Unit - I

Electrical Circuits

Fundamental laws of Electric circuits:-

Current:-

Electric current is defined as rate of flow of electric charge.

$$i = \frac{dq}{dt} \text{ amperes.}$$ ∴ q is the charge in coulombs.

Electric potential:-

It the work done in moving a charge of one coulomb b/w the two points is one Joule, then we say that the potential of one point with reference to the second point is one volt.

$$E \text{ (or) } V = \frac{dw}{dq}$$ ∴ W is the work done in Joules.

Resistance:-

The Resistance of a circuit is the property by which it opposes the flow of current.

$$R = \frac{\rho l}{a}$$

Conductance (G):

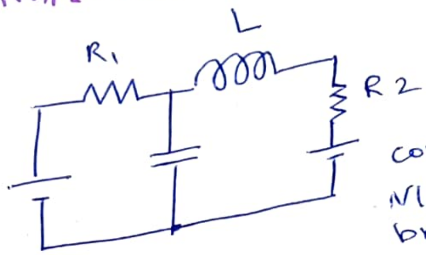
The reciprocal of resistance is called conductance its unit is Siemens and its symbol G.

$$G = \frac{1}{R}$$

|||ly the reciprocal of resistivity is called conductivity its symbol is σ.

$$\sigma = \frac{1}{\rho} \text{ Simens /meter.}$$

Network Definitions :-



Branch :-

A part of the N/W which connects the various points of N/W with one another is called branch..

loop :-

Mesh (or) loop is a set of branches forming a closed path in a N/W. ~~Forgot~~

Node :-

A point at which two (or) more elements are joined together is called node.

Ohm's law :-

When the temperature remains constant, current flowing through a circuit is directly proportional to the potential difference across the conductor.

$V \propto I$ R is the proportional constant.

$V = IR$.

Power :-

The rate at which work is done is power. and its unit is Joule per second (or) watt.

$P = VI$ watts.

Ohms law,

$P = I^2R$ (or) $\frac{V^2}{R}$.

$P = VI$ $(V = IR)$ (ohms law)

$P = (IR) \cdot I$

$P = I^2R$

$P = VI$ $(I = V/R)$

$P = V(V/R) \Rightarrow \frac{V^2}{R}$.

1, What will be the current drawn by a lamp rated at 250V, 40watts connected to a 230V supply?

Sol :- R be the resistance, $P = \frac{V^2}{R}$

$40 = \frac{(230)^2}{R}$.

$$R = \frac{(250)^2}{40} = \frac{62500}{40} = 1562.50\ \Omega$$

Current drawn from 230V supply,

$$I = V/R$$

$$I = \frac{230}{1562.50} = 0.1472 \text{ Amps.}$$

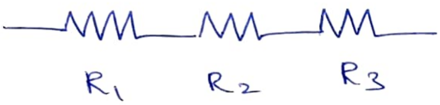
Q: An electric heater draws 8A from 250V supply. What is its power rating? Also find the resistance of the heater element?

Power rating $P = V.I = 8 \times 250$

$$P = 2000\ W$$

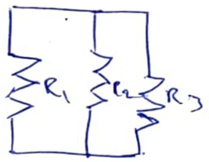
Resistance $= \frac{V}{I} = \frac{250}{8} = 31.25\ \Omega$

2. Resistance in series:-



$$R = R_1 + R_2 + R_3$$

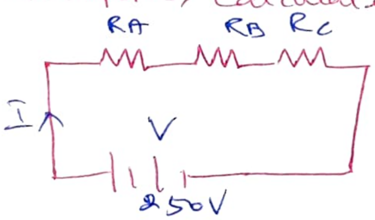
Resistance in parallel:-



$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}.$$

~~Req = $\frac{R_1 R_2}{R_1 + R_2}$~~

1. The ckt. shows 3 resistors R_A, R_B, R_C connected in series to a 250V source; Given, $R_C = 50\ \Omega$ and $V_B = 80V$ when the current is 2 amperes, Calculate the resistance R_A and R_B.



Sol:-

$$I = 2A$$

Voltage across resistor R_B, $V_B = 80V$

$$V_B = I R_B$$

$$R_B = \frac{V_B}{I} = \frac{80}{2} = 40\Omega$$

$$R_B = 40\Omega$$

Also,

$$I = \frac{V}{(R_A+R_B+R_C)} = \frac{250}{(R_A+R_B+R_C)}$$

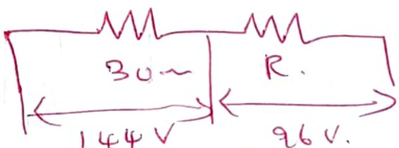
$$R_A + R_B + R_C = \frac{250}{2}$$

$$R_A + 40 + 50 = 125$$

$$R_A = 125 - 90 = 35\Omega$$

$$\boxed{R_A = 35\Omega}$$

2. A resistor of ohmic value 30Ω is connected in series with an unknown resistor. The potential drops across the two resistance are 144 and 96 volts. Find the value of the unknown resistor.



Sol:-

$(V = IR)$

Voltage across the 30Ω resistor $= 30I = 144V$

$$\therefore I = \frac{144}{30} = 4.8A$$

Let the unknown resistor be R ohms, The voltage drops across R is,

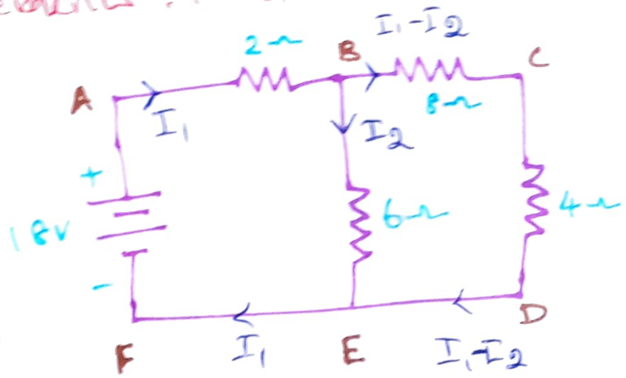
$$IR = 96V$$

$$R = \frac{96}{I} = \frac{96}{4.8} = 20\Omega$$

$$\boxed{R = 20\Omega}$$

K[illegible]off laws

[illegible] circuit find using Kirchoff's laws the current [illegible] various elements. Find also the power delivered by the battery.



Sol:- Considering ABEFA,

$$2I_1 + 6I_2 = 18 \rightarrow (1)$$

For, BCDEB,

$$8(I_1-I_2) + 4(I_1-I_2) = 6I_2.$$

$$12I_1 - 18I_2 = 0 \rightarrow (2).$$

solving these two equ,

we get $I_1 = 3A$, $I_2 = 2A$.

equ (1) ⇒ ×3

$$\hookrightarrow 6I_1 + 18I_2 = 54$$

equ (2) →

$$12I_1 - 18I_2 = 0$$

$$18 I_1 = 54$$

$$18 I_1 = 54$$

$$I_1 = \frac{54}{18} = 3 \text{ Amps}$$

$$\boxed{I_1 = 3 \text{ Amps}}$$

$$12\cancel{I_1} - 18I_2 = 0$$

$$6\times 12 \cancel{I_1} + 36 I_2 = 18$$

$$18I_2 = 18$$

6×2

$$2I_1 + 6I_2 = 18$$

$$12\cancel{I_1} + 36I_2 = 108$$

$$12\cancel{I_1} - 18I_2 = 0$$

$$(-) \quad (+) \quad (-)$$

$$54I_2 = 108$$

$$I_2 = \frac{108}{54}$$

$$I_2 = 2$$

$$\boxed{I_2 = 2 \text{ amps}}$$

The current in 2Ω resistor $= 3A$

The current in 6Ω resistor $= 2A$

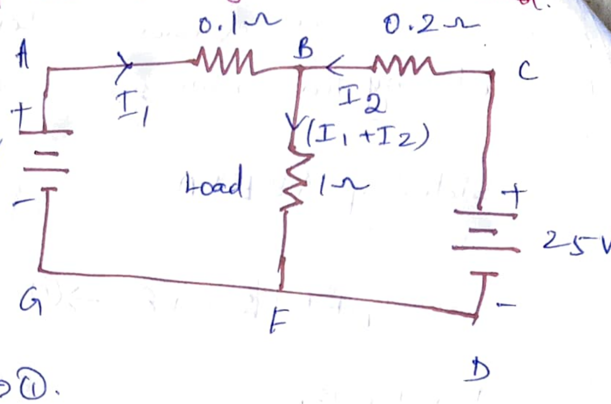
The current in 8Ω resistor $= I_1 - I_2 = 3-2 = 1A$

The current in 4Ω resistor $= 1A$

Power delivered by the battery $= 18 \times I_1 = 18 \times 3 = 54W$

2) In the circuit shows find the power supplied to the load. Also find the voltage at the load.

Sol:-



From,

ABFGA

$0.1 I_1 + (I_1+I_2)1 = 20$

$0.1 I_1 + I_1 + I_2 = 20$

$1.1 I_1 + I_2 = 20 \rightarrow (1).$

From,

~~BCDFB~~ CBFDC,

$0.2 I_2 + I_1 + I_2 = 25$

$1.2 I_2 + I_1 = 25 \rightarrow (2)$

$I_1 = \frac{-1}{0.32} = -3.125A$

$I_2 = \frac{7.5}{0.32} = 23.437\ A$

The negative sign for I_1 implies that current flows from B to A rather than from A to B. This means that the current in the load is 20.312 A. ((ie) 23.437 − 3.125 = 20.3125)

$I_1 + I_2 = I.$

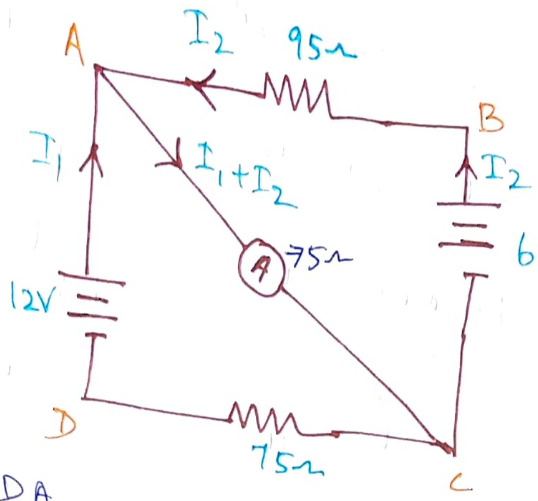
Voltage across the load $= 20.3125 \times 1$

$= 20.3125V$

Load power $= I^2R = (20.3125)^2 \times 1$

$\boxed{\text{Load Power} = 412.598W}$

3) In circuit shows, A is a ammeter of resistance 5Ω. Find the direction and Magnitude of the current through it.



For loop ACDA,

$$(I_1+I_2)5 + 75 I_1 = 12$$

$$80I_1 + 5I_2 = 12 \rightarrow ①.$$

For loop ACBA

$$(I_1+I_2)5 + 95 I_2 = 6$$

$$5I_1 + 100 I_2 = 6 \rightarrow ②$$

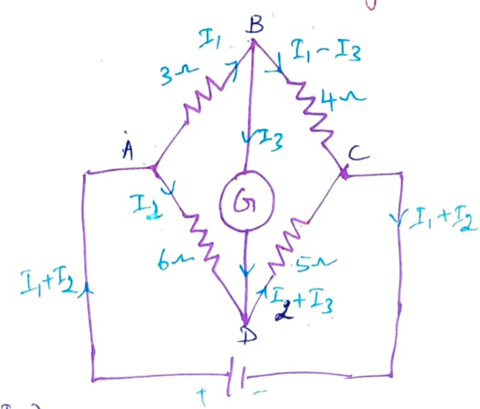
solving,

$I_1 = 0.1467$ A and $I_2 = 0.0526$ A

Current through ammeter $= I_1 + I_2 = 0.19936$ A.

4. In the wheatstone bridge circuit, shows G is a galvanometer of resistance 10Ω. Find the current through it.

sol :-



For loop ABDA,

$$3I_1 + 10 I_3 = 6 I_2$$

$$3I_1 + 10 I_3 - 6 I_2 = 0 \rightarrow ①$$

For loop ~~BDCB~~ BDCB,

$$10 I_3 + 5(I_2+I_3) = 4(I_1 - I_3)$$

$$10 I_3 + 5I_2 + 5I_3 - 4I_1 + 4I_3 = 0$$

$$-4I_1 + 5I_2 + 19 I_3 = 0 \rightarrow ②.$$

for loop ABCA, (through Battery)

$3I_1 + 4(I_1 - I_3) = 10$

$7I_1 - 4I_3 = 10$

$I_1 - 19I_3 = 0$

$7(18.22I_3) - 4I_3 = 10$

$127.555 I_3 - 4I_3 = 10$

$123.555 I_3 = 10$

$I_3 = \frac{10}{123.555}$

$\boxed{I_3 = 0.0809 \text{ Amps}}$

$3I_1 - 6I_2 + 10I_3$

$\times 5$

$15I_1 - 30I_2 + 50I_3 = 0$

eqn ② ×6

$-4I_1 + 5I_2 + 19I_3 = 0$

×6

$\Rightarrow -24I_1 + 30I_2 + 114I_3 = 0$

$15I_1 - \cancel{30I_2} + 50I_3 = 0$

$-24I_1 + \cancel{30I_2} + 114I_3 = 0$

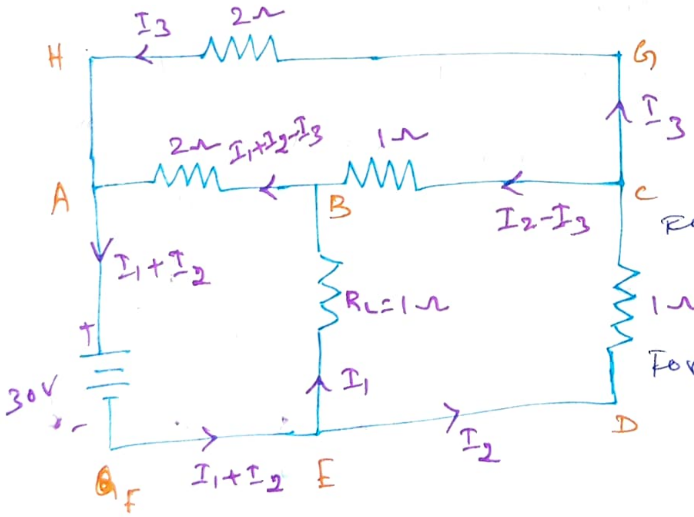
$-9I_1 + 164I_3 = 0$

$-9I_1 = -164I_3$

$I_1 = \frac{164I_3}{9}$

$I_1 = 18.22I_3$

5. In a Circuit Diagram shows, Find the current through R_L.



For loop AFEBA

$3I_1 + 2I_2 - 2I_3 = 30 \rightarrow ①$

For loop BEDCB

$-I_1 + 2I_2 - I_3 = 0$

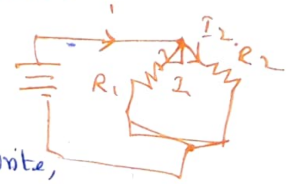
For loop ABCGHA,

$2I_1 + 3I_2 - 5I_3 = 0$

$\boxed{I_1 = 10 \text{ A}}$

Division of Current in parallel circuit:-

when Two resistors are connected in ||el,



In order to obtain the distribution, we write,

$I = I_1 + I_2 \rightarrow ①$ | $V = I_1R_1 = I_2R_2$

$$I_1 R_1 = I_2 R_2$$

$$I_2 = \frac{I_1 R_1}{R_2} \rightarrow (2)$$

equ (2) sub equ (1),

$$I = I_1 + \frac{I_1 R_1}{R_2}$$

$$I = \frac{R_2 I_1 + I_1 R_1}{R_2}$$

$$I = \frac{I_1 (R_1 + R_2)}{R_2}$$

Therefore,

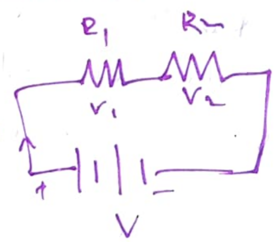
$$\boxed{\cancel{I_1 = I \frac{(R_1+R_2)}{R_2}} \quad \cancel{I_2 = I \frac{(R_1+R_2)}{R_1}}}$$

$$I_1 = I \frac{R_2}{(R_1+R_2)}$$

$$I_2 = I \frac{R_1}{(R_1+R_2)}$$

So current in the branch is equal to ~~tot~~ total current multiplied by other branch resistance and divided by sum of branch resistance.

Division of Voltage in Series circuit :-



By applying Ohms law, we can write,

$$V_1 = I R_1 \rightarrow (1)$$

$$V_2 = I R_2 \rightarrow (2)$$

KVL,

$$V = V_1 + V_2 \rightarrow (3)$$

equ (1) + (2) sub in equ (3),

we get,

$$V = IR_1 + IR_2$$

$$V = I(R_1+R_2)$$

$$I = \frac{V}{(R_1+R_2)} \rightarrow (4)$$

In equ (4) sub in equ (1).

$$V_1 = \frac{V}{(R_1+R_2)} \times R_1$$

$$V_1 = V \frac{R_1}{(R_1+R_2)} \rightarrow (5)$$

In eqn (4) sub in eqn (2),

$$V_2 = V \cdot \frac{R_2}{(R_1+R_2)} \rightarrow (6)$$

The eqn (5) & (6) can be used to find out the voltage in series connected resistance in terms of ~~the~~ total voltage across the series combination and the values of individual resistances. This equation are called voltage division rule.

AC Circuits :-

The Analysis of N/w in which the Magnitude of the source varies with respect to time. The Alternating waveforms may be in different forms such as sinusoidal, square wave, triangular wave etc...

Frequency :-

The number of cycles occuring per second. is Called frequency.

$$f = \frac{1}{T} \text{ Hz.}$$

1 Hz = 1 cycle per second

Average Value :-

We can calculate the avg. value of any function $v(t)$, with period T,

$$V_{av} = \frac{1}{T}\int_0^T v(t)\,dt$$

$$\text{avg. value} = \frac{\text{Area under the curve over one complete cycle}}{\text{Time period (or) distance.}}$$

avg. value of current,

$$i_{av} = \frac{1}{\pi}\int_0^{\pi} I_m \sin\omega t \, dt.$$

$$i_{av} = \frac{2I_m}{\pi} = 0.637 I_m.$$

$$i_{av} = 0.637 I_m.$$

avg. value of voltage,

$$V_{avg} = 0.637 V_m.$$

Root mean Square value (or) Effective value :-

R.M.S. value of an alternating sinusoidal current is,

$$I_{rms} = 0.707 I_m \Rightarrow \frac{I_m}{\sqrt{2}}$$

for voltage $\quad V_{rms} = 0.707 V_m \Rightarrow \frac{V_m}{\sqrt{2}}$

Form factor (k_f) :-

From factor is defined as the ratio b/w the Rms value and the avg. value of any alternating quantity.

$$\text{Form factor} = \frac{\text{RMS Value}}{\text{Avg. value}} = \frac{\frac{V_m}{\sqrt{2}}}{0.637 V_m}$$

$$= 1.11$$

Peack factor (or) Crest factor (k_p) :-

Peack factor is defined as the ratio b/w the peak value and RMS value of any alternating quanity.

$$\text{Peak factor} = \frac{\text{Peak Value}}{\text{RMS value}} = \frac{V_m}{V_m/\sqrt{2}}$$

$$= \sqrt{2} = 1.414$$

1) Find the period of periodic waveform with a freq. of 60 Hz.

$$T = \frac{1}{f} = \frac{1}{60} = 16.67\ \text{ms}.$$

2) An Alternating voltage is given by $V = 310 \sin 314t$. Calculate (i) freq (ii) period (iii) max. value (iv) avg. value (v) RMS value.

Sol :-

$$V = 310 \sin 314t.$$

(i) Frequency

$$V = V_m \sin \omega t \rightarrow (2).$$

$$V = 310 \sin 314t \rightarrow (1)$$

Comparing (1) & (2) we can write,

$$V_m = 310 \quad ; \omega = 314$$

Angular frequency.

$$\omega = 2\pi f$$

$$f = \frac{\omega}{2\pi} = \frac{314}{2\pi} = 50 \text{ Hz.}$$

$$f = 50 \text{ Hz.}$$

(ii) Period :-

$$T = \frac{1}{f} = \frac{1}{50} = 0.02 \text{ sec.}$$

(iii) Max. Value, $V_m = 310 V.$

(iv) Average Value

$$V_{ave} = \frac{1}{\pi} \int_0^{\pi} V_m \sin\theta \, d\theta . \frac{2V_m}{\pi} = 0.637 V_m$$

$$V_{avg} = 0.637 V_m.$$

$$V_{avg} = 0.637 \times 310 V = 197.47 V.$$

(v) RMS Value :-

$$V = \frac{V_m}{\sqrt{2}} = 0.707 V_m$$

$$V = 0.707 \times 310 V = 219.17 V$$

2.) A sine wave has a peak value of 12V. Determine the following value,

(a) rms, (b) Avg. (c) crest factor, (d) form factor.

Sol:-

(a) rms value of given sine wave,

$= 0.707 \times 12 = 8.48V$

b) Avg. value,

$= 0.637 \times 12 = 7.64 V$

(c) crest factor

$= \frac{\text{Peak value}}{\text{rms value}} = \frac{12}{8.48} = 1.415$

(d) Form factor,

$= \frac{\text{rms Value}}{\text{avg. value}} = \frac{8.48}{7.64} = 1.11$

Power:-

The instantaneous power delivered to any device is given by the product of the instantaneous voltage across the device and instantaneous current through it.

$p(t) = V(t)\, i(t)$

$V(t) = V_m \sin \omega t$

$I(t) = I_m \sin \omega t$

$\omega = 2\pi f$

$f = \frac{1}{T} = \frac{\omega}{2\pi}$

A sinusoidal voltage of $50 \sin \omega t$ is applied to a pure resistance of value of 30Ω resistor. Find the current, instantaneous power and avg. power, and also draw the phasor diagram.

Sol:-

$$i = \frac{V}{R}$$

(a)

$$V_m = 50$$

$$I_m = \frac{V_m}{R} = \frac{50}{30} = 1.667\,A.$$

Rms current $I_{rms} = \frac{I_m}{\sqrt{2}} = \frac{1.667}{\sqrt{2}} = 1.1785\,A.$

(b) To find instantaneous power,

$$p = vi = 50 \sin \omega t \times 1.667 \sin \omega t$$

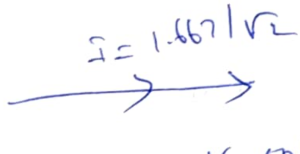
$$p = 83.35 \sin^2 \omega t \text{ watts.}$$

(c) To find avg. power,

$$p = VI = \left(\frac{V_m}{\sqrt{2}} \times \frac{I_m}{\sqrt{2}}\right)$$

$$p = 41.675 \text{ watts}$$

Phasor diagram



Voltage across the capacitor,
$v = V_m \sin(\omega t + \pi/2)$

Capacitive Reactance

$$X_C = \frac{1}{\omega C} = \frac{1}{2\pi f C}\ \Omega$$

Inductive Reactance, $X_L = \omega L = 2\pi f L\ \Omega$

2) A pure inductance $L = 2000\,mH$ has an applied voltage of $V = 100 \sin 314t$. Find the instantaneous current, instantaneous power and average power, inductive reactance, the RMS current and the phasor diagram.

Sol :-

$\frac{1}{C}\int i(t)\,dt.$

(a) Inst. Current

$$i = \frac{1}{L}\int v\,dt$$

$$= \frac{1}{2}\int 100 \sin 314t$$

$$= \frac{100}{2}\left[\frac{-\cos 314t}{314}\right]$$

$$i = -0.1592 \cos 314t \text{ amp}$$

(b)

$$P = V \times i$$

$$P = (100 \sin 314t)(-0.1592 \cos 314t)$$

$$P = -7.96 \sin 618t$$

(c) $P_{avg} = 0.$

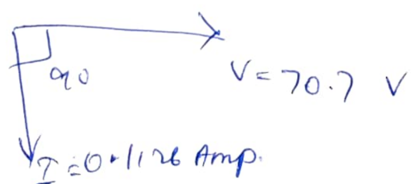
(d) $X_L = \omega L = 2\pi f L = 628\,\Omega$

(e) Rms Current,

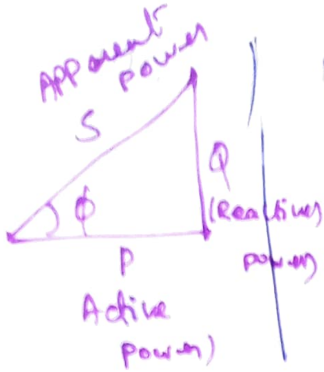
$$I = \frac{V}{X_L} = \frac{V_m/\sqrt{2}}{X_L}$$

$$I = 0.1126 \text{ Amp}$$

(f)



Power Factor:-



$$\text{Power Factor} = \frac{\text{True Power}}{\text{Apparent Power}} = \frac{\cancel{VI}\cos\phi}{\cancel{VI}}$$

Power factor = $\cos\phi$.

$$\cos\phi = \frac{kW}{kVA} \quad (\text{or}) \quad \cos\phi = \frac{R}{Z}$$

The power factor is the cosine of the phase difference b/w Voltage and current. where ϕ is the Phase difference b/w the voltage and current phasor.

Apparent Power:- (S):-

It is defined as the product of rms value of voltage and current.

$S = V \times I$

The apparent power can be expressed in complex form.

$S = P + jQ$

Real (or) Active power:- (or) True Power:-

$P = VI\cos\phi$ (It is expressed in watts)

Reactive Power:-

$Q = VI\sin\phi$ (It is expressed in volt Ampere Reactive) (VAR)

1) Find out the resistance and Inductance (or) Capacitance of the given impedance if frequency is 50Hz. (i) $25\angle 45°\Omega$ (ii) $6 + j8\Omega$, (iii) $8 - j10\Omega$.

Sol:-

(i) $Z = 25\angle 45°\Omega$

converting to rectangular form,

$Z = 17.68 + j17.68\Omega$

Comparing with $Z = R + jX_L$, we get,

$R = 17.68\Omega$

$X_L = 17.68\Omega$

$$X_L = 2\pi f L$$

$$L = \frac{X_L}{2\pi f} = \frac{17.68}{2\pi \times 50} = 0.0562H$$

(ii) $Z = 6 + j8\Omega$.

Comparing with $Z = R + jX_L$,

$R = 6\Omega$ and $X_L = 8\Omega$

W.k.That,

$$X_L = 2\pi f L$$

$$L = \frac{X_L}{2\pi f}$$

$$L = \frac{8}{2\pi \times 50} = 0.0254\ H$$

(iii) $Z = 8 - j10\Omega$

Comparing with $Z = R - jX_C$

$R = 8\Omega$ and $X_C = 10\Omega$

$$X_C = \frac{1}{2\pi f C}$$

$$C = \frac{1}{2\pi f X_C} = \frac{1}{2\pi \times 50 \times 10}$$

$$C = 318\mu F$$

2) A inductive coil consumes 1000 W and takes 10A When connected to 220V, 50Hz, AC supply. Find (i) Impedance (ii) resistance (iii) Power factor,

Sol:-

$$X_L = \frac{V}{I} = \frac{220}{10} = 22\Omega$$

$$X_L = Z = 22\Omega$$

(ii)

$X_L = 22\Omega$

(iii) $P = VI\cos\phi$

$\cos\phi = \frac{P}{VI} = \frac{1000}{220\times10} = 0.4545$ (lag)

2) Determine the active power and reactive power if the supply voltage is 200V, current down is 2A and the phase angle b/w current and voltage is 60°.

(i) Active power

$P = VI\cos\phi$

$= 200\times2\times\cos 60°$

$\boxed{P = 200\text{ watts}}$

(ii) Reactive power,

$\phi = 60°$

$Q = VI\sin\phi$

$= 200\times2\times\sin 60° = 346.41$ VAR

$\boxed{Q = 346.41 \text{ VAR}}$

$Z = \frac{V}{I}$ effective resistance of an electric ckt.

Pure Inductive Reactance

$|Z| = \sqrt{R^2+X_L^2}$

$Z = R+jX_L$

1) A 10Ω resistor and 20 mH inductor are connected in series across a 250V, 60Hz supply. Find the impedance of the ckt. voltage across the resistor and inductor, apparent power, active power and Reactive power.

Sol:-

To find Impedance $X_L = \omega L = 2\pi fL$

$X_L = 2\pi\times60\times20\times10^{-3} = 7.54\Omega$

$Z = \sqrt{R^2+X_L^2} = \sqrt{10^2+(7.54)^2} = 12.50\Omega$

To find current, $I = \frac{V}{Z} = \frac{250}{12.50} = 20A$

To find voltage across the resistor and Inductor.

$V_R = IR = 20\times10$

$V_R = 200$ volts

$V_L = IX_L = 20\times7.54 = 150.8$ volts

To find apparent power.

$S = VI = 250\times20$

$= 5000$ VA

(60) = 344.

To find Active power

$$P = VI \cos\phi$$

$$\cos\phi = \frac{R}{Z} = \frac{10}{12.50} = 0.8$$

$$\phi = \cos^{-1}(0.8) = 0.6$$

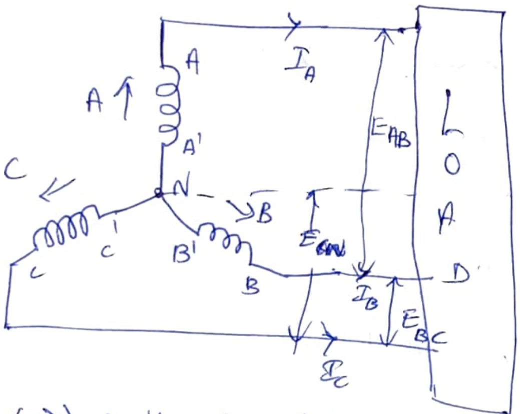
$$P = 250 \times 20 \times 0.8 = 4000 \text{ watts (or) } 4\text{ kW}$$

To find Reactive Power,

$$Q = VI \sin\phi = 250 \times 0.8 \sin(0.6)$$

$$Q = 3000 \text{ VAR (or) } 3\text{k VAR.}$$

Star (or) wye connection:-



$$E_{AB} = \sqrt{3}\, E_{ph} \angle 30^\circ$$

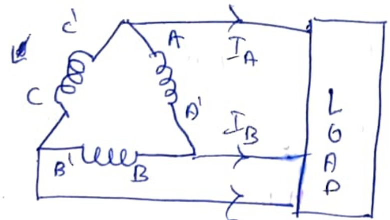
$$I_L = I_{ph}$$

Power in 3ϕ circuit,

$$= \sqrt{3} \times E_{ph} I_{ph} \cos\phi$$

$$= \sqrt{3}\, E_L I_L \cos\phi$$

Mesh (or) Delta Connection:-



$$I_A = \sqrt{3} I_{ph} \angle -30^\circ$$

Hence in delta system,

Line voltage E_L = Phase Voltage E_{ph}

Line current $I_L = \sqrt{3} I_{ph}$

$$\text{Power} = 3 E_{ph} I_{ph} \cos\phi = \sqrt{3}\, E_L I_L \cos\phi$$

1) Each phase of a 3ϕ alternator generates a voltage of 3810 Volts and carries a maximum current of 300 amps. Find the line currents, line Voltage and total kVA Capacity if alternator is (a) star (b) delta connected.

a) star connection:-

$$E_L = \sqrt{3}\, E_{ph} = \sqrt{3} \times 3810 = 6600 \text{ volts}$$

$$I_L = I_{ph} = 300 \text{ amps}$$

Capacity $= 3 E_{ph} I_{ph}$ (or) $\sqrt{3} E_L I_L$

$= 3 \times 3810 \times 300 = 3429000$ (or) 3429 kVA

b) Delta connection:-

$E_L = E_{ph} = 3810\,V$

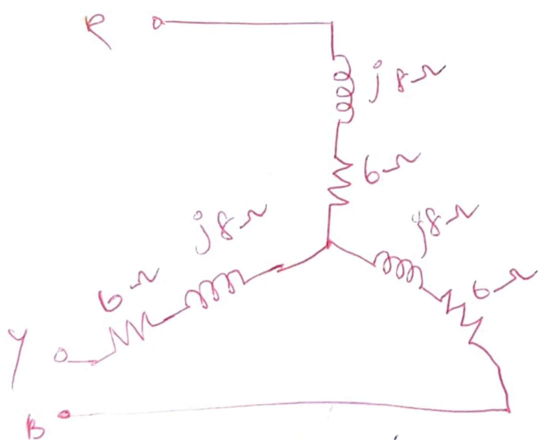
$I_L = \sqrt{3} I_{ph} = \sqrt{3} \times 300 = 519.62\,A = 3 E_{ph} I_{ph}$

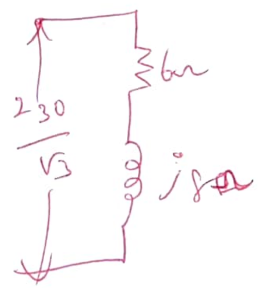
Capacity $= 3 \times 3810 \times 300 = 3429$ kVA

Balanced 3φ loads:-

A 3φ load has 3 separate load Impedances which may be connected in star (or) Delta. When the 3 impedance are identical we say the load is a balanced one.

1. A balanced 3φ load consists of a 6Ω resistor and 8Ω reactor in each phase, The supply is 230V, 3φ, 50Hz. Find (a) the Phase current (b) line current (c) the total power. Assume the load to be connected in star.





$E_L = 230V$

$E_{ph} = \frac{E_L}{\sqrt{3}} = \frac{230}{\sqrt{3}} = 132.8\,V$

Phase impedance $= 6 + j8$

$= 10 \angle 53.1^\circ\,\Omega$

$I_{ph} = \frac{E_{ph}}{Z_{ph}} = \frac{132.8}{10} = 13.28$

$I_L = I_{ph}$

Per phase power $= E_{ph} I_{ph} \cos\phi$

$= 132.8 \times 13.28 \times \cos 53.1$

$= 1059\,W$

Total power $3 \times 1059 = 3177\,W$

1) A 3ϕ 440V supply is given to a balance star connected load of impedance $(10+j8)\Omega$ in each branch. Determine the I_L, PF, & P_t. -1-

↓ total power

$Z = 10+j8$

$V = 440V$

a) $I_{ph} = \frac{V_{ph}}{Z} \Rightarrow V_{ph} = \frac{V_L}{\sqrt{3}} = \frac{440}{\sqrt{3}} = 254.03V$

$I_{ph} = \frac{254.03}{10+j8} = 19.83\angle{-38.66}$

In star, $I_L = I_{ph} = 19.83\angle{-38.66}$

b) $PF = \cos\phi = \cos(-38.66) = 0.78$ lag.

c) $P_t = 3 E_{ph} I_{ph} \cos\phi$ (or) $\sqrt{3} E_L I_L \cos\phi$

$= \sqrt{3} \times 440 \times 19.83 \times 0.78 = 11787.74$ W

2) each phase of a 3ϕ alternator produces a voltage of 6000 V and can carry a max. current of 250 amps. Find the line voltage, maximum line current and total kVA capacity of the alternator if it is (a) star connection, b) delta connections.

Star connection

line voltage $V_L = \sqrt{3} V_{ph} = \sqrt{3} \times 6000 = 10392.3$ V

line current $I_L = I_{ph} = 250A$.

Total capacity $= \sqrt{3} V_L I_L$ (VA)

$= \sqrt{3} \times \frac{10392.3 \times 250}{1000}$ kVA.

Total capacity $= 4500$ kVA.

$I_L = I_{ph} = 500$ amps

Delta connection,

Line voltage $V_L = V_{ph} = 6000$ Volts.

line current $I_L = \sqrt{3} I_{ph} = \sqrt{3} \times 250$ A.

$= 433.01$ A.

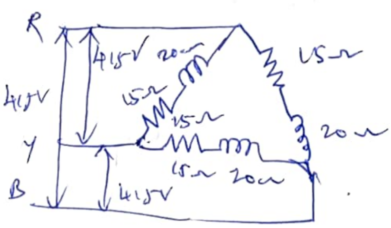
Total Capacity $= \sqrt{3}\, V_L \times I_L$ (VA)

$$= \frac{\sqrt{3} \times 6000 \times 433.01}{1000} \text{ KVA.}$$

Total Capacity $= 4500$ kVA.

3) A 415V, 3φ voltage applied to a balance delta connected load of phase impedance each equal to $15+j20\,\Omega$ — determine (i) phase and line current. ii) power consumed per phase.

Sol :-



$E_{ph} = E_L = 415$ V

Phase Impedance $Z_{ph} = \sqrt{R^2 + X_L^2}$

$= \sqrt{15^2 + 20^2} = 25\,\Omega$

Phase current $I_{ph} = \frac{E_{ph}}{Z_{ph}} = \frac{415}{25} = 16.6$A

$I_{ph} = 16.6$ A

Line Current $I_L = \sqrt{3}\, I_{ph} = \sqrt{3} \times 16.66 = 28.75$ A

$I_L = 28.75$ A

(ii) Power consumed per phase.

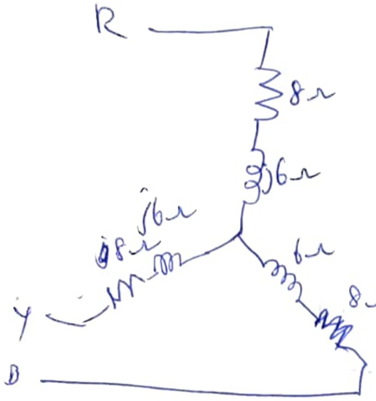
$P = E_{ph} I_{ph} \cos\phi$

$\cos\phi = \frac{R}{Z_{ph}} = \frac{15}{25} = 0.6$ (lag)

$P = 415 \times 16.6 \times 0.6 = 4133.4$ W

4) A balanced star connected load $(8+6j)\Omega$ per phase is [connected] to a 3ϕ 230V supply. Find the line current, power factor, reactive volt ampere and total volt ampere.

Sol:-



Impedance $Z_{ph} = \sqrt{R^2 + X_L^2}$

$Z_{ph} = 10\Omega$

phase voltage $E_{ph} = \frac{E_L}{\sqrt{3}} = \frac{230}{\sqrt{3}}$

$= 132.8V$

phase current $I_{ph} = \frac{E_{ph}}{Z_{ph}} = \frac{132.8}{10}$

$I_{ph} = 13.28 A$

Line current $I_L = I_{ph} = 13.28 A$

Power factor $\cos\phi = \frac{R}{Z} = \frac{8}{10} = 0.8$

Power $P = \sqrt{3} E_L I_L \cos\phi = \sqrt{3} \times 230 \times 13.28 \times 0.8$

$P = 4232.3 W$

Reactive Volt amp. $Q = \sqrt{3} E_L I_L \sin\phi$

$= \sqrt{3} \times 230 \times 13.28 \times 0.6 = 3174.2 VAR$

Total Voltamp $S = \sqrt{3} E_L I_L$

$= \sqrt{3} \times 230 \times 13.28 = 5290.37 VA$

Materials of wiring:-

Electrical wire is made of materials like copper, aluminium and silver. As silver is expensive. most of the wiring is copper and aluminium used.

Materials are classified into 3 types according to their properties.

1. conducting Materials (3) Semiconductor Materials.
2. Insulating materials.

4.7 HOUSE WIRING

The House wiring deals with distribution system arranged for domestic applications. For House wiring system generally done for single supply 230V and for Three phase supply 440V. In 3-phase system, the total load in the house is divided among for three phases. An earth wiring also run by connecting all the power plug for large electrical energy is tapped into electrical applications such as Heater, Electric Iron box, Air conditioner, Electric stove, Fridge/Freezer, Pumps, etc. The actual system of wiring is selected based on the several factors such as, cost, durability, safety from fire, mechanical protection, appearance, accessibility, etc.

MATERIALS USED FOR WIRING

The **Material used for Wiring** may be: (i) Conducting material (ii) Insulating material (iii) Cables (iv) Switches (v) Main Switches (vi) Fuse (vii) Lamp holders (viii) Ceiling roses (ix) Plug and Sockets (x) Junction Box.

1. **Conducting Materials :** The **Conducting Material** is the part of accessory inwhich the current flow occurs. It is normally made up of **Copper or Brass.** Its current rating which depends on the maximum amount of current can possible to pass through it.

2. **Insulating Materials :** The **Insulating Materials,** is a substance which doesnot allows the leakage current flow and also it controls the current flow in a definite direction. The rating of insulating material depends on the maximum safe working voltage without any leakage current through the insulation. For example, **Bakelite, Porcelain.**

3. **Cables :** For indoor wiring and underground distributed system, the insulated conductors known as **Cables.** The cable inside conducting part is made up of **Conducting Material** (Copper, Silver, Aluminium). Normally copper is the best conducting material. Next choice is silver. Nowadays, Aluminium is increased due to its light weight, less cost and readily available. The insulation is provided on the conducting material to stop the leakage current flow. The cables are generally denoted by two numbers: 3/22 cable means a cable of three strands each of 22 gauge wire.

   The **Cables commonly used for Domestic wiring may be :**

   (i) VIR (Vulcanized Indian Rubber) Insulated Cables

   (ii) TRS (Tough Rubber Sheathed) Cables

   (iii) CTS (Cab Tyre Sheathed) Cables

   (iv) PVC (Polyvinyl Chloride) Insulated Cables

   (v) Weather – Proof Cables

   (vi) Lead Sheathed Cables

4. **Switches :** A **Switch** is used to break the electric circuit. Otherwise, the switches are made to 'ON' or 'OFF' the supply to a load. They are provided only in lines and not in neutrals.

   (i) **Surface or Tumbler Switch :** These switches are mounted on mounting block directly fixed over the surface of wall. The switch can be classified into:

   (a) Single way switch(--- ---)

   (b) Two way switch (---\---)

   Most of the switches are single way. The Double or two way switches normally used in applications such as, Star case wiring.

(ii) **Rotary Snap Switches :** The **Rotary Switch** consists of insulated handle which are blades. The blades move step by movement of the handle and may contact with the terminals are connected as wire to electric circuits. The movement of the handle is controlled by cam or If the handle move a quarter term blade is released and moves quickly with spring to make or break the circuit.

(iii) **Push Button Switch :** This type of switch consists of only one blade. The blade produce racking action by press button and its movement is controlled by a cam and spring. The blade may open or close at quick movement. For example, Door bell operation switch.

5. **Main Switch :** The **Main Switch** is normally connected with energy meter. The function of main switch is to control the complete lighting system of the house. The main switch operators simultaneously with one live phase and neutral. The main switches are classified into:
   (i) **Double Pole Iron Clad(DPIC) Switch :** This is normally used in **Domestic Wiring**. Normally, it can be used for controlling single phase two wire circuits.
   (ii) **Triple Pole Iron Clad (TPIC) Switch :** It is normally, used in **Industrial Installation** applications for controlling 3-phase power with 3-wire system.
   (iii) **Triple Pole Neutral Link iron Clad(TPNIC) :** This is mainly used for controlling switch for **3-phase power 4-wire system.** (R – Y – B – N)

6. **Fuses :** A **Fuse** is a safety device used in series with the line wire. The Fuse melts when abnormal current pass through it and thus disconnect or open the circuit. The fuse base made up of porcelain with fixed copper contacts. The **Fuse Wire** may be of: Copper, Tin, Lead used according to the current rating.

7. **Lamp Holders :** The **Lamp Holders** are used to hold the lamp required for lighting purpose. The types of lamp holder may be:
   (a) Bayonet cap lamp holders:
      (i) Pendent Holder – Used for hanging light upto 250W.
      (ii) Button Holder – Used for wall fixed upto 250W.
   (b) Screw Lamp Holders – This type of holders are used with screwed type lamps upto 100W, 250V.
   (c) Fluorescent Lamp Holders – This type of holders either in bi-pin type or bayonet type, Normally pin type holders are used.

8. **Ceiling Roses :** The **Ceiling Roses** are the tapping points for the supply to fans, pendent holders, tube lights, etc. A flexible cord connects the supply from ceiling rose to the load. The ceiling Roses are two types: (i) Two plate type (ii) Three plate type. The Two plate ceiling rose is used for a single light point and Three plate ceiling rose is used for a bunch of lights.

9. **Plug and Socket :** The **Plug and Socket** are used for connecting electrical devices like, Electric iron box, Heaters, Washing machine, Hot plates, Mixes and Grinders and Refrigerators, etc. Normally, Three pin plug – Socket inwhich the male – female joined with 3-pins. The bottom two small pins for connecting line and neutral and the third larger and longer pin is used for earth connection.

10. **Junction Box :** The **Junction Box** are used to join some conductors and to provide different path for different conductors. In looping system, the junction boxes are not required.

11. **Iron-Clad-Cut-off :** The **Iron-Clad-cut-off** which consists of fuse holder with iron covers control through ON-OFF switch.

12. **Cable Wire and its Accessories :** The **Cable Wire** consists of four best conductors which can be used for conducting electrical energy. For example, Copper(Cu), Silver, Aluminium(Al), Iron(Fe).

The accessories used for House wirings are: (i) Screw driver (ii) Cutting pliers (iii) Wire strippers (iv) Knife (v) Hammer (vi) Nose pliers (vii) Drilling machine (viii) Test lamp (ix) Hack saw.

2.8 TYPES OF WIRING

The actual wiring system selected based on the factors such as Safety form fire, Consumer's budget, Durability, Mechanical protection, appearance and also depends on the factors such as

(i) Working or operating voltage

(ii) Environmental factor

(iii) Size of the building

The various systems of wiring are :

(i) Cleat wiring system

(ii) Wooden casing and clamping system

(iii) Lead sheathed system

(iv) C.T.S/T.R.S wiring system

(v) Conduit pipe wiring

(i) Cleat Wiring System : This type of wiring not practically used for permanent wiring and preferred for tempory wiring purpose. Inwhich single core cables are run in the grooves of porcelain insulation called as cleats attached to wooden wall plugs. Normally, the porcelain cleats are spaced every 60cm inorder to avoid sagging of wires.

- The wires are placed 2.5cm from branch circuits and 4cm from sub mains. The joins are enclosed with wooden junction boxes with porcelain connectors. The life time is around 5-years. The Cleat type Wiring System as shown in Fig 2.13(a).

Advantages

1. Faults can be easily located in the system.

Disadvantages

1. The main draw back is no protection from mechanical injury, fire, gas or water pipes.
2. A lot of dust is formed over the wire.

(ii) Wooden Casing and Capping System : In Wooden Casing and Copping System, the wires are enclosed in Wooden may be a (Well seasoned teak or other good hard wood) casing which are varnished. This is the most common type of wiring used for indoor and domestic installations. The systems was introduced 60 years age and considered necessary to provide some protection to the conductors. The conductors are covered by either **Volcanized Indian Rubber(VIR) and Poly Vinyl Cloride(PVC) Cables.**

- The wood casing inwhich normally Teak wood is used in Rectangular blocks. In the Rectangular blocks having a number of grooves to number of wires fixed. The casing is normally placed 3.5mm apart from the walls or ceiling by means of wooden blocks or porcelain discs. The system is suitable for domestic installation, but not in damp walls. This life time is around 20years. The Case wiring and Capping as shown in Fig 2.13(b).

Advantages

1. The above system provides sufficient Mechanical protection to the cables which we are using.
2. The wire look fine and No paint coating is require.

Disadvantages

1. Nowadays, High cost woods are used and the cost is high and there is a Great risk of wire in an accident.
2. It is very difficult for Fault identification on particular place.

-4

3. The Wood used is inflammable, even through coating of varnish, it is not damp proof.

4. The errection process is not simple, but requires more time for Installation and Skilled labour.

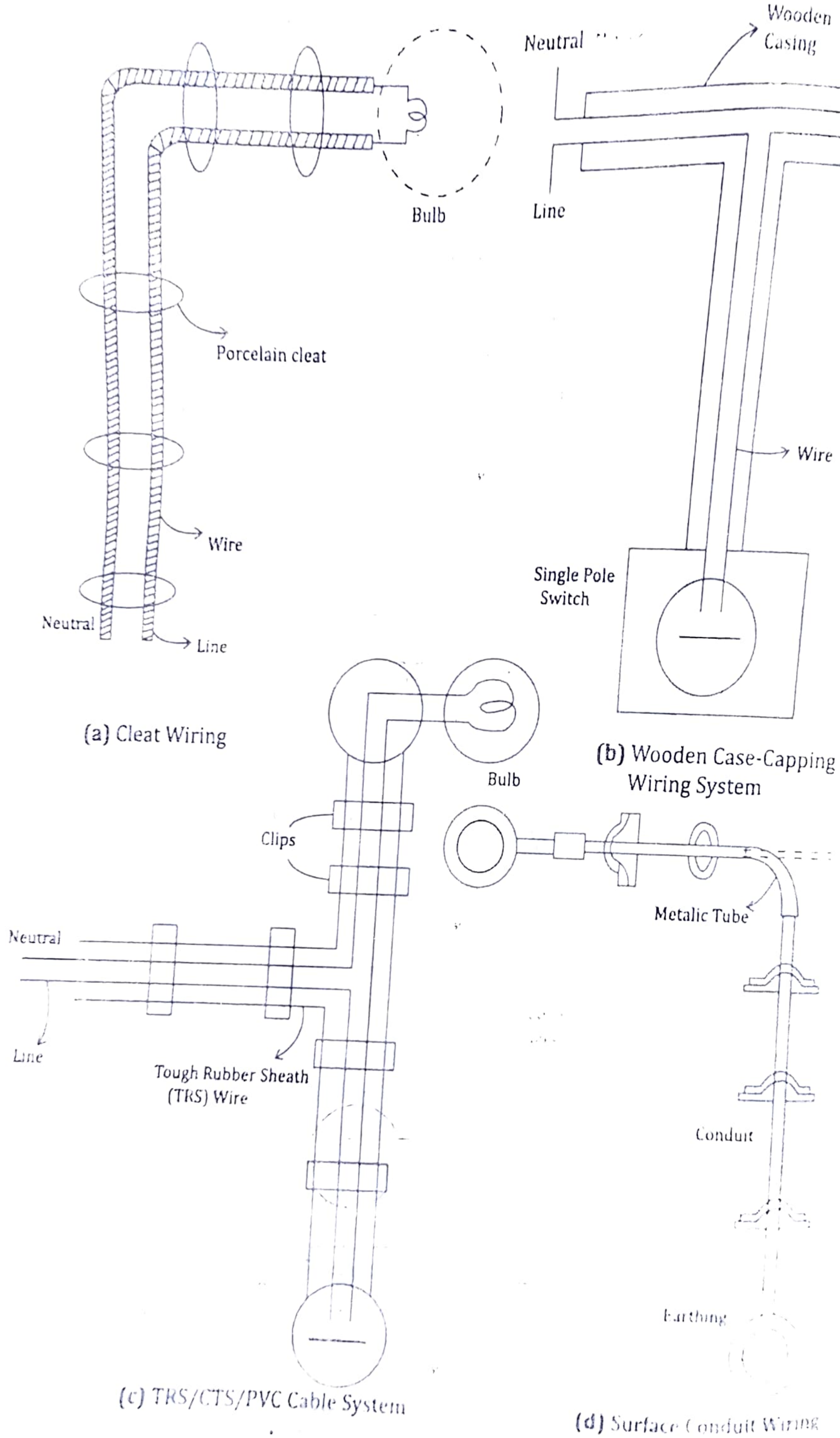


Fig 2.13 Types of Wiring

2.9 HOUSE WIRING SYSTEM

1. **A Lamp Controlled by a Switch :** A lamp controlled by a switch as shown in Fig 2.14. The main elements Lamp(L) and Switch(S) are connected with Neutral(N) and Line phase(P). In the circuit, Neutral is directly connected with Lamp(L) and the line or Phase(P) is connected through Switch(S).

   Case 1 : If the Switch(S) is ON; the Lamp(L) will glow.

   Case 2 : If the Switch(S) is OFF, the Lamp(L) will not glow.

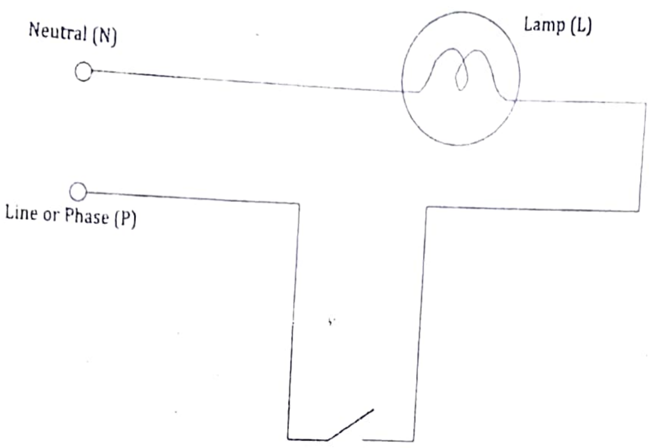


Fig.2.14 A lamp which is controlled by a single switch.

2. **Three Lamps Controlled by Three Separate Switches :** The circuit diagram for 3-lamps controlled by 3-switches separately as shown in Fig.2.15. The Main elements are: Lamps (L_1, L_2, L_3) and Switches (S_1, S_2, S_3). In which the Neutral(N) is directly connected with the Lamp(L_1, L_2, L_3) and the supply or line or Phase(P) is connected by 3-switches (S_1, S_2, S_3) for Lam1 Lamp2, Lamp3.

   Case 1 : If Switch(S_1) is ON; the Lamp(L_1) will glow.

   Case 2 : If Switch(S_2) is ON, the Lamp(L_2) will glow.

   Case 3 : If Switch(S_3) is ON, the Lamp(L_3) will glow.

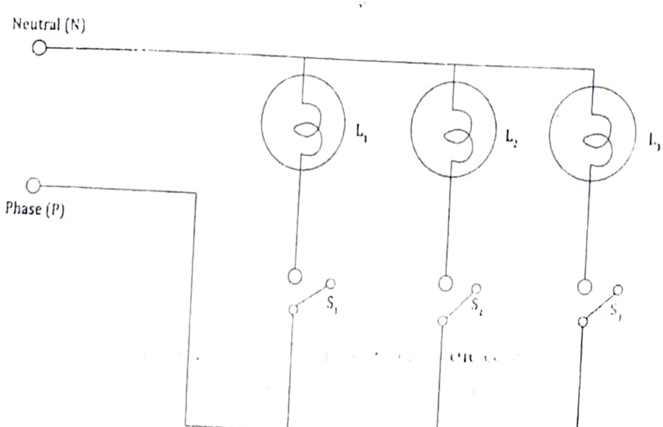


Fig.2.15 Three lamps (L_1, L_2, L_3) controlled by Separate switches (S_1, S_2, S_3).through 1φ-Supply.

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3. **Two Lamps Controlled by one Two way Switch :** The Two lamps controlled by one two way switch as shown in Fig.2.16. The Main elements are 2-lamps (L_1, L_2) Two way switch(S) and Supply (Phase (P) and Neutral (N)).

Case 1 : Two way switch in position 1, the First Lamp(L_1) will glow.

Case 2 : Two way switch in position 2, the Second Lamp(L_2) will glow.

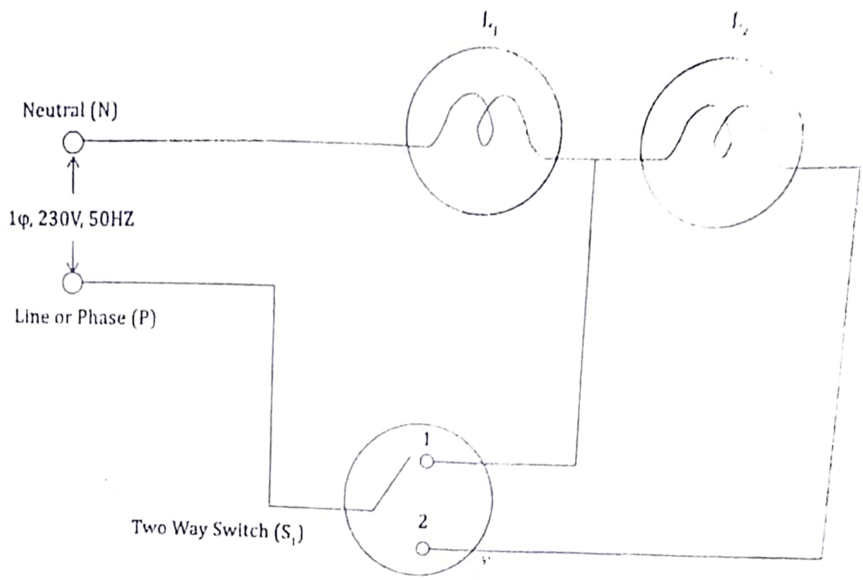

Fig.2.16 Two lamps controlled by on Two way switch.

4. **Stair Case Wiring:** The **Stair Case Wiring** is a wiring inwhich a Single lamp is controlled by the switches at two different places.

Switch 1 : Two way Switch(S_1) at the beginning of the Stair case.

Switch 2 : Two way Switch(S_2) at the other end of the end of Stair case.

The Wiring diagram of Stair case inwhich the Two position switches (S_1 and S_2) which controls a single lamp through 1φ-supply as shown in Fig 2.17. The Main elements are: 1φ supply, Lamp, Two 2-pole switch and connecting wires. In Stair case wiring a single lamp is controlled by 2-switches at two different places.

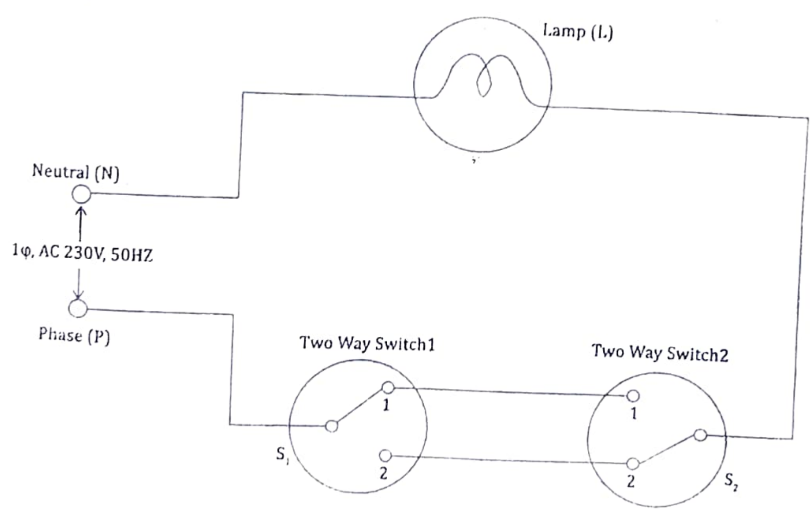

Fig 2.17 Wiring diagram of Staircase System

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1 : The Switch 1 at the beginning of the Stair case.

itch 2 : The Switch 2 at end of the Stair case.

Glow of Lamp : If the two 2-way switches at the same position(1-1, 2-2) the Stair case produce the output and the lamp will glow.

Off Position of Lamp : If the two way switches at different position (1-2, 2-1), the Stair case will not produce output and the Lamp will not glow.

Table: 2.1 Stair case switch operation position and the output

Position of Switch S_1	Position of Switch S_2	Condition of the Lamp
1	1	Lamp will ON
1	2	Lamp will OFF
2	1	Lamp will OFF
2	2	Lamp will ON

5. **Fluorescent Lamp Connection :** The **Fluorescent Lamp** is a mercury discharge lamp inwhich low pressure mercury vapour and organ gas inside. The inside walls of the tube which are coated with a suitable Phosphorescent material depending on the colour required. The Connection of Fluorescent lamp as shown in Fig. The Main elements are: Lamp, Iron cored choke, Band a Starter in series.

If the switch 'S' is mode on, the current flow through and gas discharge heat up bimetallic strips of the starter which bands and close the contacts. Every time a fluorescent lamp is switched on, electrode lose some of the emitting material. Thus, the life of a Fluorescent lamp is greatly reduced if it is frequently started.

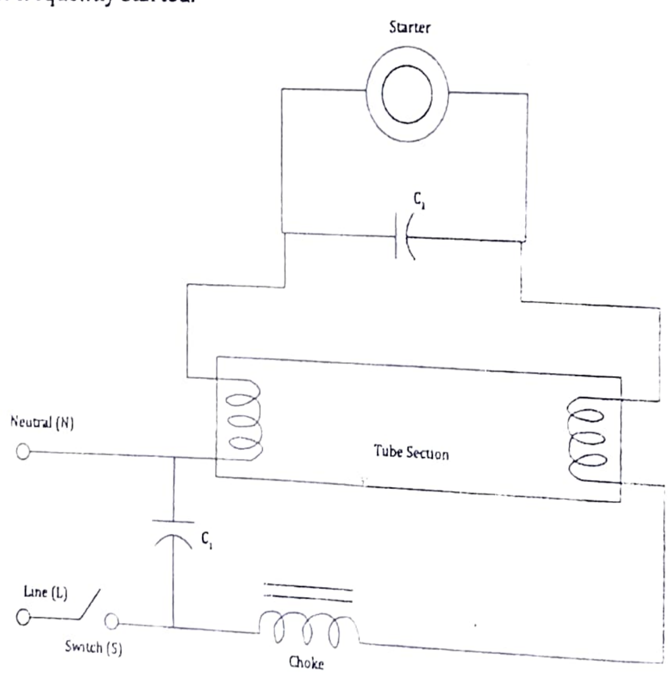

Fig.2.18 Fluorescent Lamp Connection

2.10 INDUSTRIAL WIRING

The Industrial High voltage with stand wiring systems are used in industries: Petro Chemical Industry, Power Plant Industry, Paper and Pulp Industry, Mining and manufacturing Industry, Cement and Iron Industry, etc.

Advantages of Industrial wiring as follows :

(i) Operates continuously at 482°F (250°C) environment

(ii) Operates for upto 2-house in hydrocarbon fires

(vi) No aging factor

(vii) High mechanical strength

(viii) High corrosive resistance

(ix) Water proof and sub mersible

(x) Small overall diameter and no conduit requirement.

The Industrial Electro-Pneumatic and Induction Motor operation as shown in Fig.2.19. The Main elements are: Main supply, wire system, Sub main, Induction Motors 1 and 2, Current to Pressure (I/P) Converter, Pressure Regulator.

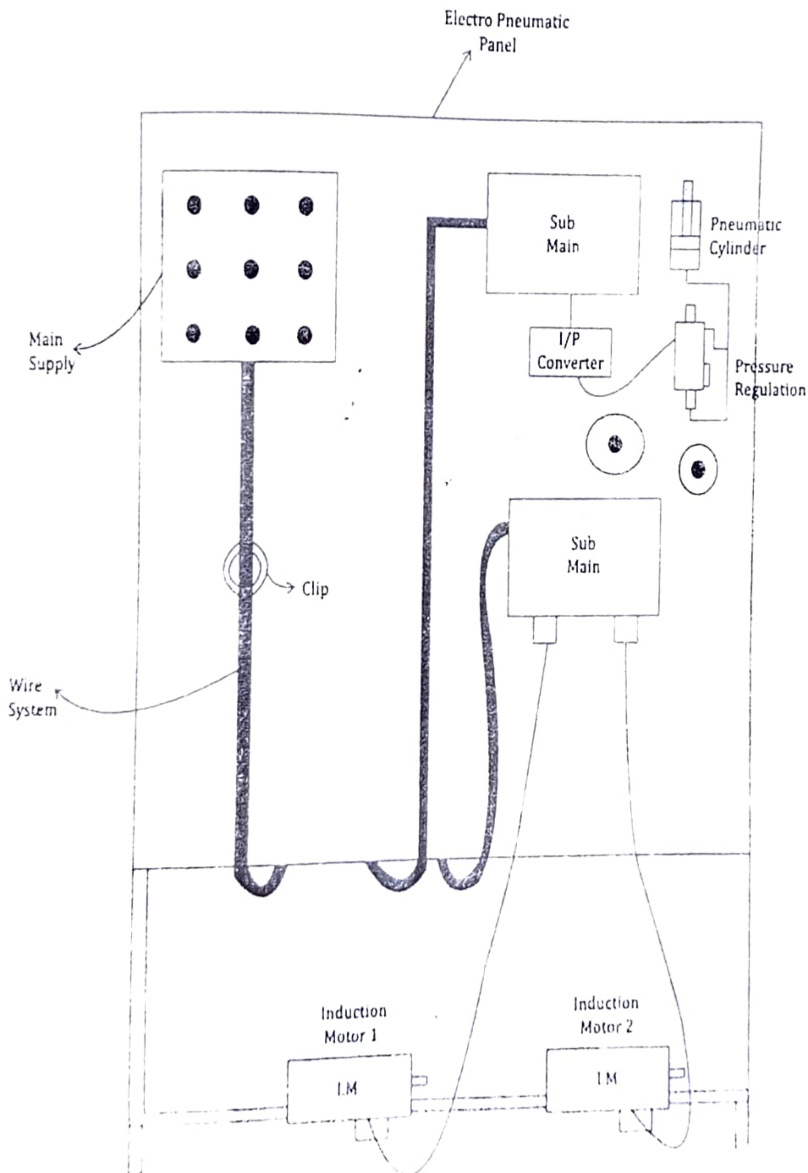

Fig.2.19 Electro Pneumatically Panel Wiring System.

Pneumatic Cylinder

The Main supply is give to 2-sub mains. The First main will give supply to operate I/P Converter, Pressure Regulator and Pneumatic Cylinder. The Second sub main will operate 2-Inductor Motors.