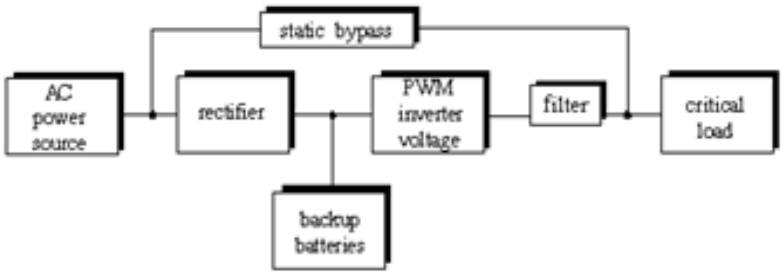


Fig.407 Block Diagram of Power Back Up System

Rectifier

The rectifier carries out several key functions. The first is to convert the input power from AC (Alternating Current) to DC (Direct Current). Its second main role is to recharge the batteries.

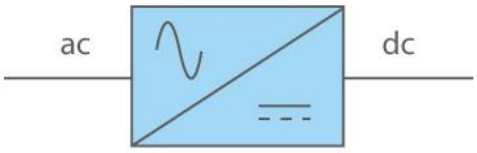


Fig.4.8 Rectifier

Depending on the size of the UPS, the rectifier module may incorporate the battery charger. With smaller uninterruptible power supply systems (i.e. below 3 kVA) it is not uncommon for the rectifier and battery charger to be separate components.

Batteries

These batteries are often large valve regulated lead-acid batteries in smaller or portable systems. Data center UPS backup batteries may be wet cell lead-acid or nickel cadmium batteries, with lithium ion cells available in some ratings. The batteries in a UPS system provide emergency power when the mains supply fails. Either the rectifier or a separate charger ensures that the batteries are always charged.

Inverter

This component is used to convert the DC voltage from the rectifier or battery back to an AC output that powers the critical load in the form of a sine wave.

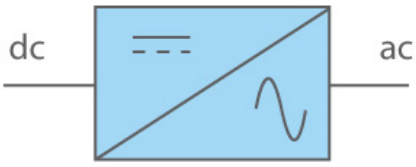


Fig.4.9 Inverter

Filter

The filter is a device that allows passing the dc component of the load and blocks the ac component of the rectifier output. Thus the output of the filter circuit will be a steady dc voltage. The filter circuit can be constructed by the combination of components like capacitors, resistors, and inductors.

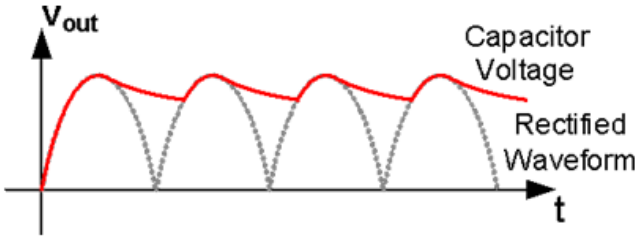


Fig. 4.10 Filter

Static Bypass Switch

This component is a safeguard in case there's a failure within the UPS system. In the event of a UPS fault, the static bypass switch automatically connects the load to the mains supply, bypassing the rectifier, batteries, and inverter.

Fig.4.11 Static Bybass Switch

Other Components

Depending on the size and type of backup system, there are several other common components that may be included. In addition, there are also components such as an External Maintenance Bypass, which enables the UPS to be removed and/or replaced without interrupting the load, Transient Volt Surge Suppressors (TVSS), and Simple Network Management Protocol (SNMP)-compliant monitoring and communications applications.

4.10 Tools / Materials for Installation of Power Backup System

Following tools / materials are used for installation of power backup systems.

1. Hammer

Hammer is used to hammering nails. Nails are used almost everywhere; in doors, windows, furniture, cabinets, shelves, tables, and everything made of wood. Where there are nails, you need to have a hammer to create it.

2. Wrench

The wrench is used to tightening or loosen a bolt. It can change size so it can be used to tighten or loosen different sizes of the bolt. Big items like bed, detachable sofas, and some crates consist of bolts that require a wrench. It is another handy tool.

3. Measuring Tape

Measuring Tape is used to measure the length of any item. Its use starts with measuring anything to install backup systems like solar plates, UPS, generator and wind turbine etc. People use them for any measurement. They are very handy, and a must-have item.

4. Level

Level's only purpose is to check the level of any item; whether it's hanged straight or not. It contains a fluid inside that moves if the level isn't straight. Even the slightest tilt would be shown by the level. It comes handy when you are working in precise measurements and want perfection in your work.

5. Flashlight

A flashlight is an essential part of any kit that we use in our daily life; it consists of a light source arranged in a reflector, a battery and a switch with a transparent cover that helps to protect light source and reflector. We can use a flashlight to find things in dark areas or to find a path in jungles.

6. Utility Knife

This knife is a little bit different than a regular knife. It is not used to cut fruits and vegetables. Either you can cut paper, sheets, cardboard, wrapping material, and other things like that. You can carry them around without any danger of hurting yourself due to its structure. They get inside a shell when not in use.

7. Saw

The saw can cut wood. It is widely used by carpenters to make furniture; tables, and much more. It's not easy to carry around due to its size, but it sure is convenient and must be kept in your tool inventory.

8. Cordless Drill

Drills are an essential tool for electricians. They need to make holes in the wall to pass wires of your television's signal or your internet's cable. Whatever it may be, holes cannot be made without the usage of a drill. With the advancement, smaller drills are available that work on batteries and are easy to keep.

9. Pliers

Pliers are used to cutting wires and thin metal rods. They are mainly used when working with electrical appliances like fixing a broken lamp. They are comfortable to hold due to their grip. This tool has extensive use by electricians, and they always keep it with them.

10. Hex Key

A hex key is a convenient tool used to tighten or loosen bolts and screws with hexagonal sockets in their heads. They come in various sizes and shape like moment arm, so it's easy to drive screws and bolts.

11. Wire Cutter / Wire Stripper

If you going to wrap the electrical wire around the terminal screw on the electrical receptacle (or a light switch terminal) you need to strip back a bit more than 1/2-inch in order to have enough copper to go around the screw leaving no insulation under the screw head when it is tightened.

4.11 Installation Techniques of the Desired Power Backup System

Stationary storage battery systems shall be installed in accordance with the manufacturer's instructions and their listing, if applicable, and shall not be installed within the habitable space of a dwelling unit.

Solar Panel Installation Process

The most common location for the installation of solar PV panels is the **roof**. Most roofs typically have the desired specifications for the installation, so that panels get the maximum sunlight**.** Nevertheless, if installation on the roof is not applicable or desired, the solar panels could also be mounted on the ground**.** You just need to make sure that there are no objects blocking access to the sun. The following steps explain solar panel installation on a roof.

1. Set up Scaffolding

Firstly, you have to erect scaffolding to ensure safety during the whole installation process when being on the roof.

2. Install Solar Panel Mounts

Then, the solar panel mounting system has to be set up. This will support the base of the solar panels. The whole mounting structure must be tilted and have an angle between 18 to 36 degrees to have maximum sunlight exposure**.**

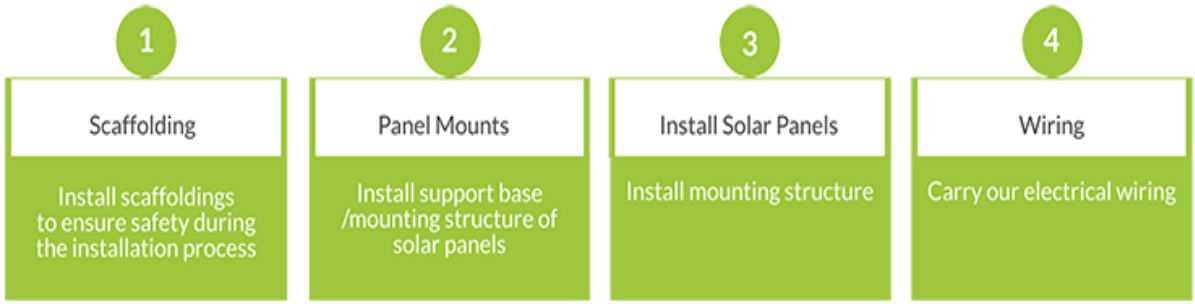
3. Install the Solar Panels

When the mounts are set up, the solar panel itself has to be installed on the mounting structure**.** Make sure to tighten up all the bolts and nuts so that it stays stable**.**

4**. Wire the Solar Panels**

The next step in the installation process is to install the electrical wiring**.** In most cases, MC4 connectors are used because they are suited for all types of solar panels. Make sure to shut off the household's electricity supply during the wiring installation.

5. Install Solar Inverter



After that, the solar inverter must be connected to the system. It is typically installed near the main panel and it could be both indoors and outdoors. Inverters are more efficient if kept in a cooler place**.** If the inverter is outdoors, it should be kept out from the afternoon sun. If it is installed indoors, the garage or utility room are usually the best places, since they stay cool for most of the year and have ventilation.

6. Bond Solar Inverter and Solar Battery

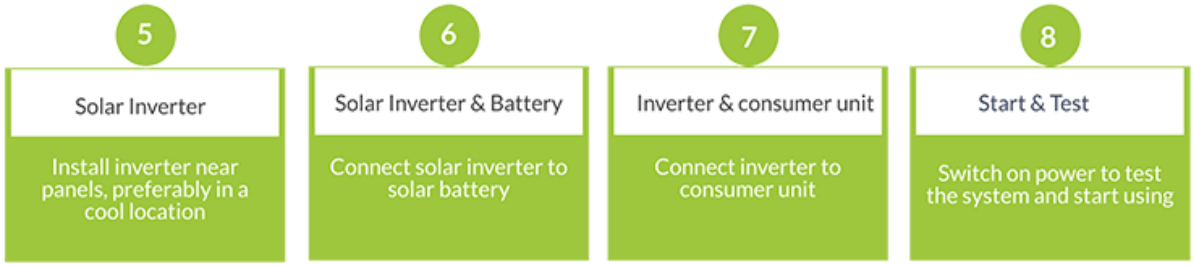
Thereafter, the solar inverter has to be connected to the solar battery. The solar battery storage can save you from worrying about the lack of usable energy during cloudy times**,** it can also lower the solar battery storage system costs during installation.

7. Connect the Inverter to the Consumer Unit

The inverter should be connected to the consumer unit to generate electricity. A generation meter should also be connected to monitor the amount of electricity the solar panels actually produce. You can use your computer or other device to check your solar system's performance. For example, you can check how much electricity you generate at different times and decide what time is suitable for using your washing machine or other utilities.

8. Start and Test Solar Panels

The final step is to switch the power on and test the newly installed solar panel system. After that, the solar panel installation process is completed.



Activity 4.6 Install the power back up System (Generator).
Components/Instruments Generator, Toolbox
Step 1: Get the information of the total load to be backed up and also identify the nature of the load. Step 2: Propose the suitable option. Step 3: Install the Generator as back-up System, following SOPs.

Activity 4.5 Install the power back up System (UPS).
Components/Instruments UPS, Toolbox
Step 1: Get the information of the total load to be backed up and also identify the nature of the load. Step 2: Propose the suitable option. Step 3: Install the UPS as back-up System, following SOPs.

4.12 Procedure for Maintaining PV Solar System

It is important that regular maintenance is carried out on your solar panel system. Undertaking regular maintenance will ensure your solar panel system is operating safely, correctly and efficiently. With the time dust and debris will build up on your solar panels, which may affect the

performance of solar panel system. In addition, water and moisture seepage, vermin, hail, wind and sunlight can all cause damage or deterioration to your system.

Who Can Undertake Routine Maintenance on My Solar Panel System?

Unlike typical electrical products, turning a solar panel system 'off' at the switch does not mean that the components no longer possess an electrical hazard. In addition, for roof mounted systems, some maintenance tasks may need to be conducted on the roof which poses additional hazards. It is recommended that solar panel systems should only be inspected and maintained by properly qualified electrician or solar panel system installer.

What is involved?

Maintaining your solar panel system involves much more than simply cleaning your solar panels. Regular maintenance of your solar panel system should ensure:

- Solar panels are clean, secure and free of defects
- No parts have deteriorated/corroded
- Vents are free of debris
- Switches do not have any defects
- Wiring has not been damaged/has not deteriorated
- Electrical checks to ensure all components are operating as intended
- Confirming fittings and cables are securely attached
- Reviewing the inverter display panel for recorded faults
- Checking that access to the isolator switches has not been impeded, and/or
- Making sure the emergency procedures for shutdown and isolation are clearly displayed

Activity 4.7 Maintain the Power backup system (PV Solar system)
Components/Instruments UPS, Solar System, Toolbox
Step 1: Follow the Instructional manual for maintenance Step 2: Perform maintenance activity under the supervision of Teacher

Key points

1. Power Backup system is defined as any device or system that provides instantaneous, uninterruptible power. The term UPS (uninterruptible power supply) is an often used term, that supply power for not more than 30 to 60 minutes. Other power back up system include generators, solar systems, batteries etc.
2. The backup power requirements of any facility depends on what loads to backup and what are their power requirements.
3. Wind Generators are suitable only for rural areas with proper zoning and weather pattern.
4. There are five main components in any online double conversion uninterruptible power supply (UPS) system:
    - **i.** Rectifier
    - **ii.** Batteries
    - **iii.** Inverter
    - **iv.** Filter
    - **v.** Static Bypass Switch.
5. The most common location for the installation of Solar PV panels is the roof. Most roofs typically have the desired specifications for the installation, so that panels get the maximum sunlight
6. Regular maintenance is required on Solar Panel system to ensure that solar panel system is operating safely, correctly and efficiently.

Exercise

Select the most appropriate option (✓)

1. UPS stands for

a. Universal Power Supply
b. Unique Power Supply
c. Uninterruptable Power Supply
d. Uninterruptable Power System

2. A system that provides instantaneous uninterruptable power is called:

a. Power Back Up System
b. Power Emergency System
c. Power Supply System
d. Supply main feeder

3. A traditional battery backup system can handle;

a. AC Load b. DC Load

c. Both AC & DC d. None

4. Solar panels produces electricity only on ----------

a. Bright days b. Cloudy Days

c. Dark Days c. All of Above

5. Rectifier is used to convert ----------

a. AC to DC b. DC to AC

c. AC into High Voltage AC d. DC into Low Voltage DC

6. There are _____ main components in any online double conversion uninterruptible power supply (UPS) system

a. Two b. three c. four d. five

7. Ideal location for installation of Solar PV is

a. Garage b. Garden

c. Roof d. None of above

8. Wind Generators are suitable for

a. Urban Area b. Coastal Area

c. Hilly Area d. None of above

ANSWER KEY

1.(c)	2. (a)	3.(c)	4.(a)	5.(c)
6.(d)	7.(c)	8. (b)		

Give short answer to the following questions

1. Define power back up system.

2. Highlight the importance of power back up system.

3. Enlist various power back up systems.

4. Define rectifier.

5. What is static bypass switch?

Answer the following questions in detail .

1. Discuss major power back up systems.
2. Explain the load requirement and calculation for a power back up system.
3. Draw the block diagram of a power back up system and explain briefly.
4. Explain various tools used for installation of power back up system.

Instructions for the Teachers

1. Adopt Health and Safety measures in the Lab.
2. Divide the students in group and properly monitor the activity and ensure the record of observations.
3. Use all the available ICT resources for better delivery of the content.
4. Ensure proper functioning of lab equipment

Chapter 05: Safety/ Security & Communication Systems

Students Learning Outcomes

After completion of this chapter you will be able to:

- describe types of safety, security and communication system (CCTV, fire alarms, smoke detectors).
- explain importance of the safety/ security & communication systems.
- explain requirements of the organization regarding safety, security and communication system.
- describe the criteria for inspection of the premises for installation of safety / security and communication system as per requirement.
- describe the required tools/equipment and testing instruments as per job requirements.
- explain procedure and techniques for laying the wires / cables according to wiring diagram.
- explain the procedure for connecting System to the Power Source
- describe the techniques required for adjustment, setting directions where necessary for correct functioning of the system.
- explain the checking procedure of the standby power backup for its proper functioning.
- describe the testing and commissioning of the system.
- explain operating procedure and periodic testing of the system.

5.1 Safety, Security & Communication Systems

Safety, Security & Communication Systems relate to the means or methods by which something is secured through a system of interworking components and devices.

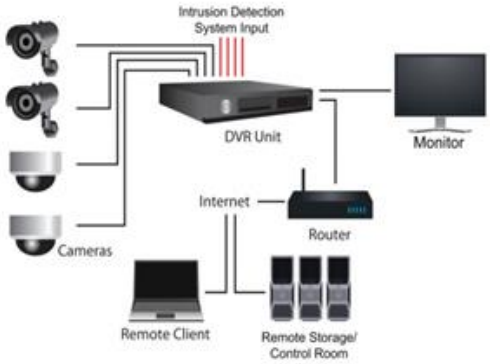


Fig.5.1 Block Diagram of CCTV

If we consider a home security system, which are networks of integrated electronic devices working together with a central control panel to protect against burglars and other potential home intruders. A typical home security system includes:

- A Control Panel, which is the primary controller of a home's security system.
- Door and window sensors
- Fire Alarm & Smoke Detectors
- Wired or Wireless Security Cameras
- Motion Sensors, both interior and exterior
- A high-decibel siren or alarm

Different Safety & Security systems are discussed as follows:

i. Close Circuit Television (CCTV)

Closed Circuit Television (CCTV), also known as video surveillance, is the use of video cameras to transmit a signal to a specific place, on a limited set of monitors. It differs from broadcast television in that the signal is not openly transmitted. In CCTV signal may employ point-to-point (P2P), point-to-multipoint (P2MP), or mesh wired or wireless links. Surveillance of the public using CCTV is common in many areas around the world. In industrial plants, CCTV equipment may be used to observe parts of a process from a central control room, for example when the environment is not suitable for humans. CCTV systems may operate continuously or only as required to monitor a particular event. A more advanced form of CCTV, using digital video recorders (DVRs), provides recording for possibly many years, with a variety of quality and performance options and extra features (such as motion detection and email alerts).

ii. Fire Alarms

A fire alarm system warns people when smoke, fire, carbon monoxide or other fire-related emergencies are detected. These alarms may be activated automatically from smoke detectors, and heat detectors or may also be activated via manual fire alarm activation devices such as manual call points or pull stations. Alarms can be either motorized bells or wall mountable sounders or horns.

Fig.5.2 Fire Alarm System

iii. Smoke Detectors

A smoke detector is a device that senses smoke, typically as an indicator of fire. Commercial smoke detectors issue a signal to a fire alarm control panel as part of a fire alarm system, while household smoke detectors, also known as smoke alarms, generally issue an audible or visual alarm from the detector itself. Smoke detectors are housed in plastic enclosures, typically shaped like a disk about 150 milli meters (6 in) in diameter and 25 milli meters (1 in) thick, but shape and size vary. Smoke can be detected either optically (photoelectric) or by physical process (ionization). Detectors may use one of the two, or both sensing methods.

Fig.5.3 Smoke Detector

5.2 Importance of the Safety/ Security & Communication Systems

Security is important for every commercial establishment because without a security system installed you're putting your entire business at a huge risk. Some of the reasons for installation of safety and security system are outlined here.

1. Wise Investment

Smart investments are what contributes to the success of a business, security systems are one example of a wise decision. You want to keep your business assets safe and security systems do a great job of minimizing your losses while installing security systems.

2. Protects Your Cash Flow

Employees are the driving force of a successful company. If the internal operations are running smoothly, you can expect your business to flourish. But if you notice that your business is suffering despite reaching your sales numbers, there might be an internal issue that needs to be addressed. Often times, unethical employees may be tempted to steal cash and/or other assets in your establishment, especially if there are no CCTV cameras installed in key areas like the cash register, warehouse, and stockroom.

To prevent these issues from happening, a security system should be installed inside your company premises. This discourages employees from attempting any unethical behavior and also protects your cash flow and other valuable assets.

3. Promotes a Safe Working Environment

As a business owner, you are responsible for the health and safety of your employees. Having security systems installed promotes a safe working environment by ensuring that your employees are monitored at all times. Should there be an unfortunate incident, local authorities can respond right away and address the issue. It also gives your employees a sigh of relief when they're working in odd hours or late shifts.

Your employees will feel safe knowing that your establishment comes installed with a modern security system and allow them to focus on the task at hand without fearing their health or safety.

4. Peace of Mind

You already have a lot of things going on in your mind when running a business and the last thing you want is to add to those thoughts. Security systems give business owners peace of mind knowing that their establishment is well-protected from both inside and out. You can leave your business on auto-pilot and not have to worry about external or internal burglary when you're outside its premises.

With a security system installed, you can go on long vacations and feel confident that none of your employees won't try to steal your assets. Thieves won't dare to break-in as they fear getting caught by CCTV cameras and risk getting caught by local police authorities.

5. Focus on other Important Matters

You can't afford to keep an eye on your business security all the time as this can affect other aspects of your business. Security systems such as Casa Security, allow you to direct your efforts

on important matters like maintaining profits, boosting sales, and reaching company objectives. The security system will take care of the safety of your business while you focus on expanding your business even further.

A security system is an absolute must for every business, whether it be big or small. Over the years, security systems have become even better at providing the level of protection business establishments need so they can protect their assets from the hands of criminals and ensure the safety of both the owners and the employees.

5.3 Requirements of the Organization Regarding Safety, Security and Communication System

It is basically the process to protect an employee from work related illness and injury and to make the workplace (building etc.) secure from intruders. Every company should have an Environmental, Safety and Health Policy statement.

In order for an organization to properly implement a CCTV system, site-specific characteristics need to be assessed by a knowledgeable multidisciplinary team of personnel. This team is critical to identifying key functional and operational requirements. Functional requirements consist of determining the area of surveillance, such as a perimeter area or an access point. Operational requirements define what information a CCTV system will be expected to provide given the existing operating conditions. One of the best ways of implementing a strong security system in the workplace is to have access control facility. An access control system runs on software that is essential for managing and monitoring who has access to the doors, printers etc. As a matter of fact, unauthorized access to buildings is one of the biggest threats for companies.

- **Gates**: If the opening and closing of the main gates of the office building are a part of the access control system then, the security check starts at the entry level itself. It should be paired with a surveillance device like CCTV such that the staff can confirm the entry of a visitor. The opening and the closing of the gates are generally operated through specialized locks.
- **Exterior Doors**: After the main entrance (gates) comes the security of the exterior doors. The employees can simply use their ID cards to open the doors or use biometric scans while the visitors are directed to a particular entrance. A visitor's card should be given to them for the time they are in the office building.

- **Accounting Areas:** There should be limited access to the HR and accounting areas. The employee or the visitor should have to take permission to get clearance to these two departments.
- **Data Closets and Warehouse Areas**: Network security should be another priority of the company. Access to server rooms or data closets should thus be limited. The same goes for warehouse areas. For more info, check out our server room security guide.
- **Electrified Lock**: The three types of electrified lock (electric strike, electromagnetic lock and electrified hardware) are easy to install in the frame of the door.
- **Contactless Readers**: It includes contactless smart card and standard prox. It has an easy installation process. If the access control system is changed in the then, it necessitates changing the smart cards.
- **Biometrics**: The biometrics has become a common part of the security system used in the office buildings. Fingerprint, retina and hand geometry are some of the common variations of the biometrics.

A company should thus employ a strong security system and the employees should also co-operate to ensure their safety and the safety of critical information.

5.4 Criteria for Inspection of the Premises for Installation of Safety / Security and Communication System as per requirement

The selection of the safety and security equipment depends on the requirement of site and accordingly design is prepared as per the client demands.

Any of various means or devices designed to guard persons and property against a broad range of hazards, including crime, fire, accidents, espionage, sabotage, subversion, and attack.

Most security and protection systems emphasize certain hazards more than others. In a retail store, for example, the principal security concerns are shoplifting and employee dishonesty (e.g., pilferage, embezzlement, and fraud). A typical set of categories to be protected includes the personal safety of people in the organization, such as employees, customers, or residents; tangible property, such as the plant, equipment, finished products, cash, and securities; and intangible property, such as highly classified national-security information or “proprietary” information (e.g., trade secrets) of private organizations. An important distinction between a security and protection system and public services such as police and fire departments is that the former employs means that emphasize passive and preventive measures.

Security systems are found in a wide variety of organizations, ranging from government agencies and industrial plants to apartment buildings and schools. Sufficiently large organizations may have their own proprietary security systems or may purchase security services by contract from specialized security organizations.

Security systems are becoming increasingly automated, particularly in sensing and communicating hazards and vulnerabilities. This situation is true in both crime-related applications, such as intrusion-detection devices, and fire-protection alarm and response (extinguishing) systems. Advances in miniaturization and electronics are reflected in security equipment that is smaller, more reliable, and more easily installed and maintained.

Types of Security Systems

Security systems can be classified by type of production enterprise, such as industrial, retail (commercial), governmental, government contractor, or hospital; by type of organization, such as contract security or proprietary; by type of security process, such as personnel or physical security; or by type of security function or emphasis, such as plant protection (variously defined), theft control, fire protection, accident prevention, protection of sensitive (national security or business proprietary) information. Some of these categories obviously overlap.

Security for small businesses constitutes a special situation. Because small firms cannot afford specialized proprietary security staffs, measures must be incorporated into regular routines and staff training or be purchased from outside organizations. Theft, both internal and external, is a prime concern.

Residential security constitutes another special category. Sizable housing or apartment complexes, especially if under one management, can employ sophisticated security measures, including, for example, closed-circuit television monitoring of elevators and hallways and trained security guards. Relatively simple equipment for houses or small apartment buildings, as, for example, exterior lighting and alarms, is increasingly used. Some neighborhoods of large cities cooperatively employ patrol services or organize resident volunteer patrols.

Activity 5.1 Inspect the premises and get the client requirements for selection of the most appropriate type of Safety / Security & Communication System.
Components/Instruments Inspection Performa
Step 1: Discuss the client regarding the safety requirements Step 2: Propose the suitable options.

Activity 5.2 Prepare the material list with labor cost, and accessories cost for the proposed option in Activity 5.1
Components/Instruments Quotation/Proposal
Step 1: Finalize the material as per requirement and available quotations Step 2: Evaluate material, labour and miscellaneous cost

5.5 Required Tools/Equipment and Testing Instruments

Various tools which can be employed for the installation of safety & security equipment are as follows:

1. Hammer

Hammer is used to hammering nails. Nails are used almost everywhere; in doors, windows, furniture, cabinets, shelves, tables, and everything made of wood. Where there are nails, you need to have a hammer to create it.

2. Wrench

The wrench is used to tightening or loosen a bolt. It can change size so it can be used to tighten or loosen different sizes of the bolt. Big items like bed, detachable sofas, and some crates consist of bolts that require a wrench. It is another handy tool.

3. Measuring Tape

Measuring Tape is used to measure the length of any item. Its use starts with measuring anything to install backup systems like solar plates, UPS, generator and wind turbine etc. People use them for any measurement. They are very handy, and a must-have item.

4. Level

Level's only purpose is to check the level of any item; whether it's hanged straight or not. It contains a fluid inside that moves if the level isn't straight. Even the slightest tilt would be shown by the level. It comes handy when you are working in precise measurements and want perfection in your work.

5. Flashlight

A flashlight is an essential part of any kit that we use in our daily life; it consists of a light source arranged in a reflector, a battery and a switch with a transparent cover that helps to protect light source and reflector. We can use a flashlight to find things in dark areas or to find a path in jungles.

6. Utility Knife

This knife is a little bit different than a regular knife. It is not used to cut fruits and vegetables. Either you can cut paper, sheets, cardboard, wrapping material, and other things like that. You can carry them around without any danger of hurting yourself due to its structure. They get inside a shell when not in use.

7. Cordless Drill

Drills are an essential tool for electricians. They need to make holes in the wall to pass wires of your television's signal or your internet's cable. Whatever it may be, holes cannot be made without the usage of a drill. With the advancement, smaller drills are available that work on batteries and are easy to keep.

8. Pliers

Pliers are used to cutting wires and thin metal rods. They are mainly used when working with electrical appliances like fixing a broken lamp. They are comfortable to hold due to their grip. This tool has extensive use by electricians, and they always keep it with them.

9. Hex Key

A hex key is a convenient tool used to tighten or loosen bolts and screws with hexagonal sockets in their heads. They come in various sizes and shape like moment arm, so it's easy to drive screws and bolts.

10. Wire Cutter / Wire Stripper

If you going to wrap the electrical wire around the terminal screw on the electrical receptacle (or a light switch terminal) you need to strip back a bit more than 1/2-inch in order to have enough copper to go around the screw leaving no insulation under the screw head when it is tightened.

11. Wire crimping tool

A crimping tool is a device that is used to make cold weld joints between wires and a connector through deforming one or both of them to hold the other. A special connector is used to join metals together.

12. Router

A router is a networking device that forwards data packets between computer networks. Routers perform the traffic directing functions on the Internet.

13. Network Switches

A network switch connects devices within a network (often a local area network, or LAN*) and forwards data packets to and from those devices. Unlike a router, a switch only sends data to the single device it is intended for (which may be another switch, a router, or a user's computer), not to networks of multiple devices.

14. Connectors

A connector is a device that terminates a segment of cabling or provides a point of entry for networking devices such as computers, hubs, and routers.

15. Digital Multimeter

A digital multimeter, DMM is a test instrument used to measure electrical values including voltage, current and resistance

5.6 Procedure and Techniques for Laying the Wires / Cables According to Wiring Diagram

The instructions for the installation of Surveillance Camera Installation are shown in Fig.5.4 below:

- First of all, check all the cameras before installation to make sure they all are working properly.

- Connect the video and power BNC and cables connectors to the "CAMERA ONLY" labeled and power respectively. For tight connection, twist and lock the Camera BNC connectors. In fig, the yellow connector from dome cameras and bullet cameras are connected to the yellow to the DVR and red cable as power connection from camera to the 12V DC power adopter connected to the 220V AC power supply.

Fig.5.4 CCTV Camera Security System

- Connect the video connector labeled as "DVR ONLY" to the rear / back side of DVR in the Camera input slot(s). In Fig.5.4, the yellow camera connector by extension wire labeled as "Video to DVR" is shown which can be connected to one of the 16 video input slots in the DVR. In the audio enabled cameras, the white RCA cable should be connected to the audio input slot in DVR to audio signal transmission.
- Now, connect all the red female power supply connector from the camera to the male connectors of power supply.
- Connect the all the power splitter from the camera to the 12V DC power supply adopter.
- Connect the Monitor / LCD or PC and laptops through VGA cables. For HD, use the HDMI cables and connect to the PC and DVR HDMI slot in DVR.
- Now, connect the power adopter to the 220V AC by connecting the three pin plug of power adopter into three pin socket. For 24/7/365 security system, it is recommended to connect the camera and DVR to the UPS (Uninterruptible Power Supply System).
- Finally, connect the DVR power adopter to the 220V AC supply as shown in Fig.5.4. You have done. Check the system if it works properly by viewing the LCD screen which shows the live camera recording.

Activity 5.3 Install the Analog/Digital dome CCTV Security System with layout / wiring diagrams.
Components/Instruments Electrical Tool Kit, Connectors, CCTV Camera (Dome Shaped), DVR/NVR, Connecting Cables
Step 1: Select the location for installation of CCTV Camera Step 2: Install the desired system as per instruction manual Step 3: Conduct a test run

Activity 5.4 Install the Network IP CCTV security with layout diagram.
Components/Instruments Electrical Tool Kit
Step 1: Select the location for installation of Network IP CCTV Camera Step 2: Install the desired system as per instruction manual Step 3: Conduct a test run

5.7 Procedure for connecting System to the Power Source

The power connection to the source is applied as per the data sheet or operating manual of the system provided by the manufacturer of the equipment. Information are also available at the tags attached to the systems.

Worldwide, many different mains power systems are found for the operation of household and light commercial electrical appliances and lighting. The different systems are primarily characterized by their

- Voltage
- Frequency
- Plugs and sockets (receptacles or outlets)
- Earthing system (grounding)
- Protection against overcurrent damage (e.g., due to short circuit), electric shock, and fire hazards
- Parameter tolerances.

All these parameters vary among regions. The voltages are generally in the range 100–240 V . The two commonly used frequencies are 50 Hz and 60 Hz. Single-phase or three-phase power is most commonly used today, although two-phase systems were used early in the 20th century. Foreign enclaves, such as large industrial plants or overseas military bases, may have a different standard voltage or frequency from the surrounding areas. Some city areas may use standards different from that of the surrounding countryside (e.g. in Libya). Regions in an effective state of anarchy may have no central electrical authority, with electric power provided by incompatible private sources.

5.8 Repair and Maintenance of Safety and Security System

A security system needs regular maintenance to make sure it functions optimally. This involves inspecting the individual components, changing the batteries when needed and ensuring that all the individual parts communicate effectively with one another. While your main control pad and a monitoring service help you keep track of system performance, you should conduct your own weekly and monthly inspections as well.

Activity 5.5 Conduct routine/preventive maintenance for the installed system
Components/Instruments Safety Tools, Electrical Tool Kit, Testing Tools
Step 1: Follow Safety Precautions Step 2: Conduct routine maintenance of the system according to operational/ maintenance manual Step 3: Generate report

Key points

1. Safety, Security & Communication Systems relate to the means or methods by which something is secured through a system of interworking components and devices.
2. Security is important for every commercial establishment because without a security system installed you're putting your entire business at a huge risk.
3. The selection of the safety and security equipment depends on the requirement of site and accordingly design is prepared as per the client demands.
4. Security systems can be classified by type of production enterprise, such as industrial, retail (commercial), governmental, government contractor, or hospital; by type of organization, such as contract security or proprietary; by type of security process, such as personnel or physical security; or by type of security function or emphasis, such as plant protection (variously defined), theft control, fire protection, accident prevention, protection of sensitive (national security or business proprietary) information.

5. Closed Circuit Television (CCTV), also known as video surveillance, is the use of video cameras to transmit a signal to a specific place, on a limited set of monitors. It differs from broadcast television in that the signal is not openly transmitted.
6. A fire alarm system warns people when smoke, fire, carbon monoxide or other fire-related emergencies are detected. These alarms may be activated automatically from smoke detectors, and heat detectors or may also be activated via manual fire alarm activation devices such as manual call points or pull stations
7. A smoke detector is a device that senses smoke, typically as an indicator of fire. Commercial smoke detectors issue a signal to a fire alarm control panel as part of a fire alarm system, while household smoke detectors, also known as smoke alarms, generally issue an audible or visual alarm from the detector itself.

Exercise

Select the most appropriate option (✓)

1. CCTV Stands for

a. Circuit Closed Television b. Close Connected Television
c. Close Circuit Television d. Circuit Connected Television

2. A typical home security system includes:

a. Control Panel b. Door & Window Sensors
c. Fire Alarm & Smoke Detectors d. All of Above

3. _____ is a device that senses smoke, typically as an indicator of fire:

a. Smoke Detector b. Fire Extinguisher
c. Fire Alarm d. None

4. _____ is important for every commercial establishment:

a. Risk b. Hazard
c. Safety d. All of above

5. A digital multimeter, DMM is a test instrument used to measure

a. Current b. Resistance
c. Voltage d. All of above

ANSWER KEY

1.(c)	2. (d)	3.(a)	4.(c)	5. (d)

Give short answer to the following questions

1. Define Safety, Security & Communication System.
2. Enlist the components of a typical security system.
3. What is a CCTV?
4. Define fire alarm system.
5. Define a smoke detector.

Answer of the following questions in detail.

1. Describe the importance of safety /security and communication system.
2. Enlist & describe the requirements of the organization regarding Safety, Security and Communication Systems.
3. Explain the criteria for inspection of the premises for installation of safety / security and communication system as per requirement.

Instructions for the Teachers

1. Adopt Health and Safety measures in the Lab.
2. Divide the students in group and properly monitor the activity and ensure the record of observations.
3. Use all the available ICT resources for better delivery of the content.
4. Ensure proper functioning of lab equipment

Chapter 06: Personal and Professional Development

Student Learning Outcomes

After completion of this chapter you will be able to:

1. learn the importance of CV in job Application.
2. create and Format CV/Resume.
3. access and register email account on various online job portals.
4. search job as per job description and title.

6.1 CV Writing

A Curriculum Vitaé (CV) is a written overview of the person's experience and other qualifications that a potential employer seeks about a job-seeker and is supposed to be carried by tenured applicants looking for a job change.

CV and Résumé - What is the Difference?

A CV can be easily mistaken for a résumé, however, there is a notable difference. A résumé is supposed to be carried by applicants with no relevant career experience or no experience whatsoever. On the other hand, CVs are to be carried by candidates with relevant experience.

CV Format

A CV normally includes the following elements:

- **Name** − Full name of the applicant without general salutations like Mr., Ms.
- **Address** − the permanent address.
- **Summary** − a brief description of what you have achieved in your profession.
- **Academic Qualification** − your academic qualification
- **Additional Knowledge** − Skills you have acquired beyond your profession.
- **Acquired Skills** − Soft Skills
- **Programming Languages** − if any
- **Software Tools** − Software tools you use in your profession (MS Word, Excel)
- **Operating System Platforms** − operating system you use (Windows, Mac)
- **Database Management System** − if any
- **Personal Skills** − Soft Skills
- **Experience Breakdown** − detailed explanation of your experience
- **Achievements & Interests** − Hobbies. Achievements in professional life
- **Declaration** − stating all information provided about the applicant as true.

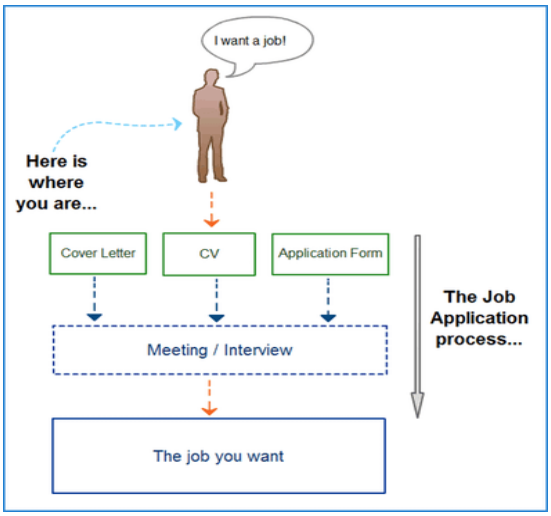
6.2 Importance of CV in job Application

Some people mistakenly think that the purpose of their CV is to get them a Job. This is not exactly accurate. No employer in their right mind will call you up the next day saying;

"Hi, I just had a look through your Curriculum Vitae and based on what I have read … you're hired! When can you start?!"

Unfortunately, it just does not work like that in the real world. Rather, the key purpose of your CV is purely to convince a prospective employer of your employability and to arrange an interview or a meeting with you.

A CV is primarily a gateway to an interview**.** This concept has been nicely illustrated in the following diagram related to the job application process.



"Your CV must speak loudly and clearly of your value as a potential employee. And the value must be spoken in a few brief seconds, because, in the business world, that's all the attention a CV will get. *The CV takes you only the first few paces toward that new job. It gets your foot in the door, and because you can't be there to answer questions, it has to stand on its own.*"

While it is true that it is during the interview stage that you have the opportunity to fully convince a prospective employer of your suitability for the job, it would be wrong to conclude from this that the expiry date of the CV is just until the job interview stage. In fact, once all the short-listed candidates have been interviewed the recruiters will then go through all the notes, application forms, cover letters and CVs to make a final decision. Hence, your CV will be your companion until you have secured the job that you seek and its importance cannot be overstated.

Tips for writing an effective CV

- Keep it short, no more than 2 A4 pages long.
- Use bullet points and short sentences rather than big paragraphs.
- Only include relevant, positive and important information.
- Let someone else double checks your CV for spelling and grammar mistakes.
- Accompany your CV with a well-written **Cover Letter**

Conclusion

A CV, or curriculum vitae, is your personal marketing tool containing information about your education, employment, personal qualities and skills. You will need a CV to apply for jobs. There are a number of different types of CV formats that one can adopt, depending on the candidate.

The purpose of a CV is to convince the prospective employer of your employability and to invite you for a job interview.

1.3 Create and Format CV/Resume

Every time you're looking for a job, you may compete against 250 other candidates on average. Yes, you read that right. Imagine *you* are the recruiter and you have to review 250 job applications. Do you thoroughly read all of them? No, of course you don't. Recruiters spend only **6 Seconds** scanning each CV. So the very first impression is key. If you submit a neat, properly organized document, you'll convince the recruiters to spend more time on your CV.

A poorly formatted CV, on the other hand, will get you discarded in the first-round review. Here's how to format a CV the right way. Start with creating a CV outline divided into the following sections:

Proper Order of Sections

1. CV Header with Contact Information
2. Personal Profile: CV Objective or CV Summary
3. Work Experience
4. Education
5. Skills
6. Additional Sections

Tip: If you're fresh out of university and need to write a student CV with no experience, or if you've graduated from a very prestigious institution within the last 5 years, put your education section above your work experience.

Choose Clear, Legible Fonts

Go for one of the standard CV typefaces: Arial, Tahoma, or Helvetica if you prefer sans-serif fonts, and Times New Roman or Bookman Old Style if serif fonts are your usual pick.

Use 11 to 12 pt font size and single spacing. For your name and section titles, pick 14 to 16 pt font size.

Be Consistent with your CV Layout

Set one-inch margins for all four sides.

Make sure your CV headings are uniform—make them larger and in bold but go easy on italics and underlining.

Stick to a single dates format on your CV: for example 11-2017, or November 2017.

Don't Cram your CV with Gimmicky Graphics

Less is more.

White space is your friend—recruiters need some breathing room!

Plus, most of the time, after you send out your CV, it's going to be printed in black ink on white paper. Too many graphics might make it illegible.

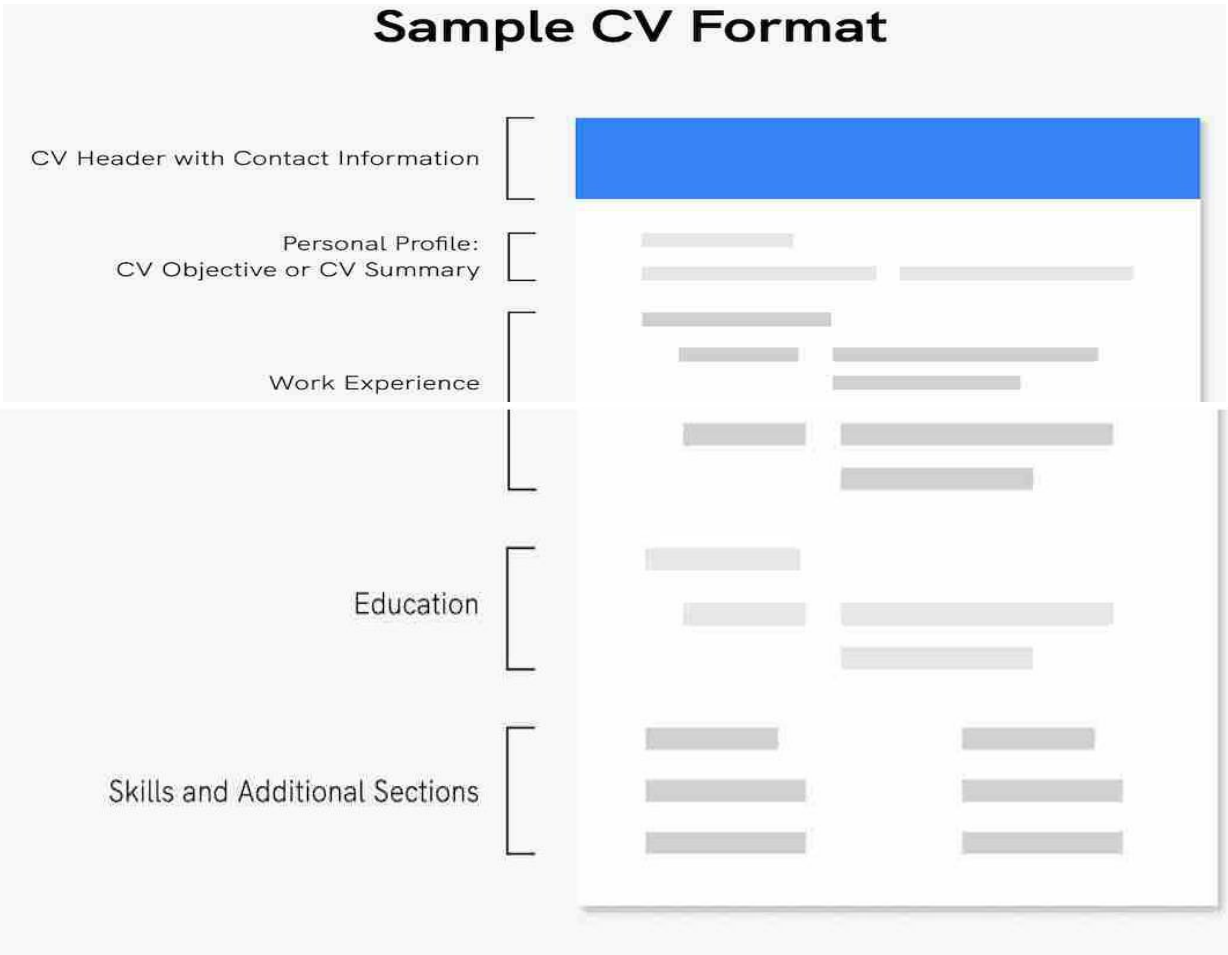
Get Photos off of your CV

Unless you're explicitly asked to include your photograph in the job ad.

If so—make sure to use a professional looking picture, but not as stiff as an ID photo.

Make your CV brief and relevant

Don't be one of those candidates stuck in the nineties who think they have to include every single detail about their lives on their CVs.



Resume

Angela Tackett

Tier 2 Technical Support Specialist

Personable tech support representative with 4+ years of experience analyzing issues with drone hardware and software. Achieved company-high retention rate of 99.32% Seeking to ignite career with the team at Argo Drones.

Personal Info

Address
350 5th Ave
New York, NY 10118

Phone
555-555-4321

E-mail
angela.tackett@gmail.com

LinkedIn
linkedin.com/in/angela-tackett

Skills

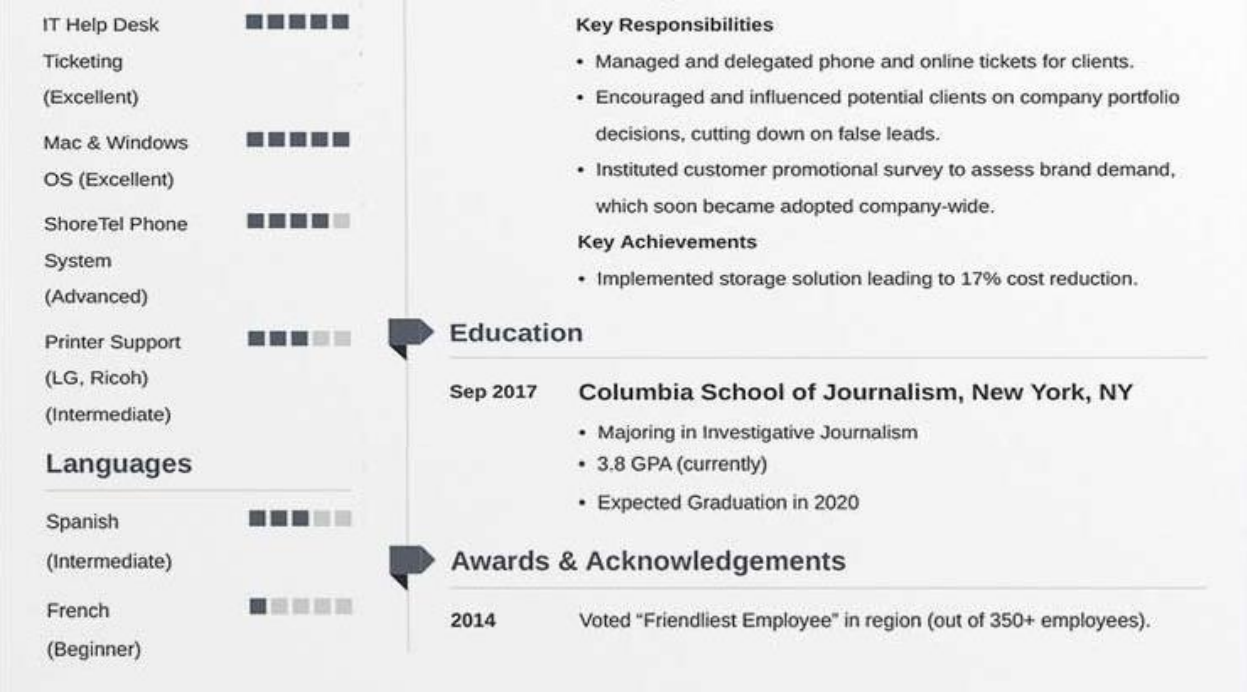
Experience

Jan 2011 - Dec 2016 — **Tier 2 Technical Support Specialist**
Silicon Circuitry, Inc.

Key Responsibilities
- Mentored fast-paced team of 12+ technical support specialists.
- Efficiently cultivated fresh outsourced help desk team.

Key Achievements
- Achieved company-high customer retention rate of 99.32%
- Quickly promoted from Tier 1 to the Tier 2 team due to extensive knowledge of help desk ticketing system and help desk software.

Jan 2010 - Dec 2010 — **Secretarial Assistant**
Carson Logistics, LLC



Tip: Once you've finished writing, save your CV in PDF to make sure your CV layout stays intact. But pay close attention to the job description. Some employers won't accept a PDF CV. If such is the case, send your CV in Word.

1.4 Access and Register Email Account on Various Online Job Portals

Job Portals

Job portals, or job boards, are sites where you can advertise jobs and search for resumes. They are an integral part of almost every hiring process and using them effectively will translate into qualified candidates for relatively low costs. Here are a few tips to ensure you get the most out of job portals for recruitment:

- Use the Search Engine i.e. Google, Wikipedia and Ask.com. etc.
- http://careers.tevta.gop.pk/
- Go to Sign Up and register yourself by using different option for the particular information.

1.5 Job Search as per job description and Title

A job title is a specific designation of a post within an organization, normally associated with a job description that details the tasks and responsibilities that go with it. Candidate is required to

read the job description in detail before applying for any position. If the candidate meets the set criteria for a specific position, only then the candidate should apply. Best ways to find a suitable position are:

- Ask your network for referral
- Contact Organization directly
- Use job search platform
- Visit Job Fairs
- Leverage Social Media
- Contact recruitment agencies

Activity 6.1 Create a CV with the help of teacher. Register on online job portals, follow job hunting procedure and steps to apply for an advertised job
Components/Instruments Computer with Internet Facility.
Step 1: Create a CV Step 2: Create an account on online job portal Step 3: Apply for the suitable position

Key points

1. CV is a written overview of the person's experience and other qualifications that a potential employer seeks about a job-seeker and is supposed to be carried by tenured applicants looking for a job change Security is important for every commercial establishment because without a security system installed you're putting your entire business at a huge risk.

2. A résumé is supposed to be carried by applicants with no relevant career experience or no experience whatsoever. On the other hand, CVs are to be carried by candidates with relevant experience.

3. **CV Writing Tips**

- Keep it short and sweet; no more than 2 A4 pages long.
- Use bullet points and short sentences rather than big paragraphs.
- Only include relevant, positive and important information.
- Let someone else double checks your CV for spelling and grammar mistakes.

4. Job Portals

Job portals, or job boards, are sites where you can advertise jobs and search for resumes. They are an integral part of almost every hiring process and using them effectively will translate into qualified candidates for relatively low costs. Here are a few tips to ensure you get the most out of job portals for recruitment:

- Use the Search Engine i.e. Google, Wikipedia and Ask.com. etc.
- http://careers.tevta.gop.pk/
- Go to Sign Up and register yourself by using different option for the particular information.

Exercise

Select the most appropriate option (✓)

1. CV Stands for :

a. Curriculum Values b. Contact Volume

c. Curriculum Vitaé d. Curriculum Vastness

2. Which is not compulsory to mention in a job description CV?

a. Date b. Name

c. Nationality d. Education

3. Curriculum vitae is a word of which language?

a. Latin b. German

c. French d. English

4. Which of the font size is used for writing a CV:

a. 11 or 12 b. 10 or 11

c. 13 or 14 d. None

5. _____ are sites where you can advertise jobs and search for resumes.

a. Job Portals b. Job Seekers

c. Job Providers d. Talent Hunt Advisers

6. A typical resume contains a summary of relevant _____ and education:

a. Job description b. Job experience

c. Job criteria d. All of above

7. A resume is supposed to be carried by applicant with the _____:

a. No experience b. Vast experience

c. Both a & b d. None of above

ANSWER KEY

1.(c)	2. (c)	3.(a)	4.(a)
5.(a)	6.(b)	7.(a)	

Give short Answer to the following Questions

1. Define CV.
2. Define Resume.
3. Differentiate between Resume & CV.
4. Enlist CV writing tips.
5. Define Job Portal.

Answer the following questions in detail.

1. Describe how to create and format a CV in detail.
2. Describe how to access and register Email account on various online job portals.
3. Explain the job search as per job description and title.

Instructions for the Teachers

1. Divide the students in group and properly monitor the activity and ensure the record of observations.
2. Use all the available ICT resources for better delivery of the content.
3. Ensure proper functioning of ICT resources.

Glossary

Words/Terms	Meanings/Descriptions
Chapter 1: Motors and Generators	
Shunt	Refers to parallel connection
Compound	Combination of Series & Parallel
Synchronous	Existing or Occurring at the same Time
Induction	Process of electromagnetic induction
Chapter 2: Introduction to AC	
Alternating Current	It changes its polarity and direction Continuously.
RMS	Root Mean Square
Inductor	An inductor, also called a coil, choke, or reactor, is a passive two-terminal electrical component that stores energy in a magnetic field when electric current flows through it. An inductor typically consists of an insulated wire wound into a coil.
Impedance	Impedance is the opposition to alternating current presented by the combined effect of resistance and reactance in a circuit.
Power Factor	Is the ratio of the real power to the apparent power in a circuit.
Chapter 3:Transformers	
Self-inductance	Induction of a voltage in a current-carrying wire when the current in the wire itself is changing.
Turn Ratio	It is defined as ratio of the secondary to the primary of a transformer.
Chapter 4: Power Backup Systems	
Rectifier	Device to convert ac to dc.
Inverter	Device used to convert ac to dc.
Filter	Device that passes the dc component and blocks ac component.
Chapter 5: Safety/ Security & Communication Systems	

CCTV	Closed Circuit Television
Biometrics	The biometrics has become a common part of the security system used in the office buildings. Fingerprint, retina and hand geometry are some of the common variations of the biometrics.
Chapter 6:Personal and Professional Development	
CV	Curriculum Vitae and reflects to a candidate profile having some prior experience.
Resume	A résumé is supposed to be carried by applicants with no relevant career experience or no experience whatsoever.

ABOUT THE AUTHOR

The Author of the Book, **Engr. Shahbaz Hussain** is a renowned TVET Expert having almost 26 years of experience in the sector. He has got his education from GCU and UET, Lahore. Apart from Pakistan, he has received his training from UK in the field of Curriculum Development. He has vast experience of teaching, TVET administration as Principal, District Manager, Director in the P-TEVTA and NAVTTC. He is the author of almost a dozens of Books for the TVET-DAE students. His famous publications/textbooks include:

i. Electric Circuits / Electrical Essential & Networks (ELTR-114)
ii. Electrical Essential & Networks (MTR-132)
iii. Electronic Devices & Circuits (ELTR-123)
iv. Microprocessor Architecture (ELTR-314)
v. Microprocessor Architecture (CIT-235)
vi. Principles of Electrical Engineering (ET-115)
vii. Propagation of Electromagnetic Waves (ELTR-212)
viii. Electrical Machines/Motors and Generators (ELTR-243)
ix. Electronics-1 (CIT-134)
x. Digital Logic Design (ET-282)
xi. Digital Circuits & Microprocessor Applications (IT-254)

قومی ترانہ

پاک سَر زمین شاد باد! کشورِ حسین شاد باد!
تو نِشانِ عزمِ عالی شان ارضِ پاکستان
مرکزِ یقین شاد باد!

پاک سر زمین کا نِظام قُوّتِ اُخوّتِ عوام
قوم ، مُلک ، سلطنت پائندہ تابندہ باد!
شاد باد منزلِ مُراد!

پرچَمِ سِتارہ و ہِلال رہبرِ ترقی و کمال
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سایۂ خُدائے ذُوالجلال!

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