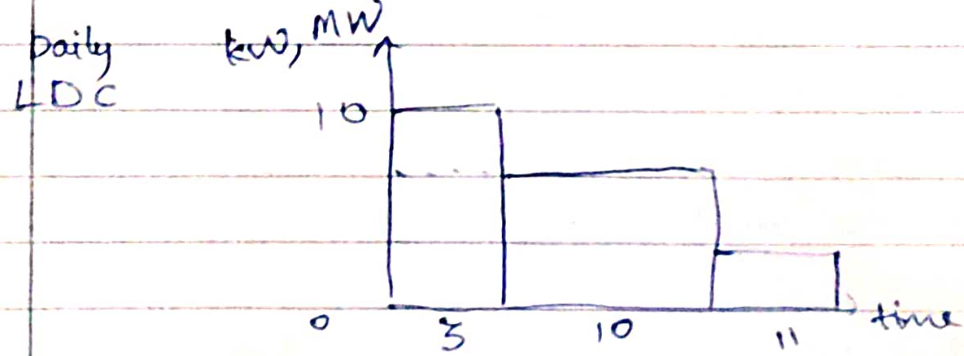
23/1/23

PSP Unit 1

1) Connected load
2) Maximum demand / Peak load.
3) Demand factor $= \frac{\text{Max. demand}}{\text{Connected load}}$
4) Average load $= \frac{\text{Energy delivered}}{\text{Time taken}}$
5) Load factor $= \frac{\text{Average load}}{\text{Peak load}}$

$= \frac{\text{Energy generated in given period}}{\text{Max demand} \times \text{hours of operation in given period}}$

6) Diversity factor $= \frac{\Sigma \text{ individual Max. demands of consumers}}{\text{Max. load on the sys.}}$
7) Capacity factor (Plant Capacity factor) $= \frac{\text{Average annual load}}{\text{Rated plant capacity}}$
8) Load Curve - graphical represen^n^ of load in proper time sequence.
9) Load Duration Curve:



10) Reserve Capacity : ← 30 MW $\boxed{+2 \text{ MW}}$

Q. A residential consumer has 8 bulbs, 100W each, 2 fans, 60W each, 2 plug points of 100W each and his use of electricity is 12 midnight to 5 am → 1 fan
5am to 7am → 2 fans & 1 plug.
7am to 9am → NIL
9am to 6pm → 2 Fans
6pm to midnight → 2 fans & 4 bulbs
Calculate 1) connected load
2) Maximum demand
3) Demand Factor
4) Energy consumed in 24 hours.
5) Energy consumed in 24 hrs if all the devices are used all the day.

Soln: 1) Connected load - 1120 W
2) Maximum demand - 520W => 120 + 400
3) Demand factor = $\frac{520}{1120}$ = 0.46

4) ~~60 + 120 + 100 + 120 + 120 + 400 = 920 W.~~
4) 12 midnight to 5am → 60W × 5 = 300W
5am to 7am → 220W × 2 = 440W
7am to 9am → 0 = 0
9am to 6pm → 120W × 9 = 1080
6pm to midnight → 520 W × 6 = 3120
∴ = 4940W.

5) 1120 × 24 = 26 880 W.

Q. A generating station supplies the following load to various consumers

Industry 750 MW

Commercial 350 MW

Domestic Power 10 MW

Domestic light 50 MW

If the maximum demand on the staⁿ is 1000 MW and no of MWh generated per yr = 50×10^5. Determine

1) Diversity factor

2) Annual load factor.

Solⁿ: 1) Diversity factor = $\frac{1160 \text{ MW}}{1000 \text{ MW}}$

$= 1.16$

2) Annual load factor = $\frac{1160}{1000 \times 50 \times 10^5}$ $\frac{50 \times 10^5}{8760 \times 1000}$

$= \frac{1160}{}$ $= 0.57$

$= 57\%$

Q. A generating staⁿ supplies the following loads 150 MW, 120 MW, 85 MW, 60 MW, 5 MW. The staⁿ has maximum demand of 220 MW and annual load factor of 48%.

1) Calculate the no of units supplied annually.

2) Diversity factor

3) Demand factor.

Solⁿ: 1) $0.48 = \frac{\text{Energy generated}}{220 \times 8760}$

(No. of units) Energy generated = 9.25×10^5 MWh = 9.25×10^8 kWh

2) Diversity factor = $\frac{420}{220}$ = 1.90

3) Demand factor = $\frac{220}{420}$ = 0.52

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Q. Load on a power plant on a typical day is

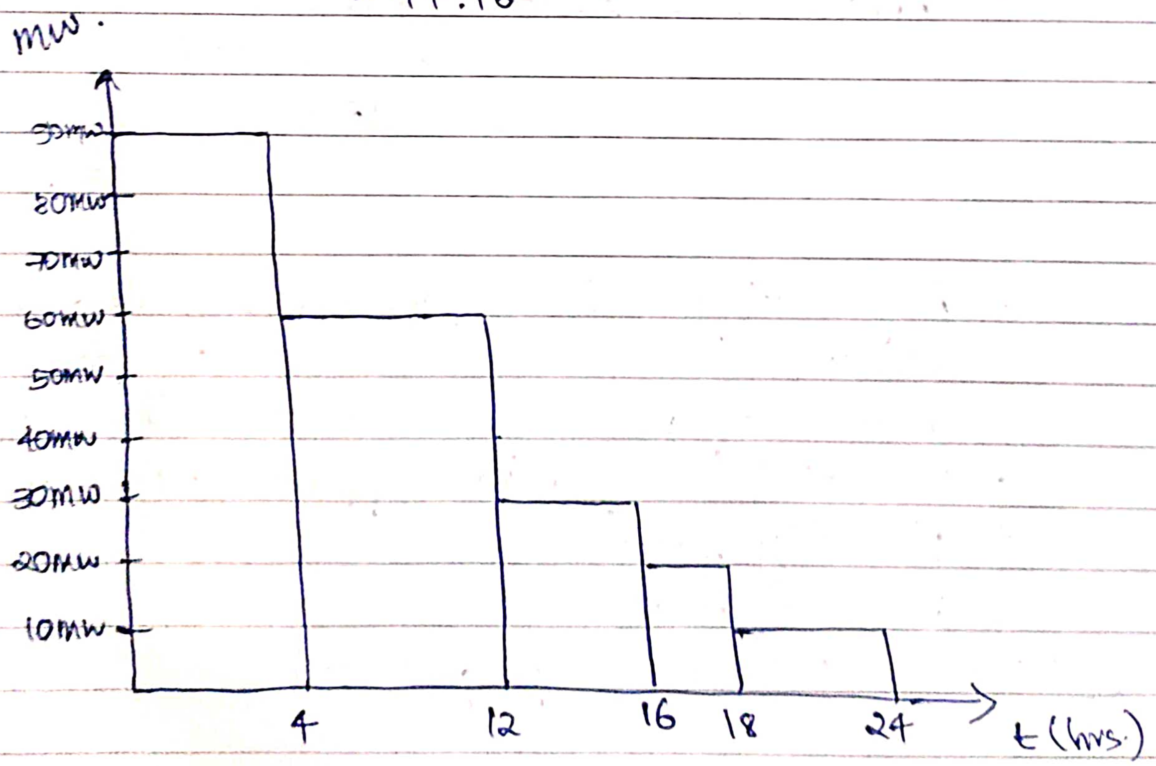
Midnight - 6am — 10mw
6am — 10am — 30mw
10am — 6pm — 60mw
6pm — 10pm — 90mw
10pm — midnight — 20mw

Plot a daily load duration curve for this given power system. Also find average demand on the plant in 24 hours.

Soln: Average demand $= \frac{10\times6 + 30\times4 + 60\times8 + 90\times4 + 20\times2}{24}$

$= \frac{1060}{24}$

$= 44.16$



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*) Diameter of stranded cond^r

$$D = (2n-1)d$$

d = dia of single strand

n = no. of layers

*) Total no. of strands

$$N = 3n^2 - 3n + 1$$

n = no. of layers

Q.

n	N	D
1	1	d
2	7	3d
3	19	5d
4	37	7d

*) Spacing bet^n cond^{r}s. $= \left(0.75\sqrt{D} + \frac{V_{kV}^2}{20000}\right)$ m

V_{kV} - vltg. in kV

D = sag in m

*) Length of the span:

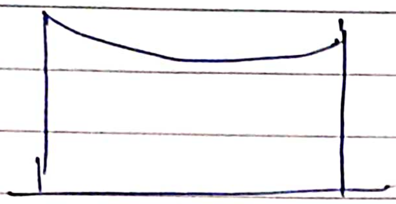
Wooden poles - 50m

Steel tubular - 50 - 80m

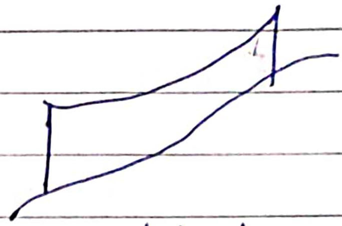
RCC poles - 80 - 100m

Steel towers - 100 - 300m.

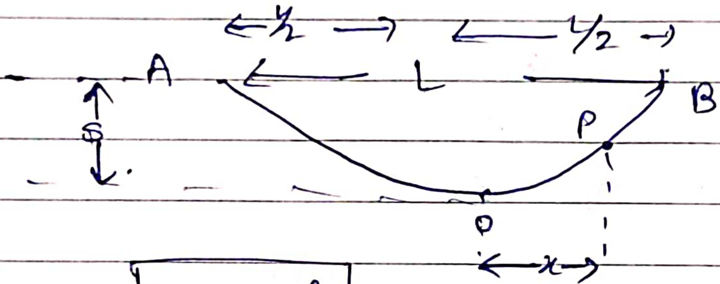
*) Sag calculation



Equal level span



Unequal level span.



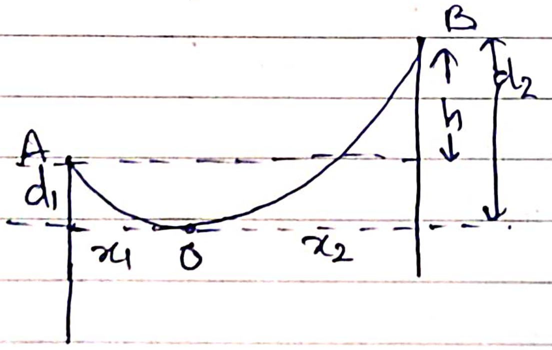
$$\boxed{S = \frac{WL^2}{8T}} \text{ m.}$$

W = weight per unit length of conductor.

L = Length of span.

T = Tension in cond^r.

Supports at unequal levels

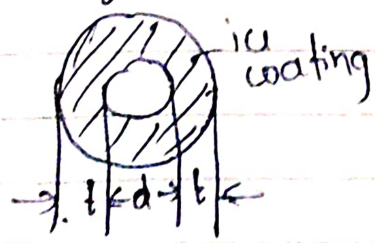


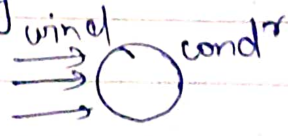
$$x_1 = 1 - \frac{hT}{2WL}$$

$$x_2 = 1 + \frac{hT}{2WL}$$

$$d_1 = \frac{Wx_1^2}{2T} \qquad d_2 = \frac{Wx_2^2}{2T}$$

*) Effect of wind & ice loading





d: dia. of cond^r

t: thickness of ice cover

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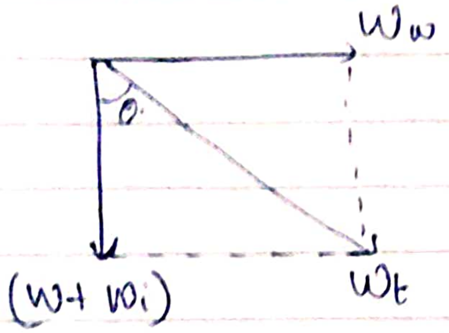


Total weight of cond^r per unit length

$W_t = \sqrt{(W + W_i)^2 + (W_w)^2}$

W = wt. of cond^r p.u. length
= cond^r material density × volume p.u. length.

W_i = wt. of ice p.u. length
= density of ice × volume of ice p.u. length.
= density of ice × $\frac{\pi}{4}[(d+2t)^2 - d^2] \times 1$.

= density × $\pi t [d + t]$.

W_w = Wind force p.u. length.
= Wind pressure × $[(d+2t) \times 1]$.

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

Sag, $S = \frac{W_t L^2}{8T}$

Here $S \rightarrow$ slant sag in a direction making angle θ.

∴ Vertical sag = $S\cos\theta$.

Q. A 132 kV transmission line has following data. Weight of the conductor 680 kg/km. Length of span is 260 m. Working tension, T = 1550 kg. Calculate the height above ground at which the conductor should be supported. Ground clearance req. is 10 m. Assume both the supports are at same level.

Sag = $\frac{W_T L^2}{2T}$

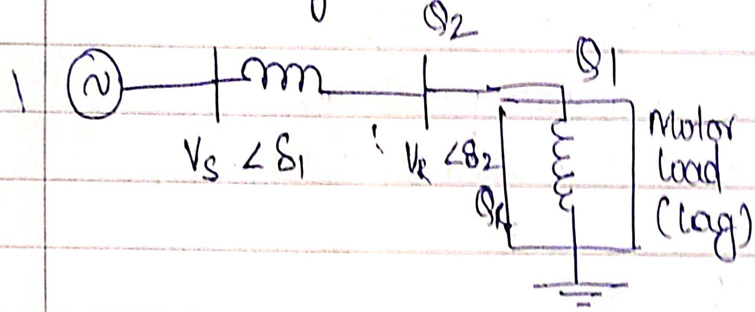
$= \frac{0.688 \times (260)^2}{8 \times 1550}$

$= 3.7m$

Height above ground = 3.7 + 10

= 13.7 m.

*) Line Insulators
1. Porcelain - 60 kV/cm thickness
2. Glass - 140 kV/cm of thickness
3. Steatite - magnesium silicate



Q_1 = demand reactive power
Q_2 = supply " ".
$Q_R = Q_1 - Q_2$

$$Q_R = \left|\frac{V_s V_R}{X_L}\right| - \cos(\delta_1 - \delta_2) - \left|\frac{V_R^2}{X_L}\right|.$$

Assume $\delta_1 \approx \delta_2$ $\cos(\delta_1 - \delta_2)$ is negligible.

$$Q_R = \left|\frac{V_s V_R}{X_L}\right| - \left|\frac{V_R^2}{X_L}\right|$$

$\therefore V_R^2 - V_s V_R + X_L Q_R = 0.$

$$V_R = \frac{V_s}{2} \pm \sqrt{\frac{V_s^2 + X_L Q_R}{2}}$$

with -ve sign, sol^n does not exist.

$$\therefore V_R = \frac{V_S}{2} + \sqrt{\frac{V_S^2 - 4X_L Q_R}{2}}$$

Case - I:

$Q_R = 0$, $V_R = V_S \rightarrow$ ideal.

Case II:

$Q_R > 0$

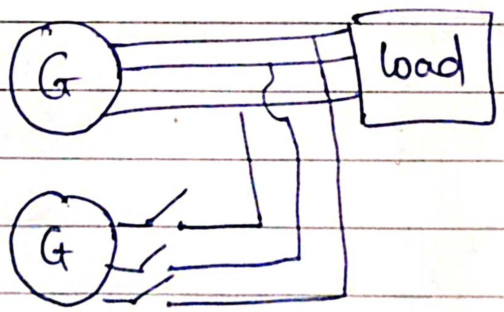
i.e. $Q_1 > Q_2$.

i.e. $V_R < V_S$.

Case - III: $Q_R < 0$ $\quad$ $V_R > V_S$

i.e. $Q_1 < Q_2$

*) Parallel operation of Alternator



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Unit 2 : T.L. Parameters & Models.

1) Representation of T.L.

Generator (G)

Motor (M)

Two winding Transformer

Three winding Trans.

C.T Pri sec.

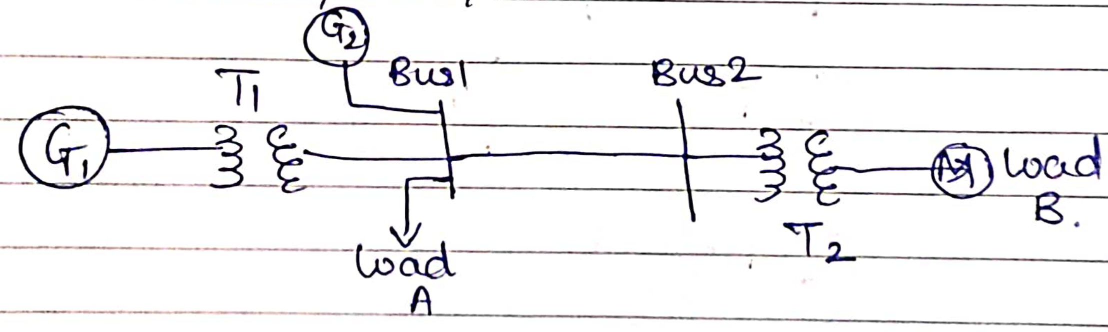
P.T.

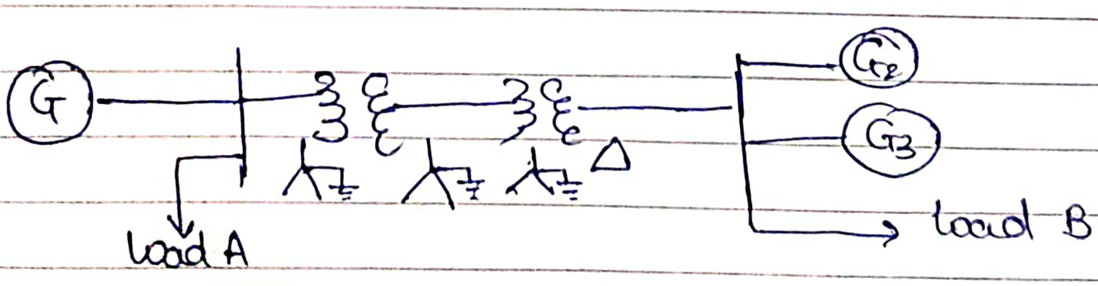
Circuit breaker (C.B).

Isolator

Bus

Overhead Line/ Cable/ T.L.





Generator → emf in series with impedance.

Short line → series impedance.

Medium & long line → π ckt.

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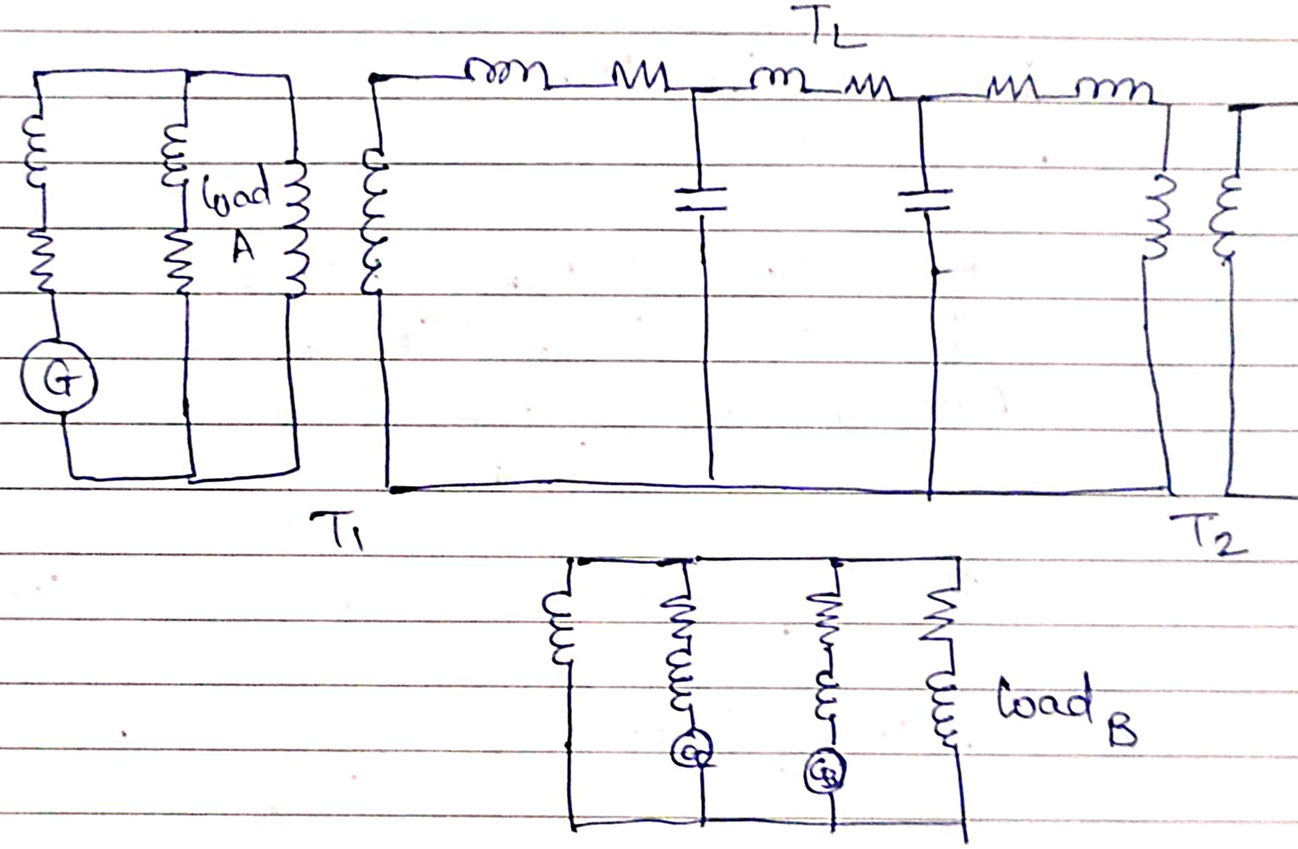
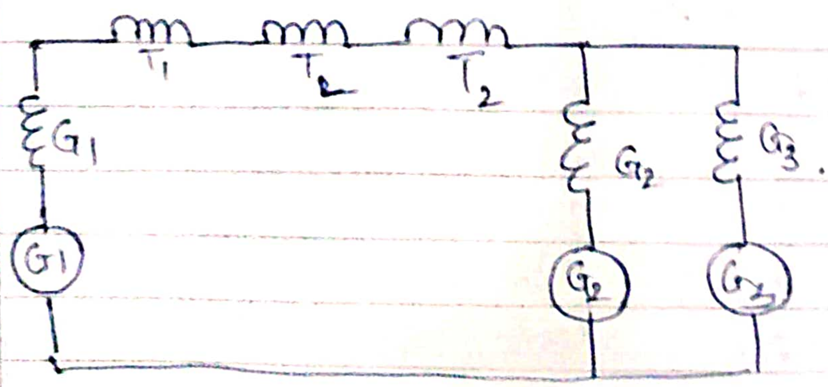
static load → resis. & react. in series
Motors → equi. ckt.
Transformer → impe. of windings.

Impedance diag.



7) Reactance Diag
1. Omit all resis. & static load.
2. Omit magnetizing currents of tran, neglect capacitance.



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$$\text{Per unit} = \frac{\text{Actual Value}}{\text{Base Value}}$$

$\underbrace{\text{KVA, kV}}_{\text{independent}}$, current, Impedance.

Base Value → kV_B.

p.u. value → $kV_{p.u.}$

Base kVA = $(kVA)_B$ / $(MVA)_B$.

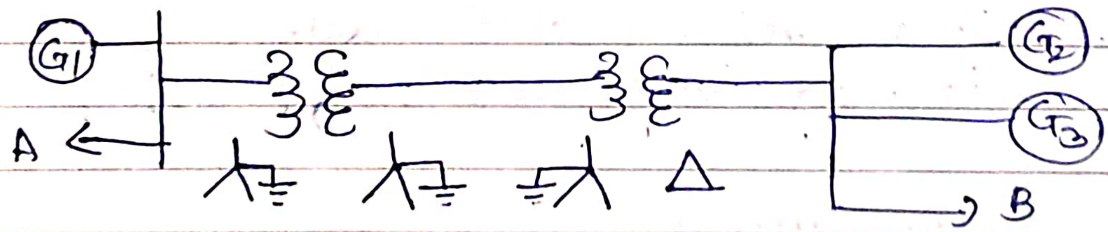
Base kV = $(kV)_B$ / $(MV)_B$.

$$\text{Base current} = \frac{(kVA)_B}{(kV)_B}$$

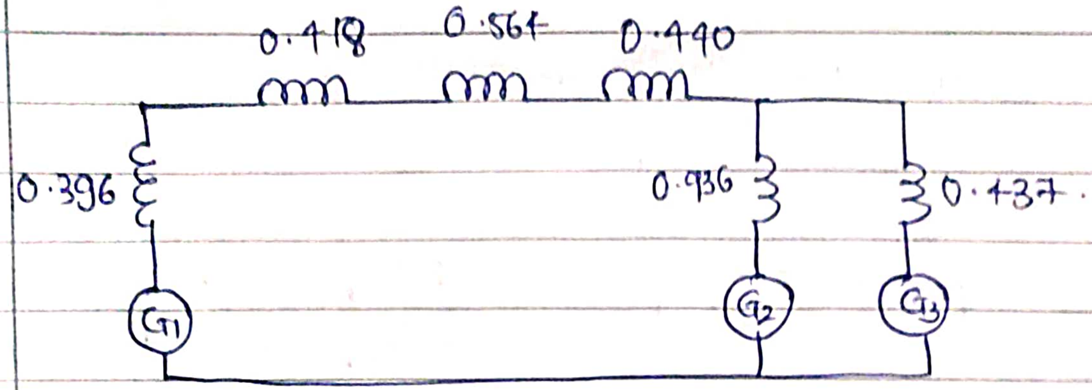
$$\text{Base impedance } Z_B = \frac{kV_B \times 1000}{I_B} \Bigg| \frac{(kV)_B^2}{MVA_B}$$

$$\text{P.U. impedance } Z_{pu} = \frac{Z \times (kVA)_B}{(kV)_B^2 \times 1000}$$

when imp. is given in Ω.

Q. 

G_1	30 MVA	10.5 kV	$X'' = 1.6\,\Omega$
G_2	15 MVA	6.6 kV	$X'' = 1.2\,\Omega$
G_3	25 MVA	6.6 kV	$X'' = 0.56\,\Omega$
T_1	15 MVA	11/33 kV	$X'' = 15.2\,\Omega$/ph.
T_2	15 MVA	33/6.2 kV	$X'' = 16\,\Omega$/ph.
Load A	40 MW	11 kV	0.9 lag p.f.
Load B	40 MW	6.6 kV	0.85 lag p.f.
T.L.	$X'' = 20.5\,\Omega$/ph.		



$$Z_{pu} = \frac{Z \times (MVA)_B}{(kV)_B^2}$$

let $MVA_B = 30$ MVA

For G_1 $\quad Z_{pu} = \frac{1.6 \times 30}{(11)^2} = 0.396.$

For G_2 $\quad Z_{pu} = \frac{1.2 \times 30}{(6.2)^2} = 0.936.$

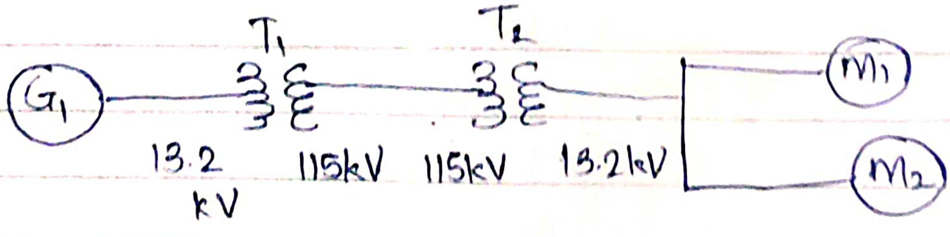
for G_3 $\quad Z_{pu} = \frac{0.56 \times 30}{(6.2)^2} = 0.437.$

for T.L. $\quad Z_{pu} = \frac{20.5 \times 30}{(33)^2} = \frac{615}{1089} = 0.564.$

T_1 $\quad Z_{pu} = \frac{15.2 \times 30}{(33)^2} = \frac{456}{1089} = 0.418$

T_2 $\quad Z_{pu} = \frac{16 \times 30}{(33)^2} = 0.440.$

Q.



G_1 – 30000 kVA, 13.8kV, $x = 15\%$

M_1 – 20000 kVA, 12.5kV, $x = 20\%$

M_2 – 10000 kVA, 12.5 kV, $x = 20\%$

T_1, T_2 – 35000 kVA $\quad x = 10\%$

TL – 80Ω.

Assuming base $(kVA)_B = \cancel{4}30000$

$(kV)_B = 13.8$

$$Z_{p.u.(new)} = Z_{pu(old)} \times \frac{MVA_{B(new)}}{MVA_B(old)} \times \frac{kV_B^2(old)}{kV_B^2(new)}$$

New kV_B for T.L $= 13.8 \times \frac{115}{13.2} = 120\ kV$

New kV_B for Motor $= 120 \times \frac{13.2}{115} = 13.8\ kV.$

New reactances,

$G_1 = 0.15$

$M_1 = 0.2 \times \frac{30000}{20000} \times \frac{(12.5)^2}{(13.8)^2}$

$= \frac{937500}{3,808,800}$

$= 0.246.$

$M_2 = 0.2 \times \frac{30000}{10000} \times \frac{(12.5)^2}{(13.8)^2}$

$= \frac{93.75}{190.44}$

$= 0.492.$

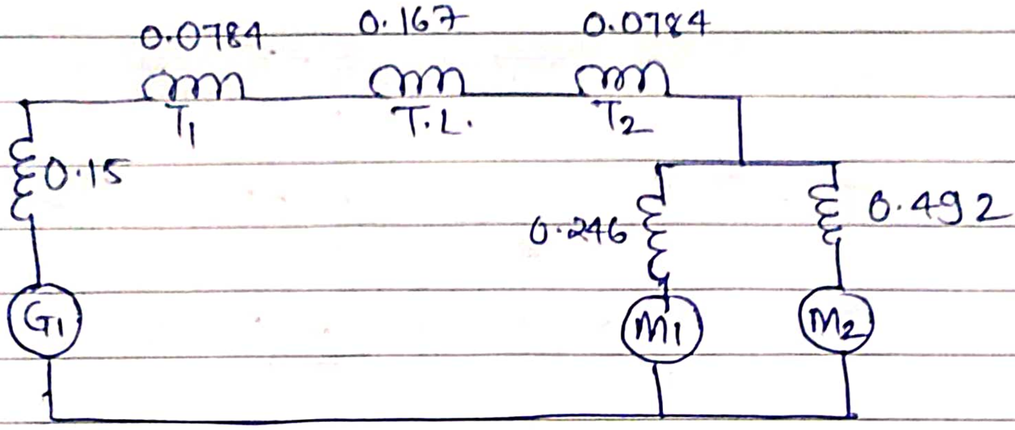
$TL = 80 \times \frac{30000}{(13.8)^2 \times 1000}$

$= 0.167$ p.u.

$T_1 = 0.1 \times \frac{30000}{35000} \times \frac{(13.2)^2}{(13.8)^2}$

$= \frac{522.72}{6665.4} = 0.0784$ p.u.

$T_2 = 0.0784$ p.u.



Q.

Gen - 40 MVA, 25 kV, 20%

M - 50 MVA, 11 kV, 30%

T_1 - 40 MVA, 33/220 kV 15%

T_2 - 30 MVA, 220/11 kV 15%

T.L. - 50 Ω

Use - $(MVA)_B = 100$ MVA, $(kV)_B = 220$ kV at T.L.

Soln: New kV_B at G_1 = $\frac{33}{220} = \frac{G}{220}$

$$G = \frac{33}{220} \times 220 = 33 \text{ kV.}$$

New kV_B at M = $\frac{220}{11} = \frac{220}{m}$

$$= \frac{11 \times 220}{220} = 11 \text{ kV.}$$

New reactances

$$G = 0.2 \times \frac{100}{40} \times \frac{(25)^2}{(33)^2}$$

$$= \frac{12500}{43560} \approx 0.286$$

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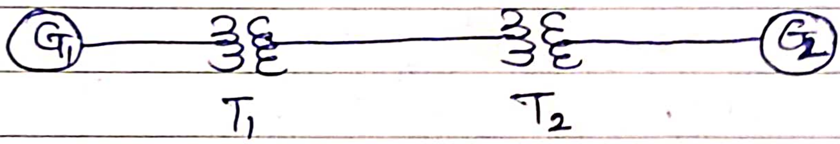
$M = 0.3 \times \frac{100}{50} \times \left(\frac{11}{11}\right)^2 = \cancel{10}\ 0.6$

$T_1 = 0.15 \times \frac{100}{40} \times \left(\frac{33}{33}\right)^2 = 0.375$

$T_2 = 0.15 \times \frac{100}{30} \times \left(\frac{11}{11}\right)^2 = 0.5$

$T.L. = 50 \times \frac{100}{(220)^2} = 0.103$

Q.



G_1 - 25 kV, 100 MVA, $X = 9\%$

G_2 - ——— " ———

T_1 - 25/220 kV, 90 MVA, $X = 12\%$

T_2 - 220/25 kV, 90 MVA, $X = 12\%$

T.L. - 220 kV, $X = 150\,\Omega$

Base kV - 25 kV at G_1, MVA base = 200.

Sol^n: New KV_B at $G_1 = \frac{25}{220} = \frac{G_1}{220}$

$KV_B\ (G_1) = 25\ kV$

New KV_B at $G_2 = \frac{220}{25} = \frac{220}{G_2}$

$KV_B\ (G_2) = 25\ kV$

New reactances

$G_1 = 0.09 \times \frac{200}{100} \times \frac{(25)^2}{(25)^2}$

$G_1 = 0.18$

$G_2 = 0.9 \times \frac{200}{100} \times \left(\frac{25}{25}\right)^2$

$G_2 = 0.18$

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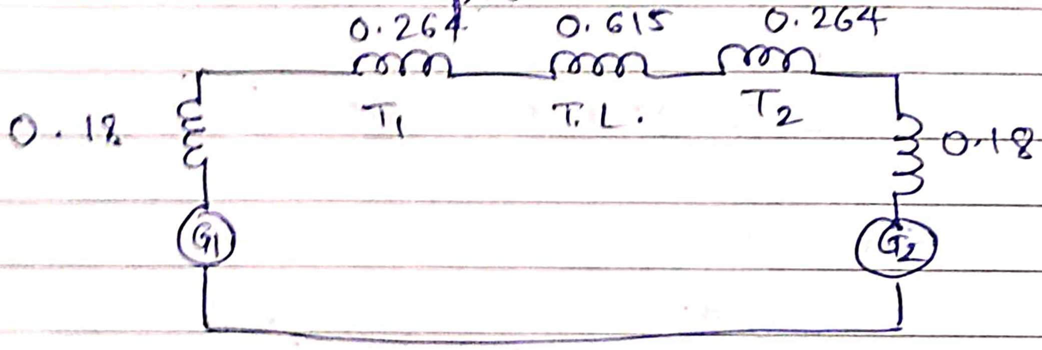
$T_1 = 0.12 \times \frac{200}{90} \times \left(\frac{25}{25}\right)^2$

$T_1 = 0.264$ p.u.

$T_2 = 0.264$ p.u.

$T.L. = 150 \times \frac{200}{(220)^2}$

$T.L. = 0.615$ p.u.



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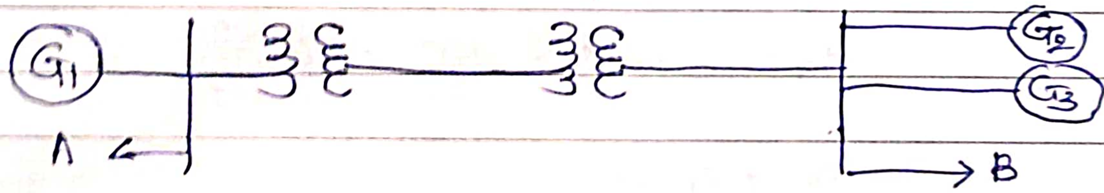

G_1 - 30 MVA 10.5 kV $X = 0.435$ p.u.

G_2 - 15 MVA 6.6 kV $X = 0.413$ p.u.

G_3 - 25 MVA 6.6 kV $X = 0.3214$ p.u.

T_1 - 15 MVA 11/33 kV $X = 0.209$ p.u.

T_2 - 15 MVA 33/6.2 kV $X = 0.220$

Load A - 40 MW 11 kV 0.9 p.f. lag.

Load B - 40 MW 6.6 kV 0.85 p.f. lag.

T.L. - 20.5 Ω/ph.

Base kV = 11 kV at G_1 $MVA_B = 30$ MVA.

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New KV_B for $G_1 = \frac{11}{33} = \frac{G_1}{33}$

$G_1 = 11\ kV$

New KV_B for $G_2 = \frac{33}{6.2} = \cancel{\frac{6.2}{G_2}}\ \cancel{\frac{G_2}{33}}\ \frac{33}{G_2}$

$G_2 = 6.2\ kV$

$G_3 = 6.2\ kV$

New reactances

$G_1 = 0.435 \times \frac{30}{30} \times \frac{(10.5)^2}{(11)^2}$

$G_1 = 0.396$

$G_2 = 0.413 \times \frac{30}{15} \times \frac{(6.6)^2}{(6.2)^2}$

$G_2 = 0.938$

$G_3 = 0.3214 \times \frac{30}{25} \times \frac{(6.6)^2}{(6.2)^2}$

$G_3 = 0.437$

$T_1 = 0.209 \times \frac{30}{15} \times \left(\frac{11}{11}\right)^2$

$= 0.418$

$T_2 = 0.220 \times \frac{30}{15} \times \left(\frac{6.2}{6.2}\right)^2$

$= 0.440$

$T.L. = 20.5 \times \frac{30}{(11)^2}$

$= 0.564$

/ /

*) Transmission line Parameters.

Inductance (L). - Henry

$$e = -L\frac{di}{dt}$$

$$L = \frac{N\phi}{I}$$

Vltg. is induced due to change in flux linkage.

$$e = \frac{d\psi}{dt} \text{ Volts}$$

ψ - flux linkage (wb-turns).

$$e = \frac{d\psi}{di} \cdot \frac{di}{dt}$$

$$= L\frac{di}{dt}. \quad L \to \text{inductance} = \frac{d\psi}{di}$$

$$L = \frac{\psi}{i} = \text{const.} \quad - \text{In linear ckt.}$$

Alternating ckt:

$$\lambda = LI$$

$\lambda \to$ rms value of flux linkage

$I \to$ RMS current.

$$L = \frac{\lambda}{I}.$$

*) Partial flux linkage:

Inductance of cond^n due to internal flux.

$$L = L_{int} + L_{ext}.$$

Mag. Field strength or intensity $H = \frac{I}{2\pi R}$ A/m. — (1)

Flux density $B = \mu H$ wb/m^2 (T).

$\mu = \mu_0 \mu_r$, $\mu_0 = 4\pi \times 10^{-7}$

$B = \mu H$ — (2)

Flux $\phi = B \cdot A \cos\phi$ — (3)

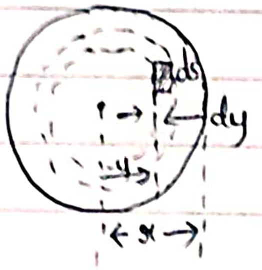
$B \rightarrow$ flux density

$A \rightarrow$ surface area through which flux lines are passing.

$\theta \rightarrow$ angle which normal of that surface makes with flux lines.

$\lambda = N\phi \rightarrow$ flux linkage. — (4)

$L = \frac{\lambda}{I}$ — (5)



Let $r \rightarrow$ radius of cond^r

Conducting with returning current is far away from cond^r under consideration.

Consider, section of radius y with thickness dy.

$ds \rightarrow$ small length in the section.

$H_y \rightarrow$ mag. field intensity at small section.

Let current in section dy is I_y which is fraction of total current I.

$$H_y = \frac{I_y}{2\pi y} \quad \text{— (6)}$$

Current is directly prop. to C.S. area.

$$\frac{I_y}{I} = \frac{\pi y^2}{\pi r^2}$$

$$I_y = \frac{y^2}{r^2} \cdot I \quad \text{— (7)}$$

Substitute (7) in (6).

$$H_y = \frac{y^2}{r^2} \cdot I \cdot \frac{1}{2\pi y}$$

$$= \frac{yI}{2\pi r^2} \quad \text{— (8)}$$

__/__/__

Mag. field density for section

$$B_y = \mu H_y$$

$$= \frac{\mu . y . I.}{2\pi r^2} \quad wb/m^2 \quad — (9)$$

$\therefore$ flux, $d\phi = B_y . dy \quad wb/m.$

$$= \frac{\mu . y . I . dy}{2\pi r^2} \quad wb/m \quad — (10)$$

Flux linkage $d\lambda$ per m,

product of flux & fraction of current

Fraction of current $I_y = \frac{\pi y^2}{\pi r^2}$.

$$\therefore d\lambda = \frac{y^2}{r^2} . d\phi.$$

$$d\lambda = \frac{\mu I y^3}{2\pi r^4} . dy \quad — (11).$$

$\therefore$ Flux linkages for whole cond^r, of radius r,

$$\lambda_{int} = \int_0^r \frac{\mu I y^3}{2\pi r^4} dy$$

$$= \frac{\mu I}{8\pi} \quad — (12)$$

$$\mu = \mu_0 \mu_r$$

$$\lambda_{int} = \frac{\mu_0 \mu_r I}{8\pi}$$

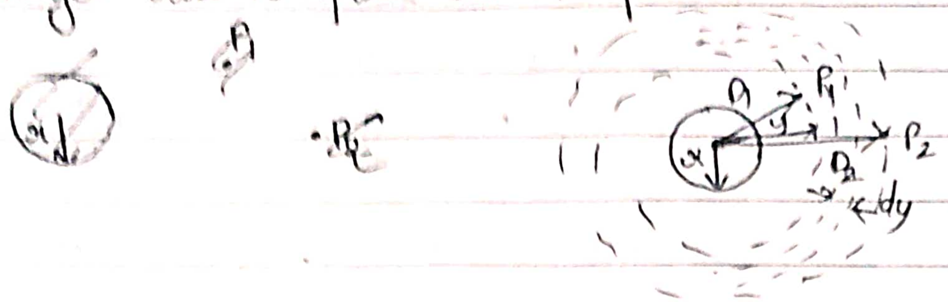
For cond^r material $\mu_r = 1$

$$\therefore \lambda_{int} = 0.5 I \times 10^{-7} \quad Wb\text{-}T/m \quad — (13)$$

$$\therefore L_{int} = \frac{\lambda_{int}}{I}$$

$$L_{int} = \frac{1}{2} \times 10^{-7} \quad H/m \quad — (14).$$

2) Flux linkages due to flux bet^n 2 points external to cond^r.



Let P_1 & P_2 are 2 points external to cond^r at dist. D_1 & D_2 resp.

Consider a small section at dist. y with thickness dy.

Mag. field intensity at dist y,

$$H_y = \frac{I}{2\pi y} \quad \text{—— (1)}$$

$B = \mu H$
$\phi = B \cdot a$

∴ Flux $d\phi$ in the tubular element of thickness dy,

$$d\phi = \frac{\mu I}{2\pi y} dy \quad \text{Wb/m.} \quad \text{—— (2).}$$

Flux linkages,

$$d\lambda = 1 \times d\phi \quad \text{—— (3)}$$

for all the current I is linking.

∴ Total flux linkages due to flux bet^n points P_1 & P_2,

$$\therefore \lambda_{12} = \int_{D_1}^{D_2} \frac{\mu I}{2\pi y} dy$$

$$= \frac{\mu I}{2\pi} \ln\left(\frac{D_2}{D_1}\right)$$

∵ $\mu_r = 1$, $\mu_0 = 4\pi \times 10^{-7}$

$$\lambda = 2 \times 10^{-7} \cdot I \cdot \ln\left(\frac{D_2}{D_1}\right) \quad \text{Wb.T/m.} \quad \text{—— (4)}$$

∴ Inductance bet^n P_1 & P_2,

$$L_{12} = \frac{\lambda_{12}}{I}.$$

__/__/__

$$L_{12} = 2\times10^{-7} \ln\left(\frac{D_2}{D_1}\right) \text{ H/m} \quad — ⑤$$

Let external point is at dist. D,

$$\therefore \lambda_{ext} = 2\times10^{-7} I. \ln\left(\frac{D}{r}\right) \quad — ⑥$$

∴ Total flux linkages,

$$\lambda = \lambda_{int} + \lambda_{ext}.$$

$$= \frac{I}{2}\times10^{-7} + \left(2\times10^{-7} I \ln\frac{D}{r}\right)$$

$$\lambda = 2\times10^{-7}. I\left(\frac{1}{4} + \ln\left(\frac{D}{r}\right)\right).$$

$$= 2\times10^{-7} I. \ln\left(\frac{D}{r\,e^{-1/4}}\right).$$

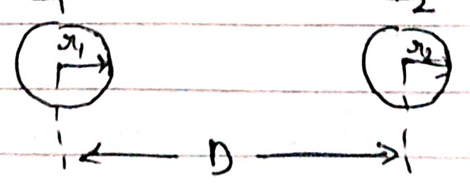
Let $r' = r.e^{-1/4} = 0.7788\,r.$

$$\therefore \lambda = 2\times10^{-7} I. \ln\left(\frac{D}{r'}\right) \text{ Wb-T/m.} \quad — ⑦.$$

∴ Inductance due to flux upto external point

$$L = 2\times10^{-7} \ln\left(\frac{D}{r'}\right) \text{ H/m.} \quad — ⑧$$

1) Inductance of 1 ph. 2 wire line.



In a single ph. line

$$I_1 + I_2 = 0$$

$$I_1 = -I_2$$

Flux linkages of ckt due to I_1

$$\lambda_1 = 2\times10^{-7} I_1 \ln\left(\frac{D}{r_1}\right).$$

$\therefore$ Inductance due to I_1

$$L_1 = 2\times10^{-7} \ln\left(\frac{D}{r_1'}\right).$$

Similarly, $L_2 = 2\times10^{-7} \ln\left(\frac{D}{r_2'}\right).$

$\therefore$ Total inductance of ckt, using superposition principle

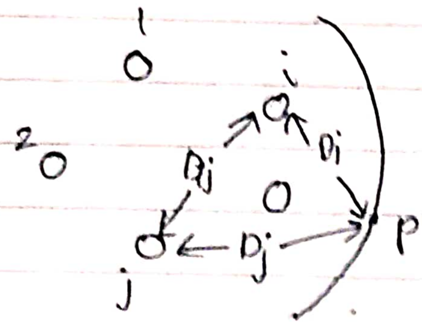
$$L = L_1 + L_2$$

$$= 2\times10^{-7} \ln\left(\frac{D^2}{r_1' r_2'}\right) \text{ H/m.}$$

If $r_1' = r_2' = r'$

$$= 4\times10^{-7} \ln\left(\frac{D}{r'}\right). \text{ H/m.}$$

*) Flux linkages of one cond^r in a group (bundled cond^r).



To derive,
Flux linkages of i^{th} cond^r.
Considering the flux upto point P only.

Let 1, 2, 3, ..., i, j, ... n are the cond^{rs} in group.
Each cond^r is of round shape.
Each cond^r carries currents $I_1, I_2, \ldots I_i \ldots I_n$ resp.

$$\therefore I_1 + I_2 + \ldots + I_i + I_j + \ldots I_n = 0.$$

$$I_n = -(I_1 + I_2 + \ldots + I_i + I_j + \ldots I_{n-1}).$$

_/_/_

*) Flux linkages of ith cond^r due to its own current.

$$\lambda_{ii} = 2\times10^{-7} I_i \ln\left(\frac{D_i}{r'_i}\right) \quad \text{--- (1)}$$

Similarly, flux linkages in i due to current in jth cond^r.

$$\lambda_{ij} = 2\times10^{-7} I_j \ln\left(\frac{D_j}{D_{ij}}\right) \quad \text{--- (2)}$$

From eq^n (1) & repeated use of (2), total flux linkages of ith cond^r,

$$\lambda_i = \lambda_{i1} + \lambda_{i2} + \dots + \lambda_{ij} + \dots + \lambda_{in}.$$

$$= 2\times10^{-7}\left[I_1 \ln\left(\frac{D_1}{D_{i1}}\right) + I_2 \ln\left(\frac{D_2}{D_{i2}}\right) + I_i \ln\frac{D_i}{r'_i} + \dots I_n \ln\left(\frac{D_n}{D_{in}}\right)\right] \quad \text{--- (3)}$$

$$\lambda_i = 2\times10^{-7}\left[\left(I_1 \ln\left(\frac{1}{D_{i1}}\right) + I_2 \ln\left(\frac{1}{D_{i2}}\right) + \dots I_i \ln\left(\frac{1}{r'_i}\right) + \dots I_n \ln\left(\frac{1}{D_{in}}\right)\right) + \left(I_1 \ln(D_1) + I_2 \ln(D_2) + I_i \ln(D_i) + \dots I_n \ln(D_n)\right)\right] \quad \text{--- (4)}$$

using, $I_n = -(I_1 + I_2 \dots I_{n-1})$. in 2^nd term of eq^n (4).

$$\lambda_i = 2\times10^{-7}\left[\left(I_1 \ln\left(\frac{1}{D_{i1}}\right) + I_2 \ln\left(\frac{1}{D_{i2}}\right) + \dots I_i \ln\left(\frac{1}{r'_i}\right) + \dots I_n \ln\left(\frac{1}{D_{in}}\right)\right) + \left(I_1 \ln\left(\frac{D_1}{D_n}\right) + I_2 \ln\left(\frac{D_2}{D_n}\right) + \dots I_i \ln\left(\frac{D_i}{D_n}\right) + \dots\right.\right.$$

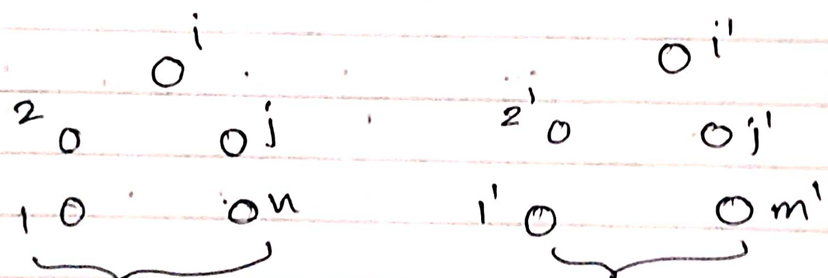
$$I_{n-1} \ln\left(\frac{D_{n-1}}{D_n}\right)\Bigg)\Bigg] \quad \text{--- (5)}$$

To find total flux linkages,
let point P move to infinity
terms like $\ln\left(\frac{D_1}{D_n}\right) = \ln(1) = 0$

For getting symmetry,
let $r_i' = D_{ii}$.

$$\therefore \lambda_i = 2\times 10^{-7}\left(I_1 \ln\left(\frac{1}{D_{i1}}\right) + I_2 \ln\left(\frac{1}{D_{i2}}\right) + \dots\dots \right.$$
$$\left. I_i \ln\left(\frac{1}{D_{ii}}\right) + \dots I_n \ln\left(\frac{1}{D_{in}}\right)\right].$$

*) Inductance of composite cond^r lines.



composite cond^r A   composite cond^r B.

cond^r A → n no. of filaments, I.
cond^r B → m' no. of filaments, −I.
Current I & −I is equally divided in n & m' no. of filaments resp.
Current in each filament (A) ⟶ I/n.
Current in each filament (B) ⟶ $-I/m'$.

_/_/_

Applying eq^n of group of cond^{rs} to filament i of cond^r A, to get its flux linkages

$$\lambda_i = 2\times10^{-7}\frac{I}{n}\left(\ln\left(\frac{1}{D_{i1}}\right) + \ln\frac{1}{D_{i2}} + \dots \ln\frac{1}{D_{ii}} \dots + \ln\frac{1}{D_{in}}\right) -$$

$$2\times10^{-7}\frac{I}{m'}\left(\ln\frac{1}{D_{i1'}} + \ln\frac{1}{D_{i2'}} - - - + \frac{1}{D_{im'}}\right) \quad (1)$$

$$\therefore \lambda_i = 2\times10^{-7} I \cdot \ln\left[\frac{(D_{i1'}\cdot D_{i2'} - - - - D_{im'})^{1/m'}}{(D_{i1}\cdot D_{i2} - - - - D_{in})^{1/n}}\right] \quad (2)$$

$\therefore$ Inductance of filament i,

$$L_i = \frac{\lambda_i}{I/n} = 2n\times10^{-7}\ln\left[\frac{(D_{i1'}\cdot D_{i2'} \dots D_{im'})^{1/m'}}{(D_{i1}\cdot D_{i2} - - - D_{in})^{1/n}}\right] \quad (3)$$

$\therefore$ Avg. inductance of filaments in cond^r A

$$L_{avg} = \frac{L_1 + L_2 + - - - L_i + - - L_n}{n} \quad (4)$$

$\therefore$ Inductance of cond^r A is $1/n$ times its avg. inductance

$$\therefore L_A = \frac{L_{avg}}{n} = \frac{L_1 + L_2 + - - - + L_n}{n^2} \quad (5)$$

$\therefore$ To get L_A, use eq^n (3) in (5),

$$L_A = 2\times10^{-7}\left[\frac{\left[(D_{11'}\cdot D_{12'} - - - D_{1m'}) \dots (D_{i1'}\cdot D_{i2'} - - - D_{im'}) \cdot (D_{n1'}\cdot D_{n2'} - - - D_{nm'})\right]^{1/mn}}{\left[(D_{11}\cdot D_{12} - - - D_{1m}) \dots (D_{i1}\cdot D_{i2} - - - D_{in}) - - - (D_{n1}\cdot D_{n2} - - - D_{nm})\right]^{1/n^2}}\right]$$

H/m.

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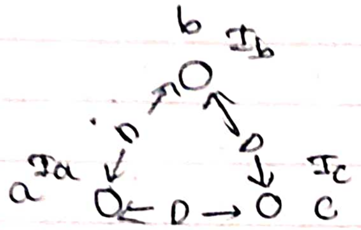
$N_r \rightarrow$ Mutual Geometric Mean distance, (D_m).
$D^r \rightarrow$ Self GMD. (Geometric mean radius) (D_{sA}).

$$L_A = 2\times10^{-7} \ln\left(\frac{D_m}{D_{sA}}\right) \text{ H/m.}$$

$$L_1 = 2\times10^{-7} \ln\left(\frac{D}{r'}\right).$$

*)



$$I_a + I_b + I_c = 0$$

$$I_b + I_c = -I_a.$$

Symm/. Equilateral

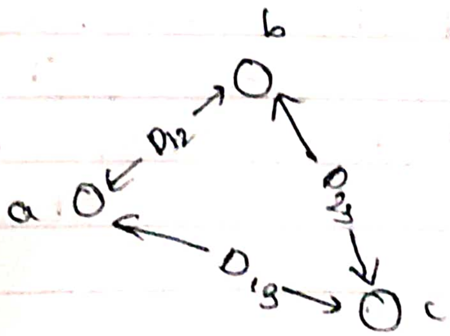
Flux linkages of condr a.

$$\lambda_a = 2\times10^{-7}\left[I_a \ln\frac{1}{r'} + I_b \ln\frac{1}{D} + I_c \ln\frac{1}{D}\right]$$

$$\lambda_a = 2\times10^{-7}\left[I_a \ln\frac{1}{r'} - I_a \ln\frac{1}{D}\right]$$

$$\lambda_a = 2\times10^{-7} I_a \left(\frac{D}{r'}\right)$$

$$L_a = 2\times10^{-7} \ln\left(\frac{D}{r'}\right) \text{ H/m.}$$



Transposition of condrs.

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At position 1, the flux linkages of a.

$$\lambda_{a_1} = 2\times10^{-7}\left[I_a \ln\frac{1}{r_a'} + I_b \ln\frac{1}{D_{12}} + I_c \ln\frac{1}{D_{13}}\right]$$

At position 2,

$$\lambda_{a_2} = 2\times10^{-7}\left[I_a \ln\frac{1}{r_a'} + I_b \ln\frac{1}{D_{23}} + I_c \ln\frac{1}{D_{12}}\right]$$

At position 3,

$$\lambda_{a_3} = 2\times10^{-7}\left[I_a \ln\frac{1}{r_a'} + I_b \ln\frac{1}{D_{13}} + I_c \ln\frac{1}{D_{23}}\right]$$

Avg. flux linkages of cond^r a,

$$\lambda_a = \frac{\lambda_{a_1} + \lambda_{a_2} + \lambda_{a_3}}{3}$$

$$= 2\times10^{-7}\left[I_a \ln\frac{1}{r_a'} + I_b \ln\frac{1}{(D_{12}\cdot D_{23}\cdot D_{31})^{1/3}} + I_c \ln\frac{1}{(D_{12}\cdot D_{23}\cdot D_{31})^{1/3}}\right]$$

$$I_b + I_c = -I_a$$

$$\lambda_a = 2\times10^{-7} I_a \ln\left[\frac{(D_{12}\cdot D_{23}\cdot D_{31})^{1/3}}{r_a'}\right]$$

Let $D_{eq} = (D_{12}\cdot D_{23}\cdot D_{31})^{1/3}$

$$\therefore \lambda_a = 2\times10^{-7} I_a \ln\frac{D_{eq}}{r_a'}$$

$\therefore$ Inductance of a

$$\boxed{L_a = 2\times10^{-7} \ln\frac{D_{eq}}{r_a'}}$$

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Q. A 3ϕ, transmission line has cond^r diameter of 1.8 cm each, cond^{rs} being spaced as 4 cm, 6 cm, 9 cm. The loads are balanced and the line is transposed. Find inductance of the line per phase per km.

Sol^n:
$r_a = 0.9\ cm$

$r_a' = 0.70\ cm$

$D_{eq} = (4 \times 6 \times 9)^{1/3}$

$= 5.89\ cm$

$L_a = 2 \times 10^{-7} \ln \frac{D_{eq}}{r_a'}$

$= 2 \times 10^{-7} \ln \frac{5.89}{0.70}$

$= 2 \times 10^{-7} \times 2.12$

$= 4.25 \times 10^{-7}\ H/cm$

$= 4.25 \times 10^{-4}\ H/km.$

Q. A 3ϕ 80 km long transmission line has conductance of 1 cm diameter spaced at the corners of equilateral triangle of 100 cm sides. Find inductance per phase for the entire system.

Sol^n:
$r = 0.5\ cm$

$r' = 0.5 \times 0.7788$

$= 0.38\ cm$

$D_{eq} = (100^3)^{1/3}$

$= 100\ cm$

$L_a = 2 \times 10^{-7} \ln \frac{100}{0.38}$

$= \cancel{1881}\ 11.1 \times 10^{-4} \times 80 = 891.6 \times 10^{-4}$

$= \cancel{8868 \times 10^{-4}} = \cancel{0.0888} = 0.089\ H/km.$

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Q. Calculate loop inductance per km of a single phase transmission comprising of 2 parallel cond^{rs} 1m apart per km and 1.25 cm diameter. Also calculate reactance of the transmission line if the frequency is 50 Hz.

Soln:

$r = 0.62$ cm

$r' = 0.48$ cm

$D = 10^{2}$ cm

$L = 2 \times 2 \times 10^{-7} \ln\left(\frac{100}{0.48}\right)$

$= 21.3 \times 10^{-7}$ H/cm.

$= 21.3 \times 10^{-4}$ H/km $= 2.13 \times 10^{-3}$ H/km

$X_L = 2\pi f L$

$= 2 \times \pi \times 50 \times 2.13 \times 10^{-3}$

$= 0.669$ Ω/km.

*) Resistance of T.L.

AC

$R = \frac{\text{Power loss in T.L.}}{I^2}$

DC

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

*) Skin effect:

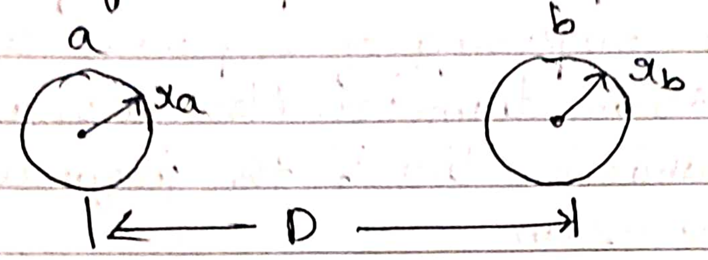
→ increase in power loss.

ACSR

*) Proximity effect

$\_/\_/\_$

*) Capacitance of 2 wire line.

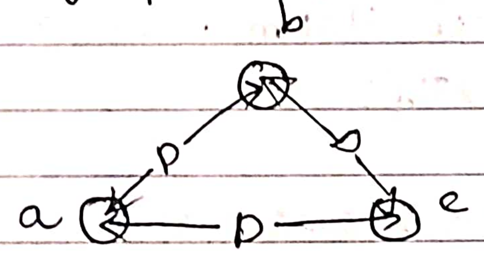


$r_a = r_b = r.$

Capacitance of each line to the neutral

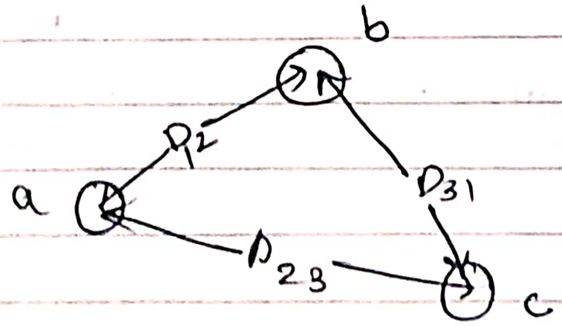
$$C_n = \frac{0.0242}{\log(D/r)} \ \mu F/km$$

*) Capacitance of 3 ph. line with equilateral spacing.



radius = r.

$$C_n = \frac{0.0242}{\log(D/r)} \ \mu F/km.$$



radius = r

$$C_n = \frac{0.0242}{\log(D_{eq}/r)} \ \mu F/km$$

$$D_{eq} = (D_{12} \cdot D_{23} \cdot D_{31})^{1/3}.$$

Q. Calculate capacitance to neutral per km of a single phase line composed of two single stranded conductors having radius 0.328 cm and placed 3m apart.

Soln:

$$C_n = \frac{0.0242}{\log(D/r)} \ \mu F/km.$$

$$= \frac{0.0242}{\log\left(\frac{300}{0.328}\right)}$$

$$= \frac{0.0242}{2.96} = 8.17 \times 10^{-3} \ \mu F/km.$$

Q. A 3Ø 50Hz transmission line has flat horizontal spacing with 3.5 m betn adjacent condrs. The conductors has diameter of 1.05 cm. The vltg. of the line is 110kV. Find capacitance to neutral and the charging current per km of line.

Soln:

$r = 0.525 cm$

$$C = \frac{0.0242}{\log\left(\frac{350}{0.525}\right)}$$

$$= \frac{0.0242}{2.82}$$

$$= 8.5 \times 10^{-3} \ \mu F/km.$$

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

$$= \frac{1}{2.67}$$

$$= 0.37$$

$I = \cancel{110 \times 10^3}$

$$D_{eq} = (3.5 \times 3.5 \times 7)^{1/3}$$

$$= 4.34 = 434$$

$$C = \frac{0.0242}{\log\left(\frac{4.34}{0.525}\right)}$$

$$= \frac{0.0242}{\cancel{0.902}\ 2.97}$$

$$= 8.3 \times 10^{-7} \ \mu F/km$$

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

$$= \frac{1}{2.60} = 0.38 \times 10^{5}$$

$$V_{ph} = 110/\sqrt{3} = 63.9\text{ V}$$

$$I = \frac{V_{ph}}{X_c} = \frac{63.9}{3.8\times10^5} = 0.16\text{ A/km.}$$

*) **T.L. Models:**

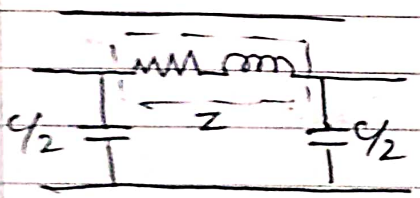
Short T.L.: – length < 100 km.
Vltg. < 20 kV.

R, L, C lumped — Medium T.L. – length – betn 100 – 250 kV.
Vltg – upto 100 kV.

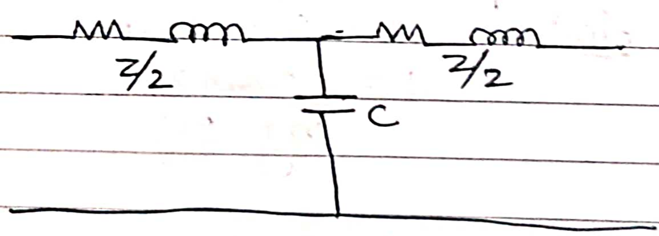
R, L, C distributed — Long T.L. – length > 250 km
Vltg > 100 kV.

*) Medium T.L.:

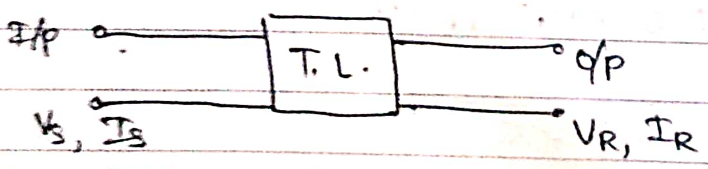
Nominal π



Nominal T



*) Generalised ckt const. A, B, C, D.

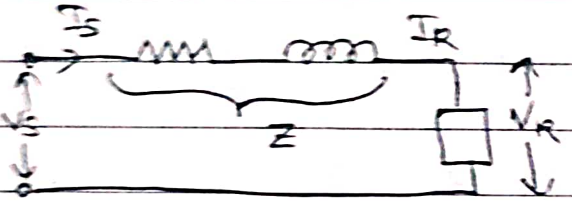


$$V_S = \bar{A}\bar{V}_R + \bar{B}\bar{I}_R$$
$$I_S = \bar{C}\bar{V}_R + \bar{D}\bar{I}_R$$

* Imp points:

1. A, B, C, D are complex no.s.
2. A & D are dimensionless.
3. Units of B & C are ohms & mho resp.
4. For given transmission line, $\bar{A} = \bar{D}$.
5. $\bar{A}\bar{D} - \bar{B}\bar{C} = 1$

* For a short T.L:

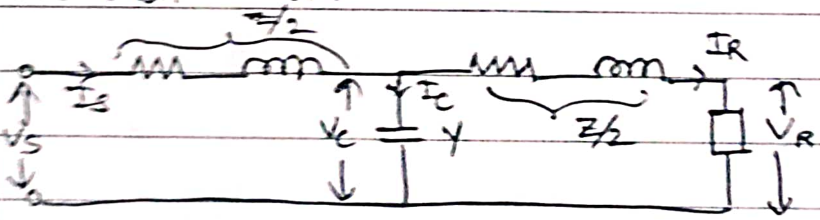


$I_S = I_R \Rightarrow I_S = 0.V_R + I_R.$

$V_S = V_R + ZI_R$

$A = 1,\ B = Z,\ C = 0,\ D = 1.$

* Nominal T ckt.



$$V_S = V_C + I_S.\frac{Z}{2} \quad — ①$$

$$V_C = V_R + I_R.\frac{Z}{2} \quad — ②$$

$$I_S = I_C + I_R \Rightarrow I_C = I_S - I_R.$$

$$I_C = V_C.Y$$

$$= Y\left(V_R + I_R.\frac{Z}{2}\right) \quad — ③$$

$$I_S = I_R + Y\left(V_R + I_R.\frac{Z}{2}\right)$$

$$I_S = Y \cdot V_R + \left(1 + \frac{YZ}{2}\right) I_R \quad \text{—— (4)}$$

$$C = Y \qquad D = 1 + \frac{YZ}{2}$$

Put value of V_C in eq^n (1).

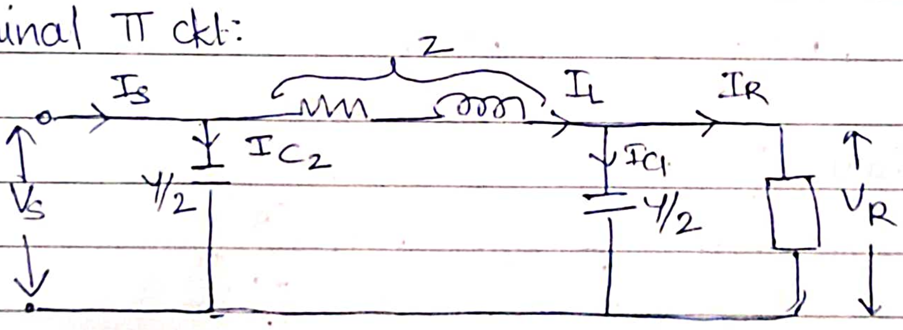
$$V_S = V_R + I_R \cdot \frac{Z}{2} + I_S \cdot \frac{Z}{2} \quad \text{—— (5)}$$

From eq^n (4), get value of I_S in (5)

$$V_S = \left(1 + \frac{YZ}{2}\right) V_R + \left(Z + \frac{YZ^2}{4}\right) I_R \quad \text{—— (6)}$$

$$D = A = 1 + \frac{YZ}{2} \qquad B = Z + \frac{YZ^2}{4} \qquad C = Y$$

*) Nominal π ckt:



$$V_S = A V_R + B I_R$$

$$I_S = C V_R + D I_R$$

$$I_S = I_L + I_{C_2}$$

$$= I_L + V_S \cdot Y/2 \quad \text{—— (1)}$$

$$I_L = I_R + I_{C_1}$$

$$= I_R + V_R \cdot Y/2 \quad \text{—— (2)}$$

$$V_S = V_R + I_L Z$$

$$= V_R + (I_R + V_R \cdot Y/2) Z$$

$$= V_R \underbrace{\left(1 + \frac{YZ}{2}\right)}_{A} + I_R \cdot \underbrace{Z}_{B} \quad \text{—— (3)}$$

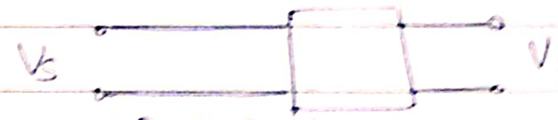
/ /

Put the value of I_L in eq^n ①.

$$I_S = I_L + V_S\, Y/2$$
$$= \left(I_R + V_R\, Y/2\right) + V_S\, Y/2$$
$$= \underbrace{Y\left(1 + \frac{YZ}{4}\right)}_{C} V_R + \underbrace{\left(1 + \frac{YZ}{2}\right)}_{D} I_R$$

$V_S = AV_R + BI_R$

$I_S = CV_R + DI_R$



If R.E is O.C

$V_S = AV_R \rightarrow A = \frac{V_S}{V_R}$ $\qquad I_R = 0$

$I_S = CV_R \rightarrow C = I_S/V_R$

If R.E is S.C

$\therefore V_R = 0$

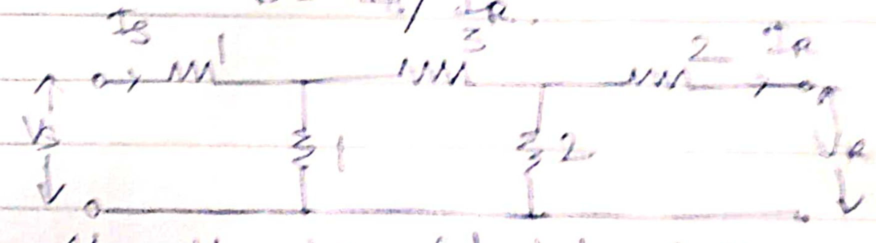
$V_S = BI_R$

$B = V_S/I_R\ \Omega$

$I_S = DI_R$

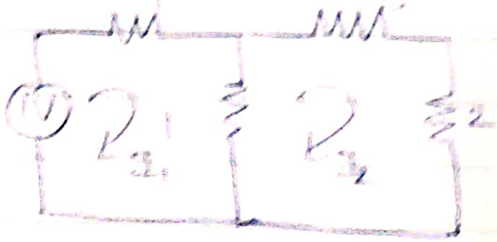
$D = I_S/I_R$

Q.



If $V_S = 1V$, calculate A, B, C, D

soln:



$-I_1 - 1(I_1 - I_2) + 1 = 0$

$-3I_2 - 2I_2 - 1(I_2 - I_1) = 0$

$-2I_1 + I_2 + 1 = 0$

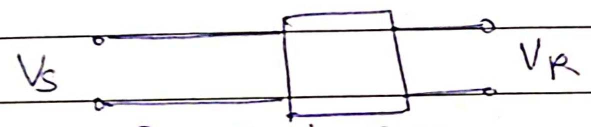
$I_1 - 6I_2 = 0$

$I_1 = 0.54\,A \qquad I_2 = 0.09$

Put the value of I_L in eq^n ①.

$$I_S = I_L + V_S \cdot Y/2$$
$$= \left(I_R + V_R \cdot Y/2\right) + V_S\, Y/2$$
$$= \underbrace{Y\left(1+\frac{YZ}{4}\right)}_{C} V_R + \underbrace{\left(1+\frac{YZ}{2}\right)}_{D} I_R$$

$$V_S = AV_R + BI_R$$
$$I_S = CV_R + DI_R$$



If R.E. is O.C.

$$V_S = AV_R \rightarrow A = \frac{V_S}{V_R} \qquad I_R = 0.$$

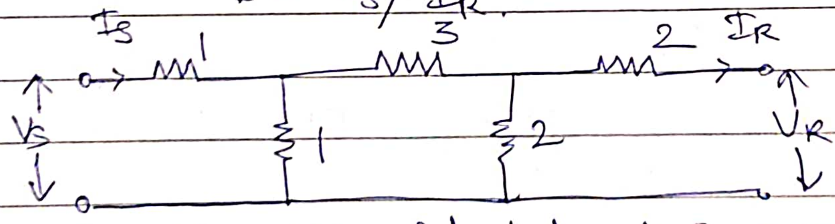
$$I_S = CV_R \rightarrow C = I_S/V_R.$$

If R.E. is S.C.

$\therefore V_R = 0.$

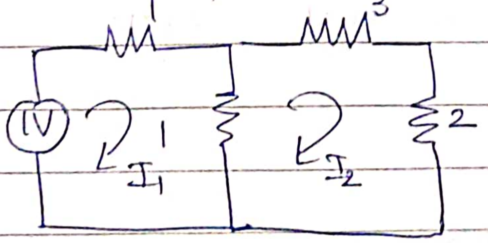
$$V_S = BI_R$$
$$B = V_S/I_R \ \Omega.$$
$$I_S = DI_R$$
$$D = I_S/I_R.$$

Q.



If $V_S = 1V$, Calculate A, B, C, D.

soln:



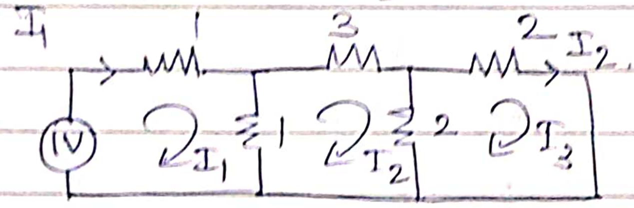
$$-I_1 - 1(I_1 - I_2) + 1 = 0$$
$$-3I_2 - 2I_2 - 1(I_2 - I_1) = 0$$
$$-2I_1 + I_2 + 1 = 0$$
$$I_1 - 6I_2 = 0.$$
$$I_1 = 0.54\text{ A} \qquad I_2 = 0.09$$

$V_R = I_2 \times 2$ $\quad$ $I_1 = I_S$

$= 0.18$ $\quad$ $I_2 = I_R$.

$A = \dfrac{V_S}{V_R} = \dfrac{1}{0.18} = 5.55$

$C = \dfrac{I_2}{V_R} = \cancel{0.55}\ \dfrac{0.54}{0.18} = 3.$



$1 - I_1 - 1(I_1 - I_2) = 0$

$1 - 2I_1 + I_2 = 0$ — ①

$-1(I_2 - I_1) - 3I_2 - 2(I_2 - I_3) = 0$

$-6I_2 + I_1 + 2I_3 = 0$

$I_1 - 6I_2 + 2I_2 = 0$ —— ②

$-2(I_3 - I_2) - 2I_3 = 0$

$-4I_3 + 2I_2 = 0$ —— ③

$I_1 = 0.55$ $\quad$ $I_2 = 0.11$ $\left(\frac{1}{9}\right)$ $\quad$ $I_3 = 0.055$ $\quad$ $I_3 = \frac{1}{18}$

$I_S = 0.55A$ $\quad$ $I_R = 0.055$

$B = \dfrac{V_S}{I_R} = \dfrac{1}{0.05} = 18.1$

$D = \dfrac{I_S}{I_R} = \dfrac{0.55}{0.055} = 10.$

Q.2 110kV, 50Hz, 200km long is open ckt. at R.E

$R = 0.3\,\Omega/km$

$X_L = 0.2\,\Omega/km$

$Y = 0.06 \times 10^{-4}\,℧/km$

Calculate A,B,C,D with nominal T n/w.

__/__/__

Sol^n: $A = D = 1 + \frac{YZ}{2}$

$Z = \sqrt{R^2 - X_L^2}$

$= \sqrt{(0.3)^2 - (0.2)^2}$

$= \sqrt{0.09 + 0.04}$

$= \cancel{\sqrt{0.05}}\ \sqrt{0.13}$

$= \cancel{0.22}\ 0.36$

$A = 1 + \frac{0.06 \times 10^{-4} \times 0.36}{2}$

$= 1 + \frac{0.0216 \times 10^{-4}}{2}$

$= 1 + 0.0108 \times 10^{-4}$

$A, D = 1.00$

$C = 0.06 \times 10^{-4}$ ℧/km

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

$= 0.36\left(1 + \frac{0.06 \times 10^{-4} \times 0.36}{4}\right)$

$B = 0.36\,\Omega$

→ For π connec^n.

$V_S = 110V.$

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

$C = Y\left(1 + \frac{YZ}{4}\right)$

$A = 1.00$

$= 0.06 \times 10^{-4}\left(1 + \frac{0.06 \times 10^{-4} \times 0.36}{4}\right)$

$B = I_R . Z$

$I_R = 0$

$= 6 \times 10^{-6}.$

$V_R = 110V.$

$D = \cancel{1 \times 10}\ 1.00.$

_/_/_

Unit-3

1) Surge Impedance (Z_s or Z_c)

$$Z_s = \sqrt{\frac{Z}{Y}}$$

Z = series impedance = $R + jX$
Y = shunt admittance = $G + jB$

$$Z = \sqrt{\frac{L}{C}}$$

Capacitive VAR = Inductive VAR

$$V \cdot I = V \cdot I$$

$$V \cdot \frac{V}{X_c} = I \cdot X_L \cdot I$$

$$\frac{V^2}{X_c} = I^2 X_L$$

$$\frac{V}{I} = \sqrt{X_L X_c}$$

$$Z_s = \sqrt{\frac{L}{C}}$$

(Surge Impedance).

Z_{oc}, Z_{sc} → S.E. impedance at O.C & S.C resp

$V_s = A V_R + B I_R$
$I_s = C V_R + D I_R$

If R.E. is O.C.

$$\frac{V_s}{I_s} = \frac{A}{C} = Z_{oc}$$

If R.E. is S.C.

$$\frac{V_s}{I_s} = \frac{B}{D} = Z_{sc}$$

$$Z_{oc} \times Z_{sc} = \frac{A}{C} \times \frac{B}{D}$$

$$Z_{oc} \times Z_{sc} = \frac{B}{C} = \frac{Z}{Y}$$

$\therefore Z_s = \sqrt{Z_{o.c.} Z_{s.c.}}$

*) A, B, C, D for Long T.L

$$\begin{bmatrix} V_s \\ I_s \end{bmatrix} = \begin{bmatrix} \cosh \gamma l & Z_s \sinh \gamma l \\ \frac{1}{Z_s \sinh \gamma l} & \cosh \gamma l \end{bmatrix} \begin{bmatrix} V_R \\ I_R \end{bmatrix}$$

$A = \cosh \gamma l = D$ where $\gamma = \sqrt{YZ}$

$B = Z_s \sinh \gamma l$ $\quad Z_s = \sqrt{\frac{Z}{Y}}$

$C = \frac{1}{Z_s \sinh \gamma l}$ $\quad l$ = length.

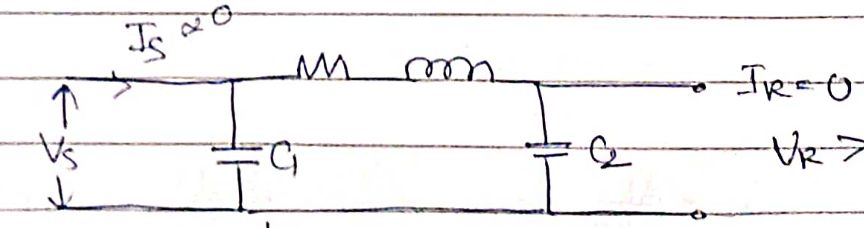
*) Surge Impedance Load → power delivered to a load value of Z_s.

*) Power transmitted under SIL condn

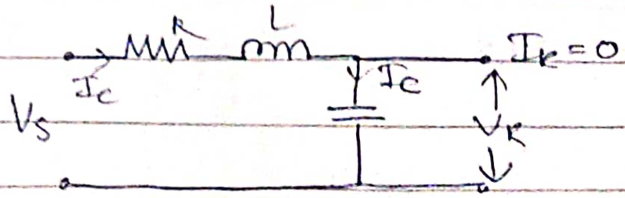
$$P_R = \frac{V_R^2}{Z_s}$$

P_R = surge impedance loading.

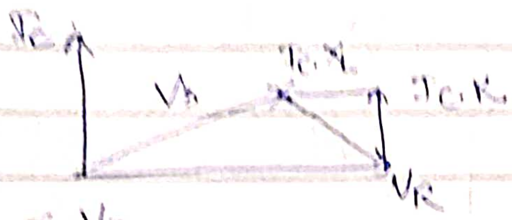
*) Ferranti Effect:



$V_R > V_s$.



$$V_S = V_R + I_C R + I_C X_L$$



$\therefore V_S < V_R$

For nominal π ckt:

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

at no load, $I_R = 0$

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

Vol drge $= V_S - V_R = V_R\left(1 + \frac{YZ}{2} - 1\right)$

$$= \frac{YZ}{2} . V_R$$

where $Z = R + jX_L$ if R is negligible

$Y = j\omega C.$ $Z = j\omega L.$

$$V_S - V_R = \frac{1}{2}(j\omega L)(j\omega C) V_R$$

$$= -\frac{1}{2} \omega^2 LC V_R$$

$V_S < V_R.$

*) Tuned Power lines

$$\begin{bmatrix} V_S \\ I_S \end{bmatrix} = \begin{bmatrix} \cosh\gamma l & Z_S \sinh\gamma l \\ \frac{1}{Z_S}\sinh\gamma l & \cosh\gamma l \end{bmatrix} \begin{bmatrix} V_R \\ I_R \end{bmatrix}$$

R & negligible
G ≃

$$\cosh\gamma l = \cos j\omega l\sqrt{LC}$$
$$= \cos\omega l\sqrt{LC}$$

using $\cosh j\theta = \cos\theta$

$$\sinh\gamma l = \sinh j\omega l\sqrt{LC} = j\sin\omega l\sqrt{LC}$$

using $\sinh j\theta = j\sin\theta$.

$$\begin{bmatrix} V_S \\ I_S \end{bmatrix} = \begin{bmatrix} \cos\omega l\sqrt{LC} & jZ_S \sin\omega l\sqrt{LC} \\ \frac{1}{Z_S}\sin\omega l\sqrt{LC} & \cos\omega l\sqrt{LC} \end{bmatrix} \begin{bmatrix} V_R \\ I_R \end{bmatrix}$$

to get, $|V_S| = |V_R|$ and $|I_S| = |I_R|$,

if $\omega l\sqrt{LC} = n\pi$ ---- $n = 1, 2, 3, ----$

$$l = \frac{n\pi}{\omega\sqrt{LC}} = \frac{n\pi}{2\pi f\sqrt{LC}} = \frac{n}{2f\sqrt{LC}}$$

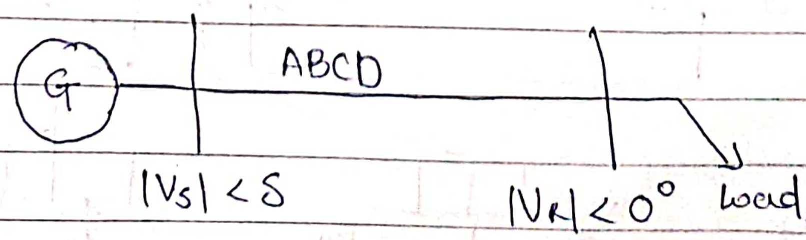
$\because \frac{1}{\sqrt{LC}} \simeq V$ ..... velocity of light

$= 300000$ km/s

$\therefore$ for 50Hz freq, to get tuned lines

$l = 3000, 6000, ----$ km.

*) Power flow through T.L.



let V_R is reference vltg
V_s leads V_R by $\delta°$.

Complex powers at SE & RE.

$$S_S = P_S + jQ_S = V_S \cdot I_S^*$$
$$S_R = P_R + jQ_R = V_R \cdot I_R^*$$

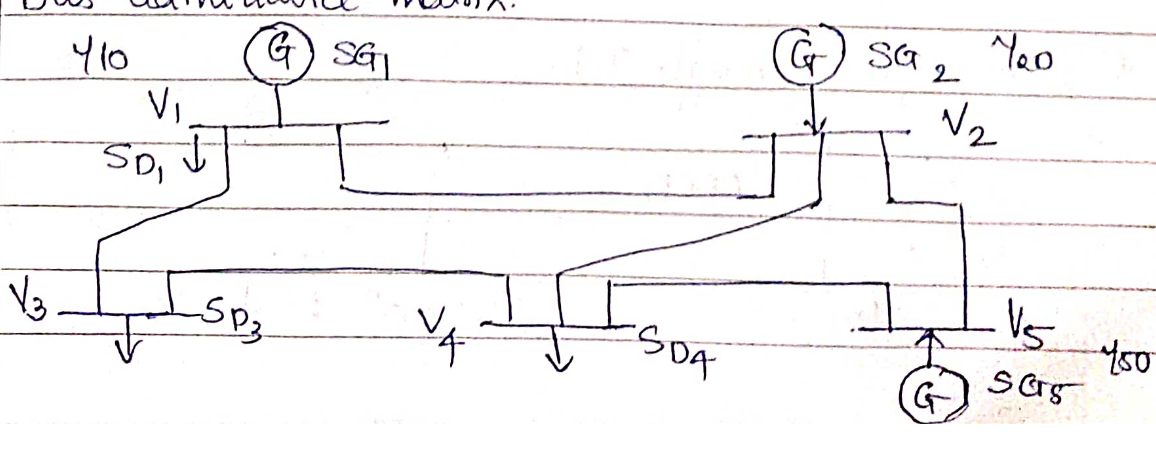
$$P_R = \frac{|V_S||V_R| \sin\delta}{X}$$

$$Q_R = \frac{|V_R|}{X}\left(|V_S| - |V_R|\right)$$
$$= \frac{|V_R|}{X}(\Delta V)$$

*) Corona Discharge
Factors affecting.

1. Freq. $(\propto)$.
2. Sys. voltage $(\propto)$.
3. Conductivity of air.
4. Conductor diameter
5. Load current.
6. Cond^r surface.

*) Bus admittance matrix.



$S_{Gi} \rightarrow$ complex power injected.

$S_{Di} \rightarrow$ complex power drawn by load.

$\therefore$ at i^{th} bus, the power is,

$$S_i = S_{Gi} - S_{Di}$$

$$S_{Gi} = P_{Gi} + jQ_{Gi}$$

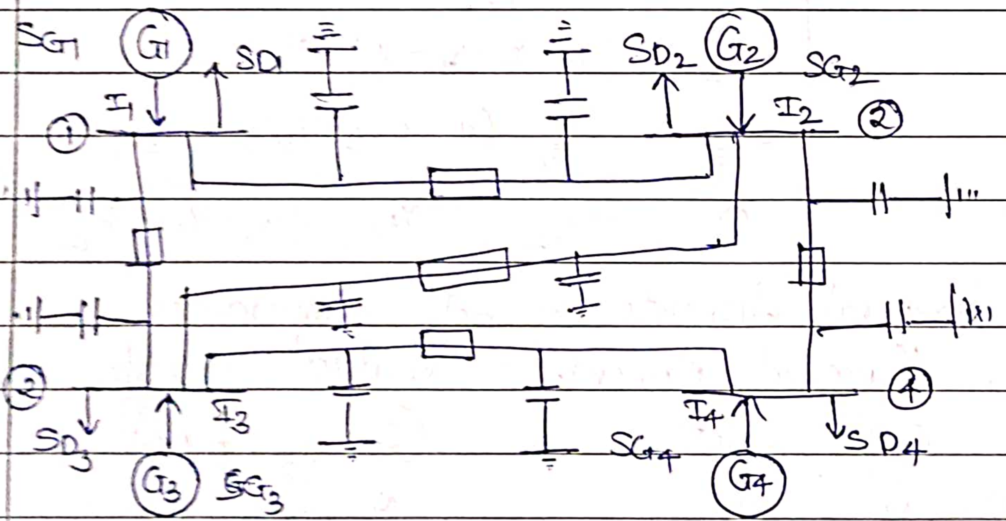
$$S_{Di} = P_{Di} + Q_{Di}$$

Current at i^{th} bus,

$$I_i = I_{Gi} - I_{Di}$$

Let y_{ik} = total admittance betn i^{th} & k^{th} bus

$y_{i0} \rightarrow$ admittance betn i^{th} bus & gnd.



Admittance $Y = \frac{1}{Z}$ $\quad I = \frac{V}{Z} = V.Y$

Apply KCL to 4 nodes

$$I_1 = V_1 Y_{10} + (V_1 - V_2) Y_{12} + (V_1 - V_3) Y_{13}$$

$$I_2 = V_2 Y_{20} + (V_2 - V_3) Y_{23} + (V_2 - V_1) Y_{21} + (V_2 - V_4) Y_{2}$$

$$I_3 = V_3 Y_{30} + (V_3 - V_1) Y_{31} + (V_3 - V_2) Y_{32} + (V_3 - V_4) Y_{3}$$

$$I_4 = V_4 Y_{40} + (V_4 - V_3) Y_{43} + (V_4 - V_2) Y_{42}$$

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$$[I_{bus}] = [Y_{bus}][V_{bus}]$$

$$I_1 = V_1(Y_{10} + Y_{12} + Y_{13}) - V_2Y_{12} - V_3Y_{13}$$
$$I_2 = V_2(Y_{20} + Y_{23} + Y_{21} + Y_{24}) - V_1Y_{21} - V_3Y_{23} - V_4Y_{24}$$
$$I_3 = V_3(Y_{30} + Y_{31} + Y_{32} + Y_{34}) - V_1Y_{31} - V_2Y_{32} - V_4Y_{34}$$
$$I_4 = V_4(Y_{40} + Y_{43} + Y_{42}) - V_2Y_{42} - V_3Y_{43}$$

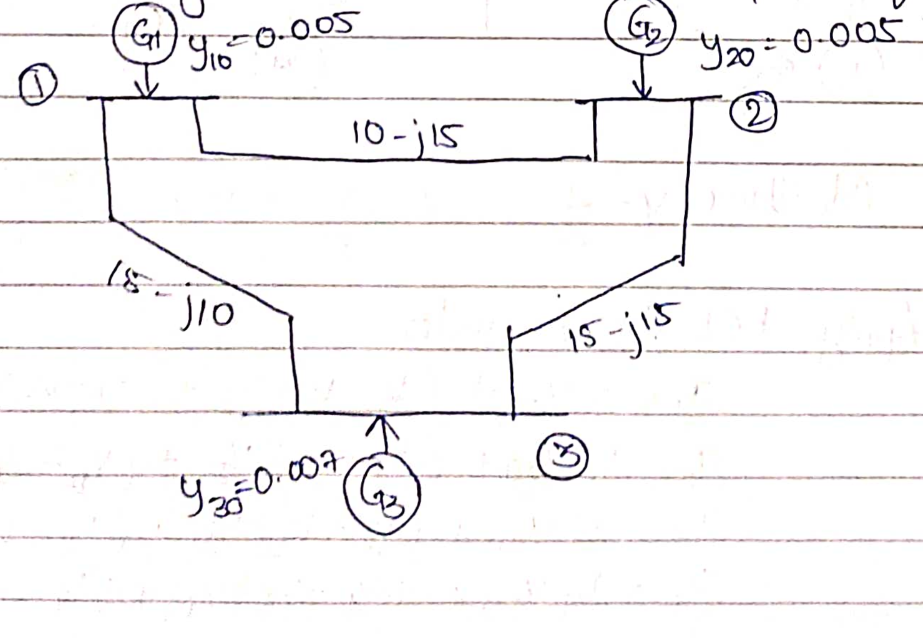
$$\begin{bmatrix} I_1 \\ I_2 \\ I_3 \\ I_4 \end{bmatrix} = \begin{bmatrix} Y_{11} & Y_{12} & Y_{13} & Y_{14} \\ Y_{21} & Y_{22} & Y_{23} & Y_{24} \\ Y_{31} & Y_{32} & Y_{33} & Y_{34} \\ Y_{41} & Y_{42} & Y_{43} & Y_{44} \end{bmatrix} \begin{bmatrix} V_1 \\ V_2 \\ V_3 \\ V_4 \end{bmatrix}$$

$$= \begin{bmatrix} \overbrace{(Y_{10}+Y_{12}+Y_{13})}^{Y_{11}} & -Y_{12} & -Y_{13} & 0 & 0 \\ -Y_{21} & \overset{Y_{22}}{(Y_{20}+Y_{21}+Y_{23}+Y_{24})} & -Y_{23} & -Y_{24} \\ -Y_{31} & -Y_{32} & \overset{Y_{33}}{(Y_{30}+Y_{31}+Y_{32}+Y_{34})} & -Y_{34} \\ 0 & -Y_{42} & Y_{43} & \overset{Y_{44}}{(Y_{40}+Y_{43}+Y_{42})} \end{bmatrix}$$

diagonal elements → self admittances

non-diagonal elements → mutual / transfer admittances.

Q.



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$$\begin{bmatrix} I_1 \\ I_2 \\ I_3 \end{bmatrix} = \begin{bmatrix} 0.005+10-j15+15-j10 & -10+j15 & 15-j10 \\ 10-j15 & 0.005+10-j15+15-j15 & 15-j15 \\ 15-j10 & 15-j15 & 0.007+15-j10+15-j15 \end{bmatrix}$$

$$= \begin{bmatrix} 25.005-25j & \overset{-10+j15}{\cancel{+10-j15}} & -15+j10 \\ -10+j15 & 28.005-j30 & -15+j15 \\ -15+j10 & -15+j15 & 30.007-j25 \end{bmatrix}$$

Q.

From Bus	To Bus	Resistance	Reactance	Admittances
1	2	0	$j0.34\,\Omega$	$-j2.94$
2	3	0	$j0.42\,\Omega$	$-j2.38$
1	3	0	$j0.30\,\Omega$	$-j3.33$
2	0	0	$j0.15\,\Omega$	$-j6.66$
3	0	0	$j0.1\,\Omega$	$-j10$

$$\begin{bmatrix} I_1 \\ I_2 \\ I_3 \end{bmatrix} = \begin{bmatrix} -j2.94-j3.33 & j2.94 & j3.33 \\ j2.94 & -j6.66-j2.94-j2.38 & j2.38 \\ j3.33 & j2.38 & -j10-j3.33-j2.38 \end{bmatrix}$$

$$= \begin{bmatrix} -j6.27 & j2.94 & j3.33 \\ j2.94 & -j11.98 & j2.38 \\ j3.33 & j2.38 & -j15.71 \end{bmatrix}$$