LECTURER NOTES

ON

BASIC ELECTRICAL

COMMON FOR 1st and 2nd SEMESTER (E&TC)

Prepared By

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Course Contents:

1. FUNDAMENTALS

1.1 Concept of current flow.
1.2 Concept of source and load.
1.3 State Ohm's law and concept of resistance.
1.4 Relation of V, I & R in series circuit.
1.5 Relation of V, I & R in parallel circuit.
1.6 Division of current in parallel circuit.
1.7 Effect of power in series & parallel circuit.
1.8 Kirchhoff's Law.
1.9 Simple problems on Kirchhoff's law.

2. A.C. THEORY

2.1 Generation of alternating emf.
2.2 Difference between D.C. & A.C.
2.3 Define Amplitude, instantaneous value, cycle, Time period, frequency, phase angle, phase difference.
2.4 State & Explain RMS value, Average value, Amplitude factor & Form factor with Simple problems.
2.5 Represent AC values in phasor diagrams.
2.6 AC through pure resistance, inductance & capacitance
2.7 AC though RL, RC, RLC series circuits.
2.8 Simple problems on RL, RC & RLC series circuits.
2.9 Concept of Power and Power factor
2.10 Impedance triangle and power triangle.

3. GENERATION OF ELECTRICAL POWER

3.1 Give elementary idea on generation of electricity from thermal , hydro & nuclear power station with block diagram

4. CONVERSION OF ELECTRICAL ENERGY (No operation, Derivation, numerical problems)

4.1 Introduction of DC machines.
4.2 Main parts of DC machines.
4.3 Classification of DC generator
4.4 Classification of DC motor.
4.5 Uses of different types of DC generators & motors.
4.6 Types and uses of single phase induction motors.
4.7 Concept of Lumen
4.8 Different types of Lamps (Filament, Fluorescent, LED bulb) its Construction and Principle.
4.9 Star rating of home appliances (Terminology, Energy efficiency, Star rating Concept)

5. WIRING AND POWER BILLING

5.1 Types of wiring for domestic installations.
5.2 Layout of household electrical wiring (single line diagram showing all the important component in the system).
5.3 List out the basic protective devices used in house hold wiring.
5.4 Calculate energy consumed in a small electrical installation

6. MEASURING INSTRUMENTS

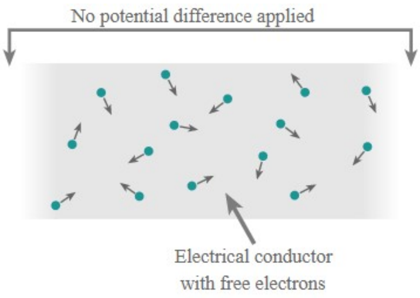
6.1 Introduction to measuring instruments.
6.2 Torques in instruments.
6.3 Different uses of PMMC type of instruments (Ammeter & Voltmeter).
6.4 Different uses of MI type of instruments (Ammeter & Voltmeter).
6.5 Draw the connection diagram of A.C/ D.C Ammeter, voltmeter, energy meter and wattmeter. (Single phase only).

Electric current:

Definition: **Electric current** is **defined** as the rate of **flow** of negative charges of the conductor. In other words, the continuous **flow** of electrons in an **electric circuit** is called an **electric current**. The conducting material consist a large number of free electrons which move from one atom to the other at random.
One very important point to note about the electrons is that they are charged particles - they carry a negative charge. If they move then an amount of charge moves and this is called **current**.

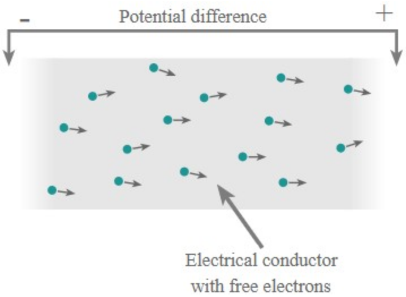
It is also worth noting that the number of electrons that able to move governs the ability of a particular substance to conduct electricity. Some materials allow current to move better than others.

The motion of the free electrons is normally very haphazard - it is random - as many electrons move in one direction as in another and as a result there is no overall movement of charge.



If a force acts on the electrons to move them in a particular direction, then they will all drift in the same direction, although still in a somewhat haphazard fashion, but there is an overall movement in one direction.

The force that acts on the electrons is called and electromotive force, or EMF, and its quantity is voltage measured in volts.



To gain a little more understanding about what current is and how it acts in a conductor, it can be compared to water flow in a pipe. There are limitations to this comparison, but it serves as a very basic illustration of current and current flow.

The current can be considered to be like water flowing through a pipe. When pressure is placed on one end it forces the water to move in one direction and flow through the pipe. The amount of water flow is proportional to the pressure placed on the end.

When the pressure is applied to the pipe, or the water is allowed to flow as a result of a tap being opened, then the water flows virtually instantaneously. The same is true for the electrical current.

The unit of current is "**Ampere**" and denoted by **I**

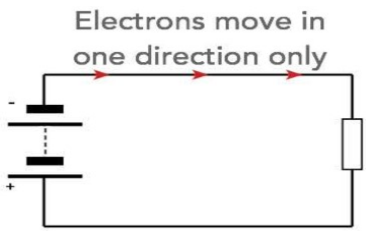
The time rate of flow of electric charge is current $I = \frac{dq}{dt}$

One of the major distinctions in the type of current flow in a circuit is whether the current is an alternating current, AC, or direct current, DC.

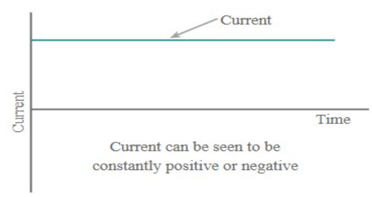
AC & DC electricity are both widely used in electrical and electronic circuits, each being used for different purposes.

What is direct current, DC:

As the name implies direct current, DC is a form of electricity that flows in one direction – it is direct and this gives it its name.



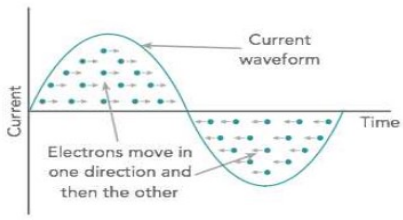
Direct current in a basic circuit



Graph showing direct current attributes

What is alternating current, AC:

Alternating current, AC is different to direct current. As the name implies, it flows first in one direction and then the other.



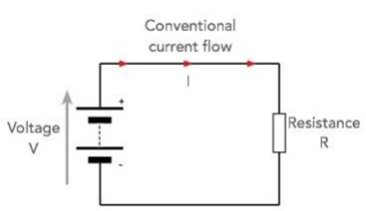
Graph explaining alternating current

The graph above shows the current waveform varying as a sine wave, with the current first moving in one direction and then the other.

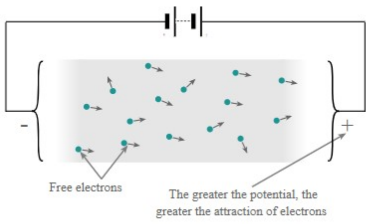
Often it is more usual to see the voltage variations. Again for an alternating waveform the voltage will vary positive and negative.

What is Voltage:

Voltage can be considered as the pressure that forces the charged electrons to flow in an electrical circuit. This flow of electrons is the electrical current that flows



Voltage shown within a simple circuit



The higher the voltage potential difference, the greater the attraction of electrons and greater the current flow

If a positive potential is placed on one end of a conductor, then this will attract that negative charges to it because unlike charges attract. The higher the potential attracting the charges, the greater the attraction and the greater the current flow.

In essence, the voltage is the electrical pressure and it is measured in volts which can be represented by the letter V.

Normally the letter V is used for volts in an equation like Ohm's law, but occasionally the letter E may be used - this stands for EMF or electro-motive force.

To gain a view of what voltage is and how it affects electrical and electronic circuits, it is often useful as a basic analogy to think of water in a pipe, possibly even the plumbing system in a house. A water tank is placed up high to provide pressure (voltage) to force the water flow (current) through the pipes. When greater the pressure, then higher the water flow.

The unit of voltage is **"Volt"** and denoted by **V.**

What is Resistance:

There are three basic measurements which can be made in an electrical circuit. Voltage and current are the first two, and the third is resistance.

Resistance is the hindrance to the flow of electrons in material. While a potential difference across the conductor encourages the flow of electrons, resistance discourages it. The rate at which charge flows between two terminals is a combination of these two factors.

In most cases conductors are required to carry current with as little resistance as possible. As a result copper is widely used because current flows easily within its structure. Also its cross sectional area is made wide enough to carry the current without any undue resistance.

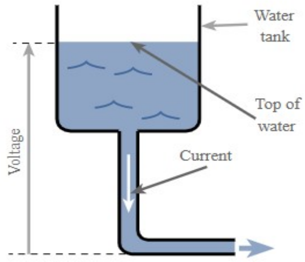
In some instances it is necessary to have elements which resist the flow of current. These items are called resistors and they are made out of materials which do not conduct electricity as well as materials like copper or other metals.

The unit of resistance is **"Ohm"** and denoted by **R.**

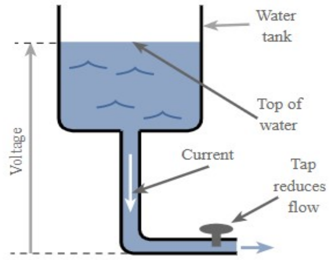
Resistance analogy:

The concept of resistance is not always easy to understand because it is not possible to visibly see the quantities involved: voltage, current and resistance itself are all rather invisible quantities to the naked eye, although they can be detected and measured in a variety of ways.

One analogy that helps introduce the concept of resistance is that of a water tank with a pipe leading down from it. Whilst we don't want to take the analogy too far it does help to explain the basic concept.



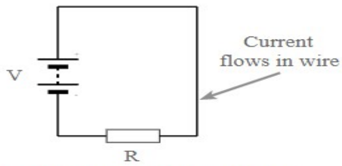
Analogy of a water tank and pipe to illustrate the concept of resistance



Adding a tap reduces the water flow and this is analogous to increasing the resistance

In this analogy, the water pressure caused but the height of the water is analogous to the voltage, the flow of water is analogous to the current, and the restriction of the water flow caused by the pipe is analogous to the resistance.

It can be seen that if the pipe was narrowed, or a tap added, the water flow would be further restricted and less water would flow. This would be analogous to increasing the resistance in an electrical circuit, and this would reduce the current flow.



Simple circuit showing voltage and resistance

In a simple circuit comprising of a battery or voltage source and a resistor, then assuming the connecting wires have no resistance, then the higher the resistance the less the current that will flow.

The tap in the analogy of the water system corresponds to changing the resistance of the resistor. When the tap is off, then this is equivalent to a switch stopping any current flow into the electrical circuit.

Relationship between resistance, voltage and current:

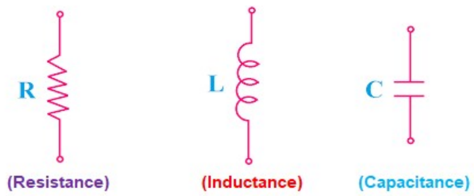
In fact there is a relationship between voltage, resistance and current. Knowing two of the variables, it is possible to calculate the third.

The relationship between resistance, voltage and current is known as Ohm's law and it is one of the fundamental relationships in electrical and electronic science.

$$V = IR$$

Load:

The electrical load is an application consuming electrical power and is represented by R(Resistance), L(Inductance), C(Capacitance), E(back EMF) etc. or combination of these circuit elements.



What is Power:

Whether power is used in a mechanical environment or an electrical environment, the definition of power is still the same. The way in which it may be discussed may be slightly different, but nevertheless the definition and actuality of it is exactly the same.

Electric power is the rate, per unit time, at which electrical energy is transferred by an electric circuit. It is the rate of doing work.

The unit of power is the **Watt** which is denoted by the symbol W

Electrical definition of the watt: one watt is the rate at which work is done when a current of one ampere, I of current flows through a network which has an electrical potential difference of one volt, V.

$$W = V\,I$$

The amount of power dissipated in a circuit can be easily determined. It is simply the product of the potential difference or voltage across the particular element, multiplied by the current flowing through it.

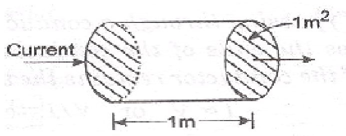
Ohm's law and concept of resistance:

"At a constant temperature, the current passing between the two points of a conductor is directly proportional to the potential difference existing between the two points."

Mathematically, $I \propto V$ or $V = IR$ (R is a constant of proportionality)

Electrical current in a conductor consists of movement of electrons. When electrons flow through a material they collide with other atomic particles and energy is lost in the form of heat due to these collisions and this is represented by resistance.

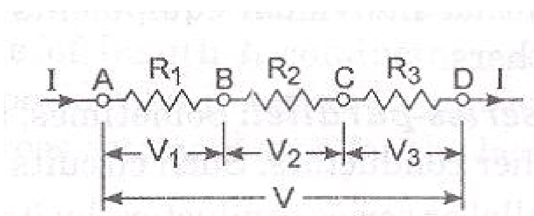
Resistance is the property of a material by virtue of which it opposes the flow of electrons (or current) through it. The opposition to flow of current is due to above collisions of electrons.
Resistance of a conductor depends on its Length (L), Area of cross-section (A) and specific resistance or resistivity (ρ) of the material and is given by: $R = \rho L/A$



[In the above figure a conductor is shown with its length (L) = 1 metre & Area of cross-section (A) = 1m2]

Relation of V and I in series circuit:

Conductors are said to be connected in series if they are connected end to end, one after another so that one end of the first conductor and one end of the last conductor are free and same current flows through all conductors and potential difference across each one is different depending upon their resistances. In figure below, A & D are free ends of three conductors AB, BC & CD connected in series and let R_1, R_2 & R_3 be the respective resistances.



Let, R = Resistance of the combination

V = Total potential difference across resistances.

I = Strength of Current

Then V=IR

But V= sum of individual potential difference across R_1,R_2 & R_3

So,

$$V = V_1 + V_2 + V_3 = IR_1 + IR_2 + IR_3$$

From above equations we get: $IR = I R_1 + IR_2 + IR_3$

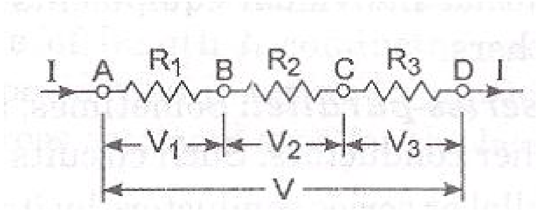
Hence, $R = IR_1 + R_2 + R_3$

It follows from the above that if a number of conductors are connected in series then the combined resistance of the combination equals the sum of the individual resistances.

Voltage division rule in Series Circuit:

The voltage division rule is one of the basic rules of circuit analysis. It is applicable to all series and combination resistor circuits.

The voltage across each resistor, by ohm's law, is the current flowing through the circuit multiplied by the value of resistance. Consider a circuit with a 3 number of resistors connected in series and with a voltage V applied across it.



The total resistance offered by this series connection of resistors to the flow of current will be equal to the sum of individual resistances.

$$R_T = R_1 + R_2 + R_3$$

The total current flowing through the resistor shall be:

$$I = V / R_T \quad \text{——————— (i)}$$

The voltage across each resistor R_1 shall be

$$V_1 = I.R_1 \quad \text{——————— (ii)}$$

The voltage across each resistor R_2 shall be

$$V_2 = I.R_2 \quad \text{——————— (iii)}$$

The voltage across each resistor R_3 shall be

$$V_3 = I.R_3 \quad \text{——————— (iv)}$$

Comparing (i) and (ii),

$$V_1 = V.R_1/R_T$$

Comparing (i) and (iii),

$$V_2 = V.R_2/R_T$$

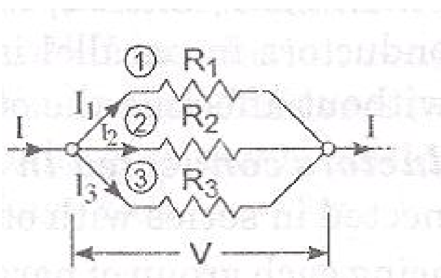
Comparing (i) and (iv),

$$V_3 = V.R_3/R_T$$

The voltage across any resistor in a series connection of resistors shall be equal to the ratio of the ohmic value of the resistor divided by the equivalent resistance of the circuit. This is called the Voltage division rule.

Relation of V and I in parallel circuit:

Conductors are said to be connected in parallel if all of them are connected across two common points. In figure P.1 below three conductors of resistances R_1, R_2 & R_3 are connected between the common points A & B. It will be observed that same potential difference exists between the ends of each conductor but the amount of current passing through each is different depending upon their resistances.



Suppose the main current I is divided into I_1, I_2 & I_3 through the resistors R_1, R_2 & R_3 respectively.

Let, R = Resistance of the combination between A & B

V = potential difference

I = Strength of Current

Then, $$I = \frac{V}{R} \text{ .... (i)}$$

By KCL, the main current entering this combination must come out as such &

Hence, $$I = I_1 + I_2 + I_3$$

Then, $$I = \frac{V}{R1} + \frac{V}{R2} + \frac{V}{R3} \text{ .... (ii)}$$

From equations (i) & (ii) we get

$$\frac{V}{R} = \frac{V}{R1} + \frac{V}{R2} + \frac{V}{R3}$$

Hence, $$\frac{1}{R} = \frac{1}{R1} + \frac{1}{R2} + \frac{1}{R3}$$

(or) $$R = \frac{R1R2R3}{R1R2+R2R3+R3R}$$

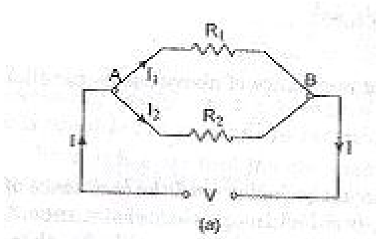
It follows from the above that if a number of conductors are connected in parallel then the reciprocal of combined resistance is equal to the sum of the reciprocals of individual resistances.

Division of Current in parallel circuit:

The ratio of total resistance to individual resistance is the same ratio as the individual (branch) current to the total current.

Let us consider two resistors connected in parallel as shown in Figure below across a voltage V. Then, by ohm's Law current in branches is

$$I_1 = \frac{V}{R1} \quad \& \quad I_2 = \frac{V}{R2}$$



Also considering the total current I & the total equivalent resistance of combination:

i.e. Total resistance: $R = \frac{R1R2}{R1+R2}$

We know that, $V = IR$

$$V = I\left(\frac{R1R2}{R1+R2}\right)$$

From above we get:

$$V = I_1R_1 = I_2R_2 = I\left(\frac{R1R2}{R1+R2}\right)$$

$$I_1 = I\left(\frac{R2}{R1+R2}\right)$$

$$I_2 = I\left(\frac{R1}{R1+R2}\right)$$

Hence, it is observed that in a parallel connected circuit of two resistances the current through a branch is the product of total current entering the combination & the Ratio of resistance of opposite side of the side through which the current is determined & the sum of individual resistances.

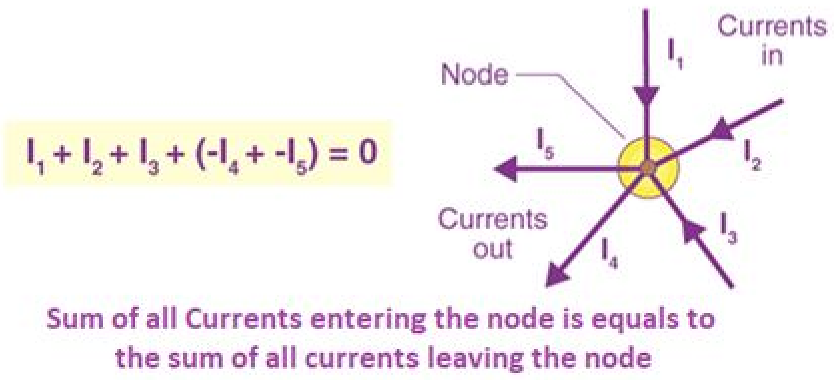
What are Kirchhoff's Laws?

In 1845, a German physicist, Gustav Kirchhoff, developed a pair of laws that deal with the conservation of current and energy within electrical circuits. These two laws are commonly known as Kirchhoff's Voltage and Current Law. These laws help calculate the electrical resistance of a complex network or impedance.

Kirchhoff's First Law or Kirchhoff's Current Law:

KCL or Kirchhoff's current law or Kirchhoff's first law states that the total current in a closed circuit, the sum of all entering currents at node is equal to the sum of all leaving current at the node or the algebraic sum of current at node in an electric circuit is equal to zero.

. This property of Kirchhoff law is commonly called Conservation of charge wherein, I(exit) + I(enter) = 0.

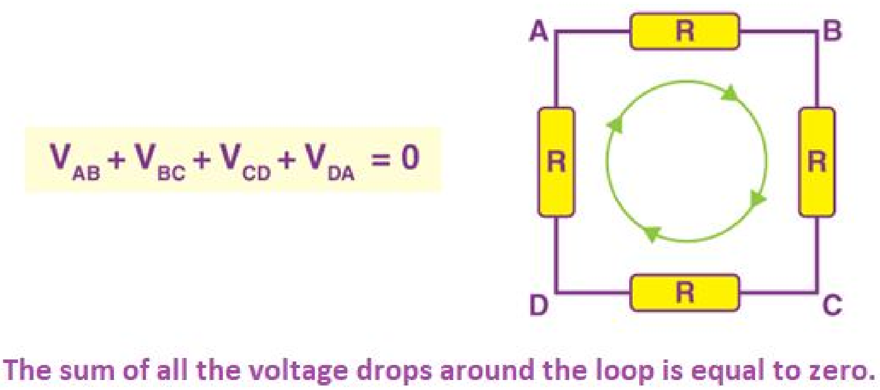


In the above figure, the currents I_1, I_2 and I_3 entering the node is considered positive, likewise, the currents I_4 and I_5 exiting the nodes is considered negative in values. This can be expressed in the form of an equation:

$$\mathbf{I_1 + I_2 + I_3 - I_4 - I_5 = 0}$$

Kirchhoff's Second Law or Kirchhoff's Voltage Law:

KVL or Kirchhoff's voltage law or Kirchhoff's second law states that, the algebraic sum of the voltage in a closed circuit is equal to zero or the algebraic sum of the voltage at node is equal to zero.

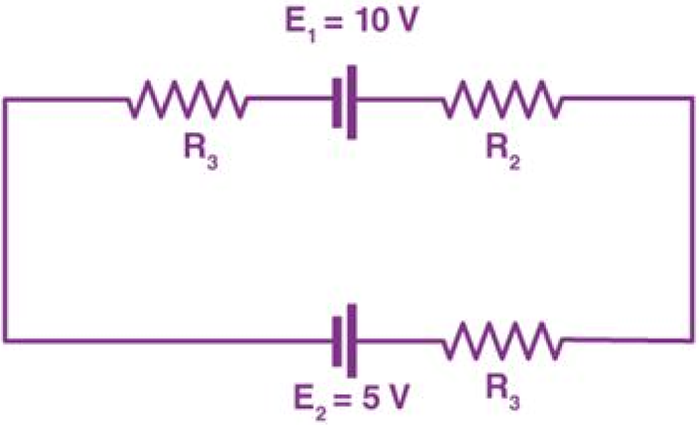


When you begin at any point of the loop and continue in the same direction, note the voltage drops in all the negative or positive directions and returns to the same point. It is essential to maintain the direction either counter clockwise or clockwise; otherwise, the final voltage value will not be zero.

When either AC circuits or DC circuits are analysed based on Kirchhoff's circuit laws, you need to be clear with all the terminologies and definitions that describe the circuit components like paths, nodes, meshes, and loops.

Assignment: 3:

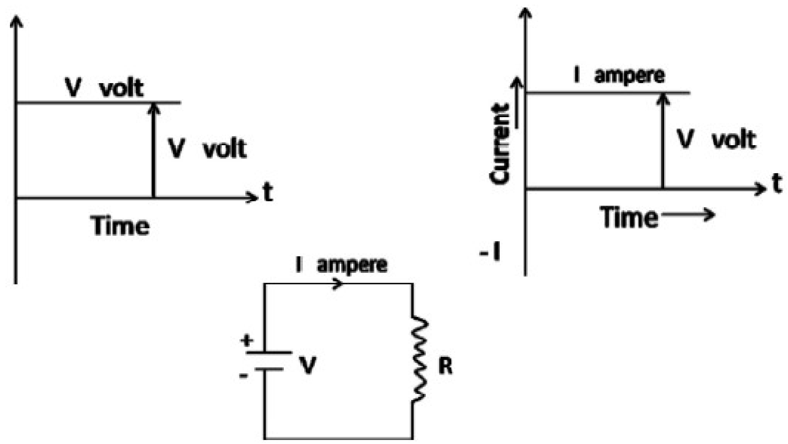
If $R_1 = 2\Omega$, $R_2 = 4\Omega$, $R_3 = 6\Omega$, determine the electric current that flows in the circuit below.



What is D.C:

1. The Direct current or D.C. always flows in one direction & its magnitude remains Unchanged.

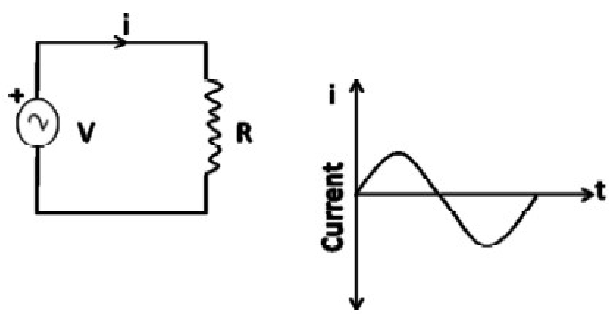
2. Here you see the voltage value is V volts & Current value is I amperes for all time to come i.e. as the time progresses.



[Figure (a)]

What is A.C:

1. The Alternating current or A.C. is one which changes both in its direction & its magnitude.



[Figure(b)]

The AC current shown in the above circuit reverses it direction after some time as you see in the wave form diagram.

AC waveforms can also be other than like a sine wave that will be discussed later on.

HOW A.C. IS DIFFERENT FROM D.C

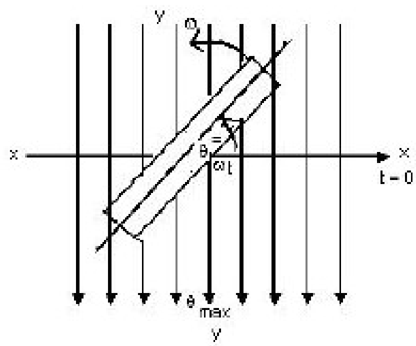
Alternating Current	**Direct Current**
1.The magnitude and direction both changes . 2. By using transformers, A.C. voltages can be increased or decreased as desired. 3. A.C. circuit current can be decreased by using choke or capacitor without any appreciable power loss. 4. A.C. can be converted into D.C. by using a device, called convertor (rectification circuit) 5. A.C. cannot be used directly for electroplating, electrotyping, etc.	1.Both magnitude & Direction remain constant. 2. No such provision can be made. 3.For decreasing D.C. circuit current, a resistance has to be used, whose power dissipation factor (I^2R) is large. 4. D.C. can be converted to A.C. by using choppers (inverters). 5. D.C. can be used directly for carrying out such operations.

Faradays laws of Electromagnetic Induction.

First Law- Whenever a coil cuts the magnetic lines of flux (φ) Electro-Magnetic Force (e.m.f) is induced in the coil i.e.

EMF Induced in a coil of N turns = $e= - N\, d\varphi/dt$

Second Law- The magnitude of e.m.f induced is directly proportional to the rate of change of Magnetic Flux cut by the coil i.e. $e= - N\, d\varphi/dt$



Generation of Alternating E.M.F.

GENERATION OF ALTERNATING EMF

Let there be a rectangular coil of N turns and is made free to rotate in a counter clockwise direction and is positioned inside the magnetic field produced by a north-south pole magnet as shown in the figure below.

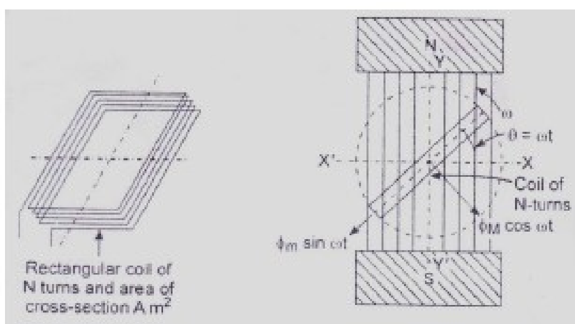


Fig. 5. Generation of alternating emf.

If the coil rotates at an angular velocity of ω radians per second then after a time of t seconds the coil will make an angle of θ= ωt degrees with the horizontal i.e. starting position.

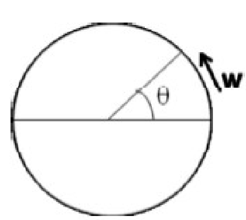
Component of flux perpendicular to the plane of the coil is : -

$\Phi=\Phi_M \cos\omega t$

Angle subtended by the coil in time t is

$\theta = \omega t$

So $\omega = \frac{\theta}{2}$



Magnetic Flux $= \emptyset = \emptyset_m \cos\omega t$

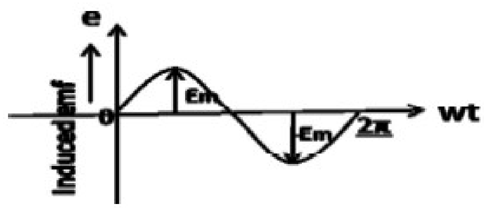
For N turns $N\emptyset = N \emptyset_m \cos\omega t$

Induced emf in the coil according to Faradays Law =

$e = -d(N\emptyset)/dt$ volt $= -d\{(N \emptyset_m \cos\omega t)\}/dt$ volts

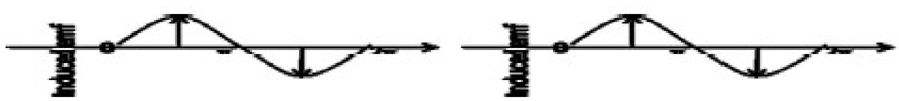
$= -N\emptyset_m\, d(\cos\omega t)/dt$ volts $= \omega N\emptyset_m \sin\omega t$ volt

$e = E_m \sin\omega t$ ($E_m = \omega N\emptyset_m$)



VARIOUS A.C. TERMS

AMPLITUDE: The maximum value (positive or negative) attained by an alternating quantity is called its Amplitude or Peak value.



CYCLE: One complete set of positive and negative values of an alternating quantity is known as cycle.

TIME PERIOD (T): The time period taken in seconds to complete one cycle of an alternating quantity is called its time period.

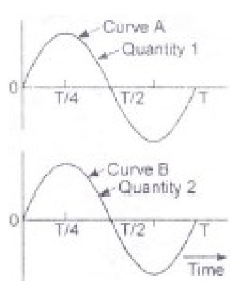
FREQUENCY (f): The number of cycles that occur in one second is called the frequency (f) of the alternating quantity.

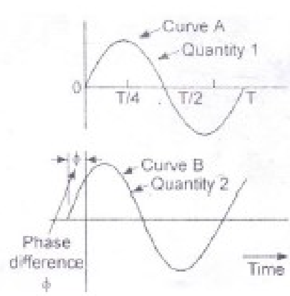
ALTERNATION: Alternation is one-half of the cycle of an alternating quantity.

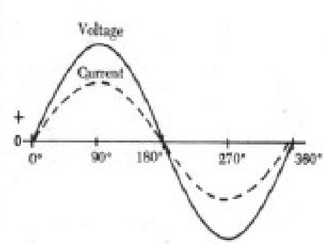
PHASE: Phase of an alternating quantity is the fraction of the time period or cycle that has elapsed since it last passed from the chosen zero position on origin.

PHASE DIFFERENCE: Phase difference between two alternating quantities is the fractional part of a period through which time of one alternating quantity has advanced over another alternating quantity.

INSTANTANEOUS VALUE: The value of an alternating quantity at any instant is called its instantaneous value.







AVERAGE VALUE

Average value of a.c. is that value of steady current (d.c.) which when flowing through a circuit transfers same amount of charge as is done by a.c. through the same circuit in same time.

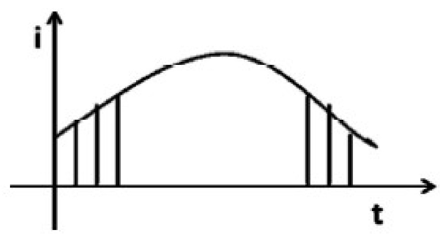
$$I_{av} = \frac{1}{T}\int_0^T i(t)dt or, I_{av} = \frac{1}{2\pi}\int_0^{2\pi} i d\theta$$

RMS / EFFECTIVE VALUE

The effective or r.m.s. value of an alternating current is that steady current (d.c.) which when flowing through a given resistance for a given time produces the same amount of heat as produced by the alternating current when flowing through the same resistance for the same time.

$$I_{rms} = \sqrt{\frac{1}{T}\int_0^T i^2 dt} = \sqrt{\frac{1}{2\pi}\int_0^{2\pi} i^2 d\theta}$$

Graphical Method



$$I_{rms} = \sqrt{\frac{i_1^2 + i_2^2 + \cdots + i_n^2}{n}}$$

Amplitude factor (peak factor)

The ratio of peak value or maximum value to r.m.s. value of an a.c. quantity is called Amplitude factor.

$$Amplitude\ factor\ (peak\ factor) = \frac{Maximum\ value}{R.M.S.value}$$

Form factor:

The ratio of R.M.S. value to average value of an a.c. quantity is called form factor.

$$Form\ factor = \frac{R.M.S.value}{Average\ value}$$

PHASOR REPRESENTATION OF ALTERNATING QUANTITY

A phasor is a vector rotating at a constant angular velocity in Counter-clockwise Direction.

At t_1, $e_1 = E_m \sin \omega t_1 = OA \sin \omega t_1$
At t_2, $e_2 = E_m \sin \omega t_2 = OA \sin \omega t_2$
At t_3, $e_3 = E_m \sin \omega t_3 = OA \sin \omega t_3$
At t_4, $e_4 = E_m \sin \omega t_4 = OA \sin \omega t_4$
At t_5, $e_5 = E_m \sin \omega t_5 = OA \sin \omega t_5$

and so on.

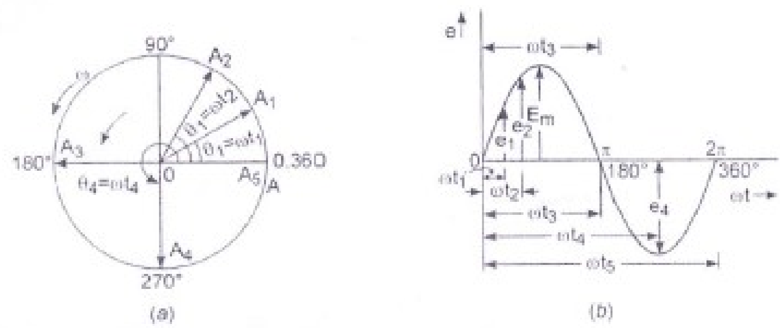


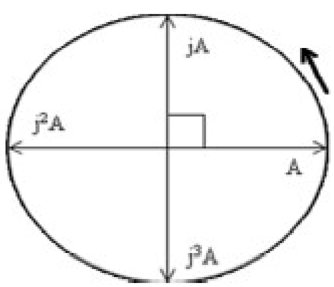
Fig. 7. Phasor (or vector) representation of alternating emf

Note: Instantaneous value of A.C. quantity is given by *projection of rotating vector at that instant on vertical axis.*

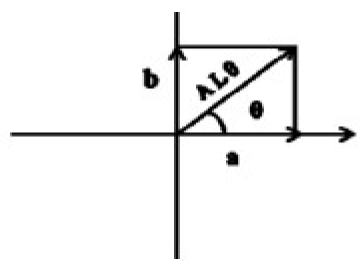
Phasor diagram is one in which different alternating quantities (sinusoidal) of the same frequency are represented by phasors with their correct phase relationship.

SIGNIFICANCE OF j- OPERATOR

Multiplication of a phasor with j rotates the phasor by an angle of π/2 or 90_0 in counter clock-wise direction.



$$j = \sqrt{-1}$$



REPRESENTATION OF PHASOR IN COMPLEX PLANE

I) Rectangular or Cartesian Form: A = a + jb, θ = tan_{-} (b / a)

II) Trigonometric Form (Euler's Identity): A = $Ae_{j\theta}$ = A (Cos θ + jSin θ)

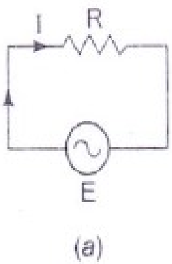
III) Polar Form: A = A ∟ θ

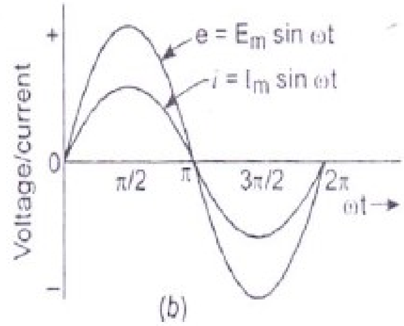
Discussion :

a. Convert 7+j24 to Polar coordinate? Modulus = = 25, But Argument\Angle =?

b. Convert 5 /_53.13_0 to Rectangular coordinate .[5(cos 53.13_0 +jsin 53.13_0)]

A.C. THROUGH PURELY RESISTIVE CIRCUIT





Ohm's law states

E = iR

E = Applied voltage

i = Instantaneous value of current

R = Ohmic resistance

Let us Find Current flowing in this circuit :

$E = E_m \text{ Sin } \theta = E_m \text{ Sin } wt$

Also e = iR (Ohm's law)

$iR = E_m \text{ Sin } wt$

$i = (E_m/R) \text{ Sin } wt = I_m \text{ Sin } wt$ (Where $I_m = E_m/R$)

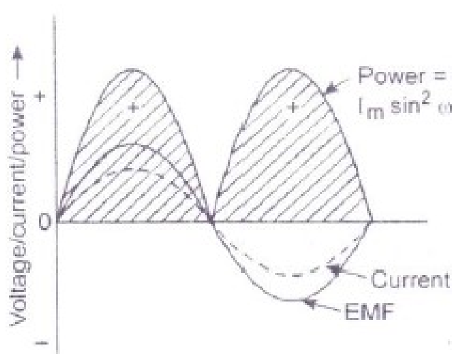
CONCLUSION: IN A PURELY RESISTIVE CIRCUIT THE APPLIED A.C. VOLTAGE & CIRCUIT CURRENT ARE IN-PHASE.

POWER IN A PURELY RESISTIVE CIRCUIT

$P = ei = E_m . I_m \text{ Sin}^2 wt = (E_m I_m/2) (1-\text{Cos } 2wt)$

CONCLUSION: AVERGE POWER DISSIPATION OVER COMPLETE CYCLE =

$$P = \frac{E_m I_m}{2} = \frac{E_m}{\sqrt{2}} . \frac{I_m}{\sqrt{2}} = E_{rms} I_{rms}$$



Comparison of power wave with that of voltage, and current in a purely resistive circuit

Let us Solve

A voltage v = 141 Sin (314t + π/3) is applied to a resistance of 10 Ω. Find the R.M.S and maximum value of current

i = V /R = (141/10) Sin (314t + π / 3)

= 14.1Sin (314t + π / 3)

Maximum value = ?

R.M.S value = Maximum value / √2 = ?

A.C. THROUGH PURELY INDUCTIVE CIRCUIT

Induced emf = e_{in} = - L

e = Applied voltage = - e_{in}

e = L di / dt = E_m Sin wt

di = (E_m /L)Sin wt .dt

On integration

i = E_m / L ∫ Sin wt . dt = E_m / wL (-Cos wt) = (E_m / wL) Sin (wt - π/ 2)

(where I_m = E_m / wL)

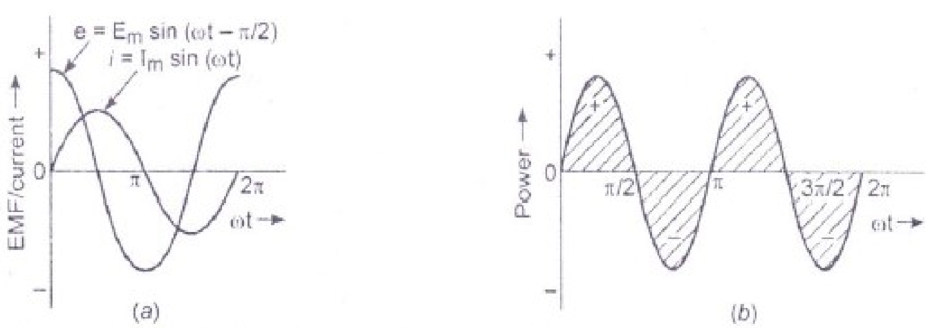
wL = 2 π fL = X_L = INDUCTIVE REACTANCE

A.C. circuit with inductance only.

CONCLUSION:

IN A PURELY INDUCTIVE CIRCUIT THE CIRCUIT CURRENT (I) LAGS BEHIND THE APPLIED A.C. VOLTAGE (e) BY AN ANGLE OF π / 2 OR 90^0.

POWER IN A PURELY INDUCTIVE CIRCUIT



Graphs for A.C. circuit containing inductance only for : (a) voltage, and current ; (b) power

p = ei = E_m . I_m Sin wt . Sin (wt - π / 2)

= - E_mI_m Sin wt . Cos wt = - (E_mI_m / 2) Sin 2wt

Power in complete cycle , P = - (E_mI_m / 2) ∫ Sin 2wt = 0

CONCLUSION:
AVERGE POWER DISSIPATION BY A PURELY INDUCTIVE A.C. CIRCUIT IS ZERO.
Discussion/Assignment

A voltage V = 141 Sin (314t + π / 3) is applied to a inductance of 0.1 H. Find X_L , i , I_{MAX}

Solution :

wL = 2 π fL

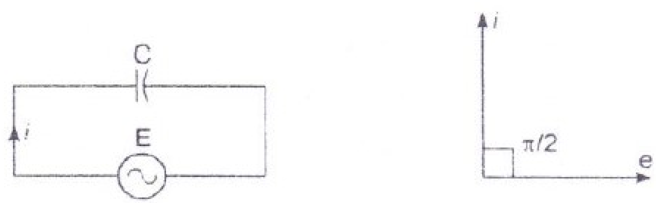
i.e., X_L = INDUCTIVE REACTANCE = 314 x 0.1 = WHAT

i = V_m / X_L = Sin (314t + (π / 3) – (π / 2))

= 141 / 31.4 Sin (314t - π / 6)

= 4.49 Sin (314t - π / 6)

Maximum value of current I_{MAX} = **FIND**
A.C. THROUGH PURELY CAPACITIVE CIRCUIT



A.C. through purely capacitive circuit

For a capacitor : C = q / v = q / e

q = C.e = C. E_m Sin ωt

(putting e=E_m Sin ωt)

i = dq / dt =

= ω.C. E_m Cos ωt

= Sin (wt+ π / 2) = Sin (wt+ π / 2)

= I_m Sin (wt+ π / 2) (where =)

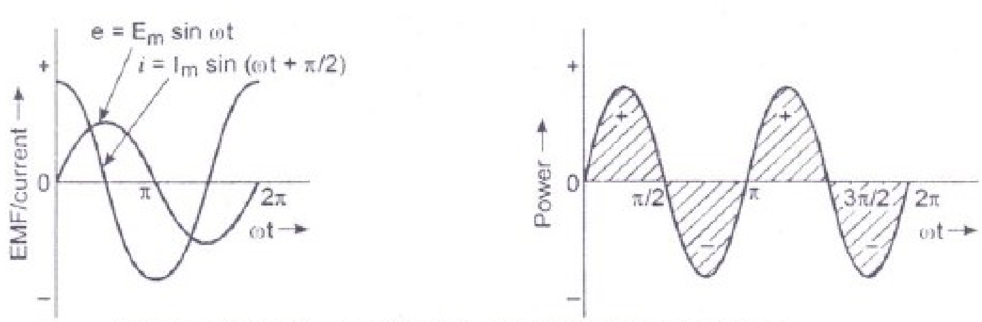
Where , Xc= = = Capacitive Reactance
CONCLUSION: IN A PURELY CAPACITIVE CIRCUIT THE CIRCUIT CURRENT (I) LEADS

THE APPLIED VOLTAGE (e) BY AN ANGLE OF π / 2 OR 90^0.

POWER IN A PURELY CAPACITIVE CIRCUIT

P = ei = E_m . I_m Sin wt . Sin (wt + π / 2)

= E_m .I_m Sin wt . Cos wt = ½ . E_mI_m Sin 2wt



Graphs of purely capacitive A.C. circuit for EMF, and current

CONCLUSION:
THE POWER DISSIPATION OVER A COMPLETE A.C. CYCLE IN A PURELY CAPACITIVE CIRCUIT IS ZERO.
Solve Yourself

A voltage V = 141 Sin (314t + π / 3) is applied to a 10 μf capacity. Find X_C , i , I_{rms}, I_{MAX}

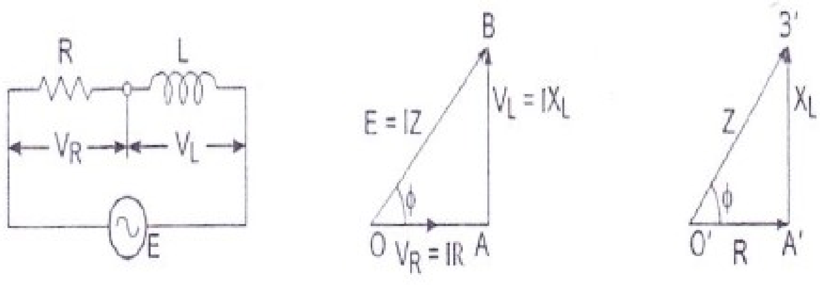
SOLUTION:

$X_C = 1/wc = 1/314 \times 10 \times 10^{-6}$ =v318.47 Ω

i = (141 / 318.47) Sin (314t + (π / 3) + (π / 2))

= 0.443 Sin (314t + 5π / 6)

Maximum value of current I_{MAX} = 0.443 Amp
I_{rms} = 0.443 / 2 = 0.313 Amp
A.C. THROUGH SERIES R-L CIRCUIT



(a) R - L series A.C. circuit ; (b) voltage triangle ; (c) impedance triangle.

Voltage across resistance = V_R = IR
Voltage across Inductance=V_L = IX_L

Supply voltage := E = $\sqrt{[V_R^2 + V_L^2]}$

= $\sqrt{[(IR)^2 + (IX_L)^2]}$

= I $\sqrt{[R^2 + X_L^2]}$

I = E / $\sqrt{[R^2 + X_L^2]}$

= E / Z

Where , Z = IMPEDANCE = $\sqrt{[R^2 + X_L^2]}$

∟Z = $\tan^{-}(X_L / R)$

CONCLUSION:
IN A SERIES R-L CIRCUIT CONNETED TO A.C. SUPPLY, THE APPLIED VOLTAGE (E) LEADS THE CIRCUIT CURRENT (I) BY AN ANGLE ϕ CALLED THE POWER FACTOR ANGLE.
POWER FACTOR IS COSINE OF THE ANGLE OF LEAD / LAG BETWEEN APPLIED VOLTAGE & CURRENT IN AN A.C. CURRENT.

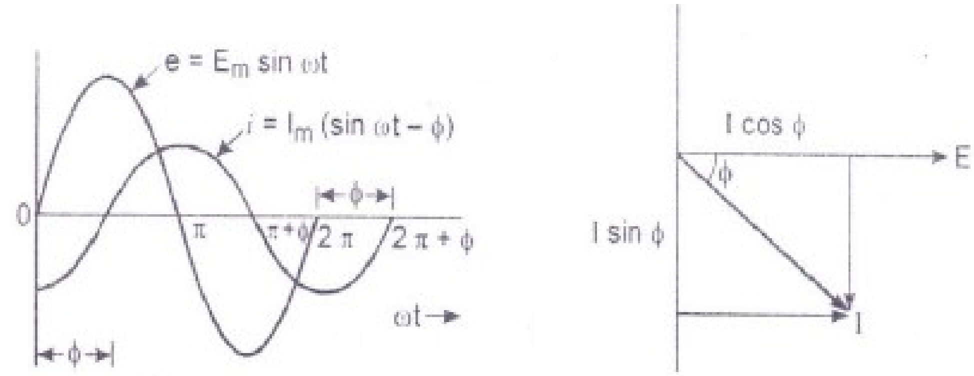
P.F. = Cos φ = (R / Z)

P = V.I. Cos φ = IZ.I.(R / Z) = I^2 R (ACTIVE POWER)

Q = V.I. Sin φ = IZ.I.(X_L / Z) = I^2X_L (REACTIVE POWER)

S = V.I = IZ.I = I^2Z (APPARENT POWER)

S = $\sqrt{(P^2 + Q^2)}$ & ∟S = $\tan^{-}(Q / P)$



Voltage, and current waves in R-L series A.C. circuit.

PROBLEM An:

Inductive coil takes 10 Amp when connected to 250v, 50hz mains. The power consumed is1000 watt. Find (a) Z, R, X_L L (b) Power factor, (c) App power and reactive power (d) Phase angle between V & I.

SOLUTION:

(a) Z = (V / I) = 250 / 10 = 25 Ω

P = VI Cos θ

Cos θ = (P / VI) = (1000 / (250x10)) = 0.4

Sin θ 0.917

R = ZCos θ = 25 x 0.4 = 10 Ω

X_L = Z Sin θ = 25 x 0.917 = 22.93 Ω

L = (X_L / W) = (22.93 / (2 π x 50)) = 0.073 H

(b) Power factor = Cos θ = 0.4 lagging

(c) App Power = S = VI = 2500 VA

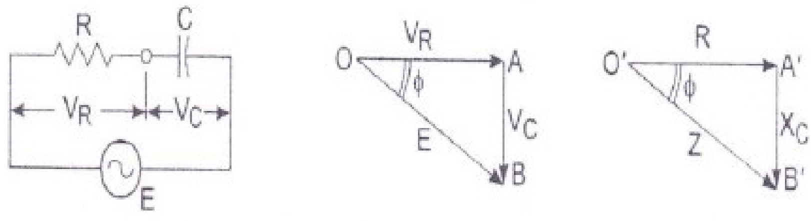
Reactive power = θ = VI Sin θ = 2500 x 0.917 = 2292.5 Vars

(d) Cos θ = 0.4

θ = 66.42^0

Current phasor lags voltage phasor by 66.42^0

A.C. THROUGH SERIES R-C CIRCUIT



(a) Series R-C A.C. circuit ; (b) voltage triangle ; (c) impedance triangle.

Voltage across resistance = $V_R = IR$

Voltage across capacitance= $V_c = IX_c$

Supply voltage := $E = \sqrt{[V_R^2 + V_c^2]}$

$V_R = IR$

$V_C = IX_C$

$E = \sqrt{[V_R^2 + V_C^2]}$

$= \sqrt{[(IR)^2 + (IX_C)^2]}$

$= I\sqrt{[R^2 + X_C^2]}$

$I = E / \sqrt{[R^2 + X_C^2]} = E / Z$

Z = IMPEDANCE = $\sqrt{[R^2 + X_C^2]}$

$\angle Z = \tan^{-1}(X_C / R)$

CONCLUSION:

IN A SERIES R-C CIRCUIT CONNETED TO A.C. SUPPLY, THE APPLIED VOLTAGE (E) LAGS THE CIRCUIT CURRENT (I) BY AN ANGLE φ CALLED THE POWER FACTOR ANGLE.

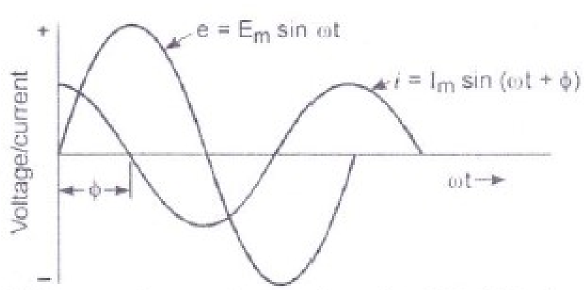
P.F. = $\cos \varphi = (R / Z)$

$P = V.I.\cos \varphi = IZ.I.(R / Z) = I^2 R$ (ACTIVE POWER)

$Q = V.I.\sin \varphi = IZ.I.(X_C / Z) = I^2 X_C$ (REACTIVE POWER)

$S = V.I = IZ.I = I^2 Z$ (APPARENT POWER)

$S = \sqrt{P^2 + Q^2}$ & $\angle S = \tan^{-1}(Q / P)$



Voltage, and current waves in series R-C A.C. circuit.

PROBLEMA

Voltage V = V2 (230) Sinwt is applied to a series RC Circuit having R = 20 Ω and C = 100 μF.

Find (a) X_C , Z, (b) Y, B, G, (C) Current and power factor (d) S, P, Q (e) Write expression for instantaneous current.

SOLUTION: V = 230 ∟ 0^0

(a) $X_C = (1 / wc) = (1 / 2 \pi \times 50 \times 100 \times 100 \times 10^{-6}) = 31.83\ \Omega$

$Z = R - jX_C = 20 – j31.83\ \Omega = 37.59 ∟-57.86\ \Omega$

(b) Y = (1 / Z) = Admittance = (1 / 37.59 ∟-57.86 = 0.0266∟57.86^0

= 0.01415 + j 0.0225 Siemens

Y = G + jB

So G = 0.01415 Siemens & B = 0.0225 Siemens

(c) I = (V / Z) = (230L0^0 / 37.59∟-57.86^0 = 6.12 ∟57.86^0 Amp

Power factor = Cos (57.86^0) = 0.522 leading

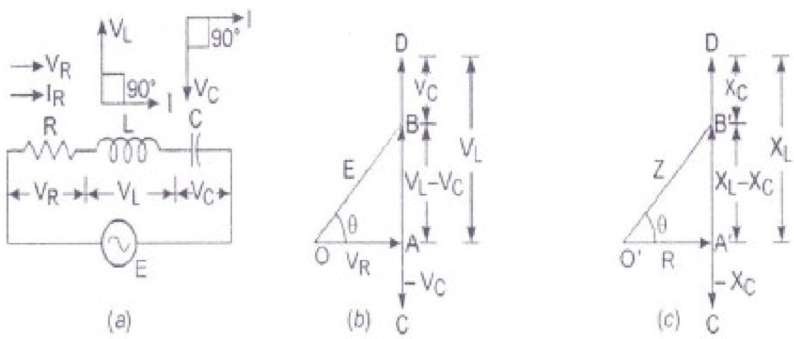
(d) App Power = S = VI = 230 x 6.12 = 1407.6 VA

Active power = P = VI Cos θ = (1407.6 x 0.532) = 748.84 watt

Reactive power = Q = - VI Sin θ = (- 1407.6 x Sin 57.86^0) = - 1191.9 Vars

(e) Instantaneous value = 2 x 6.12 Sin (wt + 57.86^0) = 8.65 Sin (wt + 57.86^0)

A.C. THROUGH SERIES R-L-C CIRCUIT



(a) Series R-L-C A C circuit ; (b) voltage triangle ; (c) impedance triangle.

Voltage across resistance = V_R = IR

Voltage across Inductance=$V_L = IX_L$

Voltage across capacitance=$V_c = IX_c$

Supply Voltage= E = √[V_R

$^2 + (V_L – V_C)^2$] = √[$(IR)^2 + (IX_L-IX_C)^2$]

= I √[$R^2 + (X_L-X_C)^2$]

I = E / √[$R^2 +(X_L-X_C)^2$] = E / √[$R^2 + X^2$] = E / Z

Z = IMPEDANCE = √[$R^2 + (X_L-X_C)^2$]

∟Z = $\tan^{-} (X_L - X_C) / R$

CONCLUSION:
IN A SERIES R-L-C CIRCUIT CONNETED TO A.C. SUPPLY, THE APPLIED VOLTAGE (E) LEADS THE CIRCUIT CURRENT (I) IF $X_L > X_C$ & LAGS BEHIND CIRCUIT CURRENT IF $X_L < X_C$ & REMAIN IN-PHASE IF $X_L = X_C$.

P.F. = Cos φ = (R / Z) = R / √{ $R^2 + (X_L - X_C)^2$

P = V.I. Cos φ = IZ.I.(R / Z) = I^2 R (ACTIVE POWER)

Q = V.I. Sin φ = IZ.I. ((X_L-X_C) / Z) = I^2 [X_L-X_C] (REACTIVE POWER)

S = V.I = IZ.I = I^2Z (APPARENT POWER)

S = √[$P^2 + Q^2$ & ∟S = $\tan^{-}$ ((X_L-X_C) / R)

PROBLEMA

Resistance of 10 Ω, inductance of 0.1 H & capacitance 50 micro farad are connected in series across a 230v, 50Hz supply. Find (a) X_L , X_C & Z, (b) I & Power factor (C) Active, reactive and apparent power (d) Y, G, B

SOLUTION: V = 230 L 0^0

(a) wL = 2 π fL = X_L = INDUCTIVE REACTANCE

2 π fL = 2 π 50 x 0.1 = 31.41 Ω

X_C = (1 / wc) = (1 / 2 π50 x 50 x 10^{-6}) = 63.66 Ω

Z = R + j (X_L - X_C) = 10 + j (31.41-63.66) = 10 – j32.25 = 33.76 ∟-72.77^0

(b) I = CURRENT = (V / Z) = (230∟0^0 / 33.76∟-72.77^0 = 6.8 ∟72.77^0 Amp

Power factor = Cos (72.77^0) = 0.296 leading

(c) App Power = S = VI = 230 x 6.8 = 1564 VA

Active power = P = VI Cos θ = (1564 x 0.296) = 462.9 watt

Reactive power = Q = VI Sin θ = (1564 x Sin -72.77^0) = -1496.80 Vars

(d) Y = (1 / Z) = Admittance = (1 / 33.76 ∟-72.77^0 = 0.0296 ∟ 72.77^0

= 0.00877 + j 0.0283 Siemens

Y = G + jB

So G = 0.00877 Siemens & B = 0.0283 Siemens

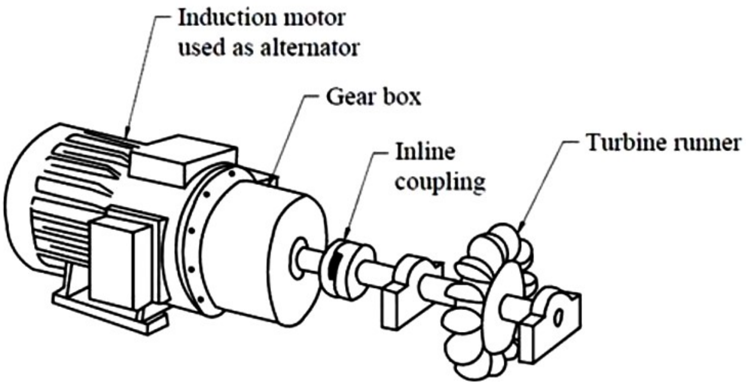
…………………xxx………………………………

CHAPTER 3:GENERATION OF ELECTRIC POWER

GENERATION OF ELECTRICAL ENERGY:

The conversion of energy available in different forms in nature into electrical energy is known as **Generation of Electrical Energy**.

Energy is available in various forms from different natural sources such as pressure head of water, chemical energy of fuels, nuclear energy of radioactive substances etc. All these forms of energy can be converted into electrical energy by the use of suitable arrangements. The arrangement essentially employs an alternator coupled to prime mover. The prime mover is driven by the energy obtained from various sources such as burning of fuel, pressure of water, force of wind etc.



Sources of Energy:

Since electrical energy is produced from energy available in various forms in nature, it is desirable to look into the various sources of energy. These sources of energy are:

(i) The Sun (ii) The Wind (iii) Water (iv) Fuels (v) Nuclear Energy

Out of these sources, the energy due to Sun and Wind has not been utilised on large scale due to number of limitations. At present, the other three sources Water, Fuels and Nuclear energy are primarily used for generation of electrical energy.

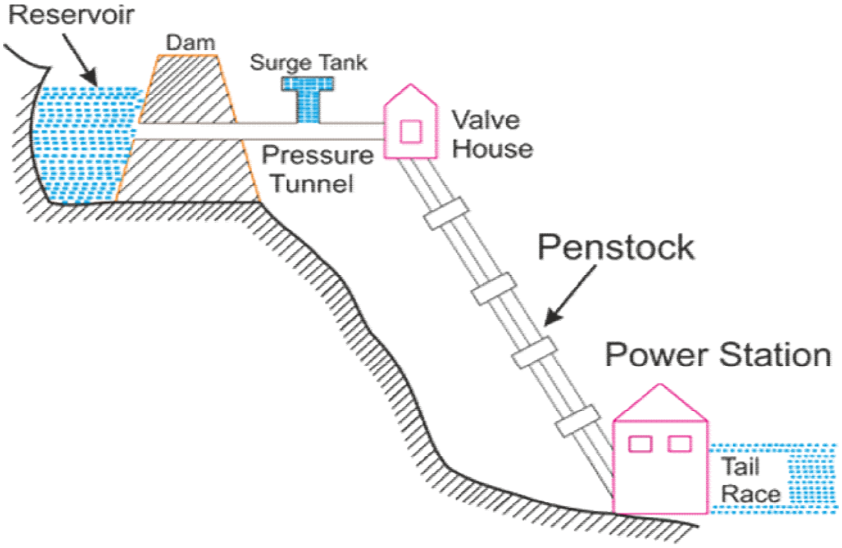
Bulk electric power is produced by special plants known as **Generating Station or Power Plants**.

A generating station essentially employs a prime mover coupled to an alternator for production of electric power. The prime mover converts energy from some other form into mechanical energy. The alternator converts mechanical energy of the prime mover into electrical energy. The electrical energy produced by generating station is transmitted and distributed with the help of conductors to various consumers.

Depending upon the form of energy converted into electrical energy, the generation stations are classified as under:

1. HYDRO-ELECTRIC POWER STATION
2. STEAM POWER STATION (THERMAL STATION)
3. NUCLEAR POWER STATION

HYDRO-ELECTRIC POWER STATION:



CHOICE OF SITE:

1. AVAILABILITY OF WATER: Since the primary requirement of a hydro-electric power station is the availability of huge quantity of water at a good head this requirement is very essential.

2. STORAGE OF WATER: There are wide variations in water supply from a river or canal during the year.This makes it necessary to store water by constructing a Dam in order to ensure the generation of power throughout the year.

3. COST & TYPE OF LAND: The land for the construction of Plant should be available at a reasonable price. Further the bearing capacity of the ground should be adequate to withstand the weight of heavy equipment to be installed.

4. TRANSPORTATION FACILITY: The site selected should be accessible by Rail and Road so that necessary equipment and machineries be easily transported.

MAIN CONSTITUENTS OF PLANT:

1. DAM: A Dam is a barrier which stores water & creates water head. Dams are built of concrete or stone masonry, earth or rock fill.

2. SPILWAYS: There are times when the river flow exceeds the storage capacity of the reservoir. In order to discharge the surplus water from the storage reservoir into the river on the down-stream side of the dam, spill ways are used.

3. HEAD WORKS: The head works consists of the diversion structures at the head of an intake. They generally include booms and racks for diverting floating debris, sluices for by-passing debris, sediments and valves for controlling the flow of water to the turbine.

4. SURGE TANK: For close conduits abnormal pressure may cause damage to the conduit leading from head works to penstock. Surge tank acts as a protection for such situation.

5. PENSTOCKS: Penstocks are open or close conduits which carry water to the turbines. They are generally made of reinforced concrete or steel.

6. WATER TURBINES: Water turbines are used to convert the energy of falling water into mechanical energy.

7. ALTERNATOR: The alternator converts the mechanical energy of turbine to electrical energy.

WORKING OF HYDRO-ELECTRIC POWER PLANT:

When the water from Reservoir is allowed to get released through pressure channel, it reaches the Valve house.
The surge tank is provided in order to safe guard the extra back-thrust of water causing heavy damage to Penstock. The valve house controls the amount of water that will flow to the power house turbines through the large sized Pen-stocks.
Inside the power house the water Turbine converts the potential energy of water with sufficient head to Kinetic energy i.e. Mechanical Energy which in turn acts as a prime-mover for the Alternator as before and generates Electrical Energy.

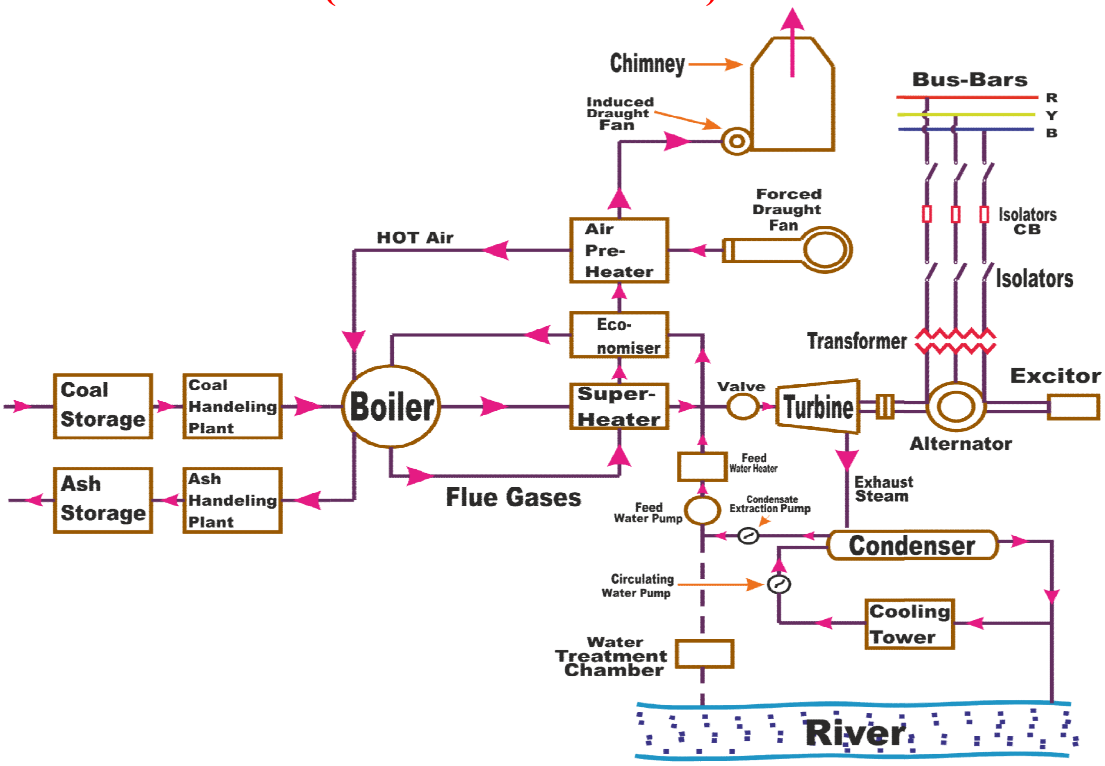
ADVANTAGES:

i) It requires no fuel as water is used for the generation of Electrical Energy.
ii) It is quite neat & clean as no smoke or ash is produced.
iii) Running cost is very less as water is used.
iv) It is simple in construction & requires less maintenance.
v) It can be started quality as compared to Thermal Power Station.
vi) In addition to generation of Electrical Energy these plants are also helpful in irrigation & control of floods.

DISADVANTAGES:

i) It involves high capital lost due to construction of dams.
ii) Generation depends on average rainfall round the year.
iii) High cost of transmission as these plants are located in hilly areas quite for off from localities.

STEAM POWER STATION (THERMAL STATION):



CHOICE OF SITE:

1. SUPPLY OF FUE:- The steam power station should be located near coal mines so that transportation cost of fuel is minimum.

2. AVAILABILITY OF WATER:- A huge amount of water is required for the condenser for which it is it is essential that the plant should be located at the bank of a river or near a canal to ensure continuous supply of water.

3. TRANSPORTATION FACILITIES:- A modern steam power station often requires the transportation of material and machinery. Therefore adequate transportation facilities by rail or Road should exist.

4. COST AND TYPE OF LAND:- The steam power station should be located at a place where land is cheap and further extension if necessary is possible.

5. NEARNESS TO LOAD CENTRES:- In order to reduce transmission cost the plant should be located near the centre of load.

6. DISTANCE FROM POPULATED AREA:- As huge amount of coal is burnt in a steam power Plant due to which smoke and fumes pollutes the surrounding area. This necessitates that plant should be locate at a considerable distance from the populated areas.

MAIN UNITS OF PLANT:

1. COAL STORAGE PLANT: Coal is transported to the power station by road or rail and is stored in coal storage plant.

2. COAL HANDLING PLANT: From the coal storage plant coal is delivered to the coal handling plant where it is pulverized for rapid combustion without using excess amount of air.

3. ASH STORAGE PLANT: The coal is burnt in the boiler & the ash produced after the complete combustion of coal is removed to the ash handling plant.

4. ASH HANDLING PLANT: the ash from ash handling plant is then delivered to the ash storage plant for subsequent use as fertilizer etc.

5. BOILER: The heat of combustion of coal in the boiler is utilized to convert water into steam at very high temperature and pressure. The flue gases from the boiler makes their journey through super heater, economizer, air pre-heater & are finally exhausted to the atmosphere through the chimney.

6. SUPERHEATER: The steam produced in the boiler is wet and is passed through super heater where it is dried and super heated.

7. ECONOMISER: An economizer is essentially a feed water heater & derives heat from the flue gases for the purpose.

8. AIR PREHEATER: Air pre-heater increases the temperature of the air supplied for coal burning by deriving heat from flue gases.

9. FORCED DRAUGHT FAN: It draws air from atmosphere which is supplied to the boiler for effective combustion.

10. INDUCED DRAUGHT FAN: it draws the flue gas and sends to chimney.

11. CHIMNEY: The hot flue gases go to the atmosphere though chimney.

12. STEAM TURBINE: The dry and super heated steam from the super heater is fed to the steam turbine which converts the heat energy of steam to mechanical energy.

13. ALTERNATOR: The alternator converts the mechanical energy of steam turbine to electrical energy.

14. CONDENSER: In order to improve the efficiency of the plant the steam exhausted from the turbine is condensed by means of a condenser. The condensate from the condenser is used as feed water to the boiler.

15. COOLING TOWER: The cooling tower provides a cooling arrangement for the feed water to be reused in boiler.

WORKING OF THERMAL POWER PLANT:

When the water from condenser is fed to the Boiler through Economiser it remains a little hot .The Boiler is extremely heated chamber because of a continuous burning of Coal in presence of air injected by F.D fan through pre-heater.

So, the water gets converted to steam with very high temperature and pressure and reaches the Steam Turbine through Super-Heater. The Internal Energy of Steam gets converted to Mechanical Energy by Turbine and the Alternator converts the mechanical Energy of Turbine output to Electrical Energy .The Electrical Energy thus produced is supplied to the Bus-Bar for Power use.

ADVANTAGES:

i) The Fuel (i.e. Coal) used is quite cheap.

ii) Less initial cost as compared to other generating stations.

iii) It can be installed at any place & the coal can be transported by Rail / Road.

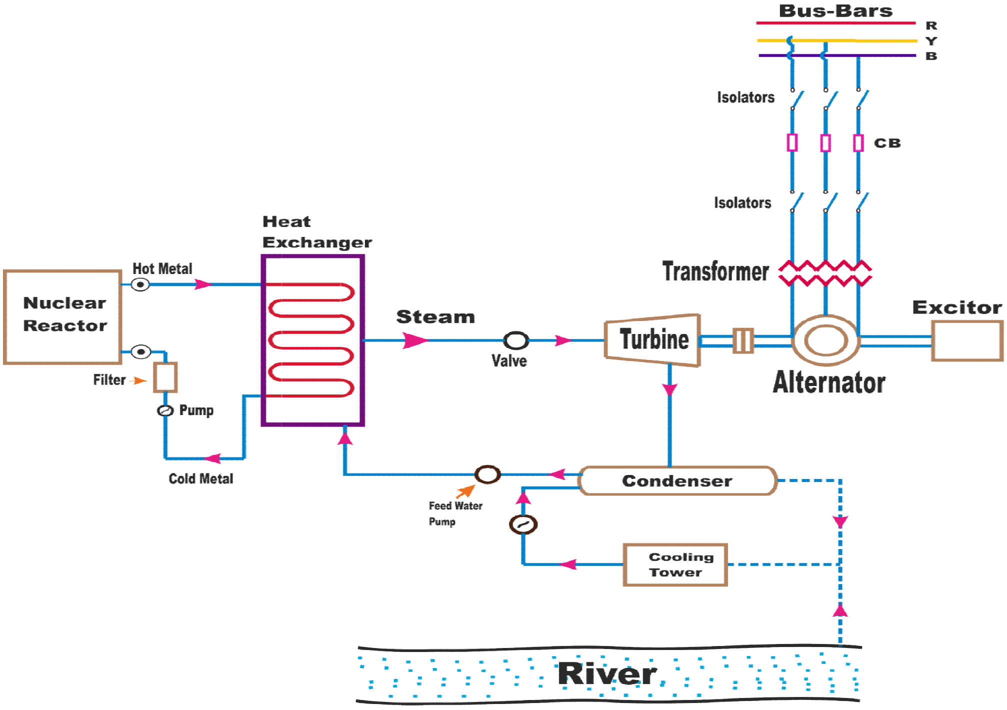
iv) It requires less space as compared to hydro-electric Power Station.

DISADVANTAGES:

i) It pollutes air / atmosphere due to smoke / fumes

ii) Running cost is higher than hydro power plant.

NUCLEAR POWER STATION:



CHOICE OF SITE:

1. AVAILABILITY OF WATER: A huge amount of water is required for the condenser for which it is it is essential that the plant should be located at the bank of a river or near a canal to ensure continuous supply of water.

2. DISPOSAL OF WASTE: The waste produced by fission in a nuclear power station is generally radioactive which must be disposed of properly to avoid health hazards for which it must be buried in deep trench.

3. DISTANCE FROM POPULATED AREA: The site for setting up a nuclear power station should be quite away from populated areas.

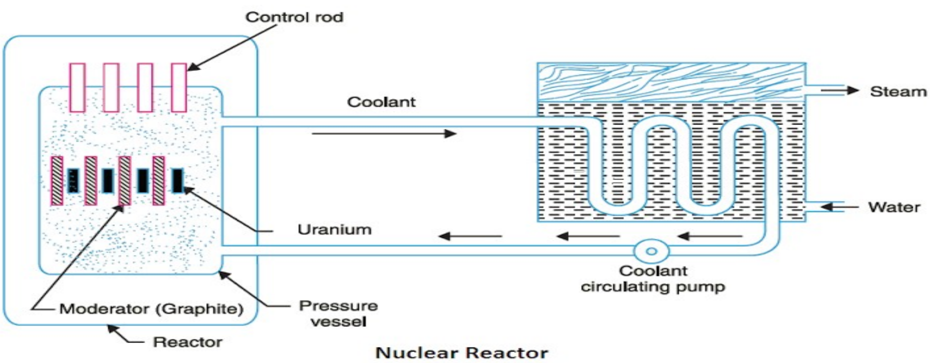
4. TRANSPORTATION FACILITY: The site selected for a nuclear power station should have adequate facilities in order to transport the heavy equipment during erection.

NUCLEAR FUEL

1. URANIUM(U_{235})
2. PLUTONIUM(Pu_{239})
3. THORIUM(Th_{232})

FISSION & CHAIN REACTION:

When a U-235 atom is struck by a slow neutron, it will split into two or more fragments. This is called a nuclear fission .This splitting (fission) is accompanied by release of thermal energy in large quantity and two or three fast neutrons. These fast moving neutrons are slowed down by moderators so that they have high probability to hit other u-235 atoms which in turn get fissioned and release heat and neutrons. This continuous self sustaining sequence of nuclear fissions is called CHAIN REACTION.



Nuclear Reactor

MAIN UNITS OF PLANT

1. NUCLEAR REACTOR: It is an apparatus in which the nuclear fuel(U_{235}) is subjected to nuclear fission.

2. HEAT EXCHANGER: The coolant gives up heat to the heat exchanger which is utilized in raising the steam & after giving up heat the coolant is again fed to the reactor.

3. STEAM TURBINE: The dry and super heated steam from the super heater is fed to the steam turbine which converts the heat energy of steam to mechanical energy.

4. ALTERNATOR: The alternator converts the mechanical energy of turbine to Electrical Energy.

WORKING OF NUCLEAR POWER PLANT:

As discussed earlier, the chain reaction produces a huge amount of heat inside the Nuclear Reactor and requires a lot of care to control this reaction. The heat of the Reactor is carried to Heat-Exchanger by molten sodium which also heats the water injected into this Heat Exchanger chamber. After the water gets converted to steam with very high temperature and high pressure, the Turbine converts the internal Energy of steam to Mechanical Energy and this is converted to Electrical Energy by Alternator as before.

ADVANTAGES:

i) There is saving in fuel transportation as amount of fuel required is less.
ii) A Nuclear Power Plant requires less space as compared to other plants.
iii) This type of plant is economical for producing bulk Electrical Energy.

DISADVANTAGES:

i) Fuel is expensive and difficult to recover.
ii) Capital lost is higher than other plants.
iii) Experienced workman ship is required for plant erection & commissioning.
iv) The Fission by-products are radioactive & can cause dangerous radio-active pollution.
The disposal of by-product is big problem.

Er. K.Srinivas
BIET, Mohada

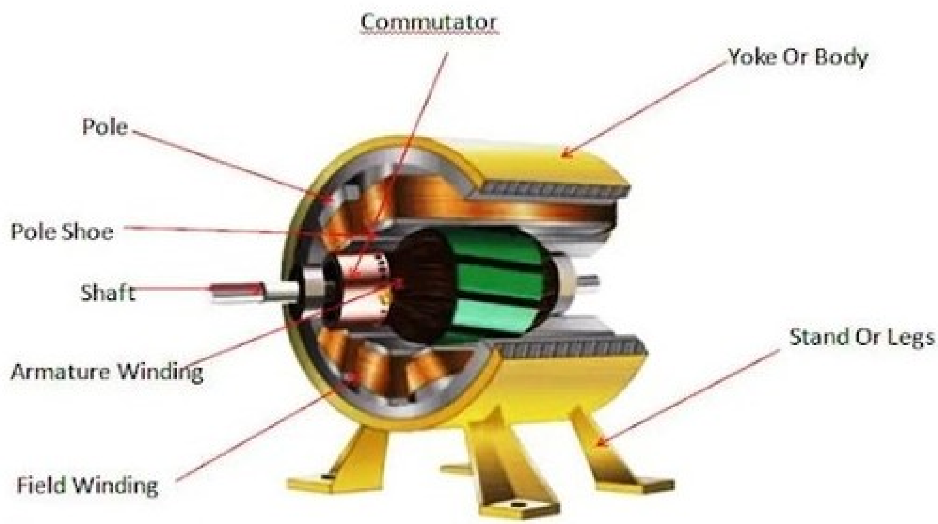
Ch-4: CONVERSION OF ELECTRICAL ENERGY:

Introduction

A d.c. machine is a device which converts mechanical energy into electrical energy. When the device acts as a generator mechanical energy is converted into electrical energy. On the other hand when the device acts as a motor, the electrical energy is converted into mechanical energy. However, during the conversion process a part of the energy is converted into heat, which is lost and is not reversible. Thus an electrical machine can be made to work either as a generator or a motor.

Main Parts of D.C. Machine

(1)Yoke or Magnetic frame (2) Pole Shoes and Pole Core (3) Armature Core
(4) Field Coils (5) Armature windings (6) Commutator
(7) Brushes and Bearings (8) Shaft (9) End Covers,
(10) Base.



Rotor

Rotor comes from the "rotate" meaning it is the electrical rotating part of a dc motor. Rotor is the moving parts of a dc motor. It dynamically moves when the voltage is applied to the armature winding. This will produce mechanical movement for a dc motor.

This one is the important parts of a dc motor. Rotor is built from:

- Shaft
- Armature core
- Brush
- Commutator
- Armature windings

Stator

Stator comes from the "stationary" meaning it is the electrical stationary parts of a dc motor. Stator does not move and only produces a magnetic field around the rotor to make the rotor rotating when the voltage is applied to it.

Stator is built from:

- Yoke or frame
- Field windings
- Poles

Brush

Brushes are attached to the commutator as a bridge to deliver the electrical energy from the supply circuit to the rotor. Brushes are usually made from Carbon or Graphite material.

Commutator

Commutator has the form of a split ring. The ring is made from copper and split in 2 or more depending on the number of armature windings. The split segment is connected to the armature winding.

The main purpose of the commutator is to deliver the electric current to the armature windings. The main idea of how a dc motor works is the interaction between North and South poles produced by armature windings and field windings. The generated north pole from the armature will be attracted to the south pole from the field winding and vice versa, producing rotating movement from the rotor. The constant torque produced by this rotor movement in one direction is called commutation.

Thus, the commutator is the part connected to the armature to do current switching for the armature windings. Each split ring segment is insulated each other with insulator material like a Mica. Summary, we deliver electric current from the supply to the brushes through to the commutator and then the armature windings.

Armature Windings

Armature winding is used to energize the static magnetic field in the rotor. We install the armature winding around the slot of the armature core.

Armature windings can be made with:

- Lap winding construction
- Wave winding construction

Further in from the armature windings we will find the armature core made from low hysterisis silicon steel lamination to reduce the magnetic losses. These laminated steel sheets will be assembled together to create the armature core with cylindrical shape. There are also slots inside the core with the same material as the core.

Field Windings

The field windings are made from copper wire and circle around the Pole Shoes. Field winding is used to energize the static magnetic field in the stator. We install the field windings around the slot of the Pole Shoes. We do not need field windings if we use permanent magnets like in a Permanent Magnet Motor or PMDC motor.

Yoke or Frame

Yoke is an iron frame as a protective cover for both rotor and stator. This part protects everything inside it, supports the armature, and the house of the magnetic poles, field windings, and the pole to provide magnetic fields for the rotor.

Poles

Poles in the stator are used to energize a specific sequence of magnetic poles to make sure the rotor is rotating. It is divided into Pole Core and Pole Shoes.

For a dc motor we need the magnetic fields to make the rotor start rotating. In order to generate magnetic fields, we put field windings around the Pole Shoe which is attached to the Pole Core in the Yoke inner part. These Pole Shoe and Pole Core parts are attached to each other using hydraulic pressure. The structure is the yoke holding the Pole Core which carries the Pole Shoes carrying field windings. This pole unit generates flux spread out into the air gap between rotor and stator.

Principle of operation of D.C. Generator:

When a conductor or conductors rotate in a magnetic field, an emf. is induced in the conductor or conductors. The instaneous value of the induced emf is given by

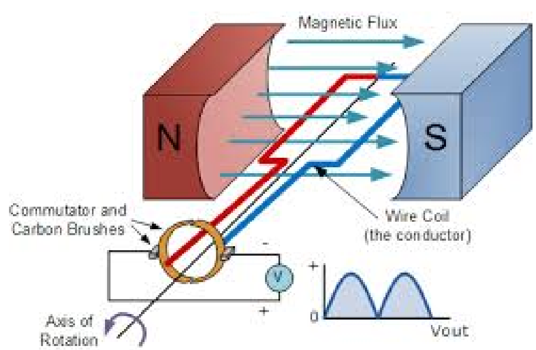
e = Blv sinq

where, B = Magnetic flux density

l = length of the conductor

v= Velocity of the conductor

And q = Angle between the magnetic field and direction of motion of the conductor with respect to magnetic field.



When shaft is rotated (by some prime mover) the rotor turns and a.c. is induced in the armature coil. The instantaneous emf given earlier as

e = Blv sinq

In the above figure the plane of the coil is in the direction of the magnetic field and the induced emf is maximum. But as the armature rotates through90o ,the induced emf reduces and becomes zero. During this period, the current direction is shown in the figure where current flows from the bottom segment and brush into the top segment and brush.

As the armature rotates further from this position, the polarity of induced emf. Is reversed and the current direction is also reversed. As the armature rotates another 90o the emf. induced in the armature is again at a maximum. The current during this period flows out of the top segment. As the polarity of induced emf. has been reversed during this period current in the external circuit flows in the same direction.

With continued rotation of the armature, the a.c. emf. induced in the armature conductors is made to enter and leave the brushes in the same direction into the external circuit at all times. The action of commutator and the coil results in a fluctuating d.c. output of a full wave rectifier.

EMF Equation of a DC Machine – Generator and Motor

Let,

- **P** – number of poles of the machine
- **ϕ** – Flux per pole in Weber.
- **Z** – Total number of armature conductors.
- **N** – Speed of armature in revolution per minute (r.p.m).
- **A** – Number of parallel paths in the armature winding.

In one revolution of the armature, the flux cut by one conductor is given as:

$$\text{Flux cut by one conductor} = P\varphi \quad \text{wb} \ldots \ldots (1)$$

Time taken to complete one revolution is given as:

$$t = \frac{60}{N} \quad \text{seconds} \quad \ldots \ldots (2)$$

Therefore, the average induced e.m.f in one conductor will be:

$$e = \frac{P\varphi}{t} \quad \ldots \ldots (3)$$

Putting the value of (t) from Equation (2) in the equation (3) we will get

$$e = \frac{P\varphi}{60/N} = \frac{P\varphi N}{60} \text{ volts} \quad \ldots \ldots (4)$$

The number of conductors connected in series in each parallel path = Z/A.
Therefore, the average induced e.m.f across each parallel path or the armature terminals is given by the equation shown below:

$$E = \frac{P\varphi N}{60} \text{ x } \frac{Z}{A} = \frac{PZ\varphi N}{60\ A} \text{ volts}$$

If the DC Machine is working as a Generator, the induced emf is given by the equation shown below:

$$E_g = \frac{PZ\,\varphi\,N}{60\ A} \quad \text{volts}$$

Where $\mathbf{E_g}$ is the **Generated Emf**
If the DC Machine is working as a Motor, the induced emf is given by the equation shown below:

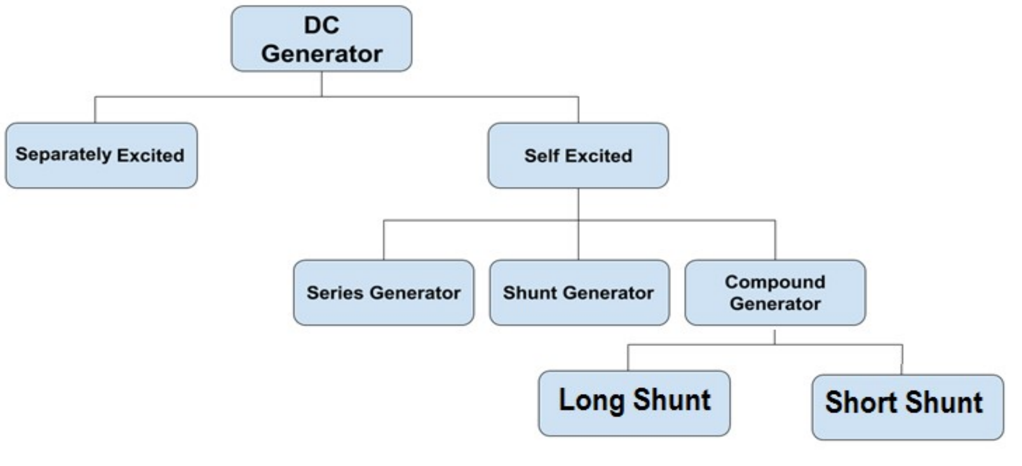
$$E_b = \frac{PZ\,\varphi\,N}{60\ A} \quad \text{volts}$$

In a motor, the induced emf is called **Back Emf (E_b)** because it acts opposite to the supply voltage.

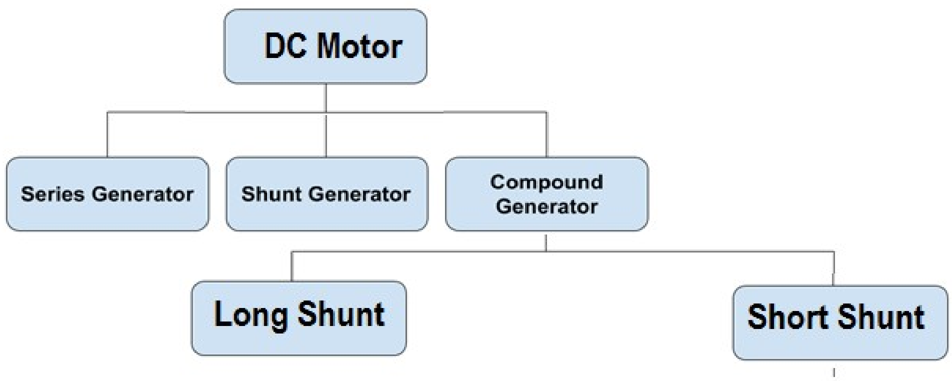
For simplex wave-wound generator Number of parallel paths **A=2**

For simplex lap-wound generator Number of parallel paths **A=P**

Classification of D.C. Generator:



Classification of D.C. Motor:



Uses of D.C. Generators :

(1) **Shunt Generator**
- (i) Lighting and Power Supply
- (ii) Charging batteries.

(2) **Series Generator** –
- (i) Boosters.

(3) **Compound Generator** –
- (i) Large range load
- (ii) Power Supply

Uses of D.C. Motors

(1) **Shunt Motor**
- (i) Constant speed drive
- (ii) Drilling machine, lathes, elevators, water pump, cutting machine.

(2) Series Motor
- (i) Electric Cranes
- (ii) Electric Trains
- (iii) Hoists

(3) **Compound Motor**
- (i) Heavy tool machines
- (ii) Printing machines

Principle of operation of single phase Induction Motor :

A single–Phase induction motor consists of a single phase winding mounted on the starter and a cage winding on the rotor. When a single - phase supply is connected to the stator winding a pulsating magnetic field is produced. By pulsating field the field builds up in one direction falls to zero, and then builds up in the opposite direction. Under these conditions, the rotor does not rotate due to inertia. Hence a single phase induction motor is initially not self starting.

To make the motor self starting another winding is provided on the stator which temporarily converted to a two phase induction motor. When supply is given a rotating magnetic field is produced and rotor starts rotating.

Two theories have been suggested to analyze the performance of a single phase induction motor.

(1) Double Field Revolving Theory
(2) Cross Field Theory

Types of Single Phase Induction Motor:

(1) Split phase motor
(2) Capacitor start motor
(3) Capacitor start – Capacitor run single phase Induction Motor.
(4) Shaded Pole Motor -
(5) Repulsion Motor

Uses of Single Phase Induction Motor:

(1) **Split phase motor** :
- (i) Small Pumps
- (ii) Grinders

(2) Capacitor start motor
- (i) Compressor
- (ii) Pumps

(3) Capacitor start capacitor Run Motor
- (i) Compressor of Air-conditioner
- (ii) Water Cooler

(4) Shaded Pole Motor
- (i) Small fans

(5) Repulsion Motor
- (i) Mixing Machine

Concept of Lumen:

A lumen is a unit of luminous flux in the International System of Units. One lumen is equal to the amount of light given out through a solid angle by a source of one candela intensity radiating equally in all directions. Expressed simply, lumens equal brightness; hence, the more lumens, the brighter the light.

Lumens (quantity of light) per square meter is also known as lux.

Different types of Lamps:

What is a Lamp?

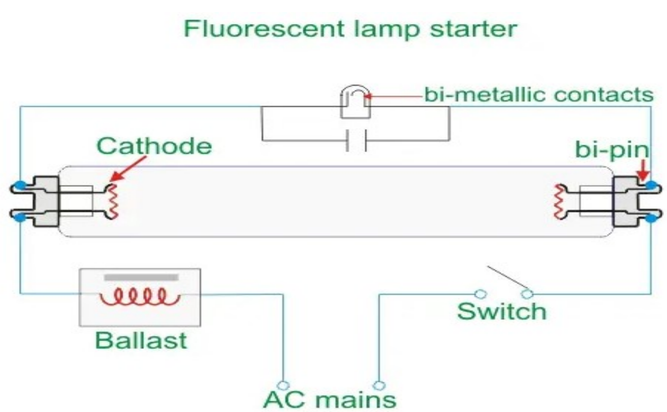
A lamp is an artificial source of light. Over the last 100 years, lamps have become an integral part of our daily lives.

Various types of lamps are available on the market. These lamps differ in their operating principle, materials used, and importantly – their energy efficiency.

The different types of lamps include:

- Incandescent Lamps
- Tungsten Halogen Lamps
- Fluorescent Lamps
- Compact Fluorescent Lamps
- Mercury Vapour Lamps
- Metal Halide Lamps
- High Pressure Sodium Vapour Lamps
- Low Pressure Sodium Vapour Lamps
- LED Lamps

What is Fluorescent Lamp?
A **fluorescent lamp** is a low weight mercury vapour lamp that uses fluorescence to deliver visible light. An electric current in the gas energizes mercury vapor which delivers ultraviolet radiation through discharge process and the ultraviolet radiation causes the phosphor coating of the lamp inner wall to radiate visible light. A fluorescent lamp has changed over electrical energy into useful light energy to a great deal more proficiently than incandescent lamps. The normal luminous viability of fluorescent lighting frameworks is 50 to100 lumens per watt, which is a few times the adequacy of incandescent lamps with equivalent light yield.
How does a Fluorescent Lamp work?
Before going through the working principle of a fluorescent lamp, we will first show the circuit of a fluorescent lamp in other words circuit of tube light.



Here we connect one ballast, and one switch and the supply is series as shown. Then we connect the fluorescent tube and a starter across it.

- When we switch ON the supply, full voltage comes across the lamp and as well as across the starter through the ballast. But at that instant, no discharge happens, i.e., no lumen output from the lamp.
- Then gas inside the starter gets ionized due to this full voltage and heats the bimetallic strip. That causes to bend the bimetallic strip to connect to the fixed contact. Now, current starts flowing through the starter. Although the ionization potential of the neon is more than that of the argon but still due to small electrode gap, a high voltage gradient appears in the neon bulb and hence glow discharge gets started first in the starter.

- As soon as the current starts flowing through the touched contacts of the neon bulb of the starter, the voltage across the neon bulb gets reduced since the current, causes a voltage drop across the inductor(ballast). At reduced or no voltage across the neon bulb of the starter, there will be no more gas discharge taking place and hence the bimetallic strip gets cool and breaks away from the fixed contact. At the time of breaking of the contacts in the neon bulb of the starter, the current gets interrupted, and hence at that moment, a large voltage surge comes across the inductor (ballast).
- This high valued surge voltage comes across the fluorescent lamp (tube light) electrodes and strikes penning mixture (mixture argon gas and mercury vapor).
- Gas discharge process gets started and continues and hence current again gets a path to flow through the fluorescent lamp tube (tube light) itself. During discharging of penning gas mixture the resistance offered by the gas is lower than the resistance of starter.
- The discharge of mercury atoms produces ultraviolet radiation which in turn excites the phosphor powder coating to radiate visible light.
- Starter gets inactive during glowing of fluorescent lamp (tube light) because no current passes through the starter in that condition.

White Light Emitting Diode:

White Light Emitting Diodes or **White LEDs** are the next big thing in lighting. Earlier LEDs were restricted to applications like indicators, displays or emergency lighting. But with the advent of white light emitting LEDs, they are now used in almost all lighting applications ranging including indoor lighting, street lighting to flood lighting. In other words, white LEDs have become omnipresent.

An LED cannot emit white light naturally. However, use of certain technologies makes an LED to emit white light. There are three prevalent technologies to produce white light in LED and they are Wavelength Conversion, Colour Mixing, and a technology referred to as Homo-epitaxial ZnSe.

What is Incandescent Lamp or Filament Lamp:

The electrical light source which works on the principle of incandescent phenomenon is called **Incandescent Lamp**. In other words, the lamp working due to glowing of the filament caused by electric current through it, is called **incandescent lamp**.

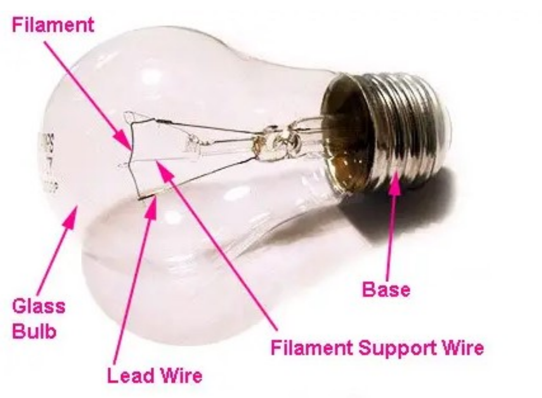
How do Incandescent Lamps Work?

When an object is made hot, the atoms inside the object become thermally excited. If the object does not melt, the outer orbit electrons of the atoms jump to higher energy level due to the supplied energy. The electrons on these higher energy levels are not stable, they again fall back to lower energy levels. While falling from higher to lower energy levels, the electrons release their extra

energy in a form of photons. These photons are then emitted from the surface of the object in the form of electromagnetic radiation.
This radiation will have different wavelengths. A portion of the wavelengths is in the visible range of wavelengths, and a significant portion of wavelengths are in infrared range. The electromagnetic wave with wavelengths within the range of infrared is heatenergy and the electromagnetic wave with wavelengths within visible range is light energy.

Incandescent means producing visible light by heating an object. An **incandescent lamp** works in the same principle. The simplest form of the artificial source of light using electricity is an incandescent lamp. Here we use electric current to flow through a thin and fine filament to produce visible light. The current rises the temperature of the filament to such extent that it becomes luminous.

The various parts of an incandescent lamp are shown below.



Star rating Terminology of home appliances:

The appliances with the lowest energy consumption in a product category are given the Most **stars and those with the highest energy consumption are given the least**. More the stars, more energy efficient the appliance is. This is a visual representation of the appliance's efficiency.

Energy Efficiency:

Nowadays, Energy Efficiency word is used a lot. You might have come across this phrase a lot on labels, on appliances, advertisements by manufacturers etc. Now, what does energy efficiency mean exactly? “Energy efficient” is affixed to products that consume less energy. Any product that uses less amount of energy and delivers same or better performance and lasts longer as compared to its counterparts could be called as energy efficient. For example, a compact fluorescent bulb is more efficient than a traditional incandescent bulb as it uses much less electrical energy to produce the same amount of light. Increasing energy efficiency often costs money upfront but in many cases this capital outlay will be paid back in the form of reduced energy costs within a short time period. The more energy efficient the product, the more is the money saved. Long term, you end up saving energy a lot, that it gives a long term return investment.

Star Rating Concept:

A star rating system depicts the energy efficiency of an electrical appliance. The higher the number of stars, the more efficient it is. The Bureau of Energy Efficiency (BEE) India devised the star rating system, with a range of 1 to 5 stars.

What do the stars mean?

The labels on televisions, computer monitors, refrigerators, air conditioners, dishwashers, washing machines and dryers, can show a maximum of ten stars. That is, the least efficient models have one star while the most efficient models can have up to ten stars.

Where a model has 6 stars or less, it will be displayed on the label out of six stars, shown in half-star increments. Super-efficient models of 7 of 10 stars have the additional stars shown in a band above the regular six star label. There are no half star increments above 6 stars so products with 6-10 stars are shown in single star increments.

How are Star Ratings calculated?

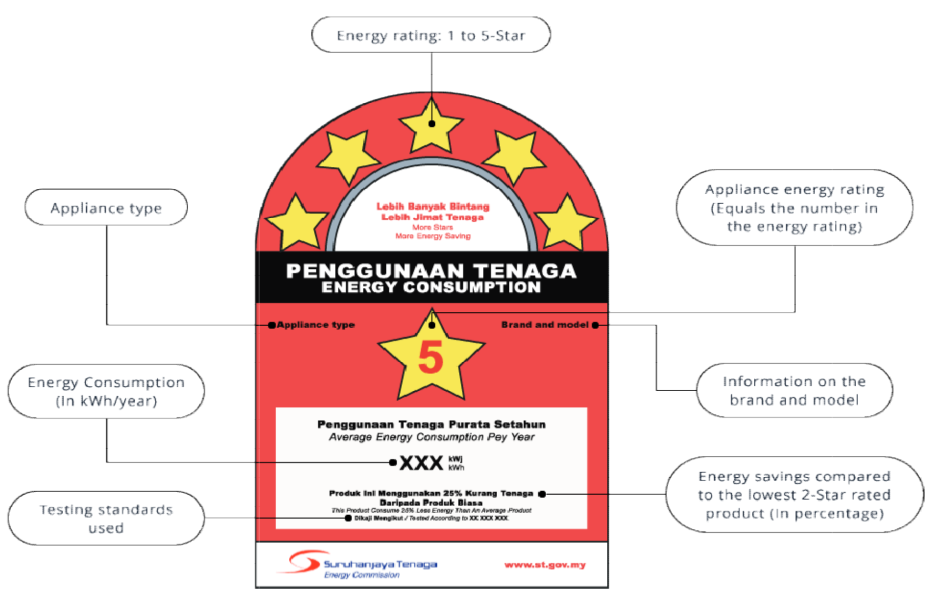
The star rating of an appliance is determined from the energy consumption and size of the product.

If you think of an air conditioner, for example, a model's cooling efficiency is the amount of cooling capacity (output) per unit of energy it consumes (input). For a television, a model's efficiency is related to its screen size. Algorithms allocate the lowest performing products one star performance in most instances and better performing products are awarded more stars.

Detailed information on performance standards can be found on the product page for each appliance.

A continuous improvement in appliance performance over time has meant that many of the products meet the performance requirements for 4, 5 or 6 stars on their label. The label design for all product categories has now been changed to incorporate up to ten stars rather than a maximum of six stars. This introduced a tougher standard for calculating star ratings which prevents clustering and encourages manufacturers to keep improving the energy efficiency of appliances.

Sample Energy Rating Labels



Ch_5: WIRING:

Introduction

Electricity is used at home for different purposes such as light loads, fans, computer, refrigerator, cooler etc. In industries most of the machines run with electricity. The electric supply is given by the distribution company supplies upto energy meter of the consumer. The process by which the electric supply is made available to various load points through a network of conductors is called the wiring.

Types of Wiring:

Different methods of wiring are used under different conditions. The selection of an individual system of wiring depends upon on the following factors.

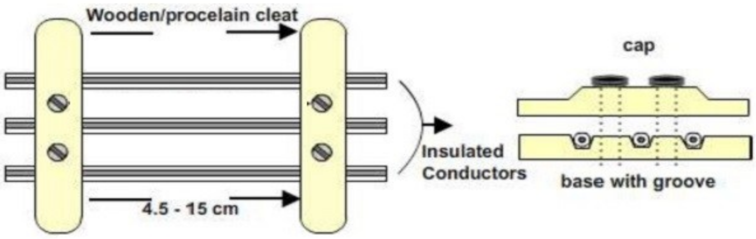
(i) Initial cost
(ii) Durability
(iii) Mechanical Protection
(iv) Fire safety
(v) Appearance
(vi) Accessibility

Taking the above factors into account, any of the following types of wining are used :-

(i) Cleat wiring
(ii) Wooden casing and capping wiring
(iii) CTS or TRS wiring
(iv) Lead sheathed wiring
(v) Conduit Pipe Wiring

1. Cleat Wiring

Single core VIR (Vulcarized India Rubber) or PVC (Poly Vinyl Chloride) cables are used in this wiring. The cables are run in grooves of glazed porcelain cleats which are fastened in wooden plugs (gutties) mounted on walls.



Merits

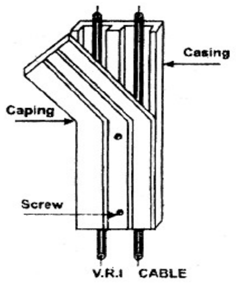
(i) It is cheapest system of wiring.
(ii) A little skill is required to lay the wining.
(iii) The wiring can be dismantled easily and used again with very little waste of material.

Demerits

(i) There is no protection from mechanical injury, fire, gas or water.
(ii) It is rarely employed for permanent jobs.
(iii) It is not good looking.

2. Wooden casing and capping wiring

The casing is base which consists of wooden block of seasoned teak wood and has usually two grooves to accommodate wires. The casing is fixed on the wall with the help of screws and gutties. After placing the wires in the grooves casing at the top is covered by means of rectangular strips of seasoned wood of same width known as capping with the help of screws.



Merits:

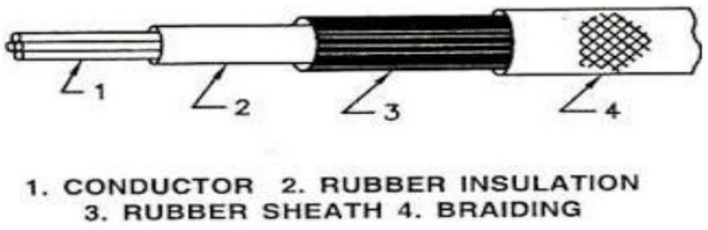
(i) It gives better appearance then cleat wiring.
(ii) There is sufficient mechanical and environmental protection to the wires/ cables used.
(iii) Easy to inspect only by opening the capping.
(iv) Easy to install and rewire.

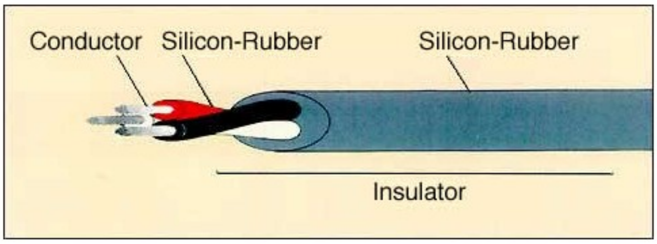
Demerits:

(i) Costlier in compare to cleat wiring.
(ii) There is risk of fire.
(iii) It is not suitable for damp situation.

3. **C.T.S. or T.R.S. wiring**

In this system of wiring generally C.T.S. (cable Tyre Sheath) or T.R.S. (Tough Rubber Sheathed) conductors are employed. The conductors are run on well seasoned perfectly straight and well varnished teak wood batten of different width. The width of the batten is chosen depending upon the number of wires to be run on it.





Merits

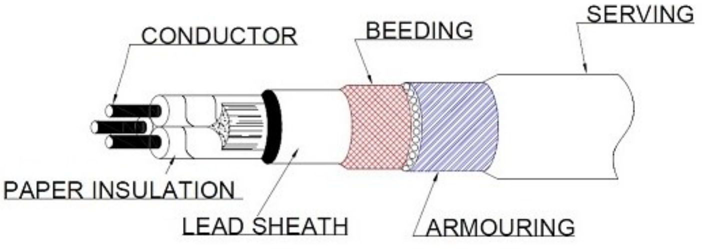
(i) It is easy to install and repair.
(ii) It gives nice appearance.
(iii) This type of wiring gives sufficient mechanical protection to the cable.

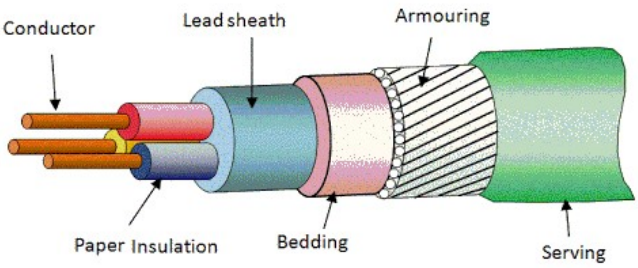
Demerits

(i) The conductors are upon and liable to mechanical injury, cannot be used in workshop.
(ii) It takes more time for installation.
(iii) The fire risk is high.
(iv) Its performance is affected under damp condition.

4. **Lead Sheathed Wiring**

This system of wiring is similar to CTS or TRS wiring. Only difference is that in this case VIR conductors covered with lead alloy sheath (metal sheathed cable) are used. The lead sheathed cables are run on the Wooden battens.





Merits

(i) The conductors are protected against mechanical injury.
(ii) It is free from fire hazards.
(iii) It can be installed in open space.
(iv) It has longer life.

Demerits

(i) It is relatively expensive due to the cost of lead sheath.
(ii) In case of leakage, there is every risk of shock.
(iii) Skilled labour and proper supervision is required. Otherwise, the durability of insulation may be affected.

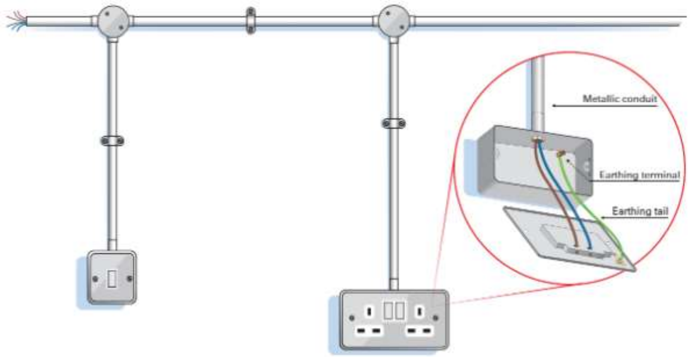
5. **Conduit wiring**

There are two types of conduit wiring

(i) Surface conduit wiring

(ii) Concealed conduit wiring

In surface conduit wiring the conduit run over the wall supported by means of saddles where as in concealed conduit wiring the conduit is embedded in the walls and ceilings by placing in the premade cavity in them.



Merits

i. The wiring presents a neat and attractive appearance.

ii. It gives good protection against fire, mechanical damage & moisture.

iii. Its durability is very high.

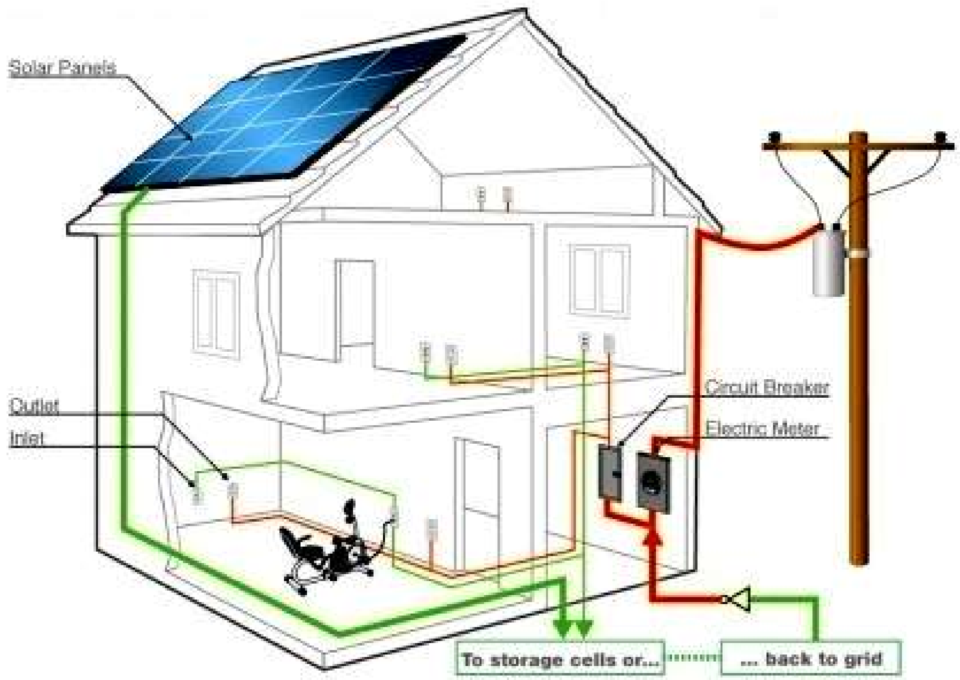
Demerits

i. It is costly system of wiring.

ii. Highly skilled technician is necessary.

iii. It requires more time for erection.

Layout of House hold Electrical Wiring (Single Line Diagram)



Basic protective Devices used in House hold wiring:

1. Fuse
2. MCB (Miniature Circuit Breaker)
3. Lightening arrester
4. Earthing Wire

Earthing

The process of connecting metallic bodies of all the electrical apparatus and equipment to the huge mass of earth by a wire having negligible resistance is called earthing.

Necessity of Earthing

(i) To prevent electrical shock to the human being if the electrical appliance (body) are charged.

(ii) To prevent risk of fire due to leakage current through unwanted path.

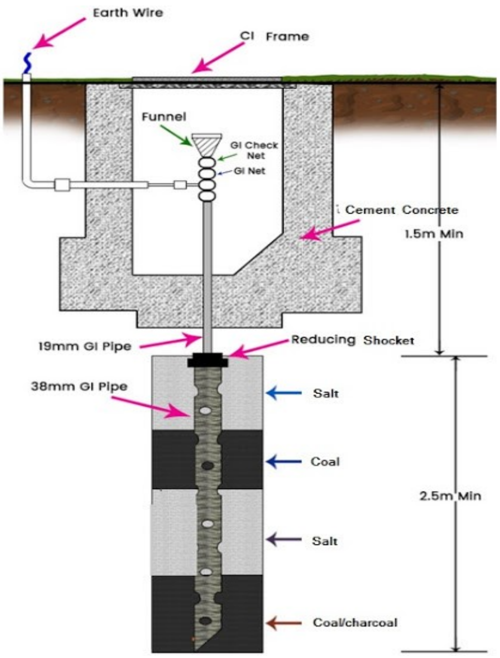
(iii) To protect large building and machines from lightning by connecting lightning arrester to the general mass of the earth.

Types of Earthing

There are two types of Earthing **(i) Pipe Earthing (ii) Plate Earthing**

(i) Pipe Earthing

In pipe earthing a galvanized iron (GI) pipe of 38mm diameter, 2m length with 12mm hoes drilled at diametrical opposite points is buried vertically in the wet Earth to work as the earth electrode.
If the soil is dry, a larger pipe may be 3m in length is used. The lower part of the pipe is tapered to make the boring easy.

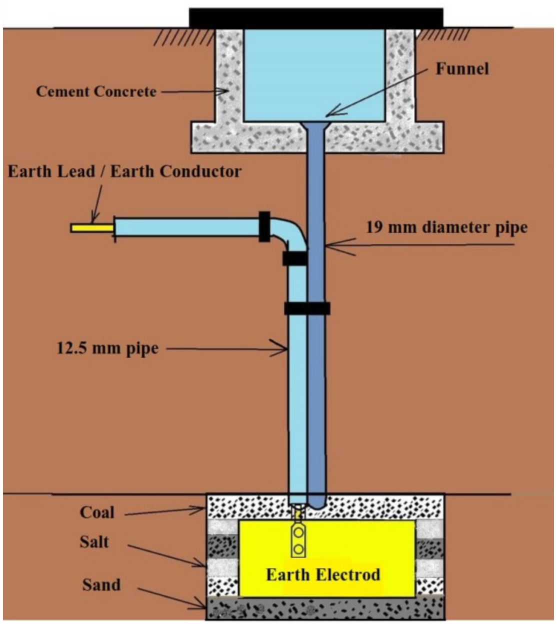


A second narrower GI pipe of about 12mm diameter is fixed over the wider pipe through a reducing socket. A funnel with wire mesh is fixed at the top of the narrower pipe.

Alternate layers of salt and charcoal are filled in the hole around the earth electrode. During summer water may be poured in the funnel to keep the soil wet and to maintain the desired value of earth resistance.

(ii) Plate Earthing

In this system of earthing an earthing pit is made in the ground. A copper plate is connected to the earth continuity conductor with nuts and bolts. The size of the plate is about 60cm X 60cm X 3.18mm.

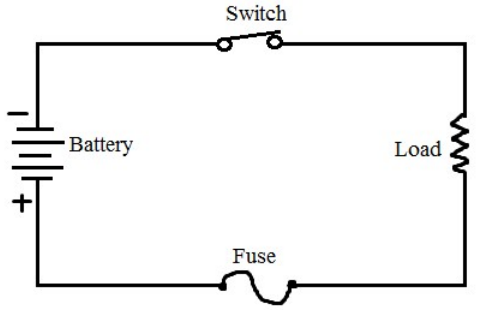


After placing the plate at the bottom of the pit, it is covered with nearly 15cm thick alternate layers of salt and charcoal. Then the bolted earth wire is drawn through GI pipe to the body of the main switch.

Generally pipe earthing is used for domestic, small commercial building and small workshop using single phase supply. Plate earthings are used for large buildings, big workshops, substations and industry using three phase supply.

Fuse:

Fuses are the protectors; these are the safety devices which are used to protect the home appliances like televisions, refrigerators, computers with damage by high voltage. The fuse is made up of thin strip or strand of metal, whenever the heavy amount of current or an excessive current flow is there in an electrical circuit, the fuse melts and it opens the circuit and disconnects it from the power supply. Also, it works as a **circuit breaker or stabilizer** which protects the device from damage. In the market, many types, features, and design of fuses are available nowadays. Their strips are made up of aluminium, copper, zinc & it is always connected in series with the **circuit to protect from over current** in the running cables. Here is the basic circuit diagram & symbol of the fuse.



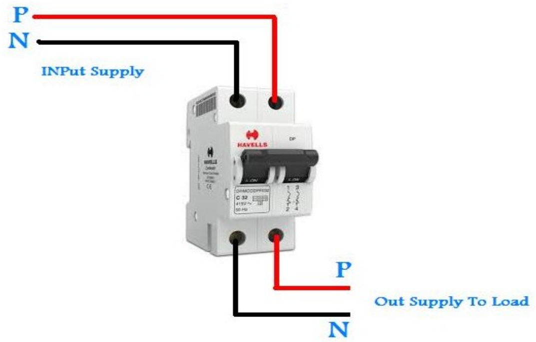
Basic circuit diagram


Different types of Fuse

MCB (Miniature Circuit Breaker):

A miniature circuit breaker is an electromagnetic device that carries a complete molded insulating material. The primary function of this device is to switch the circuit. This means to automatically open the circuit (which has been connected to it) when the current passing through the circuit goes beyond a set value or limit. The device can be manually switched ON or OFF just like normal switches whenever necessary.

MCBs are time-delay tripping devices. In these devices, the operating time is controlled by the magnitude of overcurrent passing through it, which means that the device functions whenever there is an overload existing for long periods, long enough to endanger the circuit being protected. MCBs do not respond to transients such as motor starting currents or switches surges. Typically, these devices are designed to operate at less than 2.5 milliseconds when there are short circuit faults and between 2 seconds to 2 minutes in case of overloads.



Lightening arrester:

The circuit which is protected from the strokes of lightning with the help of a protection device is known as lightning arrester. Here the lightning strokes are nothing but surges with high transient voltage, arcs of isolation, spark, and surge currents because of lightning, etc. These devices are used to defend the power systems by forwarding the high voltage surges in the direction of the ground. And these power systems and over headlines can also be protected by using ground wire or the earthing from the direct strikes of lightning. The **lightning arrester diagram** is shown below.

Electrical Power

As we have learnt that power consumed by load depends on the value of resistance, current through the resistance and voltage across the resistance.

P = VI

(or) P = V2/R

(or) P=I2R

Thus, I watt is the power consumed by resistive load when current is 1A and Voltage Across is 1V

1 Killowatt (KW) = 1000 W

1 HP (Horse Power) = 746 W

Ex. A heater takes 8A current at 250V supply. Calculate how much power does it consume?

Solution : Given I = 8A, V = 250V

P = V, I = 250 X 8 = 2000W = 2KW

Power in small Electrical Installation

Ex. A building has the following electrical appliances

(i) 1 KW Motor.

(ii) 2 bulbs 100w rating each

(iii) Two fans having 60w each

(iv) one heater 1.5 KW. Calculate the total

Power Consumed by the building if all loads are switched on.

Solution : Total Power (P) = Sum of individual Power of all appliances.

P = P1 + P2 + P3 + P4

P = 1000 + (2 X 100) + (2 X 60) + 1500

P = 1000 + 200 + 120 + 1500

P = 2820 W = 2.82 KW

Electrical Energy:

Energy = Power X Time

E = P X t

The unit of energy will depend upon the unit of Power and unit of time.

When P = 1 watt, t = 1 Second

Energy (E) = 1 W X 1S = 1 Watt Second = 1 Joule

When P = 1 Watt, t = 1 hour

Energy = 1 Watt X 1 hour = 1 Watt. hour

1 watt. hour = 1 watt X (60 X 60) Second

1 watt hour = 3600 Watt Second = 3600 J = 3.6 X 103 Joules

Similarly for bigger unit 1 Kwhr = 1000 whr.

So 1 Kwhr = 1000 X 3600 = 3.6 X 106 Joules

1 Kwh is called 1 Unit

Ex. A building has the following electrical appliances

(i) A 1 HP motor running for 5 hrs. in a day.

(ii) Three fans each of 80W running for 10 hrs. in a day.

(iii) Four tube lights of 40W running for 15 hrs. per day.

Find the monthly bill for the month of November if unit cost of bill is Rs.2.50.

Solution:

(i) Electrical Energy Consumed per day for motor = 746 X 5 = 3730 whr = 3.730 kwhr.

(ii) Electrical Energy Consumed per day by three fans = 3 X 80 X 10 = 2400 whr = 2.4 Kwhr.

(iii) Electrical Energy Consumed per day by four tube lights = 4 X 40 X 15 = 2400 whr = 2.4 Kwhr.

Total Energy Consumed = 3.73 + 2.4 + 2.4 = 8.53 Kwhr = 8.53 units.

In the month of November total Electrical Energy Consumed = 8.53 X 30 = 255.9 units.

Monthly bill = 255.9 X Rs.2.5 = Rs. 639.75P.