DETAILS EXPLANATIONS

[PART : A]

1. ***Base load plants :***

- Hydro electric plant
- Nuclear power palnt
- Coal based thermal power palnt

Peak Load Plants :

- Diesel power palnt
- Pumped storage plant
- Gas power plant

2. Hydro turbines are classified as :

- Kaplan — High specific speed
- Francis — Medium specific speed
- Pelton — Low specific speed

3. In pumped storage plant reversible turbine are used which operate as turbine for power generation during peak load and operate as a pump for pumping the water during peak off load.

4. ***Nuclear fuels are classified as :***

- ***Fertile :*** It is not self fissionable.
  Example : Uranium 238, Thorium 232.
- ***Fissile :*** By thermal neutrons fertile can be connected into fissile material.

Example : Uranium 235, Plutonium 239

5. Feeders are designed according to current carrying capacity and distributors are designed according to voltage drop.

6. Due to Skin effect on solid conductor :

- Conductor resistance increase.
- Effective cross sectional area reduces.

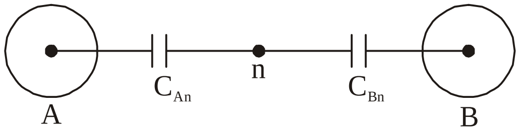
7. Internal flux linkage

$$\lambda_{in} = \frac{\mu I}{8\pi} \text{ Wb-T/m}$$

External flux linkage

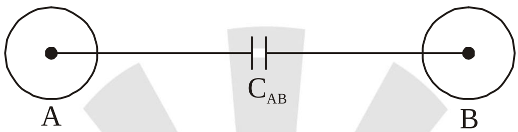
$$\lambda_{ext} = \frac{\mu I}{2\pi} \ln\frac{d}{r} \text{ Wb-T/m}$$

8. For single phase two wire line.



Line to neutral capacitance

$$C_{An} = C_{Bn} = \frac{2\pi \in}{\ln\left(\frac{d}{r}\right)}$$



Line to line capacitance

$$C_{AB} = C_{An}/2 = \frac{\pi \in}{\ln\left(\frac{d}{r}\right)}$$

9.
- A $\rightarrow$ unitless
- B $\rightarrow$ ohm
- C $\rightarrow$ mho or Siemens
- D $\rightarrow$ unitless

10. $P_C = \frac{240}{\delta}(f + 25)\sqrt{\frac{r}{d}}(V - V_D)^2 \times 10^{-5}$ kW/km/phase

where, V = Operating voltage

V_D = Disruptive critical voltage

r = Radius of conductor

d = Distance between conductor

f = Operating frequency

δ = Air density factor

11. To improve string efficiency following methods are used :
- Using longer cross-arm
- Using insulation grading.
- Using guard ring.

12. For solid double line to ground fault, fault impedance $z_f = 0$.

$V_{a_1} = V_{a_2} = V_{a_0}$ i.e., all sequential network are connected in parallel.

13. In percentage differential relay the ratio of number of turns of restraining coil and operating coil i.e. $\frac{N_r}{N_o}$ decide a perticular percentage of average current to operate the relay.

14. To prevent arc restriking due to transient recovery voltage (TRV) cassie theory is given, according to which "If rate of heat dissipation between circuit breaker contacts is greater than rate of heat developed by arc then arc will not restrike."

15. Bundled conductor increase the effective radius i.e., geomatrical mean radius which increase the corona starting voltage i.e., disruptive critical voltage so less corona formation and less power loss.

16. $r = \frac{1}{2}\sqrt{\frac{L}{C}} = \frac{1}{2}\sqrt{\frac{20\times10^{-3}}{0.02\times10^{-6}}} = 500\ \Omega$

17. To prevent false tripping due to inrush current in transformer :

- Some intentional time delay provide to relay.
- Harmonic restraint relay used for second harmonic in inrush current.

18. For open ended line $Z_L = \infty$

Current reflection coefficient

$$\tau_I = \frac{Z_0 - Z_L}{Z_0 + Z_L} = \frac{Z_L\left(\frac{Z_0}{Z_L} - 1\right)}{Z_L\left(\frac{Z_0}{Z_L} + 1\right)} = \frac{0-1}{0+1} = -1$$

19. With increase in temperature increase in length of conductor so sag will also increase.

20. For resonance

$$X_L = \frac{X_C}{3}$$

$$\omega L = \frac{1}{3\omega C}$$

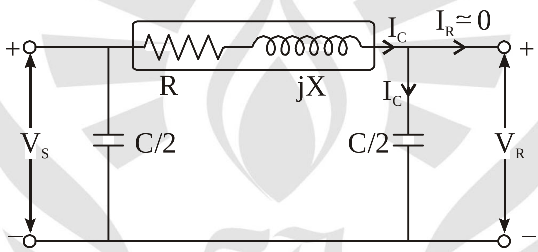
$$L = \frac{1}{3\omega^2 C}$$

$$L = \frac{1}{12\pi^2 f^2 C}$$

[PART : B]

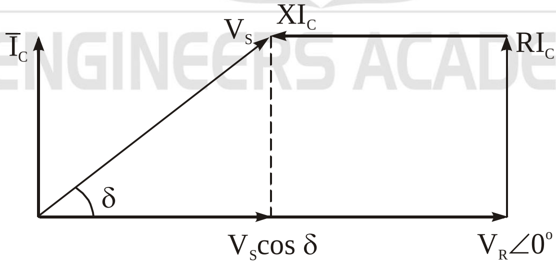
21.
- Superheater dry the steam coming out from boiler and also increase the temperature using heat from flue gases.
- Economiser heat the feed water with the heat from flue gases and its way to boiler.
- Airpreheater extract the remaining heat from flue gases and give it to the air having supplied to furnace for cooling and combustion.

22. Ferranti effect occurs
- At no load or light load condition.
- Due to shunt capacitance.
- In medium and long transmission line.
- $|V_R|_{\text{no load}} > |V_S|$
- Insulation may damage so shunt reactor used to prevent ferranti effect.



$\because \quad \overline{I_C} = jW\frac{C}{2}\overline{V}_R$

$\overline{I_C}$ leads $\overline{V}_R$ by angle 90°.



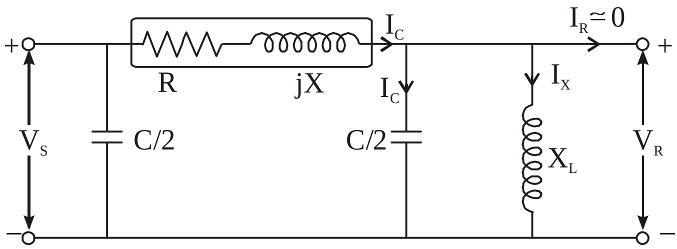
Apply KVL in loop

$$\overline{V}_S = \overline{V}_R + R\overline{I}_C + jX\overline{I}_C$$

From phasor diagram

$$|V_R|_{\text{no load}} > |V_S|$$

i.e., ferranti effect



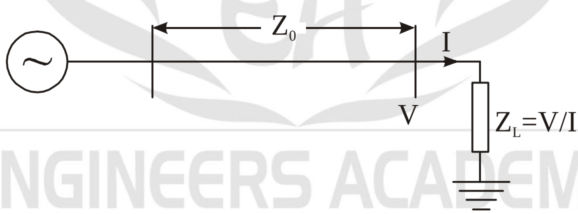
$\because \qquad \bar{I}_X = \dfrac{\bar{V}_R}{jX_L}$

$\bar{I}_X$ legs $\bar{V}_R$ by angle 90^o

$\because \qquad \bar{I} = \bar{I}_C + \bar{I}_X = 0$

So, $|V_R|_{no\ load} = |V_S|$

23. Surge impedance loading provides ideal power transfer capability using flat voltage profile.



Case-I : If $Z_L = Z_0$

$\Rightarrow \qquad \dfrac{V}{I} = \sqrt{\dfrac{L}{C}}$

$\Rightarrow \qquad \omega CV^2 = \omega LI^2$

$\Rightarrow \qquad Q_C = Q_L$

Net $\qquad VAr = Q_L - Q_C$

$\Rightarrow \qquad Q = 0$

$\Rightarrow \qquad \Delta V = 0$

$\Rightarrow \quad V_S - V_R = 0$

$\Rightarrow \quad V_S = V_R$

i.e., flat voltage profile.

Case-II : If $Z_L < Z_0$

$$\Rightarrow \quad \frac{V}{I} < \sqrt{\frac{L}{C}}$$

$\Rightarrow \quad Q_C < Q_L$

Net $\quad VAr = Q_L - Q_C$

$\Rightarrow \quad Q > 0$

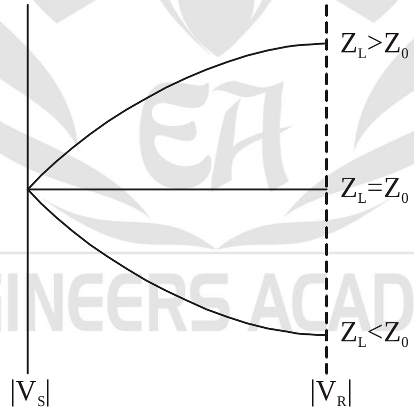
$\Rightarrow \quad \Delta V > 0$

$\Rightarrow \quad V_S > V_R$

i.e., voltage drop along the line.

Case-III : If $Z_L > Z_0$

$$\Rightarrow \quad \frac{V}{I} > \sqrt{\frac{L}{C}}$$



$\Rightarrow \quad Q_C > Q_L$

Net $\quad VAr = Q_L - Q_C$

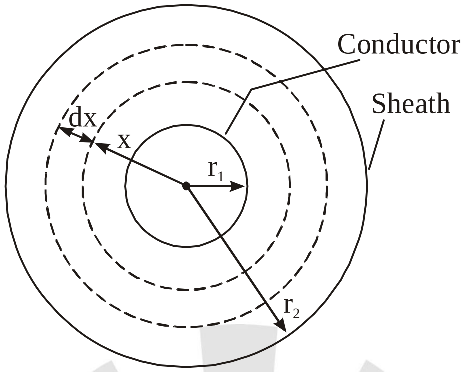
$\Rightarrow \quad Q < 0$

$\Rightarrow \quad \Delta V < 0$

$\Rightarrow \quad V_S < V_R$

i.e., voltage rise along the line.

24. Insulation resistance of cable :



r_1 = Radius of conductor.

r_2 = Radius of sheath with conductor.

Insulation between conductor and outer metallic sheath at distance x from centre.

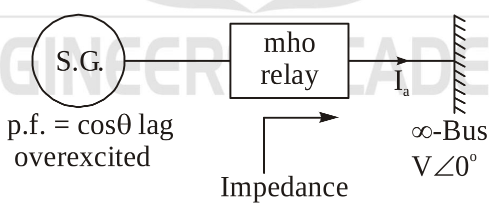
$$\because \qquad R = \frac{\rho l}{A}$$

$$\text{So,} \qquad dR = \rho \cdot \frac{dx}{2\pi x l}$$

$$\Rightarrow \qquad R = \frac{\rho}{2\pi l}\int_{r_1}^{r_2} \frac{1}{x} dx$$

$$\Rightarrow \qquad R = \frac{\rho}{2\pi l} \ln\left(\frac{r_2}{r_1}\right)$$

25.



Impedance seen by mho relay

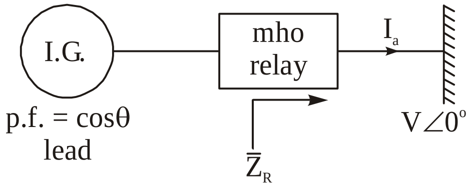
$$\bar{Z}_R = \frac{\bar{V}}{\bar{I}_a} = \frac{V\angle 0^o}{I_a\angle -\theta}$$

$$= Z_1\angle\theta \text{ i.e., Inductive}$$

$$= R_1 + jX_1 \text{ so no tripping.}$$

If excitation fails $E \propto I_f = 0$

On the failure of excitation synchronous generator behaves as induction generator due to presence of damper bar, so it starts taking magnetising current from supply. And hence it starts operating at leading p.f.



$$\bar{Z}_R = \frac{V\angle 0^o}{I_a\angle +\theta}$$

$= Z_2\angle -\theta$ i.e., capacitive so tripping

$= R_2 - jX_2$.

26. $\because$ $P = VI\cos\theta$

If a perticular power is transmitted at a perticular voltage.

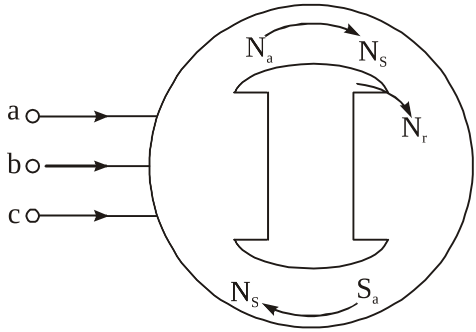
$$\downarrow I \propto \frac{1}{\cos\theta\uparrow}$$

Following are advantages of power factor improvement :

- $\downarrow S = VI\downarrow$ for same output power less KVA required so size of machines and cost reduces.
- To carry less current the cross-sectional area of conductor requirement reduces and hence transmission cost reduces.
- Transmission line loss I^2R reduces so efficiency increase.
- Voltage drop $\Delta V = IZ$ reduces along the line so voltage regulation reduces.

27. Symmetrical component are used for unsymmetrical fault analysis.

- ***Positive Sequence Current :***

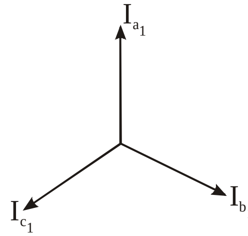


The sequence of current corresponding to which armature flux ϕ_a or mmf F_a rotates in the same direction of rotor, is called positive sequence current.

$$I_{a_1} = I\angle 0^o$$

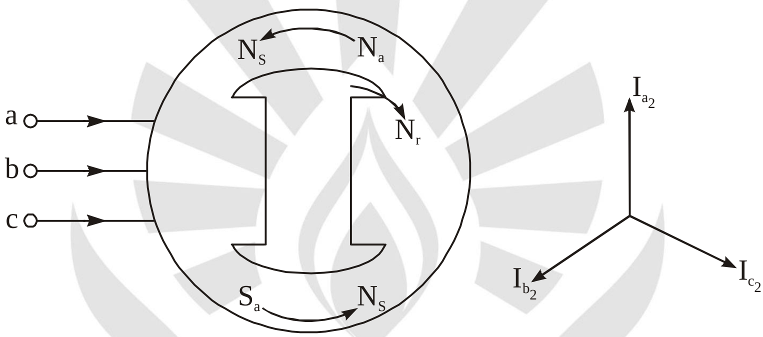
$$I_{b_1} = I\angle -120^o = \alpha^2 I_{a_1}$$

$$I_{c_1} = I\angle +120^o = \alpha I_{a_1}$$



- ***Negative Sequence Current***

The sequence of current corresponding to which armature flux ϕ_a or mmf F_a rotates in the opposite direction of rotor, is called negative sequence current.



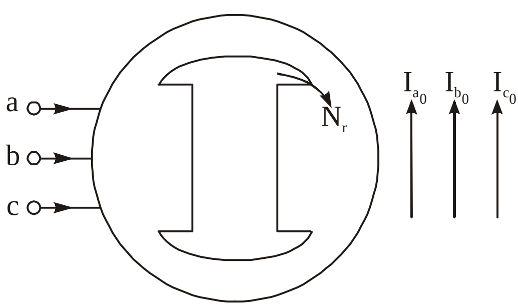
$$I_{a_2} = I\angle 0^o$$

$$I_{b_2} = I\angle +120^o = \alpha I_{a_2}$$

$$I_{c_2} = I\angle -120^o = \alpha^2 I_{a_2}$$

- ***Zero Sequence Current :***

The sequence of current corresponding to which no rotating field develop only armature leakage flux is there, called zero sequence current.

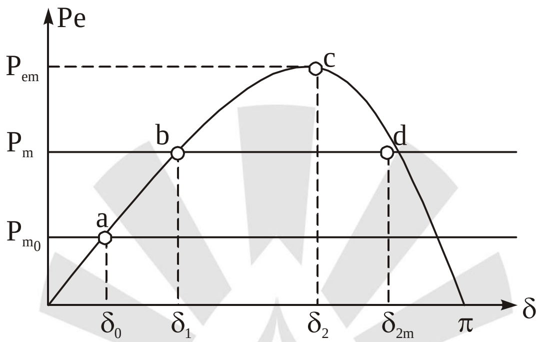


$$I_{a_0} = I\angle 0^o$$

$$I_{b_0} = I\angle 0^o = I_{a_0}$$

$$I_{c_0} = I\angle 0^o = I_{a_0}$$

28. For sudden change in shaft input or mechanical input from P_{m_0} to P_m.



From δ_0 to δ_1 due to increase in input there is acceleration in rotor of alternator and from δ_1 to δ_2 deacceleration in rotor speed and finally this swinging of rotor from δ_0 to δ_2 will settle down to δ_1 due to damper bar presence.

From swing equation

$$P_a = M\frac{d^2\delta}{dt^2}$$

$$\Rightarrow \quad \frac{d^2\delta}{dt^2} = \frac{p_a}{M}$$

$$\int 2\frac{d\delta}{dt}\cdot\frac{d^2\delta}{dt^2}\cdot dt = \int \frac{p_a}{M}\cdot 2\frac{d\delta}{dt}\cdot dt$$

$$\int \frac{d}{dt}\left(\frac{d\delta}{dt}\right)^2 \cdot dt = \frac{2}{M}\int p_a d\delta$$

$$\left(\frac{d\delta}{dt}\right)^2\Bigg|_{\delta_0}^{\delta_2} = \frac{2}{M}\int_{\delta_0}^{\delta_2} p_a\, d\delta$$

$$\left(\frac{d\delta}{dt}\right)^2\Bigg|_{\delta_2} - \left(\frac{d\delta}{dt}\right)^2\Bigg|_{\delta_0} = \frac{2}{M}\int_{\delta_0}^{\delta_2} p_a\, d\delta$$

At δ_2 maximum swing angle $\frac{d\delta}{dt} = 0$

At δ_0 minimum swing angle $\frac{d\delta}{dt} = 0$

$$0 - 0 = \frac{2}{M}\int_{\delta_0}^{\delta_2} p_a \, d\delta$$

$$\int_{\delta_0}^{\delta_2} p_a \, d\delta = 0$$

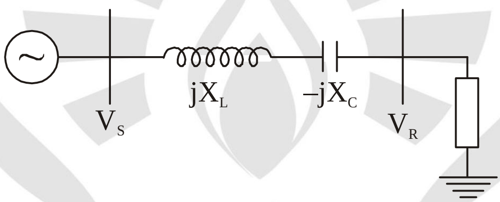
$$\int_{\delta_0}^{\delta_1} p_a \, d\delta + \int_{\delta_1}^{\delta_2} p_a \, d\delta = 0$$

$$\int_{\delta_0}^{\delta_1} (p_m - p_e) d\delta = \int_{\delta_1}^{\delta_2} (p_e - p_m) d\delta$$

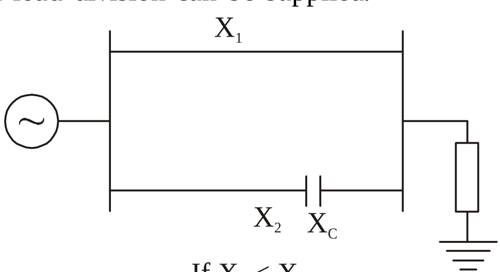
Accelerating area = Deaccelerating Area

i.e., Equal area criterion.

29. ***With series capacitive compensation Following advantage occur:***



- Steady state stability limit $P_{max} = \frac{V_S V_R}{(X_L - X_C)}$ increases due to decrease in series reactance.
- With increase in P_{max} the operating power angle δ also reduces so transient stability limit also increases.
- In double circuit transmission line by using series capacitor equal load division can be supplied.



If $X_1 < X_2$

then $X_1 = (X_2 - X_C)$

- Surge impedance loading i.e., ideal power transfer capability of line increases.

30. $\because fl = 50 \times 200 = 10{,}000$ Hz-km

As $4000 < fl < 12000$ so it is a medium transmission line.

$$\because \quad A = 1+\frac{YZ}{2} = 1+\frac{(j\omega c l)(j\omega L l)}{2}$$

$$\left(\because \text{For lossless line } \begin{matrix} r \simeq 0 \\ g \simeq 0 \end{matrix}\right)$$

$$= 1-\frac{\omega^2 l^2 LC}{2} = 1-\frac{\omega^2 l^2}{2V_C^2} \qquad \left(\because V_C = \frac{1}{\sqrt{LC}}\right)$$

$$= 1-\frac{1}{2}\left[\frac{2\pi(50)\times 200}{3\times 10^5}\right]^2$$

$$(\because V_C = 3 \times 10^5 \text{ km/sec})$$

$$= 0.978$$

$$\because \quad |V_R|_{\text{no load}} = \left|\frac{V_S}{A}\right| = \frac{220}{0.978} = 224.95 \text{ kV}$$

31. For the safety of the person working in neighbourhood of machine the body of machine is earthed through earth electrode and the value of resistance of earth electrode should be minimum for safety purpose.

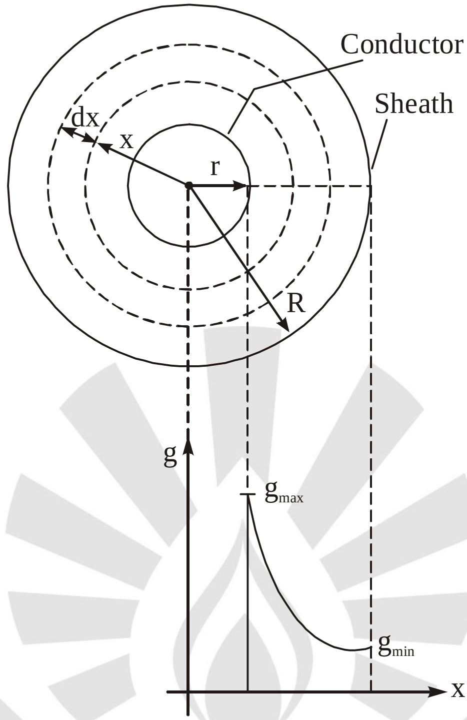
The value of resistance of earth electrode depends upon :

- Shape and size of earth electrode.
- Depth in the soil of earth electrode.
- Material of earth electrode.
- Soil condition i.e., ph value.

32. ***Following are advantage of SF_6 circuit breaker:***

- SF_6 gas provides higher dielectric strength (up to three times of air) at normal pressure, so less electrical clearance is required for arc extinction.
- Its heat transfer ability is higher. (Upto 2.5 times that of air)
- It is highly inert gas so does not form explosive mixture with air.
- It is chemically stable so does not get decomposed into gases.
- Its dielectric strength builds up at very fast rate So auxillary braking not required to reduce RRRV.

33. Electrostatic stress in single core cable :-



r = Radius of conductor

R = Radius of sheath with conductor.

At a distance x from centre of conductor of cable electric field intensity.

$$E_x = \frac{Q}{2\pi \in_0 \in_r} \cdot \frac{1}{x} \text{ V/m}$$

Potential gradient or Dielectric strength

$$g = E_x = \frac{Q}{2\pi \in_0 \in_r} \cdot \frac{1}{x} \text{ V/m} \quad ...(1)$$

Potential of conductor with respect to sheath

$$V = \int g dx = -\int_R^r E_x dx$$

$$\Rightarrow \quad V = \frac{Q}{2\pi \in_0 \in_r} \ln\left(\frac{R}{r}\right)$$

$$\Rightarrow \quad Q = \frac{2\pi \in_0 \in_r V}{\ln(R/r)}$$

equation (1)

$$g = \frac{2\pi \epsilon_0 \epsilon_r V}{\ln(R/r)} \cdot \frac{1}{2\pi \epsilon_0 \epsilon_r x}$$

$$\Rightarrow \quad g = \frac{V}{x \ln(R/r)}$$

$$\Rightarrow \quad g_{max} = \frac{V}{x_{min} \ln(R/r)} = \frac{V}{r \ln(R/r)}$$

$$\Rightarrow \quad g_{min} = \frac{V}{x_{max} \ln(R/r)} = \frac{V}{R \ln(R/r)}$$

In order to keep a fixed overall size of conductor (R) for a perticular voltage V, radius of conductor for minimum value of g_{max}.

$$\frac{d}{dr}\{r \ln R/r\} = 0$$

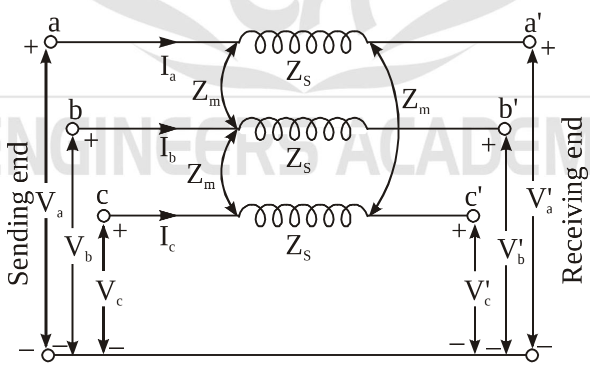
$$\Rightarrow \quad r \cdot \frac{r}{R} \cdot \left(-\frac{R}{r^2}\right) + \ln\left(\frac{R}{r}\right) \cdot 1 = 0$$

$$\Rightarrow \quad \ln\left(\frac{R}{r}\right) = 0$$

$$\Rightarrow \quad \frac{R}{r} = e$$

i.e., condition for economic size of conductor.

34. Sequential network of transmission line :



Voltage drop along the line

$$\Rightarrow \quad V_a - V_a^1 = Z_s I_a + Z_m I_b + Z_m I_c$$

$$\Rightarrow \quad V_b - V_b^1 = Z_m I_a + Z_s I_b + Z_m I_c$$

$$\Rightarrow \quad V_c - V_c^1 = Z_m I_a + Z_m I_b + Z_s I_c$$

$$\Rightarrow \begin{bmatrix} V_a \\ V_b \\ V_c \end{bmatrix} - \begin{bmatrix} V_a^1 \\ V_b^1 \\ V_c^1 \end{bmatrix} = \begin{bmatrix} Z_s & Z_m & Z_m \\ Z_m & Z_s & Z_m \\ Z_m & Z_m & Z_s \end{bmatrix} \begin{bmatrix} V_a \\ V_b \\ V_c \end{bmatrix}$$

$$\Rightarrow \quad V_p - V_p^1 = ZI_p$$

$$\Rightarrow AV_s - AV_s^1 = Z(AI_s)$$

$$\Rightarrow \quad V_s - V_s^1 = (A^{-1}ZA)I_s$$

$$\Rightarrow \begin{bmatrix} V_{a_1} \\ V_{a_2} \\ V_{a0} \end{bmatrix} - \begin{bmatrix} V_{a_1}^1 \\ V_{a_2}^1 \\ V_{a_0}^1 \end{bmatrix} = \begin{bmatrix} Z_1 & 0 & 0 \\ 0 & Z_2 & 0 \\ 0 & 0 & Z_0 \end{bmatrix} \begin{bmatrix} I_{a_1} \\ I_{a_2} \\ I_{a_0} \end{bmatrix}$$

$$\because \quad Z_{seq} = A^{-1}ZA$$

$$= \frac{1}{3}\begin{bmatrix} 1 & \alpha & \alpha^2 \\ 1 & \alpha^2 & \alpha \\ 1 & 1 & 1 \end{bmatrix} \begin{bmatrix} Z_s & Z_m & Z_m \\ Z_m & Z_s & Z_m \\ Z_m & Z_m & Z_s \end{bmatrix} \begin{bmatrix} 1 & 1 & 1 \\ \alpha^2 & \alpha & 1 \\ \alpha & \alpha^2 & 1 \end{bmatrix}$$

$$= \begin{bmatrix} Z_s - Z_m & 0 & 0 \\ 0 & Z_s - Z_m & 0 \\ 0 & 0 & Z_s + 2Z_m \end{bmatrix} \begin{bmatrix} Z_1 & 0 & 0 \\ 0 & Z_2 & 0 \\ 0 & 0 & Z_0 \end{bmatrix}$$

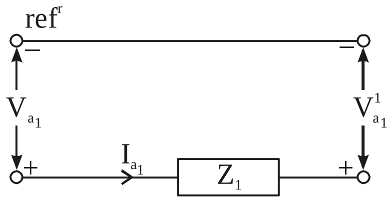
$$\Rightarrow \begin{bmatrix} V_{a_1} \\ V_{a_2} \\ V_{a0} \end{bmatrix} - \begin{bmatrix} V_{a_1}^1 \\ V_{a_2}^1 \\ V_{a_0}^1 \end{bmatrix} = \begin{bmatrix} Z_1 & 0 & 0 \\ 0 & Z_2 & 0 \\ 0 & 0 & Z_0 \end{bmatrix} \begin{bmatrix} I_{a_1} \\ I_{a_2} \\ I_{a_0} \end{bmatrix}$$

$$V_{a_1} - V_{a_1}^1 = Z_1 I_{a_1} \quad ...(1)$$

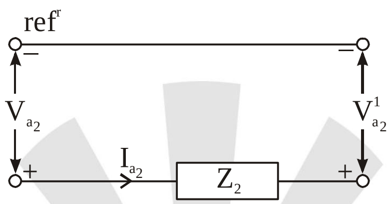
$$V_{a_2} - V_{a_2}^1 = Z_2 I_{a_2} \quad ...(2)$$

$$V_{a_0} - V_{a_0}^1 = Z_0 I_{a_0} \quad ...(3)$$

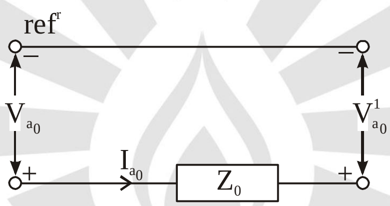
From equation (1) : Positive sequence network



From equation (2) : Negative sequence network



From equation (3) : Zero sequence network



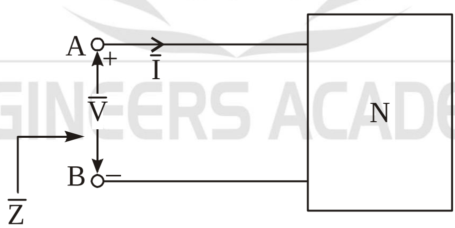
Here, $Z_1 = Z_2 = Z_s - Z_m$

$Z_0 = Z_s + 2Z_m$

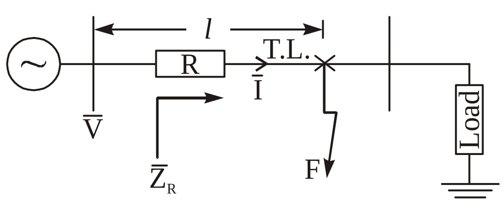
Where, Z_s = Self impedance of line.

Z_m = Mutual impedance between line.

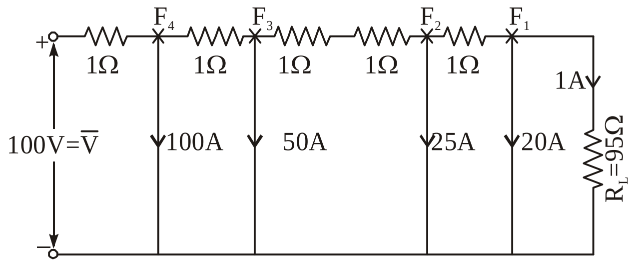
35. Distance relay is used for protection of transmission line.



$$\bar{Z} = \frac{\bar{V}}{\bar{I}}$$ i.e., impedance seen from AB



Impedance seen by relay $\bar{Z}_R = \frac{\bar{V}}{\bar{I}}$



- In the normal condition impedance seen by relay is higher i.e. load impedance as well as trnasmission line impedance.
- In the fault condition impdance seen by relay reduces and it depends upon distance of fault.
- ***Impedance Relay :*** (Voltage restraint overcurrent relay)

$$T = k_1|I|^2 - k_2|V|^2$$

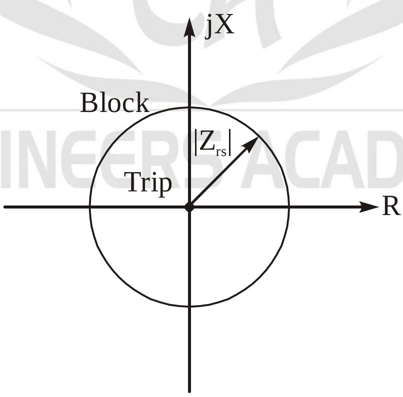
$$\Rightarrow \quad \frac{|V|}{|I|} < \frac{k_1}{k_2}$$

$$|Z| < |Z_{rs}|$$

$$|R + jX| < |Z_{rs}|$$

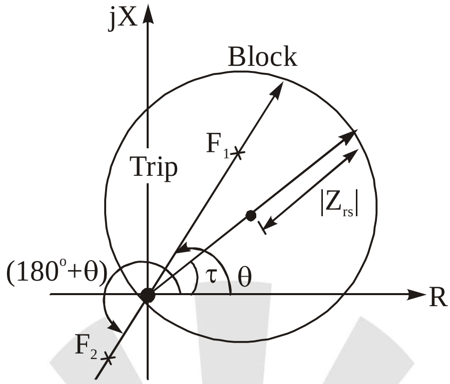
$$R^2+X^2 < |Z_{rs}|^2$$

i.e. equation of circle.



- The relay operates if fault on either side within a perticular distance 'l_R' (reach of relay) i.e., distance relay. So it is non-directional realy.

- ***Mho Relay or Modified Impedance Relay :*** (Voltage restraint directional realy)



$$T = K_3|V||I|\cos(\theta - \tau) - K_2|V|^2$$

Relay operates if

$K_3|V||I|\cos(\theta - \tau) > K_2|V|^2$

$$\Rightarrow \quad \frac{|V|}{|I|} < 2\left(\frac{K_3}{2K_2}\right)\cos(\theta - \tau)$$

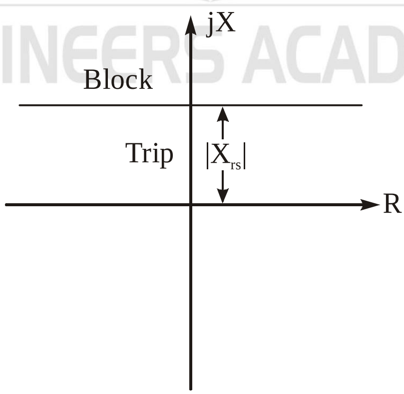
$$\Rightarrow \quad |Z| < 2|Z_{rs}| \cos(\theta - \tau)$$

F_1 at a perticular distance detect and F_2 does not detect. So it detects fault within a perticular distance in a perticular direction.

- ***Reactance Relay :*** (Directional restraint overcurrent relay)

$$T = K_1|I|^2 - K_3|V||I|\cos(\theta - \tau)$$

Relay operates if



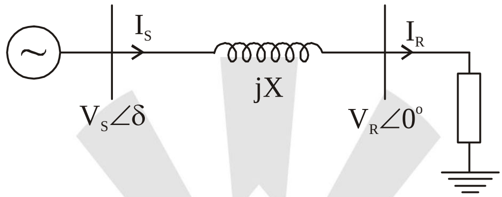
$$K_1|I|^2 > K_3|V||I|\cos(\theta - 90^o) \quad [\because \tau = 90^o]$$

$$\Rightarrow \frac{|V|}{|I|}\sin\theta < \frac{K_1}{K_3}$$

$$\Rightarrow |Z|\sin\theta < \frac{K_1}{K_3}$$

$$\Rightarrow \quad |X| < |X_{rs}|$$

36. For loss less short transmission line



$$\bar{Z} = jX = X\underline{|90^o}$$

$$A = D = 1$$

$$B = Z = X\underline{|90^o}$$

$$C = 0$$

$$\because \quad \bar{V}_S = \bar{V}_R + jX\bar{I}_R$$

$$\Rightarrow \quad \bar{I}_R = \frac{V_S}{X}\underline{|\delta - 90^o} - \frac{V_R}{X}\underline{|-90^o}$$

$$\Rightarrow \quad \bar{I}_R^* = \frac{V_S}{X}\underline{|90^o - \delta} - \frac{V_R}{X}\underline{|90^o}$$

$$\because \quad S_R = \bar{V}_R\bar{I}_R^*$$

$$\Rightarrow \quad P_R + jQ_R = \frac{V_SV_R}{X}\underline{|90^o - \delta} - \frac{V_R^2}{X}\underline{|90^o}$$

$$\because \quad P_R = \frac{V_SV_R}{X}\cos(90^o - \delta) - \frac{V_R^2}{X}\cos 90^o$$

$$\Rightarrow \quad P_R = \frac{V^2}{X}\sin\delta \qquad ...(1)$$

$[\because\ |V_S| = |V_R| = V]$

$$\because \quad Q_R = \frac{V_S V_R}{X}\sin(90^o - \delta) - \frac{V_R^2}{X}\sin 90^o$$

$$\Rightarrow \quad Q_R = \frac{V^2}{X}\cos\delta - \frac{V^2}{X} \qquad ...(2)$$

$$\because \quad \bar{I}_S = C\bar{V}_R + D\bar{I}_R$$

$$\Rightarrow \quad \bar{I}_S = \bar{I}_R$$

$$\Rightarrow \quad \bar{I}_S^* = \bar{I}_R^* = \frac{V_S}{X}\angle 90^o - \delta - \frac{V_R}{X}\angle 90^o$$

$$\because \quad \bar{S}_S = \bar{V}_S I_S^*$$

$$\Rightarrow \quad P_S + jQ_S = \frac{V_S^2}{X}\angle 90^o - \frac{V_S V_R}{X}\angle 90^o + \delta$$

$$\because \quad P_S = \frac{V_S^2}{X}\cos 90^o - \frac{V_S V_R}{X}\cos(90^o + \delta)$$

$$\Rightarrow \quad P_S = \frac{V^2}{X}\sin\delta \qquad ...(3)$$

$$\because \quad Q_S = \frac{V_S^2}{X}\sin 90^o - \frac{V_S V_R}{X}\sin(90^o + \delta)$$

$$\Rightarrow \quad Q_S = \frac{V^2}{X} - \frac{V^2}{X}\cos\delta \qquad ...(4)$$

$$\because \quad P_{loss} = P_S - P_R = 0$$

$$\Rightarrow \quad Q_{loss} = Q_S - Q_R = \frac{2V^2}{X}(1 - \cos\delta)$$

37. At lagging power factor voltage regulation is given by

$$V.R. = \frac{I_R}{V_R}(R\cos\theta + X\sin\theta)$$

$$= \frac{1}{Z_B}(R\cos\theta + X\sin\theta)$$

$$= \frac{R}{Z_B}\cos\theta + \frac{X}{Z_B}\sin\theta$$

$$= R_{pu}\cos\theta + X_{pu}\sin\theta$$

For maximum voltage regulation at lag p.f.

$$\frac{d(V.R.)}{d\theta} = 0$$

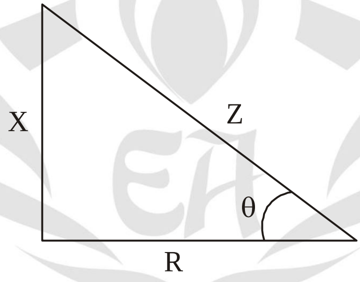
$$\Rightarrow \quad R_{pu}(-\sin\theta) = X_{pu}(\cos\theta) = 0$$

$$\Rightarrow \quad R_{pu}\sin\theta = X_{pu}\cos\theta$$

$$\Rightarrow \quad \tan\theta = \frac{X_{pu}}{R_{pu}} = \frac{X/Z_B}{R/Z_B} = \frac{X}{R}$$

$$\because \quad Z = \sqrt{R^2 \times X^2}$$

$$\because \quad \text{p.f.} = \cos\phi = \frac{R}{Z}$$



At leading power factor voltage regulation is given by

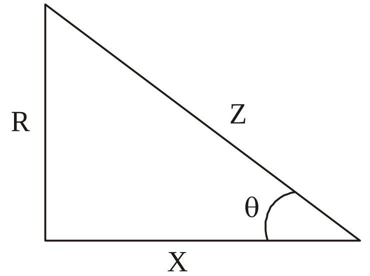
$$V.R. = \frac{I_R}{V_R}(R\cos\theta - X\sin\theta)$$

$$= \frac{1}{Z_B}(R\cos\theta - X\sin\theta)$$

$$= \frac{R}{Z_B}\cos\theta - \frac{X}{Z_B}\sin\theta$$

$$= R_{pu}\cos\theta - X_{pu}\sin\theta$$

For zero voltage regulation at lead p.f.



$$V.R. = 0$$

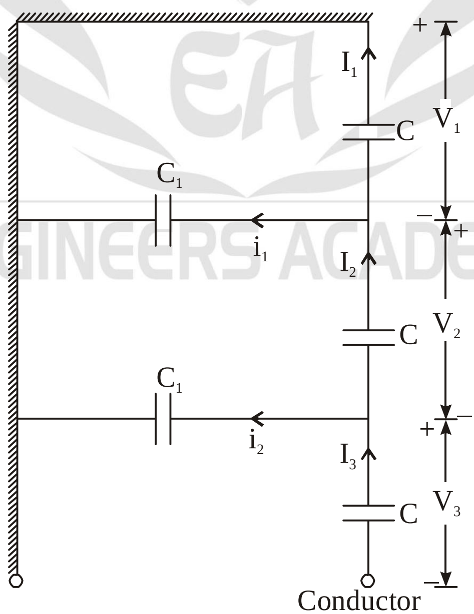
$$\Rightarrow \quad R_{pu}\cos\theta = X_{pu}\sin\theta$$

$$\Rightarrow \quad \tan\theta = \frac{R_{pu}}{X_{pu}} = \frac{R/Z_B}{X/Z_B} = \frac{R}{X}$$

$$\because \quad p.f. = \cos\theta = \frac{X}{Z}$$

38. Suspension type line insulators consist of number of porceline discs connected in series by metal links in the form of a string. Each unit or disc is designed for low voltage and number of disc depend upon working voltage.

Potential distribution over suspension insulator string :-



Where, C = Self capacitance of insulator.

C_1 = Mutual or stray capacitance

Let $\frac{C_1}{C} = K$

$\because \quad I_2 = I_1 + i_1$

$\Rightarrow \quad \omega c V_2 = \omega c V_1 + \omega c_1 V_1$

$\Rightarrow \quad CV_2 = CV_1 + (KC)V_1$

$\Rightarrow \quad V_2 = V_1(1 + K)$

Due to presence of stray capacitance unequal current and voltage distribution along the each disc of string i.e., $V_1 < V_2 < V_3$.

$\because \quad I_3 = I_2 + i_2$

$\Rightarrow \quad \omega c V_3 = \omega c v_2 + \omega(KC)(V_1+V_2)$

$\Rightarrow \quad V_3 = KV_1 + (1 + K)V_2$

$\Rightarrow \quad V_3 = KV_1 + (1 + K)(1 + K)V_1$

$\Rightarrow \quad V_3 = (1 + 3K + K^2)V_1$

This unequal potential distribution represent by storing efficiency

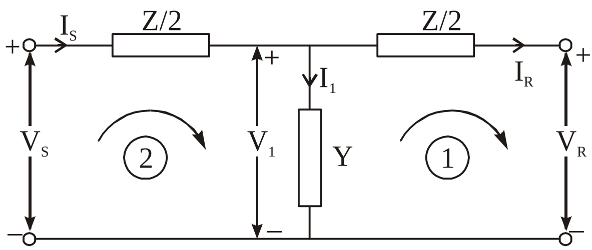
$$\eta = \frac{\text{Voltage across the string}}{\text{Number of disc} \times \text{Voltage across lowest disc}}$$

$$= \frac{V}{n \times V_n} \times 100\% = \frac{V}{3 \times V_3} \times 100\% \quad [\text{if } n = 3]$$

To improve string efficiency i.e. for equal distribution of voltage along the string.

- Using longer cross arm
- Using insulation grading ($c_1 < c_2 < c_3$)
- Using guard ring

39. T-model of medium transmission line.



Apply KVL in loop (1)

$$V_1 = V_R + \frac{Z}{2}I_R$$

$$\because \quad I_1 = YV_1 = YV_R + \frac{YZ}{2}I_R$$

$$\because \quad I_S = I_1 + I_R$$

$$\Rightarrow \quad I_S = YV_R + \left(1+\frac{YZ}{2}\right)I_R$$

Compare with

$$I_S = CV_R + DI_R$$

$$C = Y$$

$$D = 1+\frac{YZ}{2}$$

Apply KVL in Loop (2)

$$V_S = V_1 + \frac{Z}{2}I_S$$

$$V_S = \left(V_R + \frac{Z}{2}I_R\right) + \frac{Z}{2}\left[YV_R + \left(1+\frac{YZ}{2}\right)I_R\right]$$

$$V_S = \left(1+\frac{YZ}{2}\right)V_R + Z\left(1+\frac{YZ}{4}\right)I_R$$

Compare with

$$V_S = AV_R + BI_R$$

$$A = 1 + \frac{YZ}{2}$$

$$B = Z\left(1+\frac{YZ}{4}\right)$$

❍❍❍