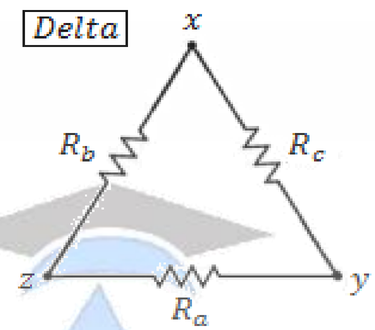
BASIC ELECTRICAL

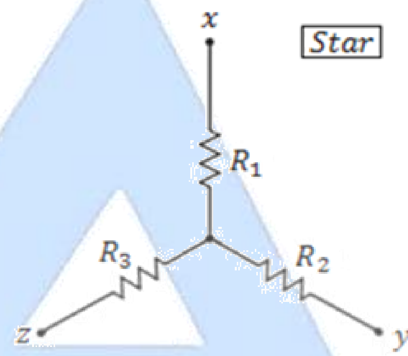
- **Current**; i = charge/time = dq/dt
- Unit of current = coulomb/second = ampere
- $q = ne$; where n = number of electron, e= charge of electron
- Number of electron in 1 coulomb = 6.28×10^{18} electron
- $\textit{Voltage} = \frac{work}{charge} = \frac{W}{Q}\left(\frac{joule}{coulomb}\right)$
- **Voltage drop**; V= IR
- **Resistance**; R = $\rho l/A$;
  Where ρ = resistivity of a wire, l = length and A = cross sectional area of wire
  Unit of resistance = ohm; Ω
  Unit of resistiviy = ohm-meter (Ω-m)
  Resistivity depends on – temperature and types of material
- **Color coding of carbon resistor**

Color	Value	Multiplier	Tolerance
Black	0	10^0	
Brown	1	10^1	±1%
Red	2	10^2	±2%
Orange	3	10^3	±3%
Yellow	4	10^4	–
Green	5	10^5	±0.5%
Blue	6	10^6	±0.25%
Violent	7	10^7	±0.10
Grey	8	10^8	±0.05
White	9	10^9	–
Gold	-	10^{-1}	±5%
Silver	-	10^{-2}	±10%
None	-	-	±20%

- **Conductance** – it is reciprocal of resistance
$$G = \frac{1}{R} \; mho, Seiman$$
- When length increased by n time and volume not change
$$R_{new} = n^2 R_{old}$$
- When area is n time of previous and volume is not change
$$R_{new} = \frac{R_{old}}{n^2}$$
- **Effect of temperature coefficient**
$$R_t = R_0(1 + \alpha_0 t)$$
$$R_{t2} = R_{t1}[1 + \alpha_1(t_2 - t_1)]$$
$$\alpha_t = \frac{\alpha_0}{1 + \alpha_0 t}$$
- **Series combination of resistance**;
$$R_{eq} = R_1 + R_2 + R_3 + \cdots R_n$$
- **Parallel combination of resistance**
$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} \ldots + \frac{1}{R_n}$$
- **Star to delta conversion-**

$$R_a = \frac{R_1R_2 + R_2R_3 + R_3R_1}{R_1}, R_b = \frac{R_1R_2 + R_2R_3 + R_3R_1}{R_2}, R_c = \frac{R_1R_2 + R_2R_3 + R_3R_1}{R_3}$$





- **Delta to star conversion**
$$R_1 = \frac{R_bR_c}{R_a + R_b + R_c}, R_2 = \frac{R_aR_c}{R_a + R_b + R_c};$$
$$R_3 = \frac{R_aR_b}{R_a + R_b + R_c}$$
- **Ohm's law-**
  Condition – temperature should be constant
  Resistance should be constant
$$I \propto V$$
$$I = \frac{V}{R}$$
$$R = \frac{V}{I}$$
- **DC power-**
$$P = VI = I^2R = \frac{V^2}{R} watt$$
- $energy; E = power \times time = I^2Rt\ Joule$
- **Active element** – Capable to delivered energy. Ex: Independent current and voltage source, primary cell etc.
- **Passive element** – Only consume energy. Ex: resistance, inductance and capacitor etc.
- **Unidirectional elements** – work only on one direction. Ex. Diode
- **Bidirectional elements** – work in both direction. Ex. Capacitor, resistor, inductor etc.
- **KCL-** At any node the algebraic sum of incoming current is equal to outgoing current.

Number of KCL equation = (n-1); where n = number of node

- **KVL** – In any loop algebraic sum of emf and algebraic sum of voltage drop is zero.
  Number of KVL equation = B-N+1
  Number of link = B-N+1; where B = no. of branch, N= no. of node
- The internal resistance of ideal current source is infinity.
- The internal resistance of ideal voltage source is zero.
- Maximum power transfer theorem –

$$P_{max} = \frac{{V_{th}}^2}{4R_{th}}$$

- **Super position theorem-**
  It is apply only when more than one active element is present in circuit (homoginity)
  It apply only for linear network.
- **Reciprocity theorem** – The ratio of excitation and response is constant when the position of excitation and response is interchange.
- **Tellegen's theorem** – In any network the power delivered by active sources is equal to power consumed by various passive elements in network.
  It can apply on linear, non-linear network and time variant or invariant system.
- Impedance = real part + imaginary part

$$impedance;\ Z = R \pm jX;$$
$$+j \rightarrow inductance, -j \rightarrow capacitance$$

Real part = resistance, imaginary part = reactance (due to inductor and capacitor)

- Inductive reactance; unit ohm (Ω)

$$X_L = 2\pi fL$$

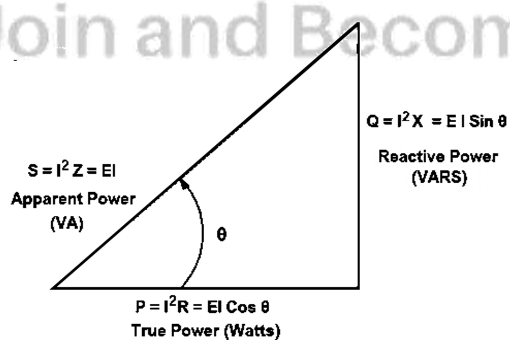
- Capacitive reactance; unit ohm (Ω)

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

- **Admittance (Y)** – unit mho or Siemens

$$Y = G \pm jB;\ where$$
$$+j \rightarrow capacitance, -j \rightarrow inductance$$
$$Impedance\ = \frac{1}{admittance}; Z = \frac{1}{Y}$$

- **Power triangle-**



- **Power factor** – The cosine of the angle between voltage and current is called power factor.

$$\cos\phi = \frac{active\ power}{apperent\ power} = \frac{R}{Z}$$

- **Inductor analysis** – it oppose the change in current itself.

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

In pure inductor current is legging, voltage by 90°.
So power consume in inductor is zero.
Active power = 0 Watt
Apparent power = VI Volt-Amp
Reactive power = VI Volt – amp-reactive
Power factor = zero lagging

- **Capacitor analysis-** it oppose the change in voltage itself.

$$i = C\frac{dv}{dt}$$

Active power = VI cos ϕ=0
Apparent power = VI volt-amp
Reactive power = VI sinϕ = VI volt-amp-reactive
Leading reactive power

- **Series resonance circuit-**
  It is also called voltage magnifier
  Condition of resonance:

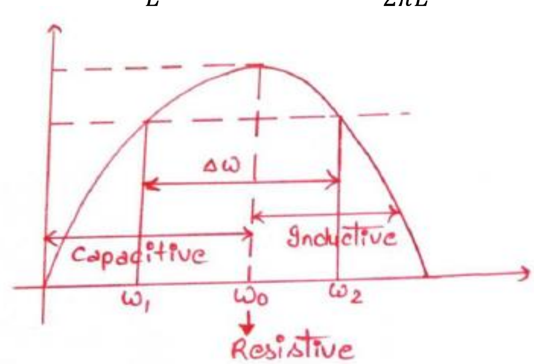
$$X_L = X_C\ but\ 180°\ out\ of\ phase$$
$$Z = R + 0j; impedance\ minimum$$
$$I = \frac{V}{R}; current\ maximum$$

Unity power factor

$$Resonance\ frequency; \omega_0 = \frac{1}{\sqrt{LC}}\ red/sec$$
$$\Rightarrow f_0 = \frac{1}{2\pi\sqrt{LC}}\ Hz$$
$$half\ power\ frequency;\ \omega_1 = \omega_0 - \frac{\Delta\omega}{2};$$
$$\omega_2 = \omega_0 + \frac{\Delta\omega}{2}$$
$$\omega_0 = \sqrt{\omega_1\omega_2}$$

- ***Quality factor –***

$$Q = \frac{|V_L|}{V} = \frac{|V_C|}{V} = \frac{X_L}{R} = \frac{X_C}{R}$$
$$= \frac{\omega_0 L}{R} = \frac{1}{\omega_0 RC} = \frac{1}{R}\sqrt{\frac{L}{C}}$$
$$quality\ factor = \frac{resonance\ frequency}{bandwidth} = \frac{\omega_0}{\Delta\omega}$$
$$\Delta\omega = \frac{R}{L}\ rad/sec \Rightarrow \Delta f = \frac{R}{2\pi L} Hz$$



$\omega = \omega_0 \rightarrow$ Unity PF

$\omega < \omega_0 \rightarrow$ Capacitive [Leading]

$\omega > \omega_0 \rightarrow$ Inductive [Lagging]

- **Parallel RLC circuit-**
  It is called current magnifier

$$Resonance\ frequency; \omega_0 = \frac{1}{\sqrt{LC}}\ red/sec$$

$$\Rightarrow f_0 = \frac{1}{2\pi\sqrt{LC}}\ Hz$$

Y = minimum, impedance = maximum, current flow minimum, unity power factor

$$Q = \frac{V}{X_L} = \frac{V}{X_C} = \frac{|I_L|}{I} = \frac{|I_C|}{I}$$

$$= \frac{R}{X_L} = \frac{R}{X_C} = \omega_0 RC = \frac{R}{\omega_0 L}$$

- **Three phase balance circuit condition –**
  - i. Each phase having 120° displacement.
  - ii. The magnitude of current will be same.
  - iii. The magnitude of voltage will be same.
  - iv. Line current are equal.
  - v. Line voltage are equal.
  - vi. Neutral having zero current.
    Impedance and phase angle in each phase is equal.
- **Star connection –**
  - i. Phase current = line current
  - ii. Line voltage = $\sqrt{3}$ × phase voltage
- **Delta connection –**
  - i. Line voltage = phase voltage
  - ii. Line current = $\sqrt{3}$ × phase current
- **Power measurement by 2 wattmeter method-**
  - i. $W_1 = W_2; \theta = 0, power\ factor = 1$
  - ii. $W_1 = -W_2; \theta = 90, power\ factor = 0$
  - iii. $W_1 = +ve, W_2 = 0; \theta = 60, power\ factor = 0.5$
  - iv. $W_1 = +ve, W_2 = -ve;\ power\ factor = less\ then\ 0.5$
  - v. $W_1 = 2W_2; \theta = 30, power\ factor = 0.866$
- Charge; Q = ne
- 1 coulomb charge = 6.25 × $10^{18}\ electron$
- **Electron –**
  Charge = 1.6 × $10^{-19}\ coulomb$
  Mass = 9.11 × $10^{-31} Kg$
- **Proton –**
  Charge = 1.6 × $10^{-19}\ coulomb$
  Mass = 1.67 × $10^{-27} Kg$

$$m_e = \frac{m_p}{1840}$$

- Maas of neutron = 1.67 × $10^{-27} Kg$
- Permittivity =
- $absolute\ premittivity;\ \varepsilon = \varepsilon_0\varepsilon_r\ farad/meter$
- $\varepsilon_0 = free\ space\ permitivity = 8.854 \times 10^{12}\ farad/meter$
- ε_r =Relative permitivity, it is unit less quantity. It is depends upon the medium.
- Relative permittivity of free space = 1
- $F = \frac{1}{4\pi\varepsilon}\frac{Q_1Q_2}{d^2} = 9 \times 10^9 \times \frac{Q_1Q_2}{\varepsilon_r d^2}\ N$
- $for\ air\ F = 9 \times 10^9 \frac{Q_1Q_2}{d^2} N$
- Field intensity,

$$E = \frac{F}{Q} = \frac{1}{4\pi\varepsilon}\frac{Q}{d^2}; unit = F/m$$

- $D = \varepsilon E$
- $V = \frac{W}{Q} = \frac{Fd}{Q} = \frac{1}{4\pi\varepsilon}\frac{Q}{d}; unit = F/m$
- Capacitor-

$$C = \frac{\varepsilon A}{d}\ farad$$

- $C = \frac{Q}{V}$
- series combination of capacitor-

$$C_{eq} = C_1 + C_2 + C_3 + \cdots$$

- parallel combination of capacitor

$$\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{\mathbf{1}}{C_3} + \cdots$$

- Energy stored in capacitor

$$E = \frac{1}{2}CV^2 = \frac{1}{2}\frac{Q^2}{C} = \frac{1}{2}Q \times V$$

- **Charging of a capacitor**

$$v = V\left(1 - e^{-\frac{t}{RC}}\right)$$

$$i = Ie^{-\frac{t}{RC}}$$

$$time\ constent = RC$$

$$v = 63.21\,\%\ of\ full\ charging\ voltage$$

- **Discharging of a capacitor**

$$v = Ve^{-\frac{t}{RC}}$$

$$i = -Ie^{-\frac{t}{RC}}$$

- Capacitance of multiple plate capacitor-

$$C = (n-1)\frac{\varepsilon_0\varepsilon_r A}{d}; where - no\ of\ plate$$

- $absolute\ permeability; \mu = \mu_0\mu_r \frac{H}{m}$
- $\mu_0 = permeability\ of\ free\ space = 4\pi \times 10^{-7} H/m$
- $\mu_r = relative\ permeability; no\ unit$

$$F = \frac{1}{4\pi\mu_0\mu_r}\frac{m_1m_2}{d^2}\ N$$

- $unit\ of\ pole\ strength - weber$
- Magnetic field density; $B = \frac{\phi}{A}\frac{wb}{m^2}$

$$Tesla = \frac{wb}{m^2}$$

- $electric\ field\ intensity; E = \frac{F}{Q}\frac{N}{C}$
- $magnetic\ field\ intensity; H = \frac{F}{m} = \frac{1}{4\pi\mu_0\mu_r}\frac{m}{d^2}\frac{N}{Wb}$
- $B = \mu_0\mu_r H$
- Magnetic intensity-

$$I = \frac{M}{V}\ A/m$$

- Magnetic susceptibility –

$$\chi_m = \frac{I}{H}$$

$$\mu_r = 1 + \chi_m$$

- Classification of magnetic material-
  i) $Ferromagnetic\ material - \mu_r >> 1$
  ii) $Paramagnetic\ material\ - \mu_r > 1$
  iii) $Diamagnetic\ material - \mu_r < 1$
- Force between two parallel conductor-

$$F = \mu_0 \mu_r \frac{I_1 I_2 l}{2\pi r}$$

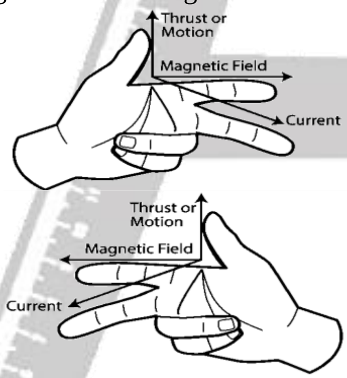
- Force at current carrying conductor placed in magnetic field; $F = BIL\sin\theta\ N$
- MMF = NI A-T
- Reluctance-

$$S = \frac{1}{\mu}\frac{l}{A} AT/Wb\,;\ S = \frac{NI}{\phi} AT/Wb$$

- $H = \frac{mmf}{length} = \frac{NI}{l}\ AT/m$
- $H = \frac{F}{Q}\ N/wb$
- Ampere circuit law-

$$\oint \vec{H}.\overrightarrow{dr} = NI$$

- Flaming left hand and right hand rule-



- $Biot\ savart\ Law = dB = \frac{\mu_0}{4\pi}\frac{Idl\sin\theta}{r^2}$
- $leakage\ factor = \frac{total\ flux}{useful\ flux}; > 1$
- **Faradays laws-**
  i. **First Law-** When conductor cuts a flux or flux cuts a conductor or any relative change between flux and conductor then emf induced in a conductor.
  ii. **Second law** – The magnitude of this induced emf depends upon the rate of change of magnetic flux.

$$e = N\frac{d\phi}{dt}$$

- $\boldsymbol{Lanz's\ Law}$

$$e = -N\frac{d\phi}{dt}$$

- $\boldsymbol{Static\ insuced\ emf} = e = N\frac{d\phi}{dt}$
- $\boldsymbol{Dynamic\ induced\ EMF} = e = Blv\sin\theta$
- **Self-induced emf-**

$$e = -L\frac{dI}{dt};\ L = \frac{N\phi}{I} = \frac{N^2\mu A}{l}$$

- $\boldsymbol{mutual\ induced\ EMF} -$

$$e = -M\frac{dI}{dt};\ \ M = -N_2\frac{k\phi_1}{I}$$

$$K = \frac{M}{\sqrt{L_1 L_2}}\ ;\ M = \frac{N_1 N_2}{reluctance}$$

i. $K = 0\,; no\ coupling$
ii. $K = 1; normally\ coupling$
iii. $K > 1; tight\ coupling$
iv. $K < 1\ loose\ coupling$

- **Charging of a inductor-**

$$i = I\left(1 - e^{-\frac{t}{\tau}}\right)$$

$$v = Ve^{-\frac{t}{\tau}};\ \ where\ \tau\ (time\ constent) = \frac{L}{R}$$

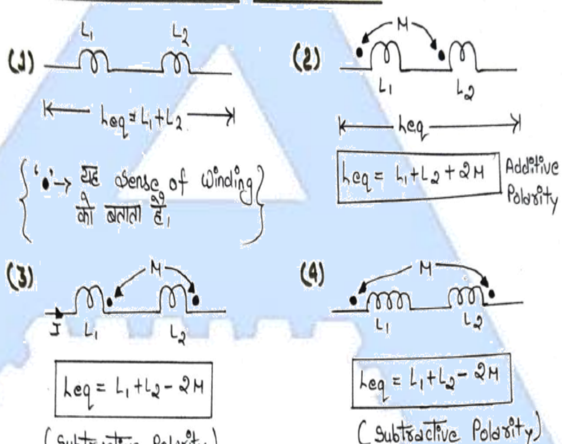
- **Discharging of a inductor-**

$$i = Ie^{-\frac{t}{\tau}}$$

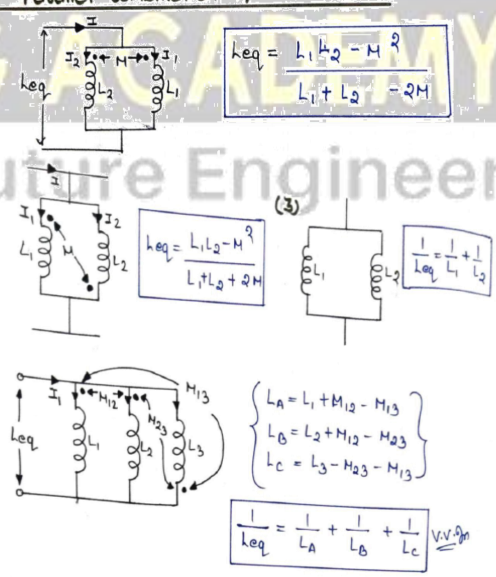
$$v = V\left(1 - e^{-\frac{t}{\tau}}\right);$$

$$where\ \tau\ (time\ constent) = \frac{L}{R}$$

Series Combination of Inductance :-



Parallel Combination of Inductance :-



- Energy stored in inductor = $\frac{1}{2}LI^2\ joule$

- Energy stored per cubic meter = $\frac{1}{2}\mu_0\mu_r H^2\ J/m^2$

ELECTRICAL MACHINE

- Transformer never change the level of apparent power-
- Input KVA = Output KVA
- EMF equation –
- $E = 4.44\phi_m fN$
- $a = \frac{E_1}{E_2} = \frac{N_1}{N_2} = \frac{V_1}{V_2} = \frac{I_2}{I_1}$
- In transformer voltage per turn never be changed.
- **Ideal transformer-**
  i. No leakage flux
  ii. No losses
  iii. 100% efficiency
- In a transformer no load current is 2 to 5% of full load current.
- Rafferd value
- If turn ratio is a= $\frac{V_1}{V_2}$
- Primary to secondary –

$$V_1' = \frac{V_1}{a};\ I_1' = aI_1;\ R_1' = \frac{R_1}{a^2};\ X_1' = \frac{X_1}{a^2};\ E_1' = \frac{E_1}{a};\ X_m' = \frac{X_m}{a^2}$$

- Secondary to primary

$$V_2' = aV_2;\ I_2' = \frac{I_2}{a};\ R_2' = a^2R_2;\ X_2' = a^2X_2;\ E_2' = aE_2$$

- Phase difference between primary to secondary voltage is 180°.
- No load power factor = 0.212
- **Voltage regulation-**

$$\%\text{regulation} = \frac{\text{no load voltage} - \text{full load voltage}}{\text{full load voltage}} \times 100 = \frac{(I_1R_{eq}\cos\phi + I_1X_{eq}\sin\phi)}{V_2'} \times 100$$

Condition for maximum voltage regulation-

$$\phi = \tan^{-1}\left(\frac{X_{eq}}{R_{eq}}\right)$$

Condition for minimum voltage regulation –

$$\phi = \tan^{-1}\left(\frac{R_{eq}}{X_{eq}}\right)$$

Maximum voltage regulation occur at lagging power factor.

Zero voltage regulation and – Ve voltage regulation possible at leading power factor.

Regulation $= R_{pu}\cos\phi \pm X_{pu}\sin\phi$

Regulation = $V_{1pu} - 1$

- Separation of eddy current loss and hysteresis loss-

$$\text{if } P_e = Af^2 \text{ and } P_h = BF$$

Then iron loss $P_i = f(Af + B)$

- **Open circuit test –**

i. It is perform to find out iron losses.
ii. High voltage winding is open.
iii. Equipment connects at low voltage side.
iv. Wattmeter reading gives iron loss.

- **Efficiency –**

$$\eta = \frac{\text{output power}}{\text{input power}}$$

$\eta = \frac{(V_2I_2\cos\phi)}{V_2I_2\cos\phi + P_i + P_C}$ where; V_2 Rated load voltage, I_2-rated load current, $\cos\phi$-load PF, P_i –full load iron loss, P_c=full load copper loss

$$\eta = \frac{m\,S\cos\phi}{mS\cos\phi + P_i + i^2P_c}$$ where; m = load ratio and S = transformer rating at full laod

- **Condition for maximum efficiency-**

$$P_i(\text{iron losses}) = P_C(\text{copper losses})$$

$$\text{load ratio; } m = \sqrt{\frac{P_i}{P_c}}$$

$$\eta_{max} = \frac{mS_m\cos\phi}{m\,S_m\cos\phi + 2P_i}$$

- **Three phase transformer-**
  i. Group 1 – 0° displacement – Y_{Y0} , D_{D0}
  ii. Group 2 – 180°displacement – Y_{Y6}, D_{D6}
  iii. Group 3 - 30° lag – Y_{D1} , D_{Y1}
  iv. Group 4 - 30° lead - Y_{D11} , D_{Y11}
- **Application of three phase transformer-**
  i. Star-star connection – rarely used due to harmonics problem.
  ii. Delta-delta connection – to fed 3-phase load in industrial load.
  iii. Star-delta – it is used in step down application.
  iv. Delta-star- step up application.
- **Open delta connection -**
  i. Rating reduced by 57.7%.
  ii. Overloaded by 73.2 %.
- **Condition for parallel operation of a transformer-**
  i. Same phase sequence
  ii. Same phase group
  iii. Same frequency
  iv. Same voltage
  v. Same polarity
- **Auto transformer-**
  i. Only one winding is consist.
  ii. Power transfer magnetically as well as conductively.
  iii. Impedance – reduced
  iv. Voltage drop – reduced
  v. Good voltage regulation
  vi. Efficiency – high
- **Application of auto transformer-**
  i. 3-phase induction motor speed control.
  ii. Inter connection of two supply.
  iii. When variable voltage is require.
  iv. If $a_a = \frac{V_H}{V_L}$ is transformer ratio of auto transformer

v. $V_{A(auto)} = \frac{a_a}{(a_a-1)} V_{Atw}$

vi. Percentage saving conductor material= $\frac{1}{a_A} \times 100$

vii. Power transfer magnetically or inductively = $\left(1 - \frac{1}{a_A}\right) \times \text{Power output}$

viii. Power transfer conductively or capacitive $\frac{1}{a_A} \times$ power output

- Three phase induction motor –

$$\text{resultant flux; } \phi_r = \frac{3}{2}\phi_m = 1.5\,\phi_m$$

$$N_s = \frac{120f}{P}\ \text{rpm}$$

- 3-phase induction motor is self-start and having a high starting torque.
- 3-phase induction motor always run less then synchronous speed and never run at synchronous speed.
- A 3-phase induction motor running at low legging power factor, it is most responsible for lagging power factor.
- **Type of induction motor-**
  1. Slip ring induction motor
  2. Squirrel cage induction motor
- Slip = $(N_s - N)/N_s$
- Rotor speed; N= (1-s)N_s
- Rotor frequency; $f_r = sf$
- In three phase induction motor the no load current is 20 to 25 % of full load current.

$$s_{tmax} = \frac{R_2'}{\sqrt{{R_{th}}^2 + (X_{th} + X_2')^2}}$$

$$T_{max} = \frac{1}{2\omega_s}\frac{{V_L}^2}{X_2}$$

$$\frac{T_{fl}}{T_{max}} = \frac{2SS_{tmax}}{{S_{tmax}}^2 + s^2}$$

$$\frac{T_{fl}}{T_{st}} = \frac{S({S_{tmax}}^2 + s)}{{S_{tmax}}^2 + s^2}$$

- **Synchronous machine –**
- Stator – armature winding; 3-phase supply
- Rotor – field winding; DC supply
- **EMF equation –**

$$E = 4.44\,K_c K_d \phi f T_{ph}$$

Where; ϕ=flux per pole, f=frequency, T_{ph}=number of turn per pole, P=no of pole, K_C =coil span factor, K_d =distribution factor

$$K_c = \frac{\text{induced voltage in short pich}}{\text{induced voltage in full pich}} = \cos\frac{\alpha}{2}; < 1$$

$$\text{where } \alpha = \frac{180}{n}\ ; n = \text{harmonics}$$

$$K_d = \frac{\text{voltage in diustributed winding}}{\text{voltage in consentreted winding}}$$

$$K_d = \frac{\sin\frac{m\beta}{2}}{m\sin\frac{\beta}{2}};\ K_d < 1$$

$$m = \frac{\text{slot}}{\text{pole} \times \text{phase}}$$

$$\text{pole pich} = \frac{\text{conductor}}{\text{number of pole}}$$

$$\beta = 180 \times \frac{\text{pole}}{\text{slot}}$$

- **Armature reaction of synchronous generator-**
  - **(i) For unity power factor-**
    Cross magnetizing effect
    Normal excited ($\phi_f = \phi_r$)
  - (ii) **For zero lagging power factor-**
    Demagnetizing effect
    Over excited ($\phi_f > \phi_r$)
  - (iii) **For zero leading power factor-**
    Magnetizing effect
    Under excited ($\phi_f < \phi_r$)
  - (iv) For 30° lead
    Cross magnetizing effect
    Magnetizing effect
- In synchronous generator ϕ_f always lead by ϕ_r
- condition for maximum power developed $\theta_s = 180 - \delta$

$$P_{dev-max} = \frac{VE_f}{jX_s}$$

- condition for maximum power developed $\theta_s = \delta$

$$P_{out-max} = \frac{VE_f}{jX_s}$$

- **V – curve**: it is draw between armature current and field current
- **Inverted V-curve** – it is draw between Power factor and field current
- **Method of Voltage regulation-**
  i. EMF method (impedance method) – more pessimistic
  ii. MMF method (ampere-turn method) – less pessimistic
  iii. Potier triangle method (zero power factor method) – least (best, optimistic method)

$$\text{Regulation} = \frac{E_f - V}{V} = \frac{E_f}{V} - 1 = (E_f)_{pu} - 1$$

- Synchronous motor –
  - Constant speed
  - Zero starting torque
  - Used for power factor correction
- **Armature reaction of synchronous motor-**
  - (i) **For unity power factor-**
    Cross magnetizing effect
    Normal excited ($\phi_f = \phi_r$)
  - (ii) **For zero lagging power factor-**
    Magnetizing effect
    Under excited ($\phi_f < \phi_r$)
  - (iii) **For zero leading power factor-**

Demagnetizing effect

Over excited $(\phi_f > \phi_r)$

- **Condition for maximum power generation-** $\delta = 180 - \theta_s$

$$P_{in(max)} = \frac{VE_f}{X_s}$$

- **condition for maximum power deliverd** $\theta_s = \delta$

$$P_{dev} = \frac{VE_f}{X_s}$$

- if excitation increase then PF also increase
- Increase in load result pf decrease
- **Starting method of a synchronous motor-**
  i. Induction motor starting
  ii. DC motor starting
  iii. Damper winding starting
- Condition for parallel operation of a synchronous generator-
  - Same frequency
  - Same voltage
  - Same phase sequence
- Methods used for synchronizing the alternators of parallel operation-
  - Three bright lamp method
  - One dark two bright lamp method
  - Synchroscope
- DC machine –
  - Field winding –placed in stator
  - Armature winding – placed in the rotor
- ***EMF equation*** $E_g = \frac{ZN\phi P}{60\ A}$

  Where; Z-no of conductor=A – no of parallel path; ϕ – flux per pole

  N- Speed in rpm, A=2-for wave winding,

  A=P – for lap winding
- Pole pitch $= Z/P$
- **Method for improving commutation-**
  1. Resistance method
  2. Voltage method
  a) Brush shift
  b) Inter-pole
  c) Compensating winding
- Testing of DC machine-
  i) Swinburne test
  ii) Hopkins test
- Breaking of a DC motor-
  i) Regenerative breaking
  ii) Dynamic breaking
  iii) Plugging
- **Characteristic of DC generator –**

  Magnetizing characteristic – it is drawn between field flux and armature voltage.

  Internal characteristic – it is drawn between armature voltages and load current.

  External characteristics – it is drawn between load current and terminal voltage.

- Demagnetizing MMF = $\frac{I_a Z}{AP} - \frac{\beta}{180°}$
- Cross magnetizing MMF = $\frac{I_a Z}{AP}\left(\frac{1}{2} - \frac{\beta}{180°}\right)$
- Maximum power condition in DC motor

$$E_b = \frac{V}{2}$$

- Maximum power condition in DC generator

$$V = \frac{E_g}{2}$$

- **Single phase induction motor-**
  - Not self-starting
  - Starting torque zero
  - Cross field theory-
  - Backward slip $(\phi_b) = \frac{\beta_{max}}{2}\sin(\omega t + \alpha)$
  - Forward slip $(\phi_f) = \frac{\beta_{max}}{2}\sin(\omega t - \alpha)$
  - Forward slip $(S_f) = \left[1 - \frac{N}{N_s}\right]$
  - Backward slip $(S_b) = \left[1 + \frac{N}{N_s}\right] = (2 - s)$
- For long duration paper type capacitor is used.
- For short duration electrolytic type capacitor used.
- **Types of motor –**

Shaded pole motor –
- Induction motor
- Self-starting
- Shaded flux always lags the main flux
- Direction always unshaded to shaded portion
- Reverse direction not possible
- Low efficiency
- Low starting torque
- Cost law
- **Application** – relay, table fan, Exhaust fans, hair dryer, record player, tape recorder, slide projection, photocopy machine

Universal motor –
- Used in AC and DC both
- Power factor low
- Starting torque high
- **Application** – portable drill, blower, grinder, polisher, hair dryers

Reactance motor –
- Self-starting
- **Application-** electrical clock, timer, signaling device, recording instrument

Hysteresis motor-
- Magnetic material – cobalt vanadium
- Nonmagnetic material – aluminium
- No noise
- Smoothing running
- **Application** – tape recorder, record player, timing device

Permanent magnetic DC motor-
- Used in automobile (wiper, window)
- Computer device
- For industries
- Electrical tooth brush
- Portable electrical tools

Servo meter –

- Used in control system
- It is available for AC and DC.
- **Application-** radar, computer, robots, process controller

Stepper motor-

$$\text{Step angle} = \frac{N_s - N_r}{N_s N_r} \times 360°$$

$$\text{Step angle} = \frac{360°}{mN_r}$$

N_s-number of stator pole (stator teeth)
N_r-number of rotor pole (rotor teeth)
m = phase

- It is digitally controlled motor
- **Application –**
  Numeric control of machine tools ,
  Tap driver, printer, X-Y plotter, Robotic textile industrial, I_c fabrication, space craft, medical sector, etc.

BASIC ELECTRONICS

- Charge – This is property of matter which causes to feel it a force when it is placed in electromagnetic field.

$$Q = ne$$
$$e = 1.6 \times 10^{-19} C$$

- Current – Rate of flow of charge is known as current.

$$i = \frac{dq}{dt} = \frac{c}{s} = A$$

- Resistance – The element that oppose flow of current.

$$R = \rho \frac{l}{A} = \text{ohm}$$

ρ = Specific resistance / resistivity

- Resistivity – Property of resisting the flow of current.

$$\rho = R\frac{A}{l} = ohm\ meter$$

- Conductivity: Current carrying capability.

$$\sigma = \frac{1}{\rho} = \frac{1}{Ohm\ meter} = \frac{siemens}{meter}$$

- Electric field intensity / field gradient: Voltage per unit length.

$$E = \frac{V}{l} = V/m$$

- Mobility: Moving ability of any charge carrier or mobility defines how fast a charge carrier is moving.

$$\mu = \frac{v_d}{E} = \frac{m^2}{v-s}\ or\ \frac{cm^2}{v-s}$$

- Drift velocity: Average velocity of charge carrier in presence of electric field, is known as Drift velocity.
  $v_d = \frac{v_{max}+v_{min}}{2}$ = m/sec or cm/sec
- Classification of temperature :
- Absolute temperature / absolute zero temperature : -273ºC or 0K
- Normal temperature : 27 ºC or 300K
- Ambient temperature : 17 ºC or 290K
- Energy gap / Energy band gap / Forbidden energy gap (Eg):

$$Eg \propto \frac{1}{T}, T \uparrow\uparrow\uparrow \rightarrow Eg \downarrow\downarrow\downarrow$$

- For semiconductor –

$$\sigma_{ins} < \sigma_{S.C.} < \sigma_{Cond.}$$
$$\rho_{ins.} > \rho_{S.C.} > \rho_{Cond.}$$

- Types of semiconductor –
  1) Intrinsic semiconductor –
     - Pure or natural form of S.C.
     - No. of free electrons = No. of holes
     - At T = 0K behaves like insulator.
     - At T = 300K very less conductive.
  2) Extrinsic semiconductor –
     Impure form of S.C.

I. N – Type – Pentavalent impurity (Donor impurity). Majority charge carrier e-.
II. P – Type – Trivalent impurity (Acceptor impurities). Majority charge carrier holes.

- Trivalent: B, Al, Ga, In
- Pentavalent: N, P, As, Sb, Bi
- Depletion region / Space charge region: No. of free electron or holes in depletion region zero.
- Effect of doping on depletion width :
  Depletion width $\propto \frac{1}{\sqrt{Doping\ concentration}}$
  Doping↑↑→ Deplection width ↓↓
- Classification of material :
  1. Conductor
  2. Insulator
  3. Semiconductor

Parameters	Conductors	Insulators	Semiconductors
Free e⁻	Very high	No free e⁻	Very less
Current	High	No current	Very low
Conductivity	High	Zero	Very less
Resistivity	Lower	High	Moderate
Resistance	Low	High	Moderate
No. of charge carrier	Electron	No charge carrier	Two (e- and holes)
Polar	Unipolar	No polar	Bipolar
Value of Eg	0ev Overlap	≥ 5ev	≅ 1ev
Temperature	Positive	Negative	Negative
No. of valence e⁻	< 4	> 4	= 4
Bond	Metallic	Ionic	Covalent
Examples	Silver, gold etc	Rubber , plastic	Si , Ge etc.

- Biasing: applying the potential difference across any electronics device is known biasing.
- Types of biasing :
  1) Reverse biasing.
     - Diode in off state.
     - High resistance $\geq 1M\Omega$
     - No current flow.
  2) Forward biasing.
     - Diode in ON state.
     - Low resistance.

Emitter base	Collector base	Operation region	Application
Reverse	Reverse	Cutoff	Digital (off switch)
Forward	Reverse	Active	Amplification
Forward	Forward	Saturation	Digital (on switch)
Reverse	Forward	Inverted	Attenuation

❖ Cut in voltage / threshold voltage / breakover voltage / offset voltage / contact / barrier potential: Minimum voltage required to make a diode forward bias.
For Si: 0.7V
Ge: 0.3V
GaAs: 1.2V

❖ If temperature increases cut in voltage decreases.

❖ Diode current equation :

$$I_D = i_S\left(e^{V_D/\eta V_T} - 1\right)$$

i_S = Saturation current.
η = Recombination factor.
For Si = 2 , Ge = 1
V_T = Thermal voltage.

❖ BJT (Bipolar junction transistor):
- Semiconducting device.
- Non – linear device.
- Active device.
- Unilateral device.
- Less thermal stable.
- Higher leakage current.
- Noisy device.
- Current controlled device.

❖ Application of BJT is amplification.

Layers	Doping	Size
Emitter	Highest	Moderate
Base	Lowest	Smallest
Collector	Medium	Largest

❖ Types of transistor :
❖ NPN: Principle of conduction due to electrons.
❖ PNP: Principle of conduction due to holes.

S.N.	Parameters	Common base	Common emitter	Common collector
1	Input resistance	Low	Medium	Highest
2	Output resistance	Highest	Medium	Low
3	Leakage current	Low	High	High
4	Phase shift	0°	180°	0°
5	Application	High frequency	Audio frequency	Impedance matching
6	Current equation	$I_C = \alpha I_E + I_{CO}$ $\alpha < 1$	$I_C = \beta I_B + I_{CEO}$ $\beta > 1$	$I_E = \gamma I_B + I_{CCO}$ $\gamma > \beta$
7	Relation $\alpha\beta\gamma$	$\alpha = \dfrac{\beta}{1+\beta}$	$\beta = \dfrac{\alpha}{1+\alpha}$	$\gamma = 1 + \beta$

❖ Configuration of BJT:

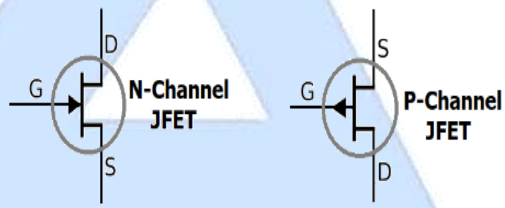
1) C.B. configuration: Voltage gain highest (only for voltage amplification).
2) C.C. configuration: Current gain highest (only for current amplification).
3) C.E. configuration: Voltage gain + Current gain (Both amplification is possible).

Note: In C.E. configuration power gain is highest.

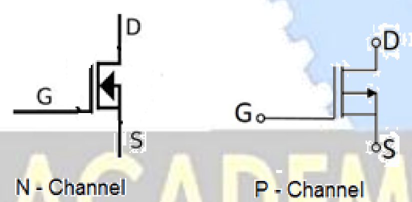
❖ FET (Field effect transistor):
- Voltage controlled device.
- It is voltage controlled correct source.
- Unipolar.
- Single charge carrier.
- Three terminal device (source, gate, drain).
- High thermally stable.
- FET has less leakage.
- FET is a less noisy device.
- FET has power dissipation.
- Low offset voltage.

❖ MOSFET (Metal oxide field effect transistor) :
- Insulating layers must be of SiO2.
- MOSFET is also known as IGFET (Insulated gate field effect transistor).

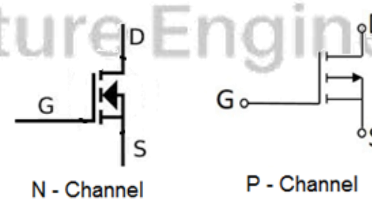
❖ Classification of FET:
❖ JFET:
N – Channel JFET and P – channel JFET.



❖ Types of MOSFET :
1) Depletion type :



2) Enhancement type :



❖ Pinch off voltage : Pinch off voltage is the drain to source voltage after which the drain to source current becomes almost constant and JFET enters into saturation region and is defined only when gate to source voltage is zero.

❖ Shockely equation:

$$I_D = I_{DSS}\left(1 - \frac{V_{GS}}{V_P}\right)^2$$

❖ OP –AMP :

- OP – AMP can amplifiy both AC signal and DC.
- Differential amplifier is used in initial state of OP – AMP.
- OP – AMP three terminal device (2- input and 1 output terminal).
- It is voltage cotrolled voltage source.
- IC – 741 used as OP – AMP.

NOTE - + → Non – Inverting terminal.
- →Inverting terminal.

Characterstics of OP –AMP :

S.N.	Charcterstics	Ideal OP -AMP
1	Voltage gain	Infinite
2	Input impedance	Infinite
3	Differential mode gain	Infinite
4	CMRR	Infinite
5	Slew rate	Infinite
6	Bandwidth	Infinite
7	Output impedance	Zero
8	Common mode gain	Zero

❖ CMRR = $\frac{A_{dm}}{A_{cm}}$

A_{dm} = Differential mode gain.

A_{cm} = Common mode gain.

❖ Slew rate : Maximum rate of change of output voltage.

❖ Inverting Amplifier-

$$A_v = \frac{V_0}{V_{in}} = \left(\frac{-R_F}{R}\right)$$

❖ Inverting Amplifier:

$$A_v = \frac{V_0}{V_{in}} = \left(1 + \frac{R_F}{R}\right)$$

DIGITAL ELECTRONICS

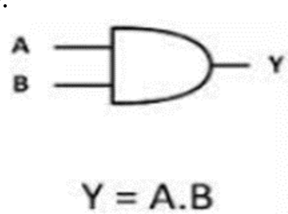
❖ Types of Basic Logic Gates :

1. OR Gate
2. AND Gate
3. NOT Gate

❖ OR Gate :

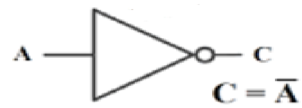
A	B	Output
0	0	0
1	0	1
0	1	1
1	1	1

❖ AND Gate:



A	B	Output
0	0	0
0	1	0
1	0	0
1	1	1

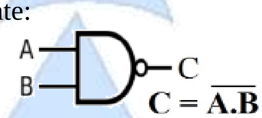
❖ NOT Gate:



A	Output
0	1
1	0

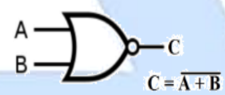
❖ Universal gate:

❖ NAND Gate:



A	B	Output
0	0	1
0	1	1
1	0	1
1	1	0

❖ NOR Gate:



A	B	Output
0	0	1
0	1	0
1	0	0
1	1	0

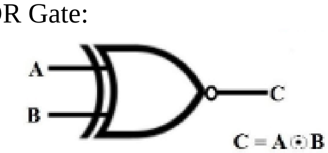
❖ Special gate:

❖ EX-OR Gate:

OUTPUT = $\bar{A}$ B +A $\bar{B}$

A	B	Output
0	0	0
0	1	1
1	0	1
1	1	0

❖ EX-NOR Gate:



OUTPUT = A B +$\bar{A}\bar{B}$

A	B	Output
0	0	1
0	1	0
1	0	0
1	1	1

❖ NAND and NOR gate as universal gate:

Logic gates	No. of NAND gates	No. of NAND gates
NOT	1	1
AND	2	3
OR	3	2
EX-OR	4	5
EX-NOR	5	4

❖ Laws of Boolean algebra:

❖ Associative law:
(A+B) + C = A + (B + C)
(A.B).C = A. (B. C)

❖ Cumulative law:
A + B = B + A
A. B = B + A

❖ Distributive law:
A (B + C) = A. B + A. C
A + B.C = (A + B). (A + C)

❖ Impotence law (repetitive law):
A + A + A + ……… = A
A . A . A + ……… = A

❖ Absorption law:

❖ A + AB = A

❖ Evolutionary law (Double complement law):
$A'' = A$

POWER SYSTEM

Transmission and distribution

- Insulator – It is made by porcelain. Porcelain is mixture of kaolin, feldspar, and quartz.
- Properties of insulator – High mechanical strength, high dielectric strength, high resistivity.
- Types of insulators – Suspension type / disc type – Each disc designed for 11Kv phase voltage.
- $String\ efficiency$

$$= \frac{Total\ Voltage\ across\ string}{No.\ of\ disc\ \times voltage\ nearest\ disc\ to\ the\ conductor}$$

- In the case of DC string efficiency is 100%.
- For two disc –

$$V_1 = \frac{V_2}{1+K} = \frac{V}{2+K}$$

Where K = $\frac{C_1}{C} = \frac{Shunt\ capcitance}{self\ capacitance}$

- For three disc –

$$V_1 = \frac{V_2}{1+K} = \frac{V_3}{1+3K+K^2} = \frac{V}{3+4K+K^2}$$

- Strain insulator – It is used, where sharp curve occur in line or dead end.
- Shackle insulator – Below 11KV strain insulator used as Shackle insulator.
- Methods of improving string efficiency:
  - By using longer cross arm.
  - By grading of insulator.
  - By using guard ring.
- Pin insulator – Used up to 33KV.
- $Saftey\ factor = \frac{Punchre\ voltage}{Flash-over\ voltage}$
- Corona – It is the phenomenon of violet glow, hissing noise, and production of ozone gases.
- Corona occurs when transmission voltage is high and distance between conductor low.
- Factor affecting corona –
Atmosphere – Less in fair weather.
Surface – High in irregular surface.
Spacing between conductors – Distance is less corona occur.
Line voltage – Line voltage is more corona occur.
Critical disruptive voltage – Minimum phase to neutral voltage which corona formation occur.

$$V_C = m_0 g_0 \delta r\ log_e \frac{d}{r}\ \text{KV}$$

$$m_0 = Irregularity\ factor.$$

$$\delta = \text{Air density factor.}$$

$$\delta = \frac{3.92b}{273+t}$$

- Critical visual voltage - Minimum phase to neutral voltage which corona visualized.

$$\text{V} = m_0 g_0 \delta r\left(1+\frac{0.3}{\sqrt{\delta r}}\right) log_e \frac{d}{r}\ kv$$

- Corona power loss-

$$P = 242.2\left(\frac{f+25}{\delta}\right)\sqrt{\frac{r}{d}}\,(V - V_C)^2 \text{Kw/ km/phase}$$

$$P_{DC} = \frac{P_{AC}}{3}$$

- Advantage of corona –Reduce steepness of surge.
- Effective diameter ↑ - Dielectric stress ↓
- Disadvantage of corona – Power loss, ozone production, non – sin current flow in surface, interference with communication line.
- Application of corona – Safety valve, ozone industry.
- Methods for reducing corona –
Ultra-high voltage – Hollow conductor.
Extra -high voltage – Bundle conductor.
Ultra-high voltage – Composite conductor.
- Sag calculation –
- Working stress = $\frac{Ultimate\ stress}{Saftey\ factor}$
- Working tension = working stress × Area
- Equal surface level –

$$S = \frac{WL^2}{8T}\ \text{m}$$

- Unequal surface level –

$$X_1 = \frac{l}{2} - \frac{Th}{wl},\ X_2 = \frac{l}{2} + \frac{Th}{wl}$$

- Effect of wind and ice –

$$s = \frac{w_t l^2}{2T},\ w_t = \sqrt{{W_w}^2 + (W + W_i)^2}$$

$$\cos\theta = \frac{W_w}{W+W_i}$$

Vertical sag = scos θ

- Conductor material property –
  High electrical conductivity, high mechanical strength, low cost, low specific gravity
- For stranded conductor n – layers total number of individual wire = $3n^2 - 3n + 1$
- Dimeter of ACSR conductor = D = (2n-1)d
- Specific gravity of copper is 2.73 gr / cc.
- Copper has less cross section area and high weight per unit volume.
- To increase mechanical strength we use steel wire in ACSR conductor.
- Earth wire is made of galvanized steel because of good mechanical properties.
- Wooden pole – life – 20 – 25 years.
- Span – 40m, voltage – 20Kv
- R.C.C. pole – life – 100year.
- Span – 125m.
- Steel tower –
  66Kv – Span – 245m -265m
  110Kv – Span – 320 m – 340m
  132Kv – Span – 350m
  220Kv – Span – 350m
  400Kv – Span – 400m – 500m

Electrical design of transmission line:

- Inductance of single phase two – wire line –
  $$L_A = 2 \times 10^{-7} \left(\frac{1}{4} + log_e \frac{d}{r}\right) \text{ H /m.}$$
- Total inductance of transmission line / loop inductance –
  $$L = L_A = 4 \times 10^{-7} \left(\frac{1}{4} + log_e \frac{d}{r}\right) \text{ H /m.}$$
- For solid conductor –
  $$L_A = 2 \times 10^{-7} \left(\frac{1}{4} + log_e \frac{d}{r}\right) \text{ H /m.}$$
- For hollow conductor –
  $$L_A = 2 \times 10^{-7} log_e \frac{d}{r} \text{ H /m.}$$
- For solid conductor –
  $$L_A = 2 \times 10^{-7} log_e \frac{d}{r'} \text{ H /m.}$$
  $$r' = 0.778\, r$$
- Three phase single line -
  $$L_A = 2 \times 10^{-7} log_e \frac{D_m}{D_S} \text{ H /m.}$$
- Three phase double line -
  $$D_S = (D_{S1} \times D_{S2} \times D_{S3})^{1/3},$$
  $$D_m = (D_{m1} \times D_{m2} \times D_{m3})^{1/3},$$
- Single phase two – wire line –
  For solid conductor $D_S = 0.7788r$, $D_m = d$
  For hollow conductor $D_S = r$, $D_m = d$
- Inductance depends upon distance between the conductors.
- Due to unequal line inductance the voltage drop across each line different.
- Due to transposition, the interference with nearby communication line also reduced.
- Calculation capacitance between single phase two – wire –
  $$C_{AB} = \frac{\pi\varepsilon_0 l}{log_e\frac{d}{r}} \text{ F}$$
- Capacitance between conductors to neutral –
  $$C_{AN} = \frac{2\pi\varepsilon_0 l}{log_e\frac{d}{r}} \text{ F}$$
- Symmetrical spacing –
  $$C_{AN} = \frac{2\pi\varepsilon_0 l}{log_e\frac{d}{r}} \text{ F}$$
- Un- symmetrical spacing –
  $$C_{AB} = \frac{2\pi\varepsilon_0 l}{log_e\frac{\sqrt[3]{d_1 d_2 d_3}}{r}} \text{ F/m}$$
- Performance of transmission line –
  $$\text{Voltage regulation} = \frac{V_S - V_R}{V_R} \times 100$$
- Transmission efficiency = $\frac{V_R I_R COS\emptyset_R}{V_S I_S COS\emptyset_R} \times 100$
- Condition for reciprocal –
  AD-BC = 1
- Condition for symmetrical –
  A = D
- Classification of transmission line –

T.L.	LENGTH	VOLTAGE
Short	0-60km	< 20 Kv
Medium	80-200km	20 Kv – 100 Kv
Long	Above 200km	Above 100 Kv

- SHORT T.L. -
  In short transmission line capacitance is neglected.
  $$\begin{bmatrix} A & B \\ C & D \end{bmatrix} = \begin{bmatrix} 1 & 0 \\ Z & 1 \end{bmatrix}$$
  Both symmetrical and reciprocal.
- MEDIUM T.L.-
  Lumped parameter.
  Source condenser method –
  $$\begin{bmatrix} A & B \\ C & D \end{bmatrix} = \begin{bmatrix} 1 & Z \\ Y & 1 + YZ \end{bmatrix}$$
  Both symmetrical and reciprocal.
- Nominal T - method –
  A = $1+\frac{YZ}{2}$, B = $Z+\frac{YZ^2}{2}$, C = Y, D = $1 + \frac{YZ}{2}$
  Both symmetrical and reciprocal.

FAULT ANALYSIS

- **Types of fault:**
  Symmetrical fault (3∅ fault)
  Un symmetrical fault
  i. LG fault
  ii. LL fault
  iii. LLG fault

Note: - symmetrical fault (3∅ fault) designs for circuit breaker and unsymmetrical fault designed for proper setting of relay.

1. Per unit system eliminates discontinuity problem and dependency of unit information.

2. **Important formula:-**

i. Ze_{pu} (LV) = Ze_{pu} (HV)

ii. Pu system=$\frac{actual\ value}{base\ value}$

iii. $Z_B = \frac{{(kv)_B}^2}{(MVA)_B}\ \Omega$

iv. $Z_{pu\ (new)} = Zpu\ (OLD) \times \frac{(MVA)_{B\ NEW}}{(MVA)_{B\ OLD}} \times \frac{(kv)_B{}^2 old}{(kv)_B{}^2 new}$ Ω

v. $Z_{PU} = \frac{I}{I_{SC}} = \%\ Z = \frac{I}{I_{SC}} \times 100$

OR

$I_{SC} = \frac{I}{\%Z} \times 100$

vi. Operator **"a"**

- a =1∠120° =-0.5 +j0.866
- a^2 = 1∠240° = -0.5 - j0.866
- a3 =1∠360° = 1

3. Fault current limit by reactor only.
4. Fault current not limit by resistor because in a resistor continuous power losses occurs.
5. Fault current not limit by capacitor because breakdown occurs in capacitors.
6. **Unsymmetrical fault analysis:-**

$$\begin{matrix} I_R \\ I_Y = \\ I_B \end{matrix} \begin{matrix} Zero \\ sequence \\ current\ '0' \end{matrix} + \begin{matrix} positive \\ sequence \\ current\ '1' \end{matrix} + \begin{matrix} negative \\ sequence \\ current\ '2' \end{matrix}$$

$$\begin{matrix} I_R \\ I_Y \\ I_B \end{matrix} = \begin{matrix} I_{RO} \\ I_{YO} \\ I_{BO} \end{matrix} + \begin{matrix} I_{R1} \\ I_{Y1} \\ I_{B1} \end{matrix} + \begin{matrix} I_{R2} \\ I_{Y2} \\ I_{B2} \end{matrix}$$

$$\begin{matrix} I_R \\ I_Y \\ I_B \end{matrix} = \begin{matrix} 1 \\ 1 \\ 1 \end{matrix} + \begin{matrix} 1 \\ a^2 \\ a \end{matrix} + \begin{matrix} 1 \\ a \\ a^2 \end{matrix} \begin{bmatrix} I_{RO} \\ I_{R1} \\ I_{R2} \end{bmatrix}$$

7. **Sequence representation of generator:-**
   - Voltage source represent only for positive sequence.
   - Voltage source replaced by short circuit for negative sequence.
   - For zero sequence, if winding is solid grounding star then voltage source replaced by short circuit.
   - If winding is ungrounded then voltage source replaced by open circuit.
   - If generator is grounded with Zn the replaced by short circuit with 3Zn connected in series with generator impendence.
8. **Sequence representation of transmission line:-**
   - Negative sequence impedance = positive sequence impedance
9. **Sequence representation of transformer:-**
   - Types of connection and grounding not affect positive and negative sequence impendence. It only affects zero sequence impendence.
10. **Line to ground fault (LG):-**
    - All sequence networks are connected in series.
    - Single line to ground fault 70-80 % fault occurs in power system.
    - Ia0 = Ia1 = Ia2
    - IF = 3Ia0 = 3Ia1 =3 Ia2
    - IF=$\frac{3Ea}{Z1+Z2+Z0+3zf}$
    - Fault current limit by positive, negative, zero and fault sequence impendence.
11. **Line –line fault (LL):-**
    - Zero sequence impendence is absence.
    - Positive and negative sequence connected in series opposition.
    - The percentage of such types of faults is approximately 15-20 %.
    - I_{a0} =0 and I_{a1} = - I_{a2}
    - $I_F = \sqrt{3}\ I_{a1} = \sqrt{3}\ I_{a2}$
    - $I_F = \frac{\sqrt{3}Ea}{Z1+Z2}$
12. **Double Line to line Ground Fault (LLG):-**
    - All sequence networks are connected in parallel.
    - The probability of such types of faults is nearly 10%.
    - $I_{a0} + I_{a1} + I_{a2} = 0$
    - $V_{a0} = V_{a1} = V_{a2}$
    - $I_F = 3I_{a0}$

Circuit breaker

- It is a series switch.
- Provide overcurrent protection.
- In circuit breaker arc is initiate due to field emission process and interrupt by thermionic process.
- There are two methods of arc interruptions.
  i. High resistance
  ii. Low resistance
- **High resistance method:- (only used for DC)**
  - **i. Lengthing: - i**ncrease the length between poles then resistance increase for the arc and arc interrupted.
  - **ii. Splitting the arc: -** The resistance of the arc can be increased by splitting the arc into a number of smaller arcs in series.
  - **iii. Force blast**
  - **iv. Reducing X-section of the arc**
- **Low resistance method or Current zero Method (only used for AC):-**
  i. When natural current passes through zero.
- **Important points:-**

1. **Restrike voltage**: - the transient voltage across the breaker part during restrike is called restrike voltage.

Vr=Vm (1-cos$\frac{t}{\sqrt{LC}}$) kV

2. **Rate of rise of restrike voltage:-**

   [RRR=$\frac{dV_r}{dt} = \frac{Vm}{\sqrt{LC}}$ sin$\frac{t}{\sqrt{LC}}$] kV/ μ sec.

3. Short line fault is more severe as compared to long line fault in terms of restrike voltage
4. **Current chopping phenomena:-**
   - When arc is interrupted before going to natural current zero.

- Current chopping phenomena are reducing by resistance switching.
  $R=0.5\sqrt{\frac{L}{C}}$

5. The insulation required for EHV line designed according switching over voltage

- **Circuit breaker rating :-**
  - i) **Breaking capacity: -** always expressed in RMS value.
  - ii) **Making capacity: -** always expressed in average value.
  - iii) **Short time rating: -** rated breaking capacity for specified duration.
  - iv) **Making capacity =2.55 × Braking capacity**
- **Types of circuit breaker :-**
  - i) **Air blast circuit breaker :-**
    - Quenching medium is air.
    - The pressure of the air is of the order of 20 kg / cm2 to 30 kg / cm2.
    - Best applications in systems at 132 kV and above (up to 400 kV) with breaking capacity up to 7,500 MVA and above.
    - **Types of air blast circuit breaker:-**
      1. Axial Blast Type
      2. Cross Blast Type
      3. Radial Blast Type
  - ii) **SF_6 Circuit breaker:-**
    - SF6 gas is 3 to 5 times better than air.
    - Electronegativity properties
    - Strong tendency to absorb free electrons
  - iii) **Vacuum circuit breaker:-**
    - Pressure 10^{-7} to10^{-5} torr.
    - Reliable and longer life.
    - No generation of gas
    - Rural electrification.(22KV to 66KV)
  - iv) **Oil circuit breaker:-**
    - Paraffin oil is used
    - It is use for 11KV to 132 KV voltage rating.
    - **Types of oil circuit breaker.**
      1. Bulk oil circuit breaker.
      2. Low oil circuit breaker.

RELAY

- It is a sensing device which detect the faulty conditions and given instructions to the circuit breaker.
- **Characteristics of relay:-**
  1. Selectivity
  2. Sensitivity
  3. Speed
  4. Simplicity
  5. Cost
  6. Reliability
- **Types of relays.**
  A. Electromagnetic attraction
  1. attracted armature.
  2. Solenoid type.
  3. Balance beam type.
  B. Electromagnetic induction
  1. Shaded pole type.
  2. Watt meter type
  3. Induction cup type relay.
- **Types of relay based upon time of operation:-**
  1. Instantaneous time relay (t≤0.1 sec.).
  2. Definite minimum time relay
  3. Inverse time relay**.**
  4. Inverse definite minimum time delay.
- **Classification of relay according to their function:-**
  1. Induction type non-directional overcurrent relay.
  2. Induction type directional overcurrent relay.
  3. Induction type directional power relay.
  4. Distance / impedance relay.
  5. Differential relay.
  6. Percent bias relay.
  7. Transley relay. (Feeder protection)
- **Overcurrent protection of radial feeder :-**
  A. Time graded protection scheme (less time multiplier setting).
  B. Current graded protection (more current multiplier setting)
  C. Time and current graded protection scheme.
- **Important points:-**
  1. Where Power swing is high mho relay is used.
  2. Over protection of generator we used thermal relay.
  3. **Reactance relay:-**earth fault / short line fault and also known as directional restrained over current relay.
  4. **Impendence relay: -** Medium line fault and it also known as voltage restrained overcurrent relay.
  5. **Mho relay: -** long line fault and it also known as voltage restrained directional relay.
  6. **% differential relay**
     [OF ∝ (i_1-i_2)] and RF ∝ $\frac{i1+i2}{2}$
     % slope ∝ $\frac{i1-i2}{\frac{i1+i2}{2}}$
  7. The current of earth relay is minimum because of it also detecting the unbalance condition.

FUSE

- Low melting point.
- Work at joule principle.
- High conductivity (low resistivity).
- Least deterioration due to oxidation.
- Low cost.
- Rating in **ampere I** $\propto d^{3/2}$
- Lead +Tin (63% tin +37% lead) up to 10 A.
- Copper silver (above 10A)
- **Important points:-**

1. Fusing factor is more than unity.
2. Cut off current is maximum value of current which flow safely without melting the fuse.
3. Pre arcing time is time between faults occur and cut-off point.
4. Arcing time is time between cut off current time and at which current becomes zero.

- **Types of fuse:-**
  1. Kit Kat fuse (5 A/250 V, 15 A/250 V)
  2. Cartridge fuse (2A to 63 A)
  3. HRC fuse (2 A /800 A)

GENERATION

- **Thermal power plant:-**
  1. A generating station that converts heat energy of coal combustion into electrical energy is known as a Thermal/Steam power station.
  2. Work at rankine cycle.
  3. Main part of thermal power plants are :-
     - Coal and ash handling plant
     - Steam generating plant: - **boiler, super heater, economizer, air preheater.**
     - Steam turbine
     - Alternator
  4. Thermal efficiency = boiler efficiency × turbine efficiency
  5. Boiler efficiency = $\frac{\text{Heat at boiler output}}{\text{heat of coal combustion}}$
  6. Boiler efficiency generally 8/5% to 90%.
  7. by the help of economizer the boiler efficiency increased by 4 to 10%.
  8. by the help of air preheater the boiler efficiency increased by 6 to 8%.
  9. Turbine efficiency $=\frac{\text{mechanical output to heat equivalent}}{\text{heat at boiler output}}$
  10. Electrical efficiency = $\frac{\text{electrical output}}{\text{electrical input equivalent to mechanical input}}$
  11. Overall efficiency of thermal power plant is 25%.

- **Hydropower plant :-**
  1. Hydroelectric power is produced by the gravity of falling water.
  2. Work at conversion of potential energy to kinetic energy then kinetic energy convert electrical energy.
  3. Runoff denotes the water stream.
  4. Hydrograph is a graphical representation between discharge and time.
  5. P= $\frac{0.736}{75}$ ×QWH kW.
  6. **Classification of hydro power plant:-**
     a. Run-off River without pond age.
     b. Run-off River with pond age.
     c. Reservoir type.
  7. **Types of Dam:-**
     - Masonry dam
     - Earth fill dam
  8. **Classification of hydro power plant according to water head:--**
     1. Low head hydro power plant:- (less than 30 m)
     2. Medium head hydro power plant:- (30 m-300m)
     3. High head hydro power plant. (above 300m)
  9. **Classification of turbine:-**
     1. **Impulse turbine**
        - Used for high head.
        - No need for draft tube.
        - It is open type.
        - Pelton wheel turbine.
        - Speed 12-70 rpm.
     2. **Reaction turbine:-**
        - Francis turbine medium head -70-400 rpm.
        - Kaplan turbine and propeller turbine – 400-1100 rpm.
        - It is closed type turbine.
        - Draft tube is used.

- **Nuclear power plant:-**
  A. Work at nuclear fission.
  B. Main parts of nuclear power plant: - reactor, heat exchanger and turbine.
  C. Control rod: - control the chain reaction. Boron, cadmium is used as control rod.
  D. Fuel: - U-235, Pu-239, U-233 used as fuel.
  E. Moderator: - it slows down the speed of neutrons before bombard. Graphite /heavy water, beryllium used as moderator.
  F. Coolant:-heat transfer reactor to heat exchanger.
  G. 1 kg uranium = 4500 ton good grade coal.
  H. Types of reactor: - pressure water reactor, boiling water reactor.

- **Variable load at power station:-**
  A. Maximum demand: - It is maximum load connected at the power system in the specified time.
  B. Load factor : $\frac{\text{average load}}{\text{maximum demand}}$
  C. Unit generated in T hrs. - load factor ×maximum demand × time (T) hrs.
  D. If load factor is high then maximum demand is low so cost of plant is also reduced.
  E. Demand factor = $\frac{\text{maximum demand}}{\text{connected load}}$
  F. Diversity factor = $\frac{\text{sum of indivisual maximum demand}}{\text{maximum demand ai power station}}$
  G. Diversity factor is always greater than unity.

H. Plant capacity factor = $\frac{\text{actual energy produced}}{\text{energy that could be produced}}$

I. Base load: - power station connected all time.

J. Peak load:- power station connected only for some hours.

K. Reverse capacity = maximum demand × ($\frac{load\ factor - plant\ capacity\ factor}{plant\ capacity\ factor}$).

- Interest: - the cost of use of money.
- Depreciation: - the decrease in the value of equipment and building to the constant use is called depreciation.
- Method to calculate the depreciation charge:-
  1. Straight line method:- annual depreciation charge = $\frac{P-S}{N}$; Where, p- initial cost, S- scrap value, n- use full life .
  2. Diminishing method x = 1- $\frac{S^{1/n}}{P^{1/n}}$.
  3. Sinking fund method = (P-S) [$\frac{r}{(1+r)^n-1}$]

MEASUREMENT

- **Measuring instrument system type:**
  1. **Type zero:** No dynamic element present
  2. **Type one:** single type dynamic element present
  3. **Type Two:** two type dynamic element present

> - Static element like resistance
> - Dynamic element like inductor and capacitor

- **Type of torque:**
  1. Deflecting torque T_D
  2. Controlling torque $T_C = k\theta$
  3. Damping torque

> - Where; k is spring constant
> θ is deflecting angle

- **Enhancement of Ammeter:**

$$Shunt\ multipling\ factor\ \ m = \frac{I}{I_m} = \frac{R_{sh} + R_m}{R_{sh}}$$

$$R_{sh} = \frac{R_m}{m-1}$$

- **Enhancement of Voltmeter:**

$$Series\ multipling\ factor\ \ m = \frac{V}{V_m} = \frac{R_m + R_{se}}{R_m}$$

$$V_m = V \times \frac{R_m}{R_m = R_{se}}$$

$$R_{se} = R_m(m-1)$$

- **Moving iron instrument deflection torque and controlling torque:**

$$T_D = \frac{1}{2} I^2 \frac{dl}{d\theta}, \qquad T_C = k\theta, \qquad where;\ \theta \propto I^2$$

- **Electro thermal instrument are two type:**
  1. **Thermo couple instrument:** Work on high frequency (50MHz) and independent from the wave form of input supply and eddy current damping is use.
  2. **Hot wire instrument:** Non uniform output, eddy current damping, no frequency loss, platinum iridium wire use in this instrument.
- **Half wave rectifier instrument**

  $I_{m(ac)} = 0.45\ I_{m(dc)}, \qquad S_{(ac)} = 0.45\ S_{(dc)}$
- **Full wave rectifier instrument**

  $I_{m(ac)} = 0.90\ I_{m(dc)}, \qquad S_{(ac)} = 0.90\ S_{(dc)}$
- **Quality Factor meter (Q-meter)**

$$Q = \frac{|V_L|}{V} = \frac{|V_C|}{V} = \frac{X_L}{R} = \frac{X_C}{R} = \frac{\omega_0 L}{R} = \frac{1}{\omega_0 CR} = \frac{1}{R}\sqrt{\frac{L}{C}}$$

$$V_L = QV = V_C$$

- **Measurement of inductance:**

$$X_L = X_C$$

$$so; L = \frac{1}{4\pi^2 {f_0}^2 C}\ Henery$$

- **Measurement of distributed capacitance:**

$$C_d = \frac{C_1 - 4C_2}{3}\ or\ C_d = \frac{C_1 - 2^2 C_2}{2^2 - 1}$$

$$\&\ for\ n\ times\ C_d = \frac{C_1 - n^2 C_2}{n^2 - 1}$$

- **Electro dynamo meter type instrument:** pointer is made by aluminum, fixed coil having thick wire and less number of turns and movable coil having thin wire and more number of turns.

$$Deflection\ torque\ \ T_D = i_1 i_2 \frac{dN}{d\theta}$$

- **Induction type instrument:** this type instrument are two category
  1. Shaded pole type
  2. Induction type wattmeter
- **Wattmeter:** Electro dynamo type meter is measure both AC and DC power.
- Power factor meter is using air friction damping method.
- **Integrating type instruments:**
  1. **Thomson watt hour meter:** use to measure both AC and DC energy, eddy current damping.
  2. **Energy meter ($1-\emptyset, 3-\emptyset$):** add energy cumulatively, measure only AC energy.
  3. **Ampere hour meter**
- **Error in energy meter:**
  1. **Lagging compensation:** for protection against this error we use a shading ring near to the potential coil.
  2. **Over voltage compensation:** for protection against this error we use two saturable magnet.
  3. **Over load compensation:** for protection against this error we use saturable magnet with series magnet.

4. **Friction compensation:** for protection against this error we designed shaded loop (copper ring).
5. **Creeping:** It occurs due to frictional compensation and to protect against this error by cutting slot or holes on the disc.
6. **Temperature error:** for protection against this error we use magenin unit (Mu) temperature material.
7. **Phantom loading:** During testing condition of measuring instrument (wattmeter) the resistance of coil is very small and it require small voltage and current rating which is easily flow in the current coil. This time the load is called phantom loading.

- **Deflecting type AVO meter** is use to check the continuity of instrument and it is an analog type instrument.
- **Ampere hour meter** is also called Ferranti mercury meter and it is measure DC energy only.
- **Digital Multimeter:** it is a testing tool and measure two or more electrical values. Like: Voltage (volt), Current (A) Resistance (ohm).
- KVAR meter is working on the principle based on electro dynamo meter instrument.
- **Measurement of RLC:**

- **Measurement of low resistance:**
1. Potentiometer Method
2. Kelvin's double bridge method

- **Measurement of medium resistance:**
1. Voltmeter – ammeter method
2. Substitution method
3. Wheatstone bridge method
4. Ohm meter method
5. Carry – foster bridge comparison method

- **Measurement of high resistance:**
1. Loss of charge method
2. Direct deflection method
3. Megger
4. Mega ohm meter

- **Measurement of inductance:**
1. Low Q – coil → Q < 1 → Anderson's Bridge
2. Medium Q – coil → 1 < Q < 10 → Maxwell capacitance – inductance bridge
3. High Q – coil → Q > 1 → Hay's bridge
4. Incremental inductance → Owen's bridge

- **Measurement of Capacitance:**
1. Schering bridge
2. De – Sauty bridge

- **Measurement of frequency:**
1. Wein bridge

- **Measurement of mutual inductance:**
1. Campbell bridge

- **Cathode Ray Oscilloscope (CRO):**
It is a digital, linear and high sensitive device. It is measuring voltage and current (peak value, peak to peak value, RMS, Average value) and frequency ratio, phase difference. It is not use for power measurement.
- **Types of CRO used in measurement:**
1. P_{11} → General Purpose CRO
2. P_4 → Black / White CRO
3. P_6 → Colored CRO
4. P_{15} → Sampling CRO
5. P_{31} → Storage CRO
- **CRO electron beam velocity:**

$$\left[v = \sqrt{\frac{2qV_a}{M}}\, m/sec. \right]$$

- **Lissajous Pattern:** is to be used for finding frequency ratio and also phase difference.
- $freq.ratio = \frac{no.\ of\ vertical\ tangent}{no.\ of\ horizontal\ tangent} = \frac{f_x}{f_y}$

ESTIMATING & COSTING

Wiring

- Cleat wiring – Cheapest, Temporary installations, Porcelain cleats at 60cm distance.
- Casing-capping wiring – Residential commercial and official building but not in common use nowadays.
- CTS or TSR wiring – Residential commercial and official building.
- Conduit wiring – Costliest, Mostly used nowadays in Godowns, Workshops and public buildings.
- Lead sheathed wiring – Service mains.

Earthing

- Size of loop earth wire – not less than 2.9mm^2 (14SWG) or half of the size of the sub-circuit conductor.
- Leakage current should not exceed 1/5000 times of rated current.
- Strip electrode of cross section not less than 25mm × 1.6mm for copper and 25mm × 4mm for GI. *used in rocky lands.
- For rod electrode (12.5mm diameter solid copper and 16 mm diameter solid rod of GI or steel), *used in sandy areas.
- For pipe electrode (generally 40mm diameter and 2.5meter length)
- Plate electrode (for cu 60cm×60cm×3mm, for GI – 60cm×60cm×6mm, for cast iron – 600mm x 600 x 12 mm)
- Earth electrode should be at vertical position.
- Charcoal and salt in earthing pit is used to reduce the earth resistance.
- Average resistance of human body – 1000 ohm.

Important points to remember –

1. Height of energy meter from ground - 1.5m minimum.
2. The height of the switch board from the ground - 1.25m.
3. Height of power socket – 0.5m.

4. Socket outlets should be installed 1.30m above floor. And in bathrooms above 1.30 height.
5. Height of lamp from the floor – 2.5 to 2.75m
6. The height of the ceiling fan from the ground - at least 2.75 m.
7. Minimum distance between fan blades and ceiling 0.3m.
8. To avoid high tensile stresses height of roof pole is maintained under 3 meter.
9. Lighting/fan circuit shall not have more than 800 Watt connected load or more than 10 points whichever is less.
10. Power circuit shall not have more than 3000 Watt connected load and 2 points whichever is less.
11. Power circuit in non-residential building will have only one outlet per circuit.
    Each power circuit in residential building can feed following outlets:
    (a) Not more than 2 Nos. 16A outlets.
    (b) Not more than 3 Nos. 6A outlets.
    (c) Not more than 1 No. 16A and 2 Nos. 6A outlets.
12. Fuse are rated in amperes. Commonly used fuse material is alloy lead-37% and tin-63%. Fuse material should have low melting point and low resistivity.
13. Fusing factor = $\frac{minimum\ fusing\ current}{current\ rating\ of\ fusing\ element} > 1$ always
14. Kit-Kat fuse (rewirable) – base used is made of porcelain. Low voltage fuse used in domestic wiring.
15. Cartridge fuse – Rated upto 660V/800A.
16. HRC fuse – High voltage fuse, rated upto 66kV.
17. Size of cable conductor used in power circuit –
    - Copper – not less than 1.25 mm^2
    - Aluminium – not less than 2.5 mm^2
18. Size of cable conductor used in domestic wiring –
    - Copper – not less than 1 mm^2
    - Aluminium – not less than 1.5 mm^2
19. Danger notice should be affix at a height of 2.5m in metal supports.
20. To prevent climbing of unauthorized persons, barbed wire should be wrapped on a pole at a height of 2.5m from the ground for at least 1m.
21. Land requirement for substation –
    - 400 kV substation – 50 acres
    - 220 kV substation – 25 acres
    - 132 kV substation – 10 acres

Most important IE Rules 1956

Rule 35 – Danger notice with a sign of skull and bones should be affix in every medium, high and extra-high voltage installation (like generator, transformer, poles, towers etc.) in Hindi, English or regional language.

Rule 44 – Instructions for restoration of a person suffering from electric shock should be affix in written format in Hindi, English and regional language.

Rule 46 – Periodical inspection and testing of electrical installation which are already connected to the supply system, should be done by supplier at regular intervals not exceeding 5 years.

Rule 48 – Precaution against leakage before connection. IR test (Insulation Resistance) is compulsory before the commissioning.
- At 500 V; DC, permissible IR value is 1M ohm at least.
- At 2500 V; DC, permissible IR value is 5M ohm at least.

Rule 54 – Permissible variation in supply voltage.
- Low and medium voltage - ±6%
- High voltage – 9% in lower side and 6% in higher side.
- Extra high voltage – 12.5% in lower side and 10% in higher side.

Rule 55 – Permissible variation in supply frequency - ±3%.

Rule 57 – Meters, maximum demand indicators and other apparatus on consumer’s premises.
- The limits of error in meters do not exceed ±3%.
- For extra high voltage consumers the limit of error shall be ±1%.
- No meter shall register at no load.

Rule 68 –outdoor substation except pole type substations should be protected by fencing at not less than 1.8 meters in height.

Rule 76 – Maximum stress / Minimum safety factor
- for metal supports - 1.5
- for mechanically processed concrete supports - 2.0
- for hand-moulded concrete supports - 2.5
- for wood supports - 3.0
- for stay-wires, guard-wires or bearer-wires – 2.5
- Conductors - 2

Rule 77 – Clearance above ground of the lowest conductor.

Clearance between ground and lowest conductor –

1. Across the street –
i) For low and medium voltage – 5.8m
ii) For high voltage line – 6.1m
iii) For extra high voltage – not less than 6.1 m + 0.3m/33kV

2. Along the street –
i) For low and medium voltage – 5.5m
ii) For high voltage line – 5.8m
iii) For extra high voltage – not less than 6.1 m + 0.3m/33kV

3. Elsewhere than across and along the street –
i) For low and medium voltage if bare – 4.6m
ii) For low and medium voltage if insulated – 4.0m
iii) For high voltage line – 5.2m

iv) For extra high voltage – not less than 5.2 m + 0.3m/33kV

Rule 78 – Clearance between conductors and trolley wires.

i) For low and medium voltage line – 1.2m
ii) For high voltage line up to and including 11 kV – 1.8m
iii) For high voltage line above 11kV – 2.5m
iv) For extra high voltage line – 3m

Rule 79 – Clearance from buildings of low and medium voltage lines and service lines.

For any flat roof, open balcony, verandah roof, lean-to-roof and pitched roof **-**

Vertical clearance – 2.5 m

Horizontal clearance – 1.2m

Rule 80 – Clearances from buildings of high and extra-high voltage lines.

Vertical clearance –

i. For high voltage line (upto -33kV) – 3.7m
ii. For extra high voltage line – 3.7m + 0.3m/33kV

Horizontal clearance –

i. For high voltage line (upto -33kV) – 2m
ii. For extra high voltage line – 2m + 0.3m/33kV

Rule 87 – clearance where line crossing each other.

Nominal System Voltage	11-66 KV	110-132 KV	220 KV	400 KV	800 KV
Low & Medium	2.44	3.05	4.58	5.49	7.94
11-66KV	2.44	3.05	4.58	5.49	7.94
110-132KV	3.05	3.05	4.58	5.49	7.94
220KV	4.58	4.58	4.58	5.49	7.94
400 KV	5.49	5.49	5.49	5.49	7.94
800 KV	7.94	7.94	7.94	7.94	7.94

Rule 88 – Guarding of overhead lines.

Rule 90 – Earthing of metal supports.

Stay wire should be earthed unless an insulator is placed in it at a height of not less than 3m from the ground.

UEET

ELECTRICAL WELDING

Advantage of electric welding:

- Economical, Clean, Easily controllable and required, less –maintenance.

Types of electrical welding:-

RESISTANCE WELDING

1. **Butt welding:**
   - V: 2 to 20 volt & I = 50 A to few 100A.
   - Application: welding pipe wire and rods.
2. **Flash butt welding:**
   - Dissimilar metal may be joint.
   - Application: tubes/rods/sheets, Manufacturing of air craft automobile house hold appliance.
3. **Spot welding:**
   - **I =** 1000 to 10000 A
   - Application: manufacturing of automobile, refrigerators and sheet metal etc.
4. **Projection welding:**
   - **Flat electrode** are used.
   - Initial cost is very high.
   - Application: welding studs and nuts and metal plate.
5. **Seam welding:**
   - Rolling electrodes are used.
   - Continuous welding is possible.

ARC WELDING

1. **Carbon arc welding.**
   - **Electrode:** carbon
   - **Filler :** used
   - Application: nonferrous metal, brass copper and their alloys.

2 **Metal arc welding:**
   - used for both AC/DC
   - Better quality of welding is achieved.

3 **Atomic Hydrogen welding:**
   - Only for AC.
   - Filler is used.
   - Used in Carbon steel, stainless steel and their alloy welding.

4 **Carbon welding:**
   - only DC supply
   - carbon or graphite electrode

GAS ARC WELDING:

1. **TIG:** tungsten inert gas welding.
2. **MIG:** metal inert gas welding.

ULTRASONIC WELDING:

- Used for high frequency (20-60 kHz).
- Application: electronics, aerospace and instrument industries, also for sealing and producing packaging.

ELECTRON BEAM WELDING:

- Equipment is costly.
- Application: automobile, aerospace, bearing.

Resistance welding	**Arc welding**
Heat develop due to resistance	Due to Arc.
AC supply is used	AC/DC both
Need external pressure	Not need
Low temperature &voltage	Both high
Good PF	Very low PF

- <u>ILLUMINATION</u>

Wavelength	**Nature**
550 m – 11 m	Radio wave.
11 m – 3 X 10^{-4}m	Broadcasting wave
3 X 10^{-4} m – 0.75 X 10^{-6} m	IR or heat rays
0.75 X 10^{-6} m – 0.4 X 10^{-6} m	Light rays
0.4 X 10^{-6} m – 3 X 10^{-8} m	UV rays
Less than 3 X 10^{-8} m	X & Y- Rays

Terms	Formula	Unit

Plane angle	$\frac{Arc}{radius} = 2\pi$	Radian
Solid angle	A/r^2 =4 π	Staradian
Luminous flux	$\varphi = \frac{dQ}{dt}$	lumen
Luminous intensity	$I = \frac{\varphi}{\omega}$	Lumen/ Std. = candela
Illumination	$E = \frac{\varphi}{A}$	Lm/m2 = lux
Brightness or luminance	$B = \frac{I}{A}$	Cd/m2

- **MSCP (mean spherical candle power) =** $\frac{Total\ flux\ emited\ by\ the\ source\ in\ all\ direction}{4\pi}$
- **Candle power (M.H.S.C.P.): =** $\frac{Total\ flux\ emited\ by\ the\ source\ in\ all\ direction}{2\pi}$
- **Lamp efficiency** : $\frac{output\ in\ lumen}{input\ in\ watt}$ Unit: lm/watt
- **Utilization factor**: $\frac{Used\ lumen}{Lumen\ total}$
- **Maintenance factor:** $\frac{illumination\ under\ normal\ working\ condition}{illumination\ when\ things\ are\ perfeclty\ clean}$

  Note – depreciation factor inverse of MF
- **Reflection factor** : $\frac{reflected\ light}{incident\ light}$
- **Law of illumination:**
  1. Inverse square law: E $\propto \frac{1}{d^2} = \frac{I}{d^2}$
  2. Lambert cosine law: E $= \frac{I}{d^2}\cos\theta$

     $$E = \frac{I}{h^2}cos^3\theta$$
- **Source of light**

Arc lamp, Incandescent lamp, Gaseous discharge lamp.
Carbon arc lamp:
Efficiency = 9lm/w, T: 3500 - 4000O C
Application: Early motion pictures Search lights, Projectors

- **Incandescent lamp:**
  - Unity PF, poor efficiency and life.
  - Melting point- high.

    Osmium & Tantalum: 2700 oC - 2200 oC

    Tungsten filament: 2400 oC - 2750 oC
  - Gas filled filament lamp:

    Working life: 1000 hrs,

    Problem of ageing effect
- **Sodium vapour lamps**:
  - Low PF, produce yellow light.
  - Efficiency : 40 to 50 lm/watt
  - Used: street lighting, highway, air field lighting.
- **Mercury vapour lamp**:
  - Good PF (0.95)
  - V = 200 – 250 Volt, P=300-500W
  - Efficiency: 40 lumen / watt.
- **Fluorescent tube:**
  - Glass diameter: 25mm,length: 0.6m, 1.2m, 1.5m, efficiency: 60-65 lm/w
  - Flicker & radio interference problem

Phosphor used	Colour
Zinc silicate	Green
Calcium Tungstate	Blue
Calcium Borate	Pink
Magnesium tungstate	Blues white

- **Comparison Between**

Tungsten filament lamp	**Fluorescent lamp**
Higher working temp^r.	Low
More brightness	Low
Life: 1000 working hrs.	6000 W. hrs
Low initial & Maintenance cost	High
Good PF	Low PF

- **Neon lamps:**
  - Operating temperature = 200ºC
  - Operating voltage = 300 to 1000 V
  - Also called cold cathode lamp.
  - Application: Advertising purpose.
- **Halogen lamps:**
  - Operating temperature = 3000ºC
  - Life: 2000 working hrs.
  - Efficiency high (33 lm/w).
  - Maintenance is difficult.
  - Halogen headlamps are used in many automobiles.
- **CFL (compact filament lamp)**
  - low pressure mercury vapor lamp
  - efficiency : 50 lm/watt
  - Life: 8000 working hrs
- **<u>Battery and electrolysis</u>**
  - **Faradays law of electrolysis:**

1. **First law:**

   M$\propto$ it , M = Zit, M = ZQ,
2. **Second law:**

   m $\propto E$ $(E\ = \frac{Molar}{valance})$

   $$\frac{\boldsymbol{m1}}{\boldsymbol{m2}} = \frac{\boldsymbol{E1}}{\boldsymbol{E2}}$$

- **Application of electrolysis:**

  Electroplating, electrotyping, purification, electric capacitor.
- **Cell:**

Primary Cell	Secondary Cell
These are not rechargeable	These can be recharged easily.
These have a lower self-discharge rate.	These have a higher self-discharge rate.
These are used in torch and other portable devices as they produce electric current immediately.	These are used in inverters and automobiles.
They have a low or small lifetime.	They have a high lifetime.
Examples of these Cells are dry Cells, Daniel Cells etc.	Examples of these Cells are lead-acid Cell, nickel – iron Cell etc.

Primary Cell

Cell	Anode, cathode	Output voltage.
Carbon Zn cell	Zn, C	1.5 V
Alkine cell	Zn, MnO_2	1.5 V
Hg cell	Zn, Hg	1.35 V
Silver oxide cell	Zn, AgO_2	1.5 V

Secondary Cell

Lead acid cell	At fully charged	Discharged
Specific gravity	1.25 to 1.28	1.11to 1.17
EMF	2.1 V/cell	1.8 V/ Cell
+ve plate	Dark brown	White
-ve plate	Gray	White

- **Lead acid cell efficiency**
  - Ampere hrs = 85 to 95%,
  - Watt hrs. =70 to 80%
  - Used: Hospitals, telecommunications systems, emergency lighting systems etc.

Nickel iron cell	At fully charged	Discharged
Specific gravity	1.25 to 1.28	1.11to 1.17
EMF	1.4 V/cell	1.0 V/ Cell

Nickel iron cell

Efficiency: 80%, high cost and more internal resistance.

Used: backup power source for railroads, mines and other industries etc.

Resistance heating

Voltage: 2-20 volt

Current: 3000 amp.

Direct resistance method example:

Electric cremation furnace, salt bath furnace filament bulb.

Indirect resistance method example:

Hair dryer, electric press, resistance oven

- **<u>Electrical hating</u>**

Transfer of heat by conduction, convection & radiation.

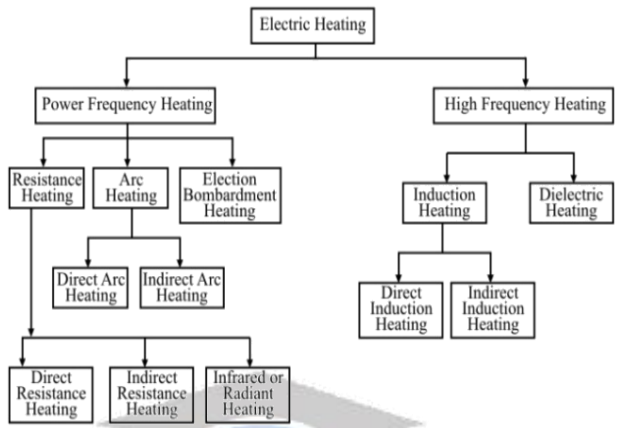
Arc heating:

Require high voltage

Work with electrostatic force.

Temperature 3500 to 4000ºC

Direct arc method: high heat than indirect arc



Indirect arc method: used in iron foundries

Induction heating:

$$Pe \propto \frac{Bm^2 f^2}{\delta}\ w/m^2$$

- **Depth of heat penetration:**

$$\delta = \frac{1}{2\pi}\frac{(\rho \times 10^7)}{\mu f}\ m$$

- **Core type induction furnace.**
  Happen pinch effect, low PF
- **Vertical core type as Ajax Wyatt furnace:**
  Low leakage reactance, Good PF, no pinch effect.
- **Dielectric heating:**
  Frequency: 10-30 kHz
  Voltage: 20V

$$C = \frac{\varepsilon A}{d}\ farad$$

Heat insulating material like plastic, ceramics.

Infra - red radiant heating:

Used for – dehydration, paper and textile etc.

- **<u>Electrical Drive</u>**

  Types of electric drive:

  Group drive- single motor connect with whole system. Huge power loss and low PF

  Individual drive: each device connected with single motor. High initial cost

Motor	Application
DC series motor	Cranes, Air compressor, Lifts, Elevators, Winching system, Electric traction.
DC shunt motor	Centrifugal Pumps, Lifts, Lathe Machines, Blowers, Fans, Conveyors, Spinning machines, etc.
Cumulative compound DC motor	compressors, pressure blowers, door lifts, circular saws, passenger elevators, freight elevators, etc.
Synchronous motor	Ball mills, watches, record players, and turntables. etc
3 phase slip ring induction motor	Rolling mills, lift & hoists, large pumps prime mover. Etc.
Squirrel cage induction motor	Printing machinery, Flour mill, pumps, prime mover with large generator etc.

Single phase motor

Single phase motor	Application
Split phase IM	Oil burner, grinder air compressor etc.
Capacitor Start motor	Pumps, compressor, etc.
Capacitor run motor	Refrigerator, cooler, Compressors, pumps, & conveyors.
Shaded pole motor	Toys.

ELECTRIC TRACTION

Advantage:

- Cleanliness.
- Maintenance Cost.
- Starting Time.
- High Starting Torque.
- Braking.
- Saving in High Grade Coal.
- Lower Centre of Gravity.

Disadvantage

- Power failure for few minutes causes distortion in traffic.
- It can be used only at the places which are electrified.
- Electric traction is tied to electric routes.

DC system:

V = 1500 to 3000 V

Tram way = 750V

For sub urban services.

AC System:

- **3 Phase:** 3.3 kV,16 $\frac{2}{3} Hz$
- **1 phase:** 25Kv , 50 Hz
- **1 phase low frequency:**15Kv,16 $\frac{2}{3} Hz$
- **Cando system:** 1 phase to 3 phase

$$\boldsymbol{Avg.speed = \frac{distance\ b/w\ two\ stop}{actual\ time\ to\ run}}$$

$$\boldsymbol{Schedule\ speed = \frac{distance\ b/w\ two\ stop}{actual\ time\ to\ run + stop}}$$

Typical Railway Services

S.No	Parameter of Comparison	Urban or City Service	Sub-Urban Service	Main Line Service
1	Acceleration	1.5-4Kmphps	1.5-4Kmphps	6-8Kmphps
2	Retardation	3-4Kmphps	3-4Kmphps	1.5Kmphps
3	Max. Speed	120Kmph	120Kmph	160Kmph
4	Distance between stations	1Km	1-8Km	>10Km
5	Special remarks if any	Free running period is absent and coasting period is small.	Free running period is absent and coasting period is long.	Long free running and coasting periods. Acceleration and braking periods are small comparatively.

System	Volume of copper required on the basis of	
	Maximum voltage between conductor and earth	Maximum voltage between any two conductors
a) DC System		
➢ Two wire	1	1
➢ Two wire with midpoint earth	0.25	1
➢ Three wire	0.3125	1.25
b) AC single phase system		
➢ Two wire	$2/\cos^2\phi$	$2/\cos^2\phi$
➢ Two wire with midpoint earth	$0.5/\cos^2\phi$	$2/\cos^2\phi$
➢ Three wire	$0.625/\cos^2\phi$	$2.5/\cos^2\phi$
c) AC two phase systems		
➢ Two phase four wire	$0.5/\cos^2\phi$	$2/\cos^2\phi$
➢ Two phase three wire	$1.457/\cos^2\phi$	$2914/\cos^2\phi$
d) AC three phase systems		
➢ Two phase three wire	$0.5/\cos^2\phi$	$1.5/\cos^2\phi$
➢ Two phase four wire	$0.583/\cos^2\phi$	$1.75/\cos^2\phi$

Building Materials

- **Classification of rocks**
  - Geological classification
  - Physical classification
  - Chemical classification
- Geological classification

1. Igneous rock
   - Generally magma consists of " quartlz mica & felspar"
   - The texture of the rock is greatly influenced by the rate of cooling of magma
   - Mostly these rocky on crystalline glassy or fused texture

Example: granite, syenite (deep rocks, plutonic) & dolerite, basalt (surface rocks, effusive volcanic)

2. Sedimentary rocks
   - Also knows as " Aqueous or stratified rocks"

Example: dolomite, magnesite, gypsum (chemical deposits)

Limestone, shale, chalk (organogenous rocks)

Sandstone (fragmental rocks)

3. Metamorphic rocks
   - Igneous and sedimentary rocks as a result of the action of the earth movements, temp. changes liquid pressure. Etc.
   - Igneous rock metamorphic rock

I. Granite/ syoenite gneiss

II. Dolerite / basalt schist

- sedimentary rocks metamorphic rock

I. limestone/ dolomite marble

II. sandstone quartzite

III. slate slate

- Physical classification
  - Stratified rocks
  - Unstratified rocks
  - Foliated rocks
- Chemical classification

1. Siliceous rocks : the principal constituent is silica(Sio_2) i.e. sand
   - These rocks are very hard & durable

Example: Almost all igneous and metamorphic rocks

2. Argillaceous rocks: the principal consistent is clay (Al_2O_3)
   - These are hard & brittle

Example: Slate, laterite (A sandy clay stone)..

3. Calcareous rocks: the principal consistent is lime (Cao)
   - These are good surface texture

Example: Dolomite, limestone, marble, etc

- Classification of bricks

1. First class brick
   - Water absorption should be 12-15% of it's dry weight when immend in cold water for 24 hours.
   - Water absorption not more than 20 %
   - Crushing strength of brick $\nless$ 10 N/mm^2
2. Second class bricks
   - Water absorption 16-20% is allowed
   - Crushing strength of brick $\nless$ 7 N/mm^2
3. Third class bricks
   - Water absorption is about 25%
   - Recommended for building temporary structures

- Composition of good brick Earth

Constituent	Proportion
Lime	< 10%
alumina	20-30%
Silica	50-60%
Magnesia	< 1%
Iron oxide	< 7%
alkalis	< 10%

- Manufacture of bricks

I. Unsoiling
II. Digging
III. Cleaning
IV. Weathering
V. Blending
VI. Tempering

1. Molding
   I. Hand molding
   II. Machine molding
2. Drying
3. Burning

- Testing of bricks

1. Water absorption test:
   - A brick will be considered as good quality if it does not consume more than 20% water of its own weight.
2. Compressive Strength Test:
3. Efflorescence Test:

Classification	Efflorescence
Nil	No Deposition
Slight (Ok)	10% of the brick surface.
Moderate	10% – 25 % of the brick surface.
Heavy	25% – 50% of the brick surface.
Extreme (Serious)	>50% of the brick surface.

4. Impact test
   In this test few bricks are dropped from 1-meter height.
5. Soundness Test