Power "1" 5/2 SUN

Power system :-

Generation

NEPCO
شركة نقل

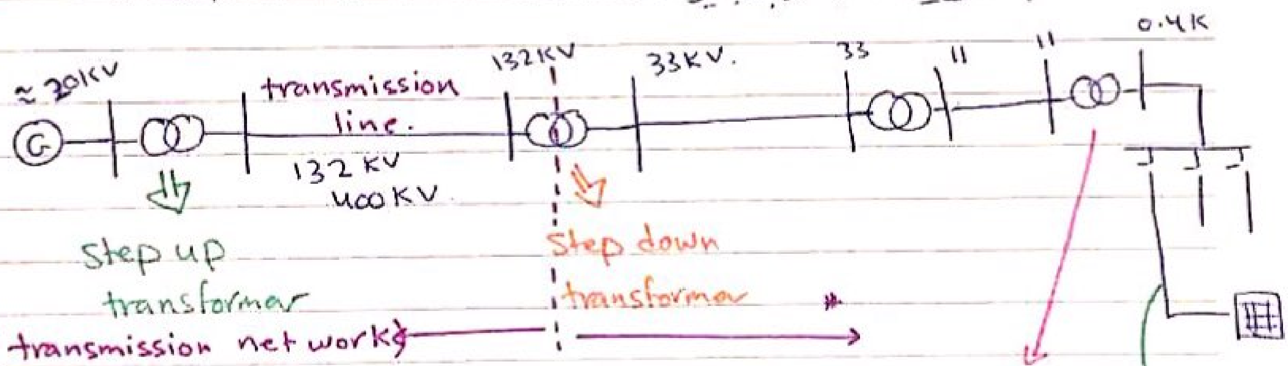
Transmission and Distribution → شركات توزيع ← IDECO, EDCO, JEPCO

Customers ← ☐ ☐ ☐ ☐

- customers → residential, Commerical, industrial

fuel → (G) → electrical.

NEPCO → بشتري الغاز وبتبيعو لـ Gen.



" في البيت بكون قيمة الـ volt = 400 "

LV low Volt عبارة عن سلك إلي في الشارع .

* distribution transformer (33 KV, 11 KV, 6.6 KV)

ERC Regulator → منظم performance standard

ERC = هيئة تنظيم الطاقة

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* Power system modeling => "transmission lines."

* power system studies.8-
  - load flow studies
  - Fault analysis.

* الكتب - power system analysis.
  - Saddat
  - Tom overbye.

* software → power world.

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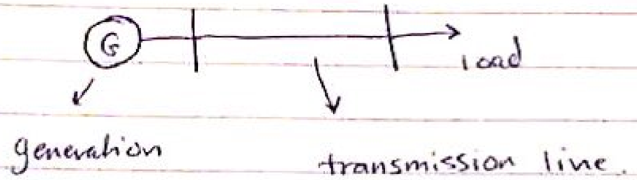
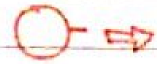
* Single line diagram :-

one - line diagram

- relative interconnection between generators, transformer, transmission lines, loads.

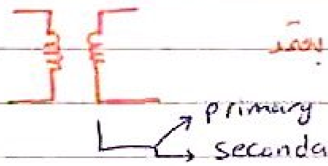


* Symbols :-

①  ⇨ generators / motors.

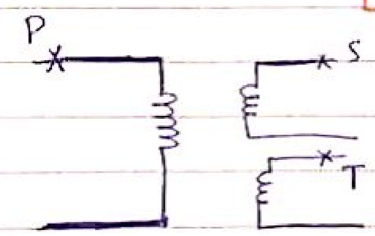
②  ⇒ two winding transformer

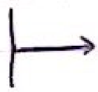
IEC



في الكتب بنفس

③ Three winding transformer.
- primary.
- secondary.
- tertiary.



④ loads "  "

⑤ bus " "

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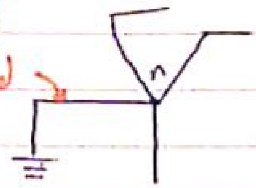
(6) connections → Δ
→ Y
→ grounded Y — grounded.

solidly grounded



(7) earth

* Switching element:-

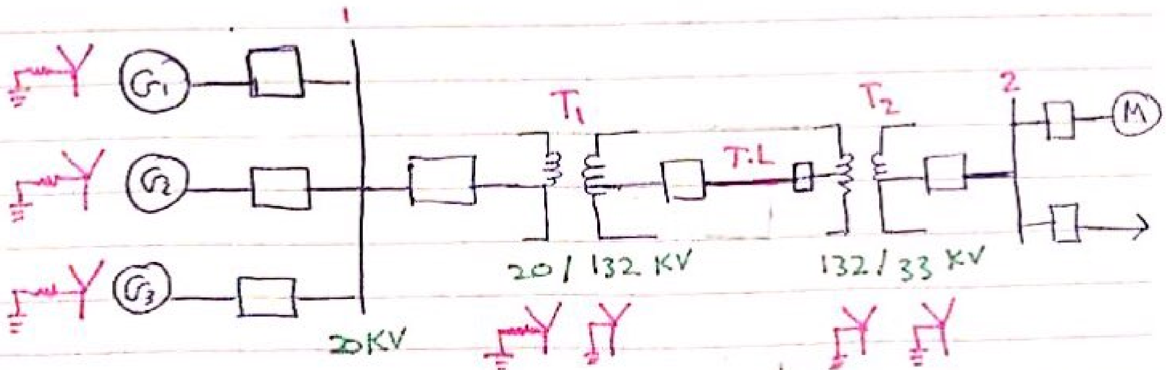
(8) Isolator

(9) Circuit breaker , — بقدر افصلو ع الـ fault.

(10) Fuse → حرائق

- Load break switch
- Recloser
- sectionalizer.

(11) current transformer
- voltage transformer



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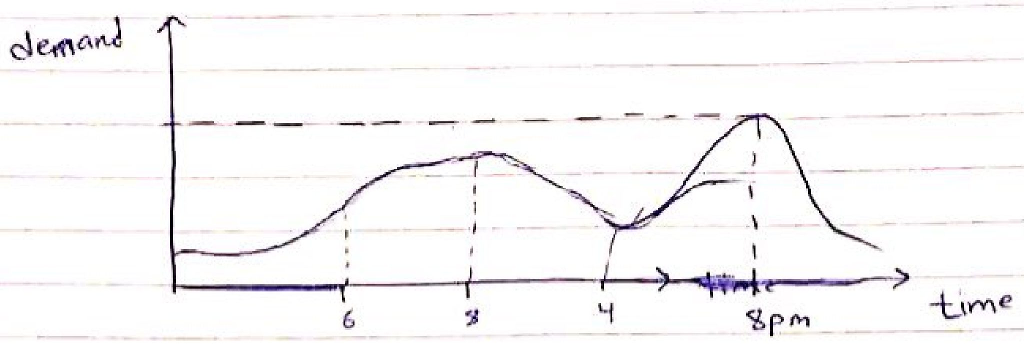

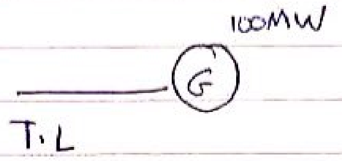

* rating 50MW

Impedance diagram / reactance diagram:-

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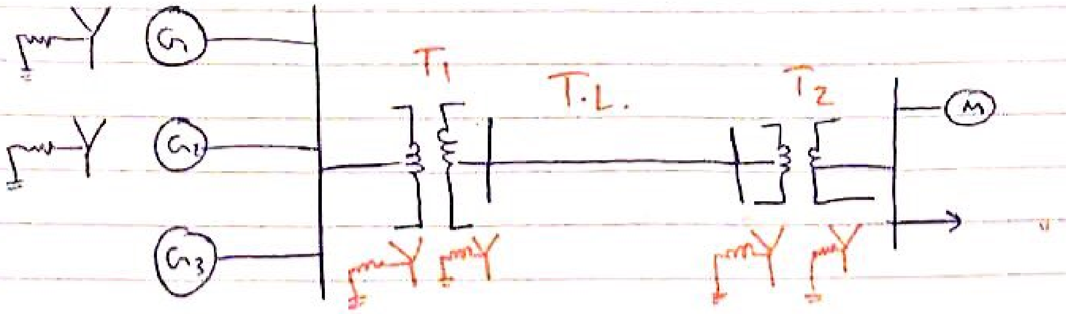
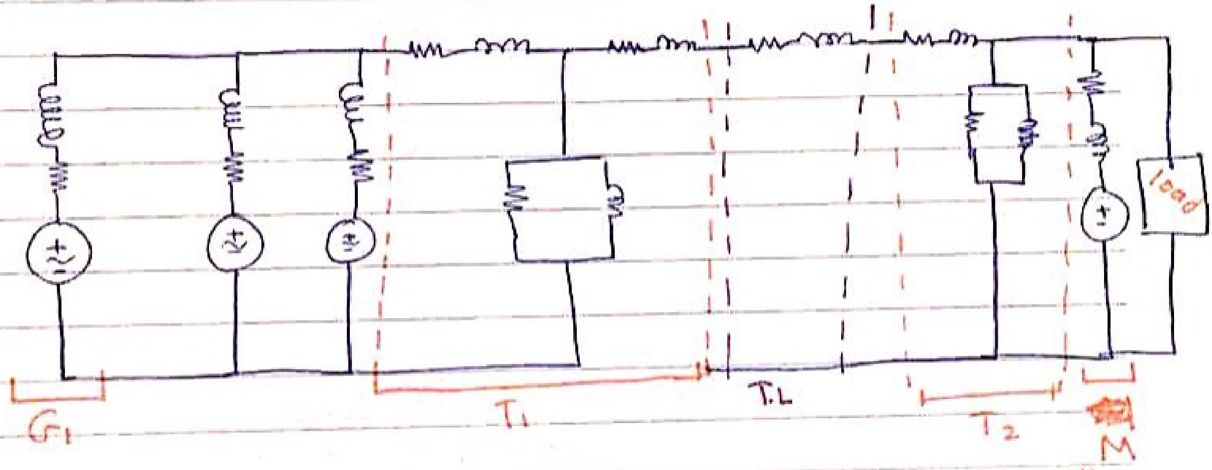


"4 bus System"

- power flow studies.
- Short circuit studies.

* Impedance diagram / Reactance diagram :-



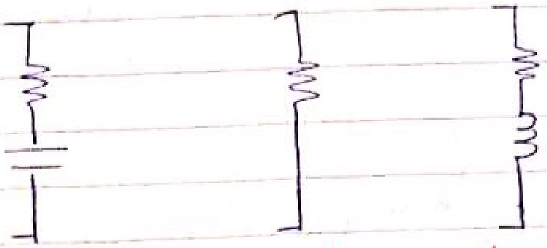
Refrence → Nutral
Refrence → earth.

* لو كان الـ Balance Sys.
ما بيفرق الـ earth / nutral
بس اذا كان الـ unbalance Sys.
بيفرق الـ nutral/earth "

LV $R > X$ → ما بقدر اهمل الـ R.
HV → $R = 0$. نعم, اهمل (R=0)

* (في Distribution / اغلب اشتغل بس Reactance X)

Load:



lead P.F unity PF. lag PF

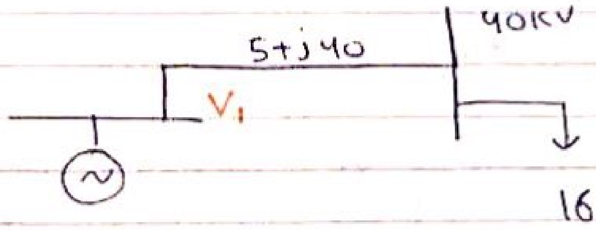
Z const.

$$Z = \frac{|V|}{|\hat{I}|}$$

$V\downarrow \rightarrow \hat{I}\downarrow \longrightarrow P\downarrow$

Single - phase Power System

Ex:



load
16 MW
unity PF.

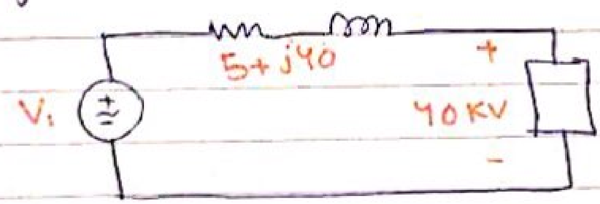
" دايمًا السؤال "
3-ph
الا اذا قالي انو
single-phase.

control generator

Sol:

بدي يطلع عند ال (V=40KV) قديش بدي V_1 اكبر.

neglecte Reactance.



16MW
unity PF.

unity PF
S = P.

$S = V\hat{I}^*$

$\hat{I} = 400 \angle 0 \ A$

$V_1 = 40KV\angle 0 + \hat{I}\,(5+j40)$

$$\boxed{V_1 = 45 \angle 24^\circ \ KV}$$

لازم نطلع ال (45k= V)

اذا اطلعت V=45 ما بطلع عندي V=40.

$S_{Gen} = V_1 \hat{I}_1^* = 16.8MW + j\,6.4\,MVAr$

* ال 0.8 هي عبارة عن losses م T.L.

* $P = |V||\hat{I}|\cos\theta$

$= |\hat{I}| \angle 0 \rightarrow$ unity , $-\cos PF \rightarrow$ lag.

$+\cos PF \rightarrow$ lead

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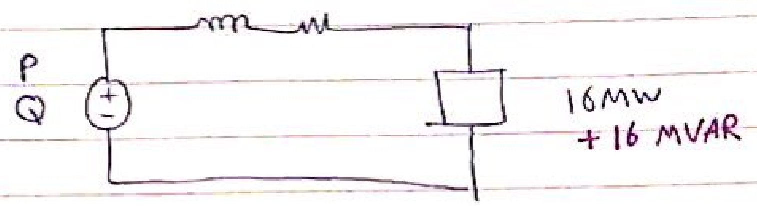
$S\uparrow \rightarrow I\uparrow \rightarrow$ real power losses $\uparrow \rightarrow P\uparrow$

* ممكن تضل p const اذا كانت ماعندي R ← lossless line.



$S_{load} = V I^*$

$I = 565.7 \angle -45^\circ$ A   lag pF. (inductive) لما زدت Q.

$V_1 = \uparrow 59.6 \angle 13^\circ$ KV.

زدت ال Q ← تزداد ال I↑ عشان احافظ على V=40K لازم ازيد ال V_1

$S_{Gen} = 17.6 + j\,28.8$ MVAR

زادت ال Q كثير لانو عندي : losses.

$\uparrow Q$ reactive power $\rightarrow \uparrow V_1$

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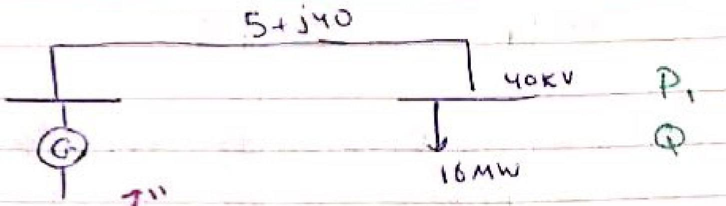
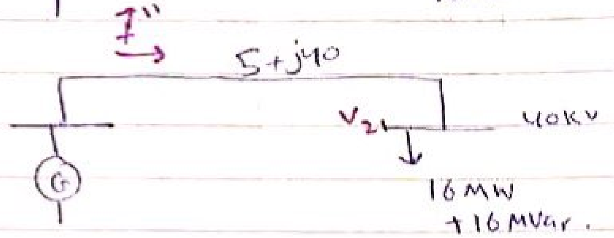


P_1
Q



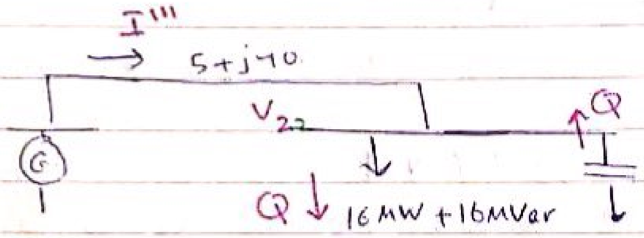
P_2
Q

$S = VI^*$

$S\uparrow \quad I\uparrow$

$I\uparrow \rightarrow I^2R\uparrow \rightarrow P = R + I^2R \uparrow \rightarrow$ (losses↑).

$P_2 > P_1$



P_3

16MVar. Q

تيار اكبر

$C \rightarrow Q\uparrow$.

~~Capacitor~~ ~~[illegible]~~

Load → $Q\downarrow$

$P_1 = P_3$

$V_{22} > V_{21}$ ~~[illegible]~~ $\boxed{I'' > I'''}$

capacitor bank → تعدل الـ volt

↑ voltage drop ← تيار اكبر

Capacitor: $X_c = -ve$, $y_c = +ve$

$$y = \underset{\text{conductance}}{g} + j\underset{\text{susceptance}}{b}$$

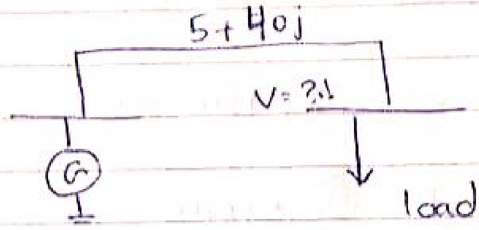
KeshinColor

loads:
- → Constant power.
- → " impedance [تقدر احط مكانها R]
- → " current.

$Z_{const} = \frac{V}{I}$, $V\downarrow$, $I\downarrow$, $P\downarrow$.

Z constant ⟹ بتغير كل ال Volt

Ex:



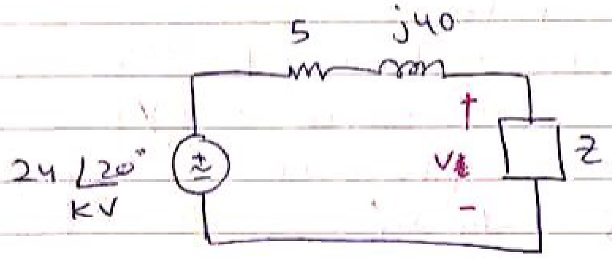
load can be modelled as a constant impedence.

single-phase power system
Find V ?!

load: consume 16MW with unity PF when V is 40KV

"عند هذه النقطة بكون قيمة ال V=40K"
(يعني V ≠ 40KV الا عند هذه النقطة)

Sol:



$Z = \frac{V^2}{S} = \frac{(40K)^2}{16M} = 100\,\Omega.$

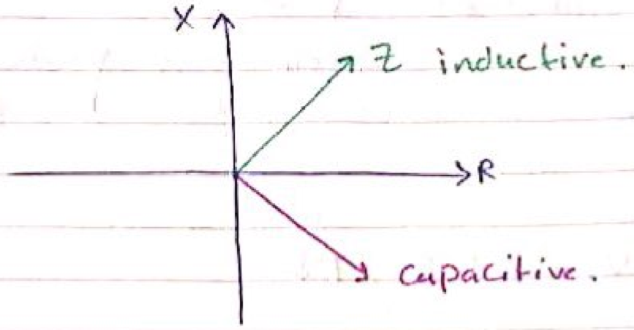
$V = 45\angle 20 * \frac{Z}{Z+5+40j}$

$$\boxed{V = 40\angle -20°\ KV}$$

if load ↑ " 16MW With 0.707 PF lagging). (const Z)
when V is 40KV.

(S>P)

$Z = \frac{(40)^2}{16/0.707} = 70.7\angle + \cos^{-1}(0.707)$



$I \angle -ve$ lag

$I \angle +ve$ lead.

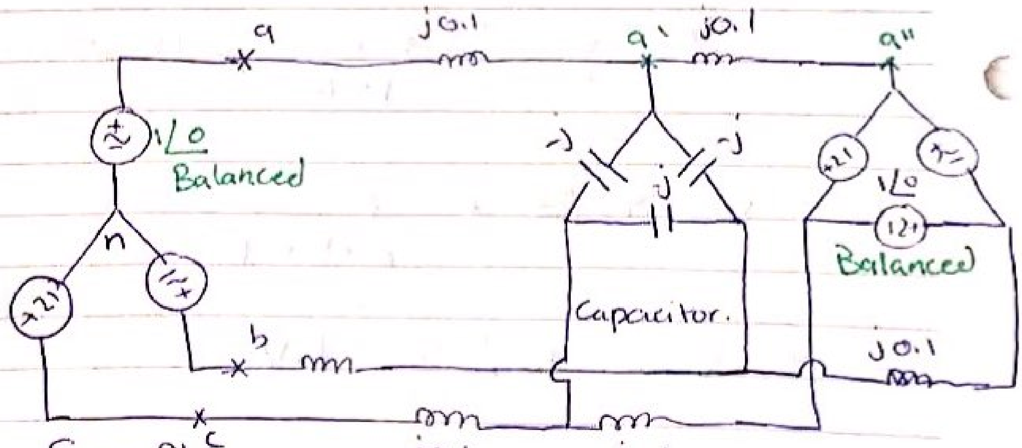
Ex: * three-phase system. 8Δ

- Balanced system.
- per phase analysis

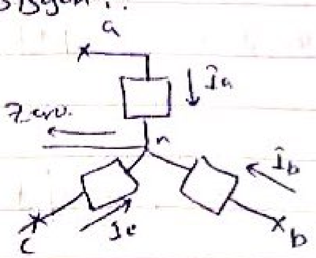
"load → LV ⇒ unbalanced"

* per phase rules:
  - [1] Convert Δ loads to Y's
  - [2] " " source " Y's
  - [3] Solve phase a
  - [4] $S = 3 V_a I_a^*$

Ex:



find S_{Ygen}, $S_{\Delta gen}$?!



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$\boxed{\text{sol:}}$ ① Convert Δ load to Y's

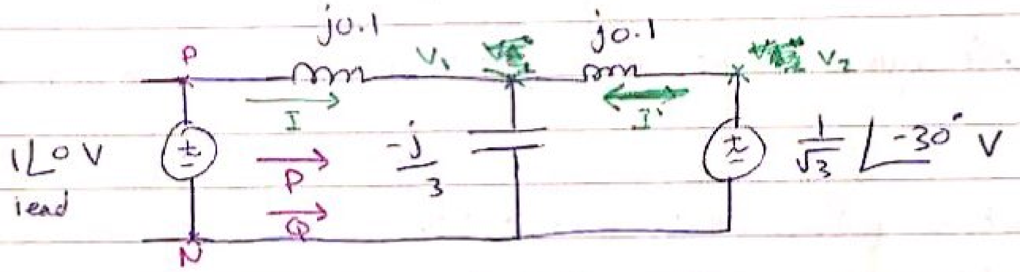
$$Z_Y = \frac{-j}{3}$$

② Convert Δ Source to Y's

$$V_{LL} = \sqrt{3}\, V_{LN} \angle 30$$

$$V_{LN} = \frac{V_{LL}}{\sqrt{3}} \angle -30$$

$$V_{LN} = \frac{1}{\sqrt{3}} \angle -30^\circ$$



(Q ⇒ HV → LV)

" Q reactive power flow mover from HV to LV "
magnitude.

$P \propto \Delta\delta \rightarrow$ power angle.

$Q \propto \Delta V$
↳ magnitude.

$S_{Ygen} = 3 V_a I^*$

Nodal analysis ⇒

$V_1 = 0.9 \angle -10.9$ V "lag"

" Real power move from lead to lag "

$$S_{Ygen} = 3 * 1\angle 0 \left(\frac{1\angle 0 - 0.9\angle 10.9}{j0.1} \right)$$

$= \underset{+ve}{5.1} + j3.5$VA → +ve (inject reactive power).

(inject real power)

12

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14/2 Tue

* اذا طالع (-) ⇐ consumed. "Power بتطلع Gen"
"source بتروح ع"

$$S_{\Delta gen} = 3 * \frac{1}{\sqrt{3}} \angle -30^\circ \left(\left(\frac{1}{\sqrt{3}} \angle -30^\circ \right) - 0.9 \angle -10.9 \right) / j0.1$$

$$= -5.1 - j\,4.7 \text{ VA.}$$

↳ -ve (consumed reactive power)

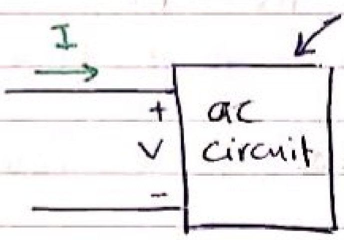
↓ -ve (consumed real power)

* Capacitor ⇐ Q زادت الـ source 2 الـ source 1 من ← Q بتعطي

* لو حاسبنا C ← الـ V بقل, و الـ Q بتجيب الـ Source 1 أكبر من Q source 2

* Direct of power flows

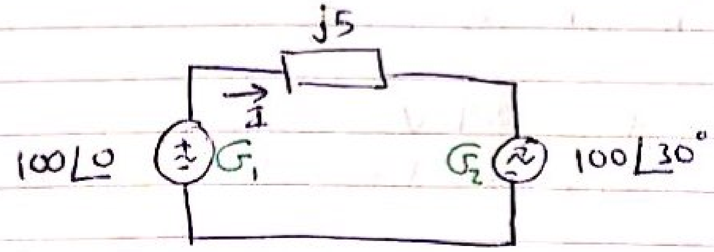
- passive sign convention :-



* consume real power.
  " reactive power.

"بفرض انو الـ I داخل.
اذا طالع سالب يعني عكس
" supply ⇐ يعني

Ex:



Single phase. Power-syst.

which machines is Gen. or consuming real power?

(real pow بنولد ⇐ Gen
consumed ⇐ Motor)

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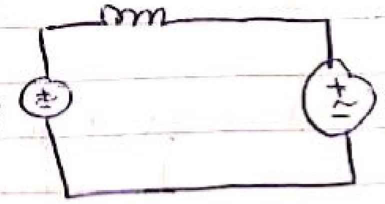
* H.W

Prove ?:
$P \propto \Delta\delta$
$Q \propto \Delta V$.

$E_1\angle 0$  $E_2\angle\delta$

Sol Ex: passive sign convention

$$I_6 = \frac{100\angle 0 - 100\angle 30}{j5} = 10.35\angle 95^\circ \text{ A}$$

$S_{G_1} = V(-I)^*$ $-ve \rightarrow$ لأنو التيار اذا بفرضو داخل .
$= 100\angle 0 * (-I)^*$ passive مطابقة
تيار خارج من الـ G_1 .

$= \underline{1000} - j\underline{268}$ VA.

+ve consume real power.   -ve inject reactive power.

* لازم لما افرض تيار +ve ← نطلع P, Q +ve.

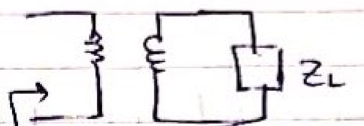
$S_{G_2} = V(I)^*$ passive sign.
$= (100\angle 30) * (10.35\angle 95)^*$ تيار داخل على G_2

$= \underline{-1000} - j\,\underline{268}$ VA. $\angle 95 \rightarrow (\angle 95)^* = \angle -95$

-ve inject real power   -ve inject reactive power.

* Per unit System 8A

$$\text{per unit} = \frac{\text{actual}}{\text{Base}}$$



$$Z_{eq} = Z_L\left(\frac{N_1}{N_2}\right)^2$$

$Z_{L\,pu}\,HV = Z_{L\,pu}\,LV$

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* The per unit system 8Δ

power system Quantities (Voltage, current, power, impedance). can be expressed in per unit (% base value).

$V = 0.97$ pu ⇒ voltage drop = 3%.

Calculations:

$$\text{per unit} = \frac{\text{actual}}{\text{base}}.$$

$\boxed{1}$ dimonsion less

$\boxed{2}$ angle is the same as the original quantity.

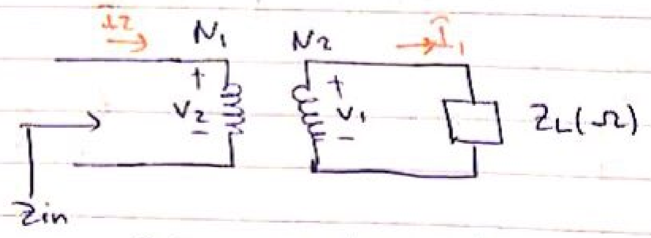
Ex: $V = 200\,V \angle 5^\circ$

$V_{LN,\,base} = 230$.

$$V_{pu} = \frac{200}{230} \angle 5 \text{ pu}$$

⇦ الزاوية مابتتغير .

* Calculation → perunit (V p.u, I p.u) → actual value.



$$Z_{in} = Z_L \left(\frac{N_1}{N_2}\right)^2$$

لما اشتري transformer أول عليه . ⇒ Name plate $\left(\begin{array}{c} 33/11 \text{ KV} \\ 25 \text{ MVA} \\ Z = 15\% \end{array}\right)$

↳ per unit (base $\overset{\text{هي}}{\Rightarrow}$ rated)

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V, I, S, Z

two independent base value can be arbricaily selected in one poin in power system.

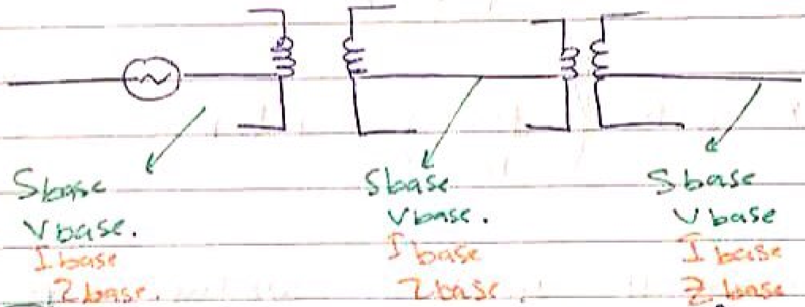
for $1\phi \Rightarrow$ $V_{base_{LN}}$, S_{base}. "single phase"

$$I_{base} = \frac{S_{base\,1\phi}}{V_{base}}$$

$$Z_{base} = \frac{V_{base}^2}{S_{base}}.$$

* 1ϕ power system 8.1

$\boxed{1}$ pick 1ϕVA for the entire system



" Sbase ما بتنقل ع ال system "

$\boxed{2}$ pick a voltage base for each different voltage level "transformer turns ratio"

to Zpu old (Sbase old, Vbase old).

Zpu new (Sbase new, Vbase new).

$$\hookrightarrow Z_{pu\,new} = \frac{Z_{actual}}{Z_{base,\,new}}.$$

$$Z_{pu\,new} = \frac{Z_{pu\,old} * Z_{base\,old}}{Z_{base,\,new}}$$

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$$Z_{pu\,new} = \frac{Z_{p.u\,old} * (V^2_{old} / S_{base\,old})}{(V^2_{new} / S_{base\,new})}$$

$$\boxed{Z_{pu\,new} = Z_{p.u\,old} * \left(\frac{S_{base\,new}}{S_{base\,old}}\right) * \left(\frac{V_{old}}{V_{new}}\right)^2}$$

Ex: (A) 25MVA , 33/11 KV transformer , X = 15%

(B) 10MVA , 33/11 KV transformer , X = 15%

Which one will result is higher Voltage drop given a base 100 MVA ?!

sol:

$\boxed{A} \Rightarrow X = 0.15 * \left(\frac{100}{25}\right) = 0.6\ pu$

$\boxed{B} \rightarrow X = 0.15 \left(\frac{100}{10}\right) = 1.5\ pu.$

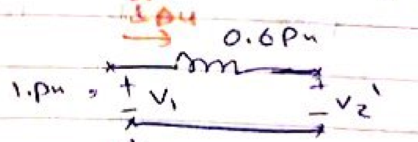
B → will result in large voltage drop.

B عليها Vd اكبر لانو مقاومتها اكبر . الـ مقاومة بتزيد الـ (Voltage drop

(($\uparrow R \rightarrow \uparrow$ Voltage drop.))

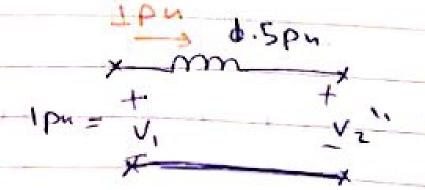
* لما يعطيني قرايك بـ (pu) بتاخد الـ base تبعوم الـ rated.

$V_2' > V_2''$?!



$V_2' = V_1 - I' j(0.6)$

Give $I'pu = I''pu$.



$V_2'' = V_1 - I'' j(1.5)$

$V_2' > V_2''$

لانو الـ Voltage drop ← أقل لانو المقاومة أقل.

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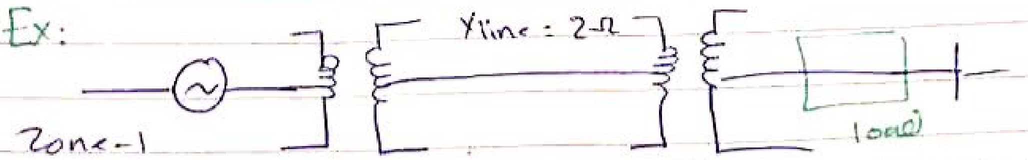
Ex:



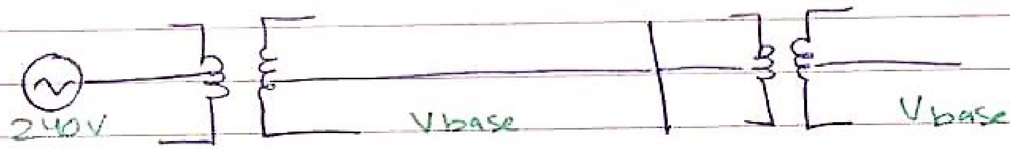
$Z_{load} = 0.9 + j0.2\ \Omega$

T_1	T_2
30 KVA	20 KVA
240/480 V	460/115 V
X = 0.1 pu	X = 0.1 pu
Zone-2	Zone-3

" single phase "

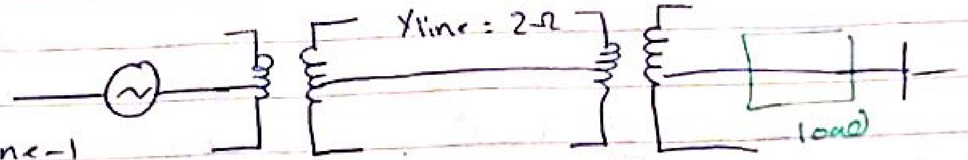
① Draw impedance diagram (all value in pu) base in Zone-1 (30 KVA, 240V)

Sol:



$V_{base} = 30$ KVA

Ex:



Zone-1

T_1 | T_2 | $Z_{load} = 0.9 + j0.2\ \Omega$

30 KVA
240/480 V
$X = 0.1$ pu

20 KVA
460/115 V
$X = 0.1$ pu

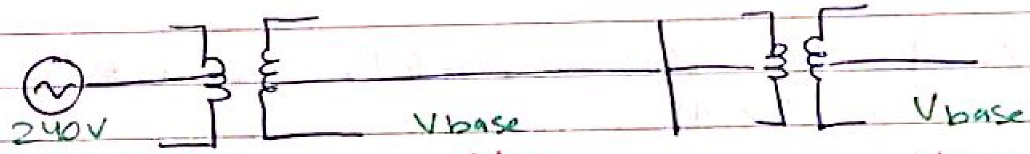
Zone-2 | Zone-3

" single phase "

① Draw impedance diagram (all value in pu) base in Zone-1 (30 KVA, 240V)

② Find load current ?:

Sol:



base 240V | V_{B2} | V_{B3}

$S_{base} = 30$ KVA

$$V_{B2} = 240 * \left(\frac{480}{240}\right) = 480.\ V$$

$$V_{B3} = 480 * \left(\frac{115}{460}\right) = 120\ V$$

$T_1 \Rightarrow\ X = 0.1\ (30\ KVA,\ 240/480V)$

$$X_{new} = 0.1\left(\frac{30}{30}\right)\left(\frac{240}{240}\right)^2 = 0.1\ pu.$$

$$T_2 \Rightarrow\ X_{new} = 0.1 * \left(\frac{30}{20}\right) * \left(\frac{460}{480}\right)^2$$

$$= 0.1 * \left(\frac{30}{20}\right) * \left(\frac{115}{120}\right)^2$$

$$= 0.1378\ pu$$

Zone 2:

$$Z_{base} = \frac{V_{base}^2}{S_{base}} = \frac{(480)^2}{30K} = 7.68\ \Omega$$

$$\text{line} \Rightarrow X_{pu} = \frac{2}{7.68} = 0.2604\ pu.$$

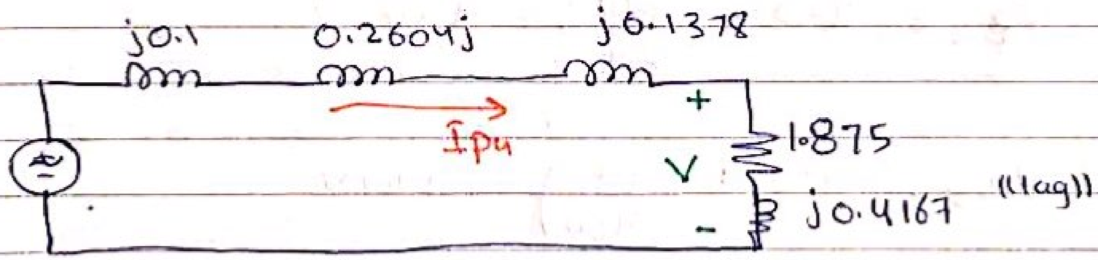
Zone 3:

$$Z_{base_{pu}} = \frac{V_{base}^2}{S_{base}} = \frac{(120)^2}{30K} = 0.48\ \Omega.$$

~~$X_{pu} =$~~

$$Z_{load} = \frac{0.9 + j0.2}{0.48} = 1.875 + j0.4167\ pu.$$

$$S_{base} = P_{base} = Q_{base}.$$
$$Z_{base} = R_{base} = X_{base}.$$



$\boxed{2}$ If Voltage of the Source is $220\,V\angle 0$ Find load current ?!

Sol: $V_{source\,pu} = \dfrac{220V}{240} = 0.91\ pu\ \angle 0$

$$I_{pu} = \frac{0.91\angle 0}{j0.1 + 0.2604j + j0.1378 + 1.875 + j0.4167}$$

$$I_{pu_{base}} = \frac{S_{base,1\phi}}{V_{base \cdot LN}} = \frac{30K}{120} = 250\ A$$

$I_{actual,load} = I_{pu} \cdot I_{base}$ (Zone 3).

* $V_{sec} = 220V \times \frac{480}{240}$ V.

$$V_{sec\,pu} = \frac{220 \times \frac{480}{240}}{240 \times \frac{480}{240}} = \frac{220}{240}$$

V_{pu} primary $= V_{pu}$, secondary.

* The per unit system - three phase ckts.

- In balanced system ⇒ per-phase analysis.
  $(\Delta \longrightarrow Y)$

$$S_{base,3\phi} = P_{base,3\phi} = Q_{base,3\phi}$$

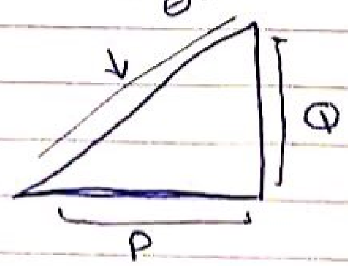
Ex: load 10 MW, pF = 0.707 lag, $S_{base,3\phi} = 100$ MVA

Find P_{load} pu, Q_{load} pu ?!

Sol: $P_{load\,pu} = \frac{10}{100} = 0.1$ pu.

$\cos\theta = 0.707$
$\theta = 45°$

$Q_{load\,pu} = \frac{10}{100} = 0.1$ pu.



$\theta = 45 \rightarrow$ مثلث متساوي الضلعين $(P = Q)$

$S_{base\,3\phi}$, V_{L-L}, Z_{base}, I_{base}.

$S_{base\,3\phi}$, $V_{LL,base}$ ⇒ -

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$$\boxed{I_{base\,3\phi} = \frac{S_{base\,3\phi}}{\sqrt{3}\, V_{LL-base}}}$$

Proof:

$$I_{base\,3\phi} = \frac{3\, S_{base\,1\phi}}{\sqrt{3}\,(\sqrt{3}\, V_{L,base})}$$

$$= \frac{S_{base,1\phi}}{V_{LN,base}}$$

$$= I_{base,1\phi}$$

$$Z_{base} = \frac{V_{base,LN}}{I_{base,1\phi}} = \frac{V_{base,LN}}{\dfrac{S_{base,1\phi}}{V_{base,LN}}} = \boxed{\frac{V^2_{base\,LN}}{S_{base\,1\phi}}}$$

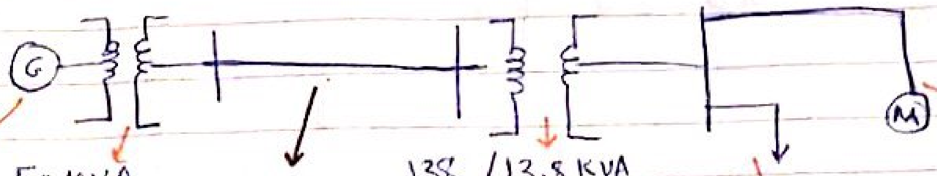
$$= \frac{(V_{bas\,LL}/\sqrt{3})^2}{S_{base,3\phi}/3} = \frac{V^2_{base,LL}}{S_{base,3\phi}}$$

$$Z_{pu\,new} = Z_{pu\,old} * \left(\frac{S_{base\,3\phi\,new}}{S_{base\,3\phi\,old}}\right) * \left(\frac{V_{LL,old}}{V_{LL\,new}}\right)^2$$

* اثبتي ؟!

21/2/2017 Tue

$\boxed{\text{Ex:}}$ 3ϕ power system.



50MVA
13.8 KV
$X = 35\%$

50 MVA
13.8/138 KV
$X_{pu} = 10\%$

40 mile
138 KV
$X = 0.85\ \Omega/\text{mile}$.

138 / 13.8 KVA
50 MVA
$X = 10\%$

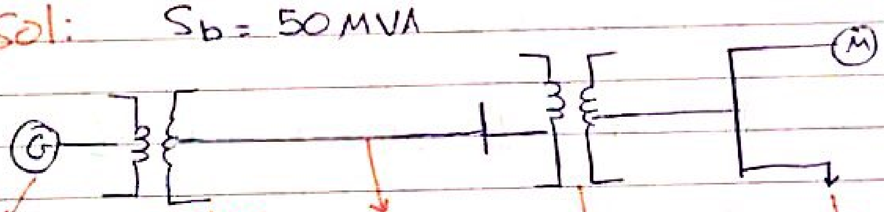
13.8 KV
20 MVA
0.707 lag PF
"Const. impedance"

30 MVA
13.8 KV
$X = 10\%$

"Ⓜ"
P ثابتة
Q < يعطي
ياخذ

Draw impedance diagram (Mark all value in pu) base 13.8 KV, 50 MVA at the generation side !?

Sol: $S_b = 50\,MVA$



13.8 KV base

13.8/138 KV

base 138 KV

138/13.8 KV

13.8 KV.

$T_1 \Rightarrow$

$$X_{pu} = 0.1 * \left(\frac{50}{50}\right) * \left(\frac{13.8}{13.8}\right)^2 = 0.1\ pu.$$

line $\Rightarrow$

$$X_{pu} = \frac{\text{actual}}{Z_{base}}$$

$$Z_{base} = \frac{V_{LN}^2}{S_{1\phi}} = \frac{(V_{LL})^2}{S_{3\phi}}$$

$$Z_{base} = \frac{(138k)^2}{50\,M} = 380.88\ \Omega$$

$$X_{pu} = \frac{0.85 * 40}{380.88} = 0.089\ pu.$$

KoshinColor

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$T_2 \Rightarrow \quad X_{pu} = 0.1 \text{ pu.}$

$$G \Rightarrow \quad X = 0.35 \times \left(\frac{50}{50}\right)\left(\frac{13.8}{13.8}\right)^2$$

$$= 0.35 \text{ pu.}$$

$$M \Rightarrow \quad X = 0.1\left(\frac{50}{30}\right)\left(\frac{13.8}{13.8}\right) = 0.167 \text{ pu.}$$

$$\text{load} \Rightarrow \quad |Z_{actual}| = \frac{V^2}{S} = \left(\frac{13.8K}{20M}\right)^2$$

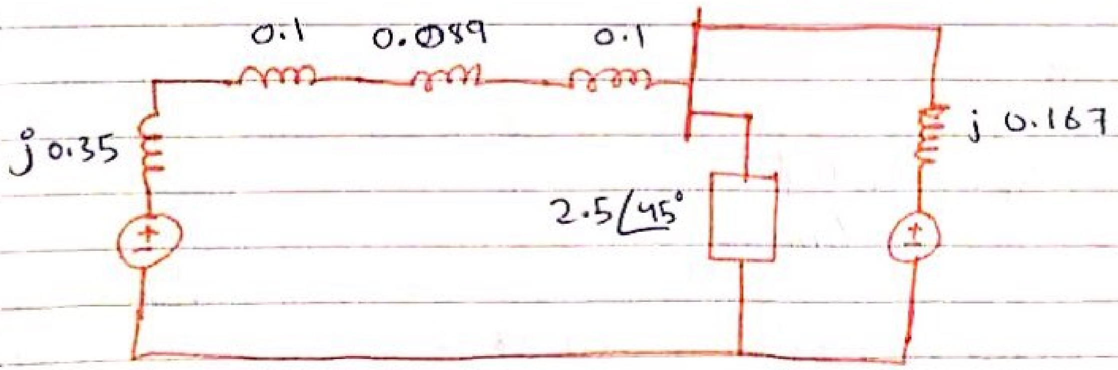
$$= 9.52\,\Omega.$$

$$Z_{actual} = 9.52\angle +\cos^{-1}(0) = 9.52\angle 45^\circ$$

lag $\rightarrow Z\angle +ve \rightarrow I\angle -ve.$

$$Z_{base} = \frac{V^2}{S} = \frac{(13.8)^2}{50} = 3.81\,\Omega.$$

$$Z_{load\,pu} = \frac{9.52\angle 45^\circ}{3.81} = 2.5\angle 45^\circ$$



$$I_{base\,(load)} = \frac{S_{3\phi}}{\sqrt{3}\,V_{LL}} = \frac{S_{1\phi}}{V_{LN}}$$

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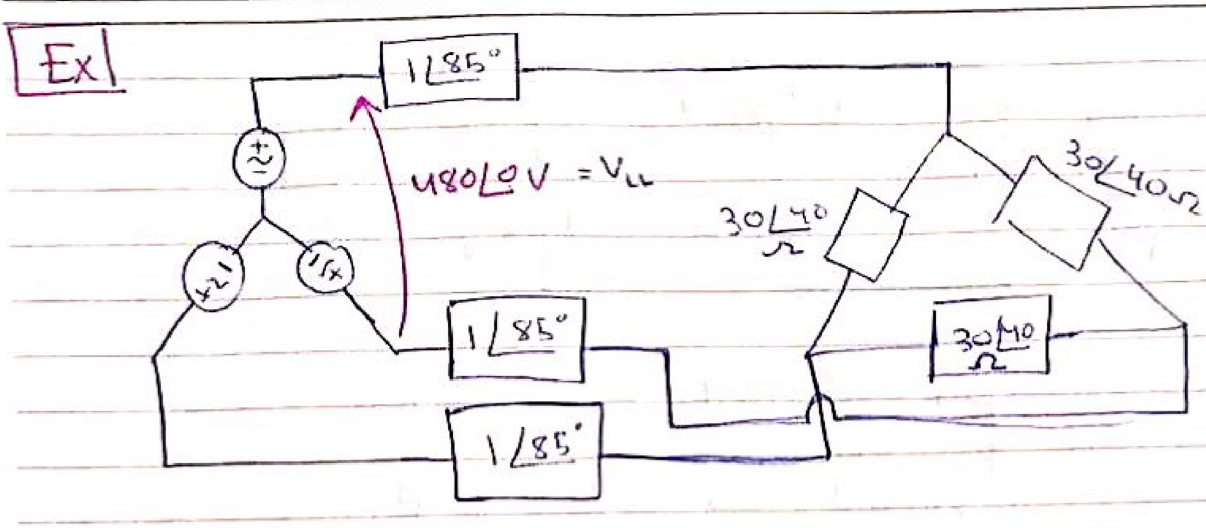
Ex



Calculate pu and actual current in phase using $S_{1\phi} = 10\,KVA$, $V_{base,L-L} = 480V$.

Sol:

$$Z_\Delta \Rightarrow Z_y$$

$$Z_y = \frac{Z_\Delta}{3} = \frac{30\angle 40}{3} = 10\angle 40^\circ\ \Omega$$

$$Z_{L\,pu} = \frac{Z_{actual}}{Z_{base}}$$

$$Z_{base} = \frac{(V_{base,LL})^2}{S_{base,3\phi}} = \left(\frac{(480V)^2}{30\,KVA}\right) = 23.04\,\Omega.$$

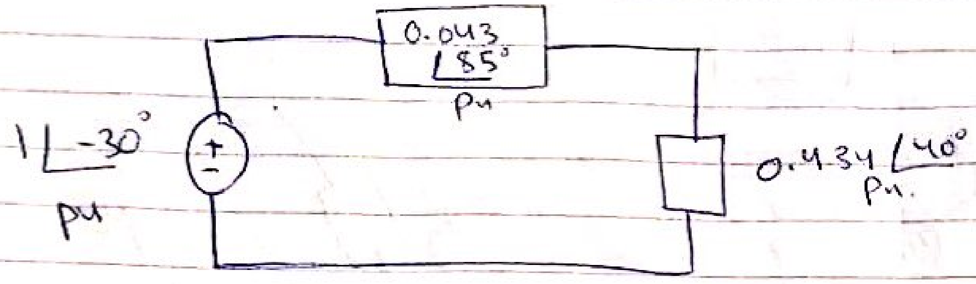
$$= \frac{(V_{base\,LN})^2}{S_{base\,1\phi}} = \frac{(480/\sqrt{3})^2}{10}$$

$$Z_{L\,pu} = \frac{10\angle 40^\circ}{23.04} = 0.434\angle 40^\circ\ pu.$$

$$Z_{line} = \frac{1\angle 85^\circ}{23.04} = 0.043\angle 85^\circ\ pu$$

Source = $\rightarrow V_{LN} = \frac{480}{\sqrt{3}}\angle -30^\circ\ V$

$\rightarrow V_{pu} = \frac{480/\sqrt{3}}{480/\sqrt{3}} = 1\ pu.$



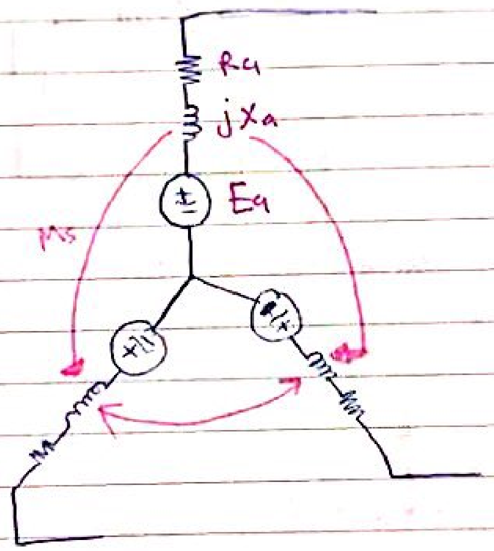
$I_{pu} = 2.147 \angle -73.78$ pu

$I_{actual} = 25.83 \angle -73.78$ A.

model
- Generator.
- transmission lines
- transformer. → two-winding transformer
  → three-winding transformer

Power system
① models
② analysis → load flow
→ fault analysis

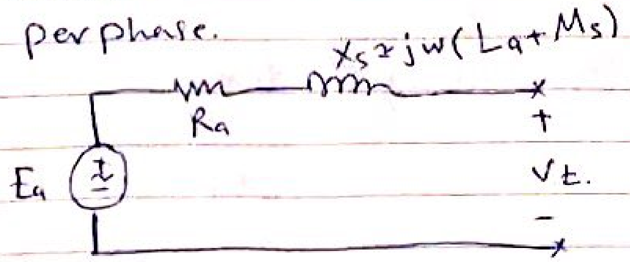
Three-phase synchronous Generator:-

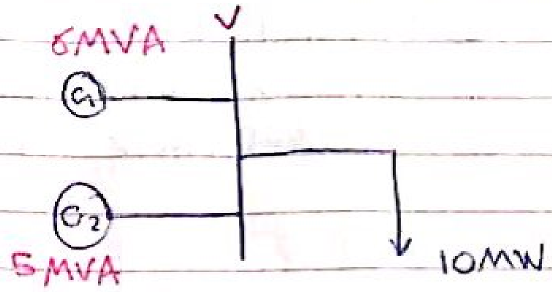


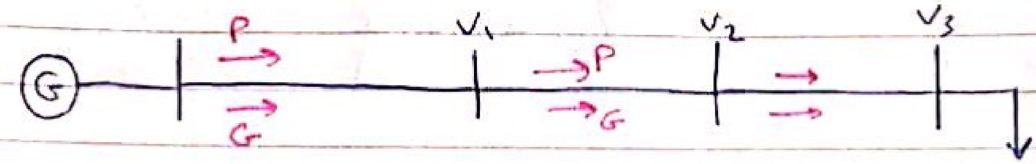
Ea ≡ internal Voltage.
Ra, jXa ≡ armature winding

M_s ≡ mutual inductance.

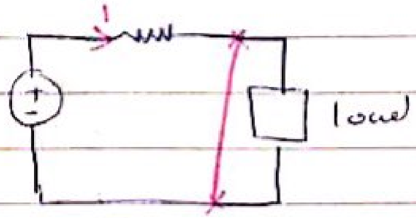
equivalent ckt :
- balanced
- perphase.





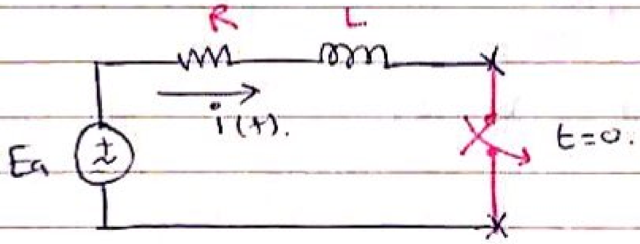


Fault analysis

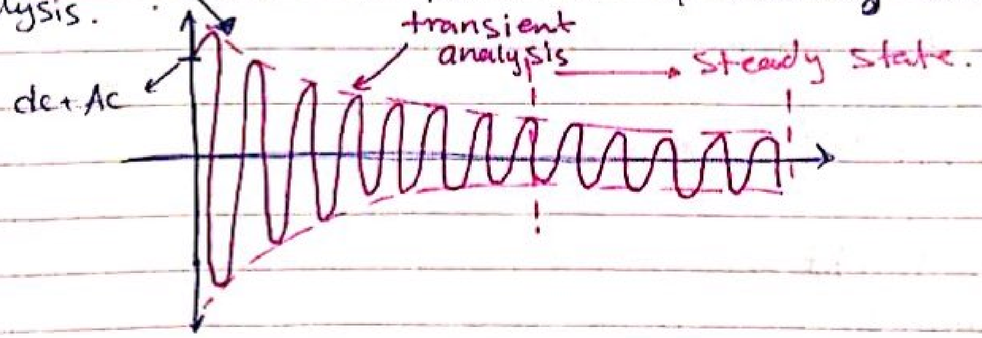


↑ i ← (Short ckt) fault بس يصير عندي

three-phase short ckt.



Subtransient analysis. $i(t) = i$ transient $+ i$ ~~steady~~ steady state.



Subtransient analysis ~~8A~~

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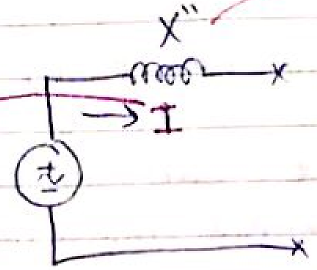
* Analysis 8Δ

* Subtransient 8-

X'' → tire - varying reactance.

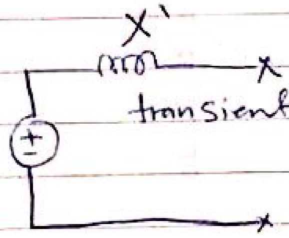
Subtransient current



$I \uparrow$ "أعلى تيار"

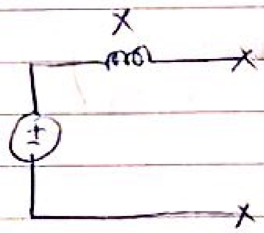
X'' ≡ subtransient reactance.

* transient 8-



transient reactance

* Steady state 8-



تيار أقل.

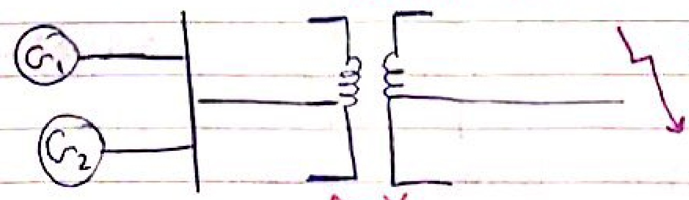
⇐ X أعلى.

" load flow "

$$X'' < X' < X$$

$\boxed{\text{Ex:}}$

75MVA, 13.8/69 KV



3ϕ fault

" balanced System "

Δ Y

G_1: 50MVA, 13.8 KV, $X'' = 25\%$

G_2: 25MVA, 13.8 KV, $X'' = 25\%$

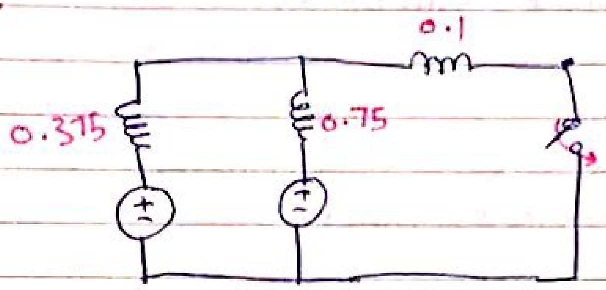
T_1: 75MVA, 13.8 Δ/69 Y KV, $X'' = 10\%$

Unload condition, No circulating current
[Before fault].

HV side of the transformer is 66 KV

Find Sub-transient current at
the HV side of the transformer ?!

Sol:



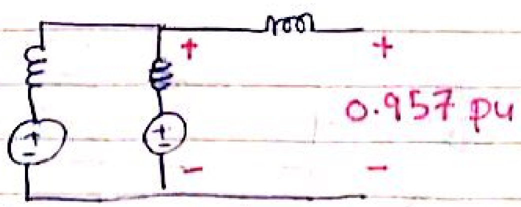
" $S_b = 75$ KVA "
,اخذه دماغ كتار

$G_1 \Rightarrow X'' = 25\% * \left(\frac{75}{50}\right) = 0.375$ pu

$G_2 \Rightarrow X'' = 25\% * \left(\frac{75}{25}\right) = 0.75$ pu.

$T_1 \Rightarrow X = 0.1$ pu.

I_g.



before fault. "66 KV"

$\frac{66}{69} = 0.957$ pu.

Keshin Colors

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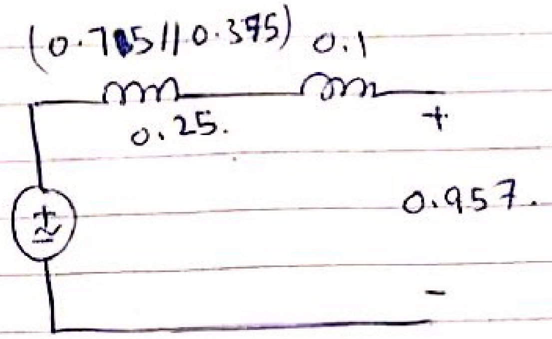

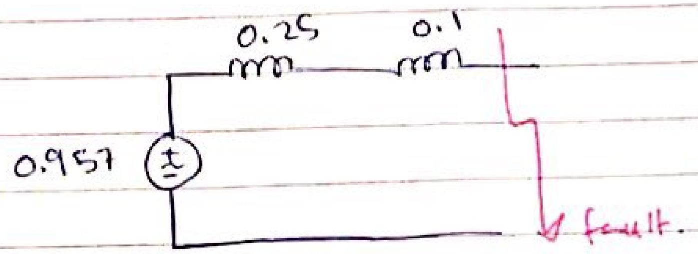

$$I''_{pu} = \frac{0.95}{j0.25 + j0.1} = -j\,2.734\ pu.$$

$$I''_{actual} = -j\,2.734 * \left(\frac{75M}{\sqrt{3} * 69KV}\right)$$

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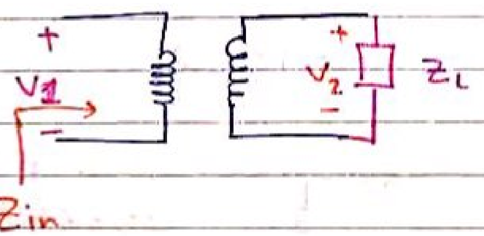
* Three-phase transformer Analysis :

Turns ratio $\triangleq \dfrac{\text{Phase voltage } V_2}{\text{Phase voltage } V_1}$

Transformation ratio $\triangleq \dfrac{\text{L-to-L voltage secondary}}{\text{L-to-L voltage primary}}$

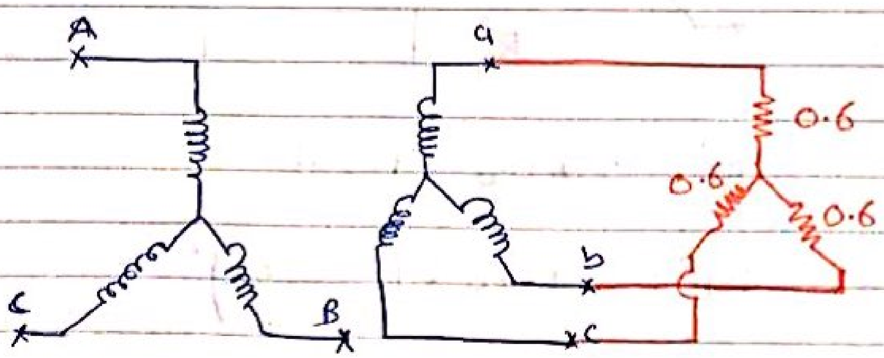
$$Z_{in} = Z_L \left(\frac{N_1}{N_2} \right)^2$$



$$Z_{in} = \frac{V_2 \, (N_1 / N_2)}{I_2 \, (N_2 / N_1)}$$

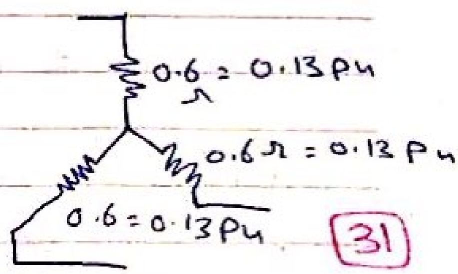
Ex

10 MVA
66/6.6 KV



① reffered to secondary :

$$R_{pu} = \frac{0.6}{(6.6)^2/10} = 0.13 \text{ pu}.$$



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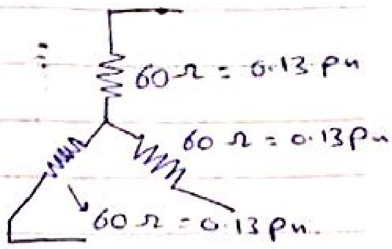
② reffered to primary $\delta\Delta$

$$R_p = 0.6 * \left(\frac{66/\sqrt{3}}{6.6/\sqrt{3}}\right)^2$$

$$= 0.6 * \left(\frac{66}{6.6}\right)^2$$

$$= 60\ \Omega$$



reffered to P.

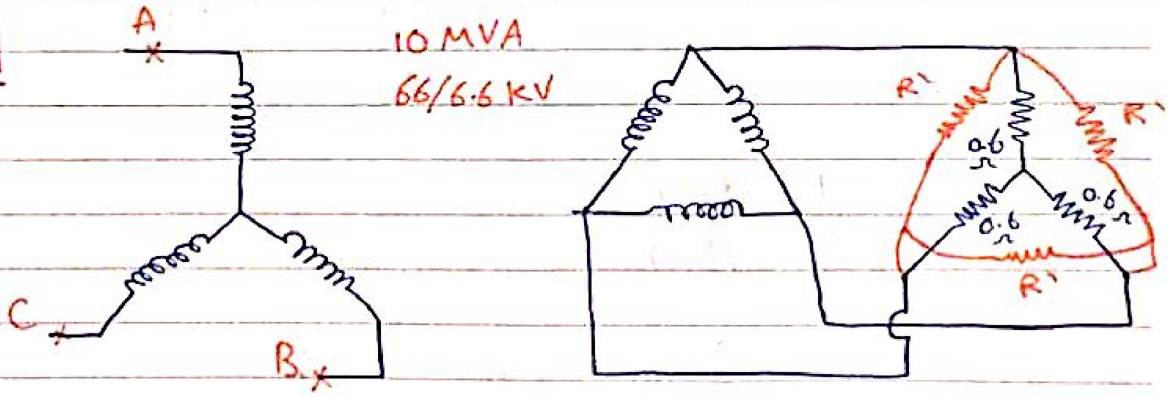
$$R_p (pu) = \frac{0.6 * \left(\frac{66}{6.6}\right)^2}{66^2/10} =$$

$$= \frac{0.6}{(6.6)^2/10}$$

$$= R_s\ pu$$

$$= 0.13\ pu.$$

$\boxed{Ex}$



$$R` = 3 * 0.6 = 1.8\ \Omega$$

$$R_p` = 3 * 0.6 * \left(\frac{66/\sqrt{3}}{6.6}\right)^2$$

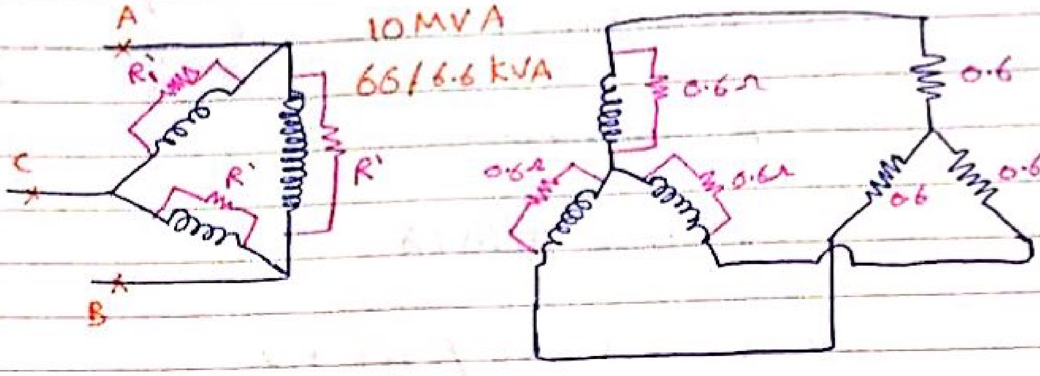
$$= 0.6 * \left(\frac{66}{6.6}\right)^2$$

$$= 60\ \Omega.$$

$$R_{p,pu} = \frac{60}{(66)^2/10} = 0.13\ pu$$

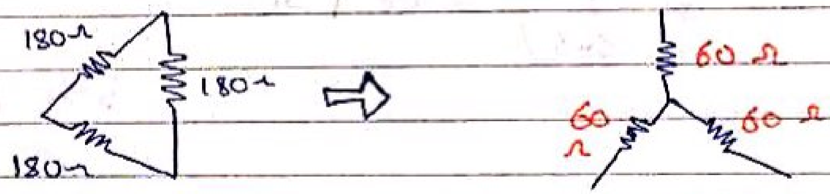
$$R_{s,pu} = \frac{0.6}{(6.6)^2/10} = 0.13 \text{ pu.}$$

Ex



$$R' = 0.6 \times \left(\frac{66}{6.6/\sqrt{3}}\right)^2$$

$= 180\ \Omega \rightarrow \Delta$ equivalent at primary.



Y-equivalent at primary

$$Z_p = 0.6\left(\frac{66}{6.6}\right)^2$$

$\therefore$ Y equivalent $\xrightarrow[\left(\frac{V_{LL}}{V_{LL}}\right)^2]{\text{transformation ratio}}$ Y equivalent

$\therefore Z_{P(pu)} = Z_{S(pu)}$ irrespective of transformer connection.

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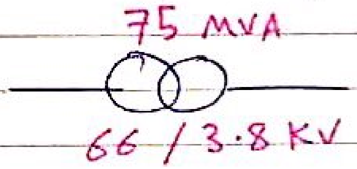
Ex 3 (1ϕ transformer, each 25 MVA, 38.1/3.8 KV are connected Y-Δ with a balanced Y-connected load "resistor" R (Ω/phase) R = 0.6 Ω, Find the Y-equivalent resistors seen at primary side?!

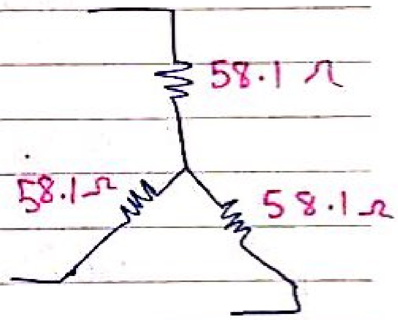
Sol: 3ϕ transformer.

$S \Rightarrow 3 \times 25 = 75$ MVA

$66 = 38.1 * \sqrt{3} \;/\; 3.8$ KV



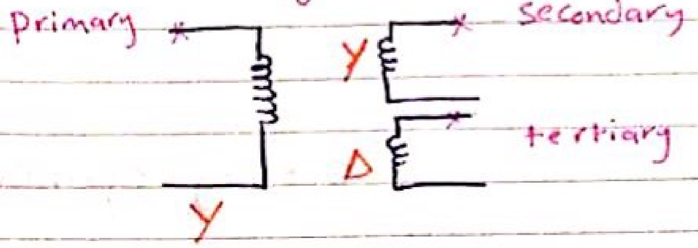
$\Rightarrow 0.6 * \left(\frac{66}{3.8}\right)^2 = 58.1\ \Omega.$



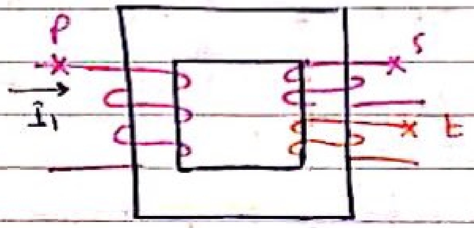
$$Y_{equivalent} \xrightarrow[\text{ratio}]{\text{transformer}} Y_{equivalent}.$$

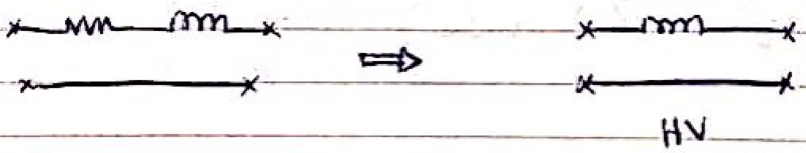
$$\left(\frac{V_{LL}}{V_{LL}}\right)^2$$

* three-winding transformer :-

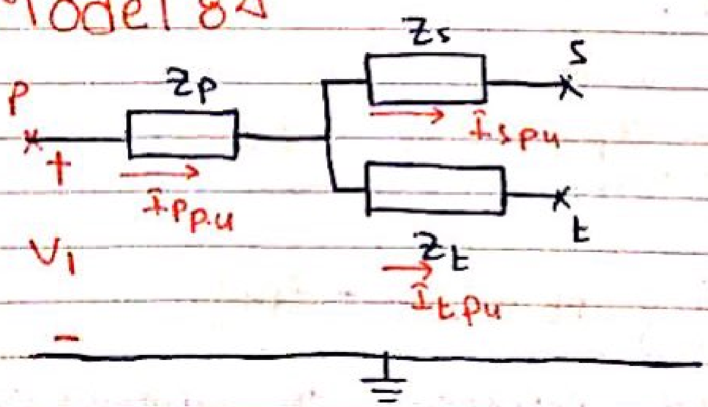


1. auxiliary voltage.
2. Reactive power compensation. "عشان ازبط ال volt"
3. harmonic Superession.





* Model 8Δ



Kashia Color
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Short circuit test :

Z_{ps}

Z_{pt}

Z_{st}.

Z_{ps} ⇒ tertiary open circuit.

seen in primary

secondary short ckt

* Z_{ps} تعني اي واقفين ع p والـ S ← S/C و t ← o/c.

based on the model :

$$Z_{ps} = Z_p + Z_s' \quad \dots (1)$$

((actual value))

$$Z_{pt} = Z_p + Z_t' \quad \text{refered to primary} \quad \dots (2)$$

$$\underbrace{Z_{st} = Z_s + Z_t'}_{\text{refered to primary}} \quad \text{refered to secondary}$$

$$Z_{st}' = Z_s' + Z_t'' \quad \dots (3)$$

$$Z_p = \frac{1}{2}(Z_{ps} + Z_{pt} - Z_{st})$$

$$Z_s = \frac{1}{2}(Z_{ps} + Z_{st} - Z_{pt})$$

$$Z_t = \frac{1}{2}(Z_{pt} + Z_{st} - Z_{ps})$$

all should reffered to primary side

KoshinColor

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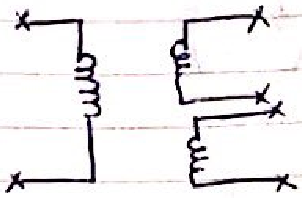


different rating.

Z_{ps}, Z_{pt}, Z_{st} [in per unit, rating winding]

all values are converted to common base.

$\boxed{\text{Ex}}$ three winding transformer

primary, Y connected, 66 KV, 15 MVA

secondary, Y connected, 13.2 KV, 10 MVA

tertiary, Δ connected, 2.3 KV, 5 MVA

short circuit test ⇨ $Z_{ps} = 7\%$ (15 MVA, 66 KV)

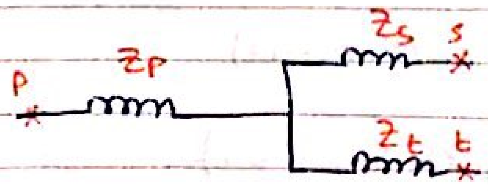
$Z_{pt} = 9\%$ (15 MVA, 66 KV)

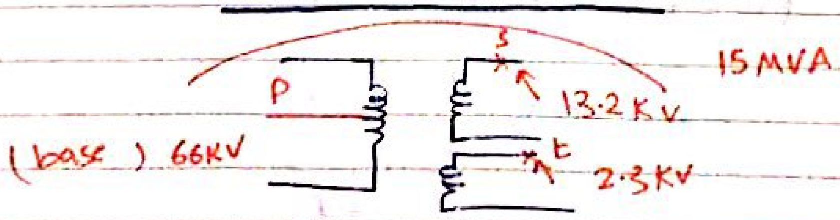
$Z_{st} = 8\%$ (10 MVA, 13.2 KV)

Draw reactance diagram base [15 MVA, 66 KW at primary] ?

"neglect resistance"

sol:





$$X_{pu,new} = X_{pu_{old}} * \left(\frac{S_{new}}{S_{old}}\right) * \left(\frac{V_{old}}{V_{new}}\right)^2$$

$$= 0.08 * \left(\frac{15}{10}\right) * \left(\frac{13.2}{13.2}\right)^2$$

$$= 0.12 \text{ pu}$$

8% (10MVA, 13.2kV)

pu (15MVA, 13.2kV)

OR $$Z_{st} \text{ (actual)} = 0.08 * \left(\frac{(13.2)^2}{10}\right) = 1.39\ \Omega$$

$$Z_{st}' = 1.39 * \left(\frac{66}{13.2}\right)^2\ \Omega.$$

$$Z_{st}' \text{ pu} = \frac{1.39 * \left(\frac{66}{13.2}\right)^2}{(66)^2/15} = 0.12 \text{ pu}$$

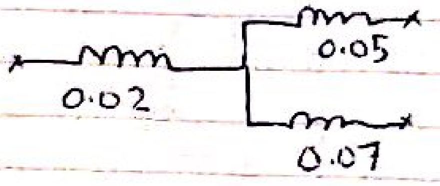
$$= \frac{0.08 * \left(\frac{13.2^2}{10}\right) * \left(\frac{66^2}{13.2^2}\right)}{66^2/15}$$

$$= 0.08 * \left(\frac{15}{10}\right) = 0.12 \text{ pu.}$$

$$Z_p = \frac{1}{2}(0.07 + 0.09 - 0.12)$$

$$Z_s = \frac{1}{2}(0.07 + 0.12 - 0.09)$$

$$Z_t = \frac{1}{2}(0.09 + 0.12 - 0.07)$$



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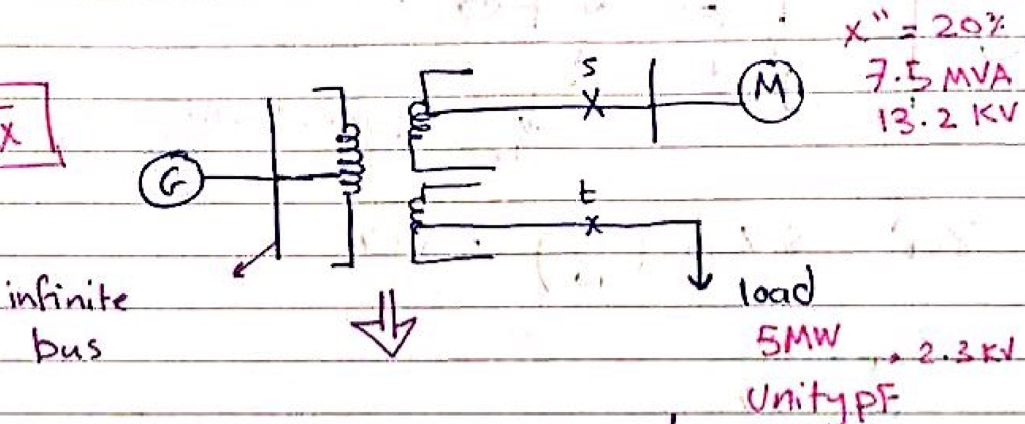
$Z_{pt}(pu) \neq Z_{tp}(pu)$

KVAR $\neq$ KVAR

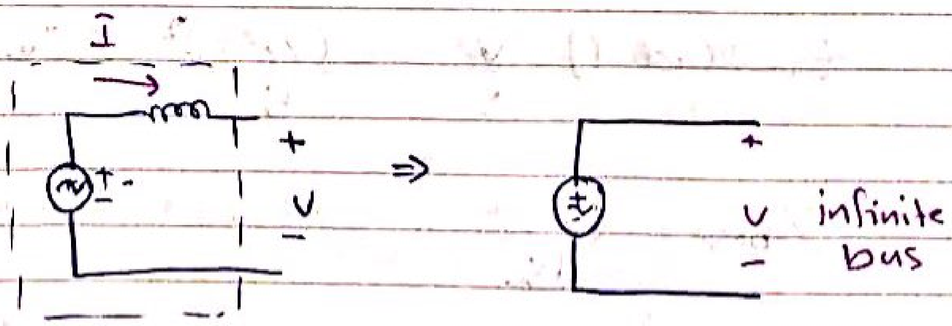
Ex



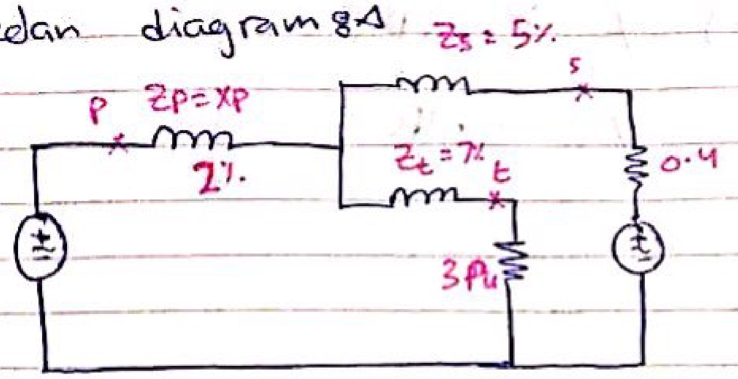
primary	15 MVA , 66 KV		$Z_{ps} = 7\%$
secondary	10 MVA , 13.2 KV		$Z_{pt} = 9\%$
tertiary	5 MVA , 2.3 KV		$Z_{st} = 8\%$

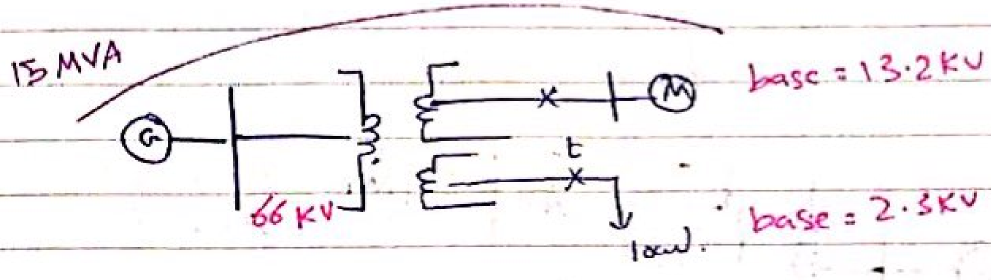
base 15 MVA , 66 KV at Generation Side.

Sol:



impedan diagram 8A





$$Z_{st}' = 8\% * \left(\frac{15}{10}\right) = 12\%$$

$Z_p = 2\%$

$Z_s = 5\%$

$Z_t = 7\%$

* Motor :-

$$X''_{motor} = 20\% * \left(\frac{15}{7.5}\right) = 0.4 \text{ pu}$$

* load :-

$$Z_{load}(\text{actual}) = \frac{V^2}{5} = \frac{(2.3K)^2}{5} = \text{"unity PF"}$$

$$Z_{base} = \frac{(2.3)^2}{15}$$

$$Z_{load}\Big|_{pu} = \frac{15}{5} = 3 \text{ Pu}$$

$$\boxed{S = \frac{P}{P.F}}$$

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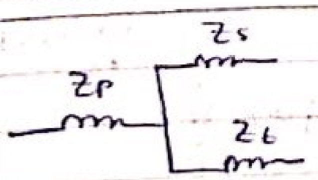
$$Z_{tp}\,(pu) = \frac{Z_t + Z_p}{(V_{LL_t})^2 / S_t}$$ ① referred to tirtiary

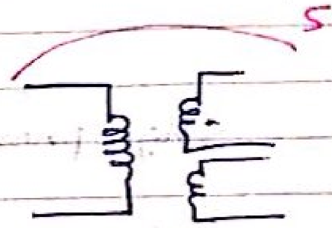


$$Z_{pt}\,(pu) = \frac{Z_p + Z_t}{(V_{LL\,p})^2 / S_{primary}}$$ ① reffered to primary.

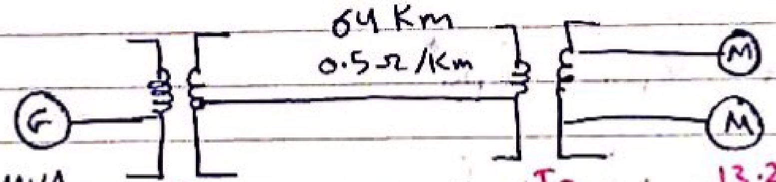
$S_{tp} \neq S_{pt}$.

reffered to common base :-

$$Z_{tp}(system)\,(pu) = Z_{pt}(system)\,(pu)$$



Ex



13.2 KV
200 MVA
$X'' = 20\%$.

300 MVA
20 KV
$X'' = 20\%$.

T_1
350 MVA
20/230 KV
$X = 10\%$.

T_2
3, 1Ø transformer
1Ø ⇒ 127/13.2 KV
100 MVA
$X = 100\%$.

13.2 KV
100 MVA
$X'' = 20\%$.

base 300 MVA, 20 KV at generation side.

Sol:

ع TL وصلني 230 عشان نقدر نحلله بكونه ⇒ T_2 (Y Δ) كيف مثلا
($\sqrt{3}(127) = Y$) ونعدين فرق الفولت نفسه Δ .

$T_2 \Rightarrow 127 * \sqrt{3}$ KV / 13.2 KV
300 MVA (3 * 100 MVA)
⇒ 220 KV / 13.2 KV , 300 MVA.

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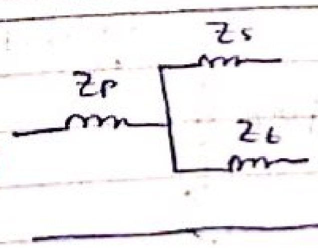
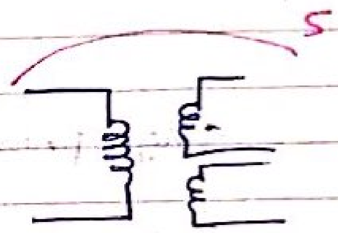
$$Z_{tp}\,(pu) = \frac{Z_t + Z_p}{(V_{LL_t})^2 / S_t}$$ ① referred to tirtiary



$$Z_{pt}\,(pu) = \frac{Z_p + Z_t}{(V_{LL\,p})^2 / S_{primary}}$$ ① referred to primary.

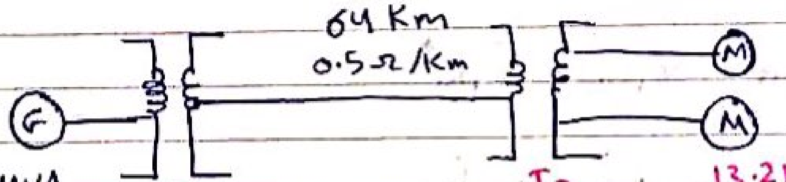
$S_{tp} \neq S_{pt}$.

reffered to common base:-



Z_{tp} (system) (pu) $=$ Z_{pt} (system) (pu)

Ex



G: 300 MVA, 20 KV, $X'' = 20\%$

T_1: 350 MVA, 20/230 KV, $X = 10\%$

T_2: 3, 1Ø transformer, 1Ø ⇒ 127/13.2 KV, 100 MVA, $X = 100\%$

M: 13.2 KV, 200 MVA, $X'' = 20\%$

M: 13.2 KV, 100 MVA, $X'' = 20\%$

base 300 MVA, 20 KV at generation side.

Sol:

عـ TL وصلي 230 عشان نقدر نحمله نكونه ⇐ T_2 (Y Δ) كيف مثلا

($\sqrt{3}(127) = Y$) وبعدين ضل الـ Volt نفسه ⇐ Δ .

$T_2 \Rightarrow 127 * \sqrt{3}$ KV / 13.2 KV

300 MVA (3 * 100 MVA)

$\Rightarrow$ 220 KV / 13.2 KV , 300 MVA.

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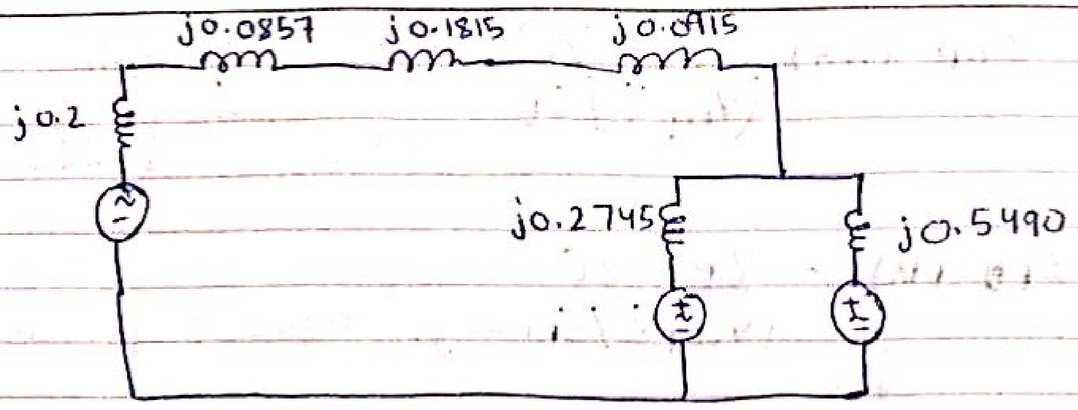

prove: $S_{pu} = |V_{pu}||I_{pu}|$ for 3ϕ system.

Single phase $\rightarrow$ $S = V I^*$

3ϕ, balanced $\rightarrow$ $S = 3 V I^*$

$S_{pu} = V_{pu} \cdot I_{pu}^*$

Sol: $S_{3\phi} = \sqrt{3}\, V_L I_L$

$$S_{3\phi\,pu} = \frac{S_{3\phi\,actual}}{S_{3\phi\,base}}$$

$$= \frac{\sqrt{3}\; V_{LL} * I_L}{\sqrt{3}\; V_{L\,base} * I_{L\,base}}$$

$$\boxed{S_{3\phi\,pu} = |V_{pu}| \cdot |I_{pu}|}$$ #

Keskin Color

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7/3 Tue

* تكملة السؤال السابق

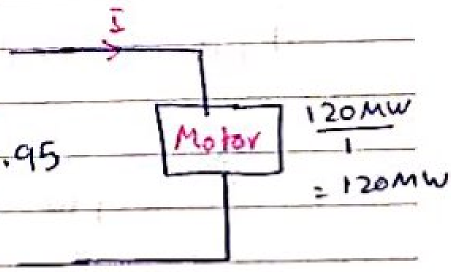
[2] If the ~~[illegible]~~ Motor have input

$M_2 : 160$ MW , [$M_1 = 120$ MW , 13.2 kV , unity PF]

Find the Voltage terminal at generator ?!

Sol:

$$V_{motor}\Big|_{pu} = \frac{13.2}{13.8} = 0.95 \text{ pu} \angle 0^\circ$$



$$S = V I^*$$

$$|S| = |V|\,|I|$$

$$\frac{120 \text{ MVA}}{3000 \text{ MVA}} = 0.95\, I_1$$

$$I_1 = \frac{120 \angle 0}{300 * 0.95} \text{ pu}$$

$$I_2 = \frac{60 \angle 0}{300 * 0.95} \text{ pu}$$

$$I = I_1 + I_2 = 0.6273 \angle 0^\circ \text{ pu.}$$

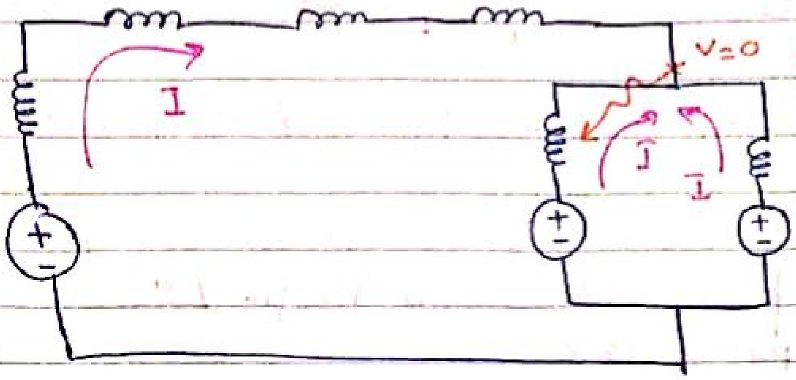
$$V = 0.6273 \angle 0 \,(j0.0857 + j0.185 + j1815 + j0.0915) + 0.95 \angle 0$$

$$\boxed{V = 0.9829 \angle 13.3^\circ}$$

$$V_{LL}(G) = 0.9829 * 20 \angle 13.3 \text{ kV}$$

$$|V_{LL}(G)| = 0.9829 * 20 \text{ kV}$$

3. if a 3ϕ fault at the Motor bus pre-fault voltage 13.2 KV, find fault current ?!



اذا صار عنا fault
ال Motor
بيقلب وبصير Gen.
بطلعلي power
+
current.

$$\hat{I}_{f\,pu} = \hat{I}_{G\,pu} + \hat{I}_{M_1\,pu} + \hat{I}_{M_2\,pu}$$

$$\hat{I}_G = \frac{E_g}{j(0.27 + 0.0857 + 0.1815 + 0.915)} \; pu$$

$$\hat{I}_{M_1} = \frac{E_{m_1}}{j(0.5490)} \; pu$$

$$\hat{I}_{M_2} = \frac{E_{m_2}}{j(0.2745)} \; pu$$

$$\hat{I}_{actual} = \hat{I}_{f\,pu} * \underbrace{\left(\frac{300\,M}{\sqrt{3} * 13.8\,K}\right)}_{\hat{I}\ base}$$

$$E_g = E_{m_1} = E_{m_2} = \frac{13.2\,K}{13.8\,K} = 0.95$$

Since the system unload ($\hat{I} = 0$)

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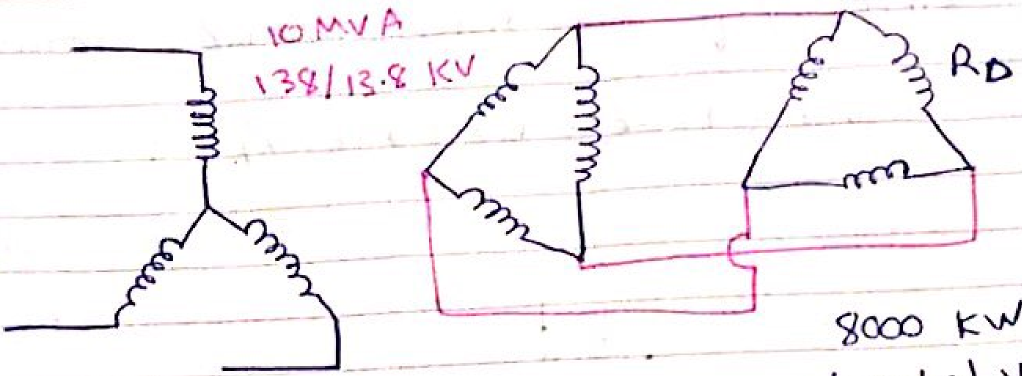
Ex



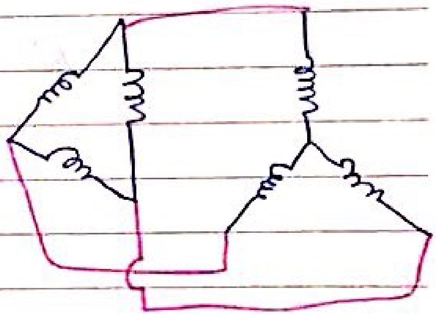
8000 KW
at rated volt
(balanced)

1 Find Yeq resistance seen from HV-side ?!

Sol: $P_{load} = 3 * \left(\frac{13.8}{R_\Delta}\right)^2 \Rightarrow$

$$8000\,k = 3 * \frac{V_L^2}{R_\Delta}$$

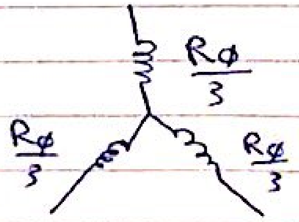
$$R_y = \frac{R_\Delta}{3} * \left(\frac{138}{13.8}\right)^2$$



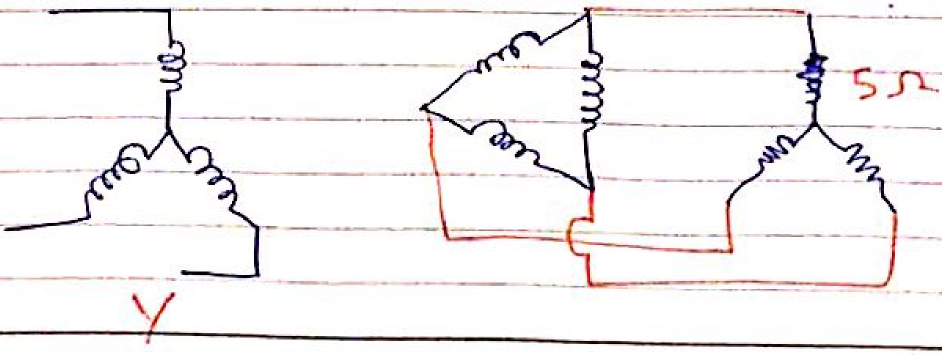
Seen HV side.

* ممكن احول ال load لـ (Y) :

$$8000\,k = \frac{3 * \left(\frac{13.8\,k}{\sqrt{3}}\right)^2}{R_\Delta/3}$$



Ex 1φ transformer (1.2/0.12 KV) 7.2 KVA
X = 0.05



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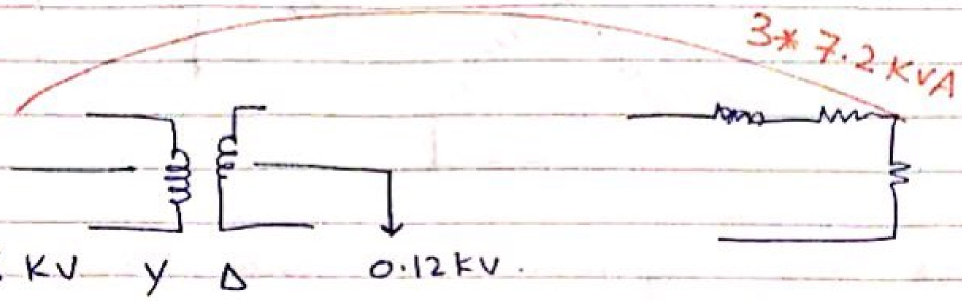
Find Y_{eq} seen from primary transformation.

ratio ($1.2 * \sqrt{3}$ KV / 0.12 KV) ?!

Sol



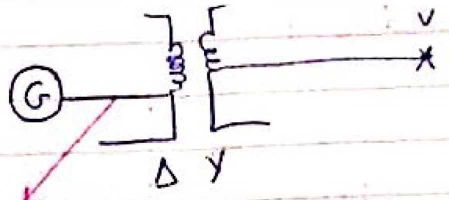
7.2 KV → for 1∅

R'_L (Y eq load resistance seen for primary)

$$R'_L = 5 * \left(\frac{1.2\sqrt{3}}{0.12} \right)^2$$

$$X' = 0.05 \left(\frac{(1.2\sqrt{3}\,k)^2}{3 * 7.3k} \right)$$

Ex :-



$V_{LL} =$ 11.9 kV

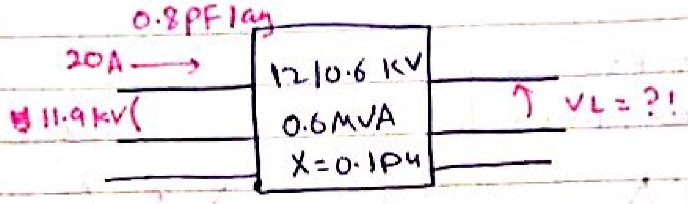
$I_L = 20$ A

p.F = 0.8 lag

0.6 MVA

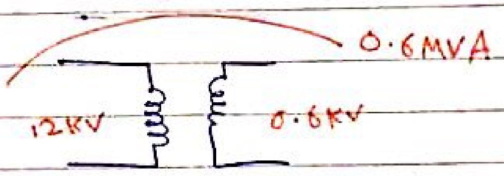
X = 0.1 pu

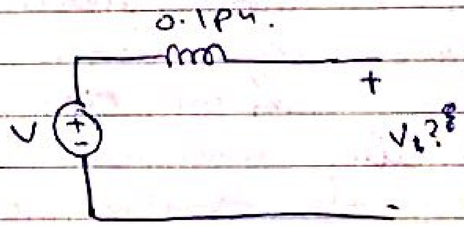
12/0.6 kV



Voltage drop — بتطلع Vpu أقل لانو في *

Sol:





$$V_{s\,pu} = \frac{11.9}{12}\ pu \angle 0^\circ$$

$$I_{\text{generator base}} = \frac{S_{base}}{\sqrt{3}\, V_{LL}} = \frac{0.6\,M}{\sqrt{3} * 12K} = 28.875\ A.$$

$$I_{pu} = \frac{20}{28.875} \angle \cos^{-1}(0.8) = 0.693 \angle -36.87^\circ\ pu.$$

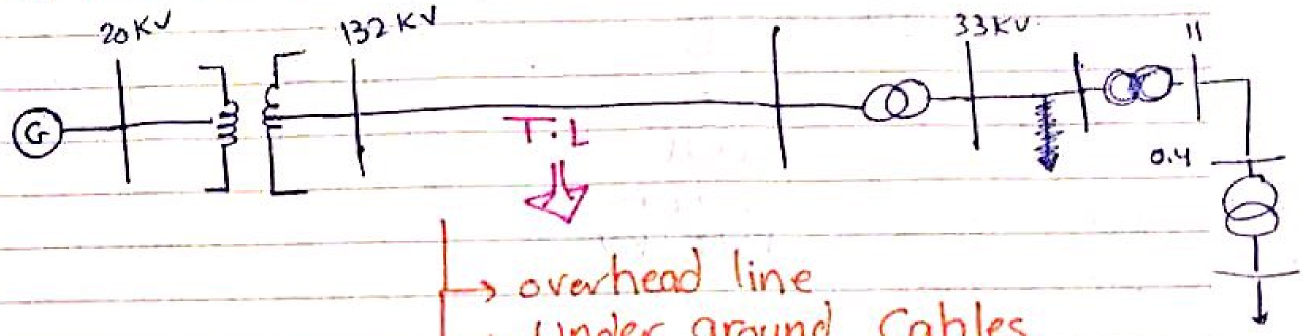
KVL:

$$V = V_s - I\,(j0.1)$$

$$V_{pu} = \frac{11.9}{12} - (0.693 \angle -36.87)(j0.1) =$$

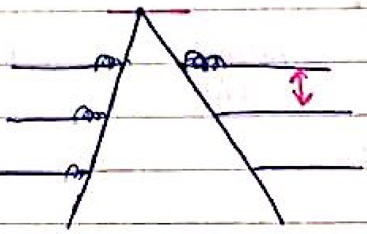
$$V_{L-L\ actual} = V_{pu} * 0.6\,K.$$

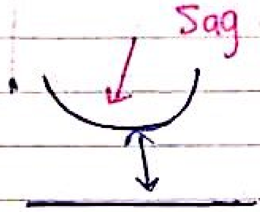
* Transmission Lines 8A



- overhead line
- Under ground Cables

[transmission networks
132 KV, 275 KV, 400 KV]

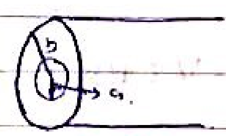




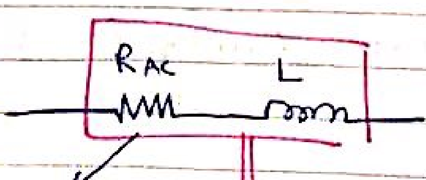
* Power flow
* Voltage and current along T.L.
* Voltage regulation.
* line compunsation techniques.
* circle diagram.

⇒ Models of transmission lines

G, L, R, C



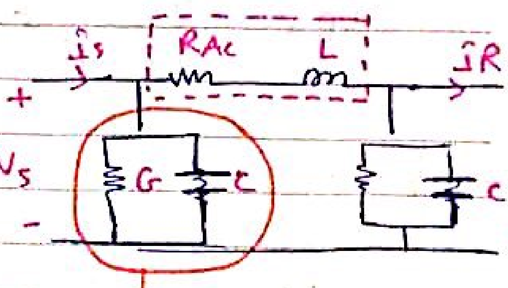
transmission line
- Short (≤ 80 Km)
- medium (80Km $\leq$ ≤ 240 Km)
- long (≥ 240 Km).



power losses

voltage drop

⇒



addmitance

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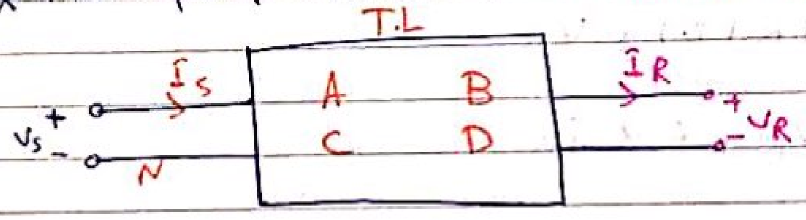
Tables $3 \times 1C \times 240\,mm^2$, Cu, XLPE.

$R(\Omega/km)$	$L(H/km)$	$C(F/m)$	G S/m

G = conductance "loss between conductors, conductors and ground"

Corona ⇒ "هي ظاهرة يصبح فيها الهواء متأين ⇐ موصل"

* Two - port network ((ABCD constant))



$$\begin{bmatrix} V_s \\ I_s \end{bmatrix} = \begin{bmatrix} A & B \\ C & D \end{bmatrix} \begin{bmatrix} V_R \\ I_R \end{bmatrix}$$

⇓

- → short
- → medium
- → long.

$V_s = A V_R + B I_R$

$I_s = C V_R + D I_R$

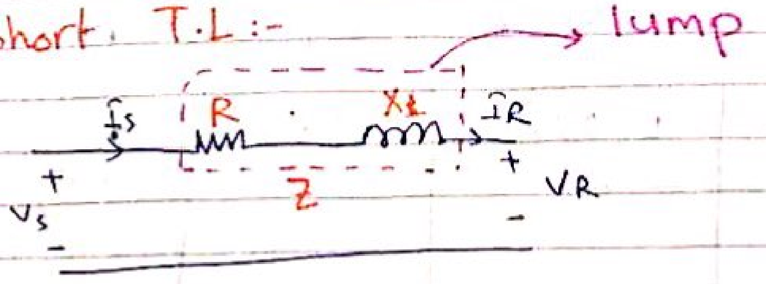
$$A = \left. \frac{V_s}{V_R} \right|_{I_R = 0} \quad ((\text{No-load}))$$

$B(\Omega)$

$C(S)$

D (dimision less).

* Short T.L :-



$R' = 0.1\ \Omega/Km$, length = 50 Km

$R = 5\Omega$

$L = H/Km$

$X_L = j\omega L = (j2\pi f * L) *$ length

$V_s = i_R(Z) + V_R$

$V_s = V_R + Z\, i_R$

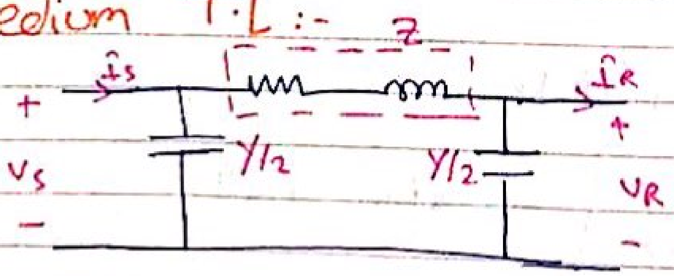
$\boxed{A = 1}$, $\boxed{B = Z}$

$i_s = i_R$

$\boxed{C = 0}$, $\boxed{D = 1}$

$AD - BC = 1$

* Medium T.L :-



$C = X\ \mu F/Km$

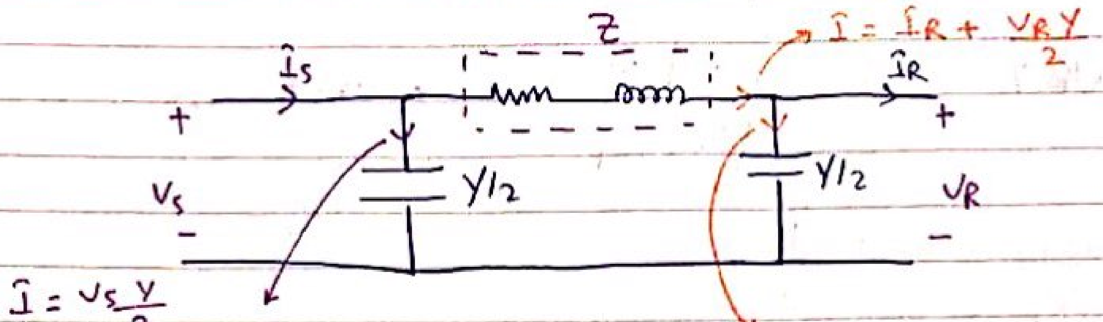
$y = j\omega c\ \ S/Km$

$Y = (j\omega c) *$ length.

Lump shunt capacitance located half at each end.

KokinColor

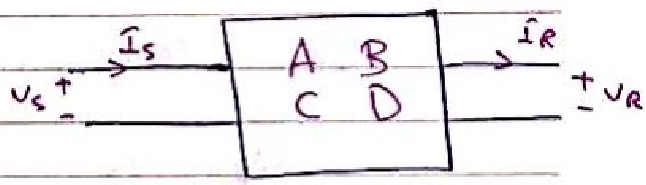
Medium transmission lines (80km - 240Km)



$Z(\Omega / Km)$

$y(S / Km)$

$$\begin{bmatrix} V_s \\ \hat{I}_s \end{bmatrix} = \begin{bmatrix} A & B \\ C & D \end{bmatrix} \begin{bmatrix} V_R \\ \hat{I}_R \end{bmatrix}$$



$$V_s = \left(\hat{I}_R + V_R \frac{Y}{2}\right) Z + V_R$$

$$V_s = \underbrace{V_R\left(1 + \frac{YZ}{2}\right)}_{A} + \hat{I}_R \underbrace{Z}_{B}$$

A (diminlion loss) B (Ω)

$$\hat{I}_s = \frac{V_s Y}{2} + \hat{I}_R + \frac{V_R Y}{2}$$

$$\hat{I}_s = V_R\left[Y\left(1 + \frac{YZ}{4}\right)\right] + \hat{I}_R\left[1 + \frac{YZ}{2}\right]$$

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

$\Rightarrow B = Z$

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

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* Voltage Regulation :-

$$VR\% = \frac{|V_{RNL}| - |V_{RFL}|}{|V_{RFL}|} * 100\%$$

V_{RNL} = No load
V_{RFL} = Full load

V_s fixed.

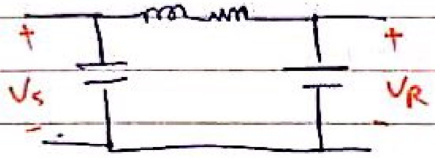
V_{RNL} — No load
↓
V_{RFL}. — Full load

$V_s = A V_R + B I_R$ at No load $I_R = 0$.

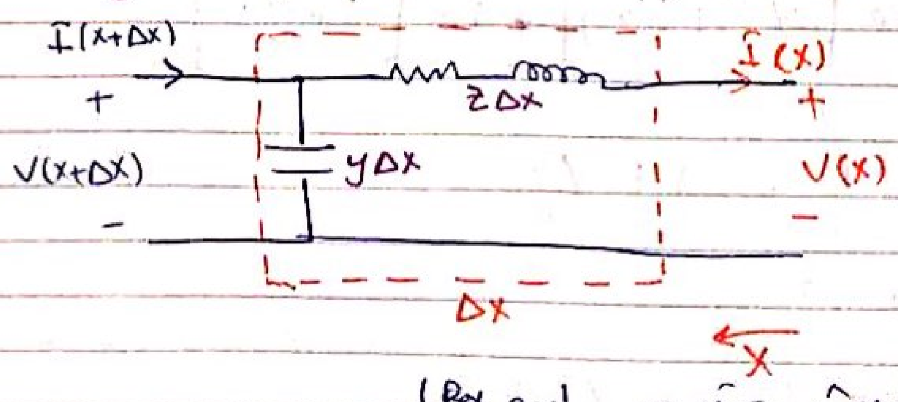
$V_R = \frac{V_s}{A}$ $\boxed{A \approx 1}$

$V_R > V_s$ under No load condition.

(($V_{FL} < V_{RNL}$)) *



* Long Transmission lines ($\geq$ 240km)



x = (قديش بتبعد عن Rec end)

$*$ $V_{nominal} = 230V$
$V.D\% = 6\%$
$V = 94\% * 230$

length $= L$
$V(x=L)$

$V_R = V(x=0)$

$V(x+\Delta x) = V(x) + (Z\Delta x)\hat{I}(x)$

$$\frac{V(x+\Delta x) - V(x)}{\Delta x} = Z\,\hat{I}(x).$$

$\Delta x \longrightarrow 0$

$$\boxed{\frac{\partial V(x)}{\partial (x)} = Z\,\hat{I}(x)} \longrightarrow (1)$$

$\hat{I}(x+\Delta x) = \hat{I}(x) + V(x+\Delta x)\,y\,\Delta x$

$$\therefore \frac{\hat{I}(x+\Delta x) - \hat{I}(x)}{\Delta x} = V(x+\Delta x)\,y$$

$\Delta x \longrightarrow 0$

$$\boxed{\frac{\partial \hat{I}(x)}{\partial x} = y\,V(x)} \longrightarrow (2)$$

$$\frac{\partial^2 V(x)}{\partial (x)} = Z\frac{\partial \hat{I}(x)}{\partial (x)}$$

$$\boxed{\frac{\partial^2 V(x)}{\partial (x)} = Zy\,V(x)}$$

$$\boxed{\frac{\partial^2 \hat{I}(x)}{\partial (x)} = \underbrace{Zy}_{\gamma^2}\,\hat{I}(x)}$$

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$V(x) = A_1 e^{\gamma x} + A_2 e^{-\gamma x}$

x → distance from load

$\gamma \triangleq$ propagation constant.

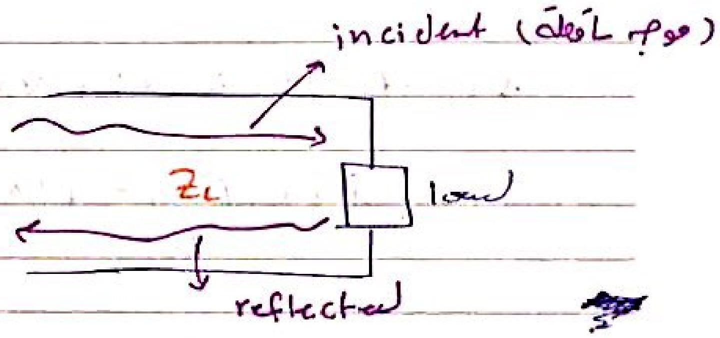
$\gamma = \sqrt{yz}$

$= \alpha + j\beta$

α → attenuation constant

β → phase constant

I $\dfrac{\partial V(x)}{\partial x} = A_1 \gamma e^{\gamma x} - A_2 \gamma e^{-\gamma x}$



$\dfrac{\partial V(x)}{\partial (x)} = z\, I(x)$

$I(x) = \dfrac{A_1 e^{\gamma x} - A_2 e^{-\gamma x}}{z/\gamma}$

$\dfrac{z}{\gamma} = \dfrac{z}{\sqrt{yz}} = \sqrt{\dfrac{z}{y}}$

$$\boxed{I(x) = \dfrac{A_1 e^{\gamma x} - A_2 e^{-\gamma x}}{\sqrt{z/y}}}$$

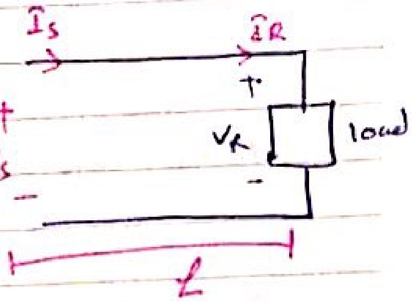
Z_c (c/s impedence)

14/3 Tue

long transmission line :-

$$V(x) = A_1 e^{\gamma x} + A_2 e^{-\gamma x}$$

$$I(x) = \frac{A_1 e^{\gamma x} - A_2 e^{-\gamma x}}{Z_c}$$



$A_1, A_2 = ?!$

Initial condition $x=0 \Rightarrow V(x=0) = V_R$
$I(x=0) = I_R$

$$A_1 + A_2 = V_R \quad \ldots \text{(1)}$$

$$\frac{A_1 - A_2}{Z_c} = I_R \quad \ldots \text{(2)}$$

$$\boxed{A_1 = \frac{V_R + Z_c I_R}{2}}$$

$$\boxed{A_2 = \frac{V_R - Z_c I_R}{2}}$$

$$V(x) = \frac{V_R + Z_c I_R}{2} e^{\gamma x} + \frac{V_R - Z_c I_R}{2} e^{-\gamma x}$$

$\Rightarrow$ $Z(\Omega/Km) = r + j\omega L$, $y(S/Km) = j\omega C \rightarrow \frac{MF}{Km}$

$\frac{\Omega}{Km}$ $\frac{H}{Km}$

$$\gamma = \sqrt{Zy} = \alpha + j\beta$$

$$Z_c = \sqrt{\frac{Z}{y}}$$

$$I(x) = \frac{((V_R + Z_c I_R)/2)\, e^{\gamma x} - ((V_R - Z_c I_R)/2)\, e^{-\gamma x}}{Z_c}$$

$$V(x) = V_R\left(\frac{e^{\gamma x} - e^{-\gamma x}}{2}\right) + \hat{I}_R Z_c\left(\frac{e^{\gamma x} - e^{-\gamma x}}{2}\right)$$

$$\boxed{V(x) = V_R \cosh\gamma x + \hat{I}_R Z_c \sinh\gamma x.}$$

$$\hat{I}(x) = \frac{V_R}{Z_c}\left(\frac{e^{\gamma x} - e^{-\gamma x}}{2}\right) + \hat{I}_R\left(\frac{e^{\gamma x} + e^{-\gamma x}}{2}\right)$$

$$\boxed{\hat{I}(x) = \frac{V_R}{Z_c}\sinh\gamma x + \hat{I}_R \cosh\gamma x}$$

((receiving end من بدأت X))

* at sending end $(x = l)$

$$V(x=l) = V_S = V_R \cosh\gamma l + \hat{I}_R Z_c \sinh\gamma l.$$

$$\hat{I}(x=l) = \hat{I}_S = \frac{V_R}{Z_c}\sinh\gamma l + \hat{I}_R \cosh\gamma l.$$

$A = \cosh\gamma l$

$B = Z_c \sinh\gamma l$

$C = \frac{\sinh\gamma l}{Z_c}$

$D = \cosh\gamma l$

$AD - BC = 1$

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$$\cosh \gamma \ell = \frac{1}{2}\left(e^{\gamma \ell} + e^{-\gamma L}\right)$$

$$\boxed{\gamma = \alpha + jB}$$

$$\cosh \gamma \ell = \frac{1}{2}\left(e^{\alpha \ell} e^{jB\ell} + e^{-\alpha L} e^{-jBL}\right)$$

$$* \boxed{\cosh \gamma L = \frac{1}{2}\left(e^{\alpha L}\angle B\ell + e^{-\alpha L}\angle -B\ell\right)}$$

$$* \boxed{\sinh \gamma \ell = \frac{1}{2}\left(e^{\alpha L}\angle BL - e^{-\alpha L}\angle -BL\right).}$$

$\angle BL \Rightarrow$ radian $\Rightarrow$ نحولها لل degree
عشان نحلها ع calculator.

OR 8

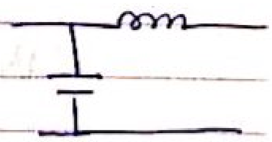
$$\boxed{\cosh(\alpha + jBL) = \cosh(\alpha e)\cos(BL) + j\sinh(\alpha L)\sin(BL)}$$

$$\boxed{\sinh(\alpha + jBL) = \sinh(\alpha L)\cos(BL) + j\cosh(\alpha L)\sin(BL)}$$

$A = \cosh \gamma L$, $B = Z_c \sinh \gamma \ell$

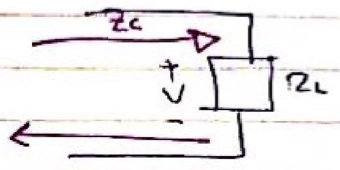
$C = \dfrac{\sinh \gamma L}{Z_c}$, $D = \cosh \gamma L$.

* Lossles T.L 8Δ $(R = G = 0)$



$z = j\omega L$, $y = j\omega c$

$$Z_c = \sqrt{\frac{z}{y}} = \sqrt{\frac{L}{c}} \ \Omega \ \text{((real))}$$



$\gamma = \sqrt{zy} = \alpha + j\beta$

$= \sqrt{j\omega L \; j\omega C}$

$= j\omega\sqrt{LC}$

$\boxed{\alpha = 0}$

$\boxed{\beta \text{ (phase constant)}}$

$A = \cosh \gamma l = \frac{1}{2}\left(e^{\alpha L}\angle \beta L + e^{-\alpha L}\angle -\beta L\right)$

$\Rightarrow$ lossles

$\alpha = 0$

$A = \frac{1}{2}\left(\angle \beta L + \angle -\beta L\right) = \frac{1}{2}\left(e^{j\beta L} + e^{-j\beta L}\right)$

$\boxed{A = \cos \beta L = D}$

$B = Z_c \sinh \gamma L$

$\sinh \gamma L = \frac{1}{2}\left(e^{\alpha L}\angle \beta L - e^{-\alpha L}\angle -\beta L\right) = \frac{1}{2}\left(1\angle \beta L - 1\angle \beta L\right)$

$= j \sin \beta L$

$\boxed{B = Z_c (j \sin \beta L)}$

$\boxed{C = \frac{j \sin \beta L}{Z_c} = \frac{j \sin \beta L}{\sqrt{L/C}}}$

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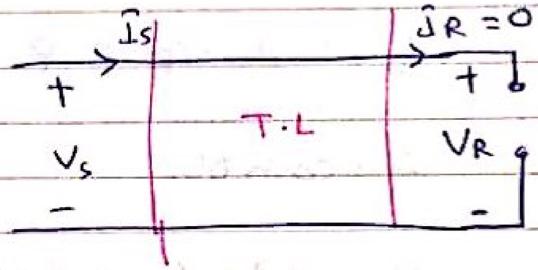
lossless ⇒ $A = \cos \underbrace{\beta L}_{real}$, $B = j Z_c \sin \beta L$

$C = \dfrac{j \sin \beta L}{Z_c}$, $D = \cos \beta L$.

$A \Rightarrow 1$ اعلى قيم أقل من ، $B \rightarrow \theta = 90^\circ$ اعلى قيم

at O.C :

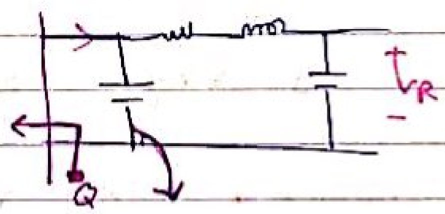
$V_s = A V_R + B \cancel{I_R}^{0}$



$$\boxed{V_R = \frac{V_s}{A} = \frac{V_s}{\cos \beta L}}$$

↳ voltage rise.

$I_s = C V_R + D \cancel{I_R}^{0}$



$I_s = \dfrac{j \sin \beta L}{Z_c} V_R$

Charging current

☑ لو ما عندي load باوه عندي تيار في Cap.

$$\boxed{|I_s| = \frac{\sin \beta L}{Z_c} V_R}$$

Q بتزيد عندي لما اكون في حالة العاصمة فاصدي الكول ← أطفي الخط

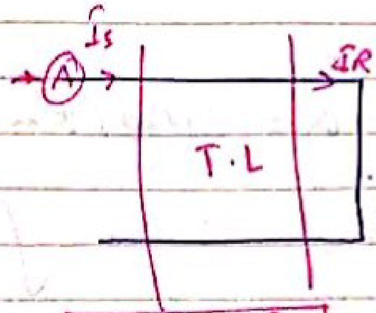
↳ اضيف L «بتشحن».

at S.C :-

$V_R = 0$

$V_s = A \cancel{V_R}^{0} + B I_R$

$I_s = C \cancel{V_R}^{0} + D I_R$



$$\boxed{I_R \neq I_s}$$

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Ex 370 Km T.L, $Z = 0.5240\angle 79.04$ Ω/Km

$y = 3.1728 \times 10^{-6}$ S/Km ($\Rightarrow j\omega c \angle 90^\circ$)

load 125 MW, 215 KV, unity pF.
Find V_s, I_s, P_s, V.R% ?!

sol: $Z = r + j\omega L \rightarrow \angle Z \rightarrow \angle 60^\circ - 90^\circ$

$V_s = A V_R + B I_R$

$A = \cosh \gamma L$

$\gamma L = \sqrt{zy}\, L = \sqrt{(zL)(yL)} = \sqrt{ZY}$

$\gamma = \sqrt{zy} = \sqrt{0.5240\angle 79.04 * 3.1728\times10^{-6}\angle 90^\circ}$

* بدي اطلع γ ⇐ بضرب الـmagnitude والزاوية ← بجمع وبقسم على 2 للحصول على الجذر.

$= \sqrt{0.5240 + 3.1728} \angle \dfrac{79.04 + 90}{2}$

$= \underbrace{0.0456}_{\alpha L} + j \underbrace{0.4750}_{BL}$

$\gamma = \alpha + jB$

$\gamma L = \alpha L + jBL$

$B \triangleq$ phase constant $= \dfrac{0.4750}{370} = 0.001284$ rad/Km

$\alpha =$ Nep/Km

$Z_c = \sqrt{\dfrac{z}{y}} = \sqrt{\dfrac{0.5240\angle 79.04}{3.1728 * 10^{-6}\angle 90^\circ}}$

* عشان اطلع Z_c ← نقسم الـmagnitude والزاوية ← بطرح وبقسم على 2 عشان الجذر، نقسم على 2.

$\angle Z \rightarrow 60 \rightarrow 90^\circ$
$\angle y \rightarrow 90^\circ$
$Z_c \rightarrow -30$ $(60 - 90)$
$Z_c = \sqrt{-30}$
range $Z_c \rightarrow (-15^\circ \rightarrow 0^\circ)$

$$Z_c = \sqrt{\frac{0.5240}{3.1728\times10^{-6}}} \angle \frac{79.04-90^\circ}{2}$$

$$= \underbrace{406.4}_{} \angle -5.48 \ \Omega .$$

↳ OHL ⇒ 400 Ω.

$V_S = A V_R + B \hat{I}_R$, per phase.

$$V_{RLN} = \frac{215K}{\sqrt{3}} = 124.13 KV \angle 0^\circ$$

$$= 124.13 \angle 0^\circ \ KV.$$

↳ refrence.

$\hat{I}_R$?! → $S = \sqrt{3} V_L \hat{I}_R$

$$\frac{25MW}{1} = \sqrt{3} * 251K * I_L$$

$$\boxed{I_L = 335.7 \angle 0}$$

$$\cosh \gamma L = \frac{1}{2}\left(e^{\alpha L}\angle BL + e^{-\alpha L}\angle -BL\right)$$

$\alpha L = 0.0456$, $\beta L = 0.4750$ rad.

$$\cosh \gamma L = \frac{1}{2}\left(e^{0.0456}\angle 27.22^\circ + e^{-0.0456}\angle -27.22^\circ\right)$$

$$\boxed{\cosh \gamma L = 0.8904 \angle 1.34^\circ}$$

$$\sinh \gamma L = \frac{1}{2}\left(e^{\alpha L}\angle BL - e^{-\alpha L}\angle -BL\right)$$

$$\boxed{\sinh \gamma L = 0.4597 \angle 84.93^\circ}$$

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$V_S = \cosh \gamma L \, V_R + Z_c \sinh \gamma L \, I_R$

$A = \cosh \gamma L$

$= 0.8904 \angle 1.34^\circ$

$0.8 \leq A \leq 1$

$0^\circ \leq \angle A \leq 5^\circ$

$B = Z_c \sinh \gamma L =$

$= 406 \angle -5.4 * [0.45 \angle 84.93^\circ$

$\boxed{B \approx \angle 90^\circ}$

$V_{S_{LN}} = 137 \angle 27.77^\circ$ kV

$I_S = C V_R + D I_R$

$= 332.31 \angle 26.33^\circ$

$P_S = Re\{3 V_S I_S^*\}$

$= \sqrt{3} \, I_L V_L \cos(\angle V - \angle I)$

$= \sqrt{3} * [\sqrt{3} * 137k * 332 * \cos(\angle 27.77 - 26.33^\circ)$

$= 137.4$ MW

$$VR\% = \frac{|V_{RNL}| - |V_{RFL}|}{|V_{RFL}|}$$

(fixed) 

VR يعني "قديش تغير في الـ volt لما تقيم الـ load."

at No-load $(\hat{I}_R = 0)$

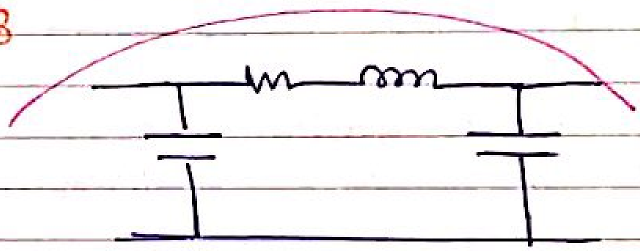
$V_S = A V_R + \cancel{B\hat{I}_R}$

$V_{RNL} = \dfrac{V_S}{A} = \dfrac{137\,KV}{0.89}$

$VR\% = \dfrac{\frac{137\,KV}{0.89} - 124K}{124K} * 100\%$

$= 24.7\%$

In PU :



215 KV
125 MVA
→ base

$V_{R\,pu} = \dfrac{215\,KV}{215\,KV} = 1\angle 0 \ pu.$

$\hat{I}_R = ?!$

$S_{pu} = V_{pu} \cdot \hat{I}^*_{pu}$

$\dfrac{125}{125} = 1 * \hat{I}^*_{pu} \rightarrow \hat{I}_{pu} = 1\angle 0^\circ$

$V_{Spu} = A V_R + B\hat{I}_R = \underbrace{\cosh\gamma L}_{pu.} \underbrace{V_R}_{pu} + \underbrace{Z_c \sinh\gamma L}_{\Omega} \underbrace{\hat{I}_R}_{pu}.$

$Z_{base} = V^2/S$

$= \dfrac{(215)^2}{125} = 370\,\Omega$

$V_{pu} = 1.102\angle 27.75 \ pu$

① 10% رفع الـ Volt بمقدار ⇐ ②
(voltage Resiving) V_R بالنسبة لـ

بدي أقللها عن طريق
أضيف C $(\Delta V \propto Q)$

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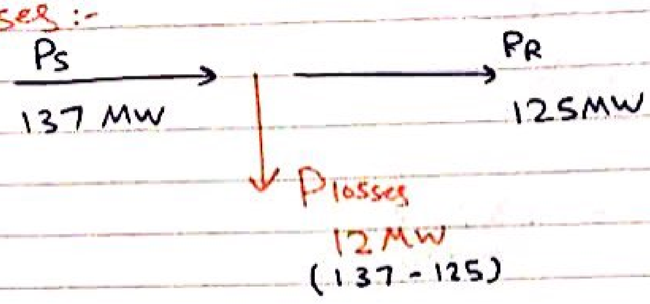
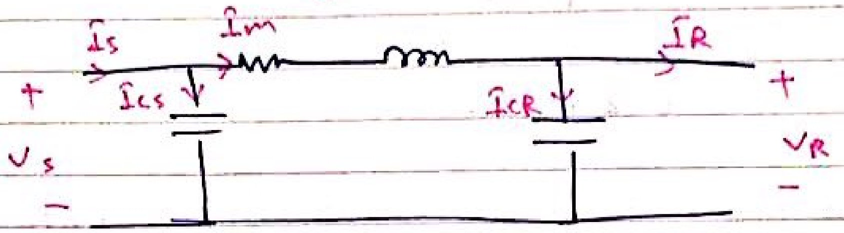
losses :-

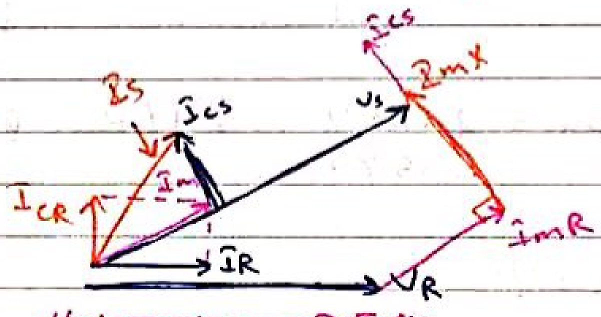


* Phasor diagram :



$\hat{I}_{cs}$ ≡ current capasitior sending.
$\hat{I}_{cR}$ ≡ " " resiving.

unity P.F:



~~((lagging P.F))~~

$$V_s = \overrightarrow{I_m R} + j\overrightarrow{I_m X} + V_R$$

$V_s > V_R$
$\angle V_s > \angle V_R$

$\hat{I}_s < \hat{I}_R$

$\hat{I}_s = \hat{I}_m + \hat{I}_{cs}.$

I_c
I_m > عند I_s

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

$i = C\frac{d}{dt}(ve^{j\omega t})$

$i = \underbrace{j}_{90^\circ}\omega C\frac{dv}{dt}$

* $\hat{I}_c < \hat{I}_R$
لانه داخل
ال model

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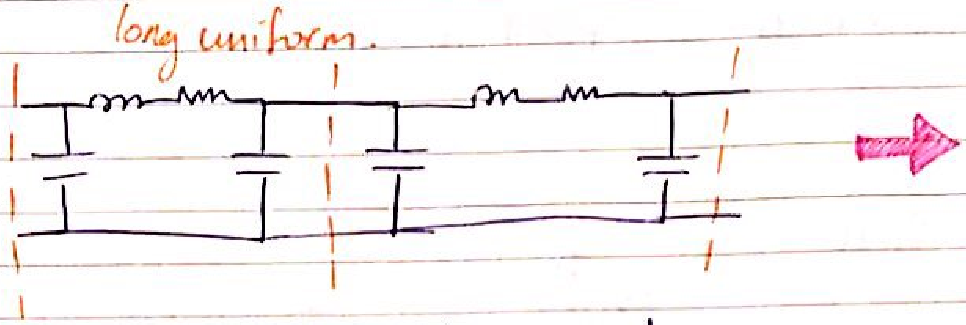
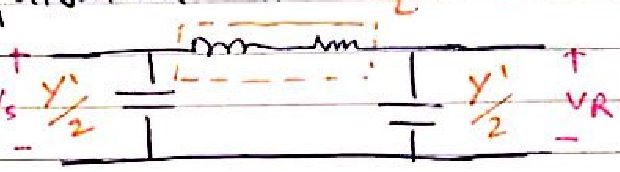
π equivalent ckt of along line. 8∆



uniform distributed

equivalent π



A constant (π model) = $1 + \frac{Y'Z'}{2}$

B constant. (π model) = Z' ~~sin~~

$$\boxed{Z' = Z_c \sinh \gamma L} \quad \cdots ①$$

$$Z' = \left(\sqrt{\frac{z}{y}} \sinh \gamma L\right) * \frac{zL}{zL}$$

$$Z' = zL \sqrt{\frac{z}{yz^2L^2}} \sinh \gamma L$$

$$= Z \sqrt{\frac{1}{zy\ell^2}} \sin \gamma L$$

$\sqrt{zy} = \gamma$.

$$= Z * \frac{\sin \gamma L}{\gamma L}$$

exact

$$\boxed{Z' = Z * \frac{\sin \gamma L}{\gamma L}}$$

correction factor ≈ 1

$$1 + \frac{Y' Z'}{2} = \cosh \gamma L$$

$$\frac{Y'}{2} = \frac{\cosh \gamma L - 1}{Z'}$$

$$\boxed{\frac{Y'}{2} = \frac{\cosh \gamma L - 1}{Z_c \sinh \gamma L}} \qquad \boxed{Z' = Z_c \sinh \gamma L}$$

$$\frac{Y'}{2} = \frac{Y}{2} * \text{correction factor.}$$

$$\frac{\cosh \gamma L - 1}{\sin \gamma L} = \tanh \gamma L/2$$

$$\frac{Y'}{2} = \frac{\tanh \gamma L/2}{Z_c} = \left(\frac{\tanh \gamma L/2}{\sqrt{Z/y}} \right) * \frac{yL/2}{yL/2}$$

$$\frac{Y'}{2} = \frac{yl}{2} \frac{\tanh \gamma L/2}{\sqrt{Z/y * y^2 * L/2}}$$

$$\frac{Y'}{2} = \frac{Y}{2} \left[\frac{\tanh \gamma L/2}{\gamma L/2} \right]$$

correction factor ≈ 1

*لما حط Z' ← طلع ال exact.

*لما حط Z ← بطلع ال approximation.

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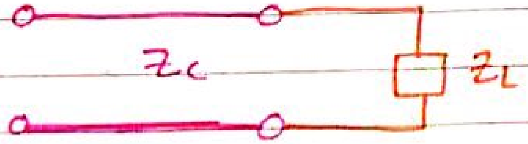
* Surge impedance loading 8Δ



line is terminated by its C/S impedance (Z_c)

$$\boxed{Z_L = Z_c}$$

$$Z_c = \sqrt{Z/y}$$

lossless ⇒ $Z_c = \sqrt{\dfrac{j\omega L}{j\omega C}} = \sqrt{\dfrac{L}{C}}$

* overhead line. 8

132 KV	150 Ω
275 KV	315 Ω.

cables :-

132 KV	37.1 Ω.
275 KV	50.4 Ω.

* Capacitance (Q يطلع)

21/3 Tue

Surge Impedance loading

$$Z_L = Z_c$$

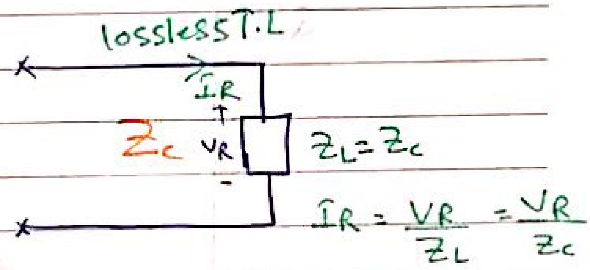
* lossless T.L

$Z_L = \sqrt{\frac{L}{C}}$, real number.

Voltage is constant $\Rightarrow V = V_R \angle \beta x$

current is constant $\Rightarrow I = I_R \angle \beta x$

$$SIL = \frac{(V_{rated})^2}{Z_c}$$



$$V_S = A V_R + B I_R$$

$V(x)$

↳ distance from load

$\boxed{X = L}$

$$V(x) = \cos \beta x \, V_R + j Z_c \sin \beta x \, I_R$$

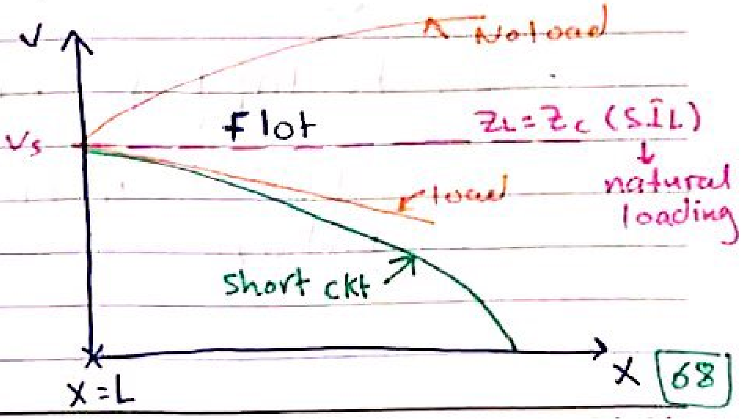
$$V(x) = \cos \beta x \, V_R + j \cancel{Z_c} \sin \beta x \, \frac{V_R}{\cancel{Z_c}}$$

$$V(x) = \cos \beta x \, V_R + j \sin \beta x \, V_R$$

$$V(x) = V_R (\cos \beta x + j \sin \beta x)$$

$$V(x) = V_R e^{j\beta x} = V_R \angle \beta x$$

$$|V(x)| = V_R$$



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$$I(x) = I_R \angle \beta x$$
$$V(x) = V_R \angle \beta x$$

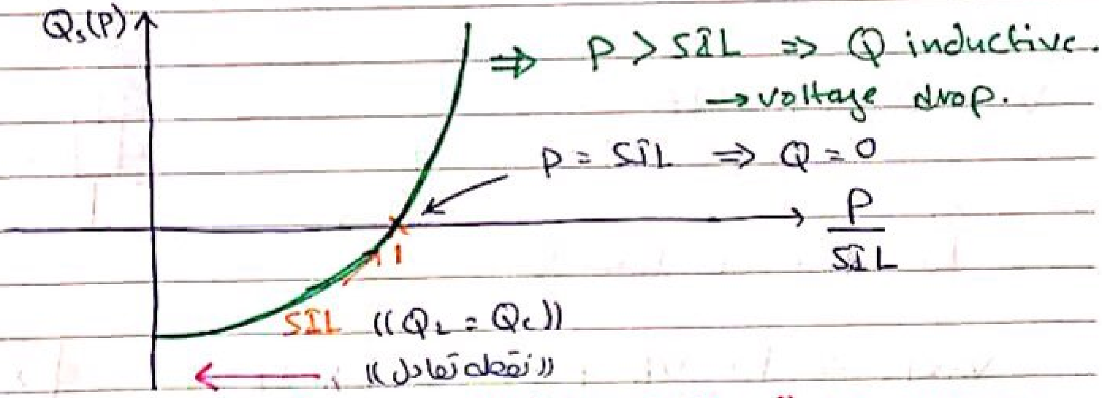
$$SIL = 3 * \frac{|V_{R\,LN}|^2}{Z_c} \text{ MW}$$

$Z_c \longrightarrow$ resistance " lossless T.L "

$$SIL = 3 * \frac{\left(\frac{V_{LL}}{\sqrt{3}}\right)^2}{Z_c}$$

$$SIL \triangleq \text{natural loading} = \frac{V_{LL}^2}{Z_c} = \frac{(V_{L\,rated})^2}{Z_c} \text{ MW}$$

$$Z_c = \sqrt{\frac{L}{C}} \quad \text{in lossless.}$$



$P < SIL \Rightarrow Q$ " capacitive " $\Rightarrow$ voltage rise

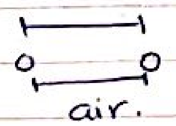
$$SIL = \frac{(V_{rated})^2}{Z_c} = \frac{(V_{rated})^2}{\sqrt{L/C}} \text{ MW}$$

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

$$L = K \ln\left(\frac{D}{r}\right) \quad , D \equiv \text{spacing} \quad H/Km$$

$$C = \frac{K}{\ln(D/r)} \quad \mu F/Km.$$, $D \equiv$ spacing between conductors.

Over head line (OHL).



" D_{in} cables < D_{in} OHL "

" $L_{OHL} > L_{cables}$. "

" $C_{OHL} < C_{cables}$ "

" $Z_{c\,cables} < Z_{OHL}$. "

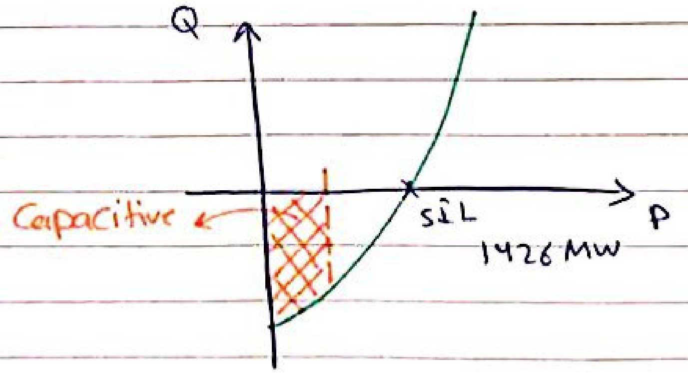
" $\hat{SIL}_{cables} > \hat{SIL}_{OHL}$ "

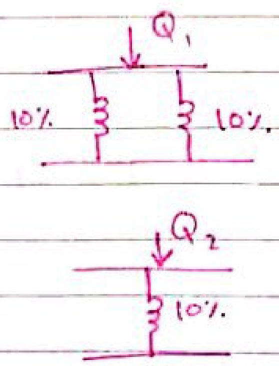
at 275 KV.

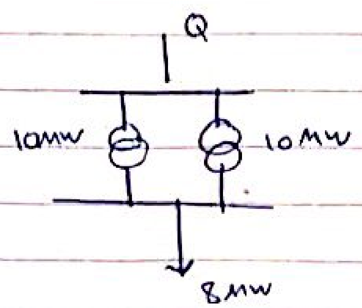
$SIL_{OHL} = 240$ MW

$\hat{SIL}_{cables} = 1426$ MW

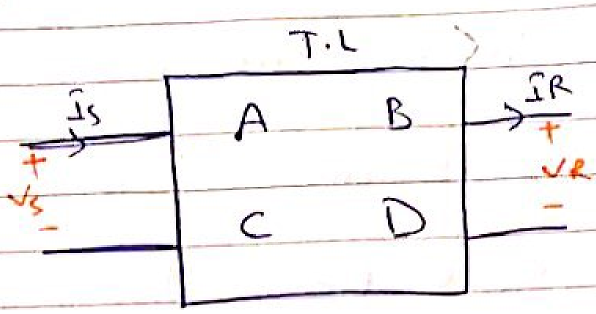
" injecting Q "   ((capacitive ⇐ يكون غالباً cables))







Complex power flow throughout T.L :-



$$\begin{bmatrix} P_R \\ Q_R \\ P_s \\ Q_s \end{bmatrix} = f\begin{pmatrix} A & B \\ C & D \end{pmatrix}$$

* Circle diagram [maximum power through T.L]

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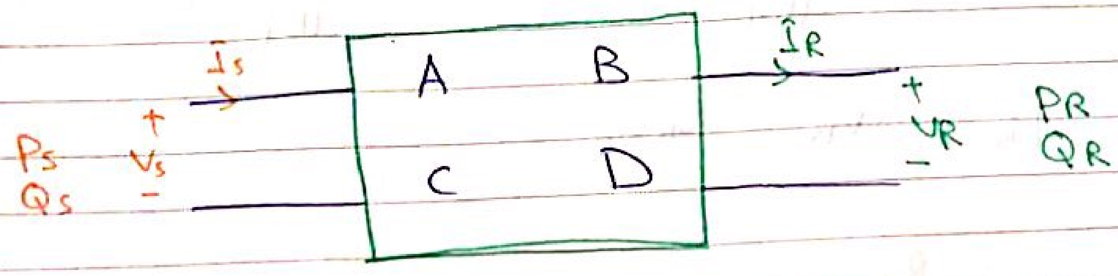
Complex power flow through transmission lines.



$A = |A| \angle \theta_A$

$B = |B| \angle \theta_B$

$V_s = |V_s| \angle \delta$

$V_R = |V_R| \angle 0$

$$V_s = A V_R + B \hat{I}_R \quad , \quad S_R = V_R \hat{I}_R^*$$

$$\hat{I}_R = \frac{V_s - A V_R}{B}$$

$$\hat{I}_R = \frac{|V_s| \angle \delta - |A||V_R| \angle \theta_A}{|B| \angle \theta_B}$$

$$S_R = V_R \cdot \hat{I}_R^*$$

$$= V_R \cdot \left(\frac{|V_s| \angle \delta - |A||V_R| \angle \theta_A}{|B| \angle \theta_B} \right)^*$$

$$S_{R1\phi} = \frac{|V_{R\,LN}||V_{S\,LN}|}{|B|} \angle \theta_B - \delta - \frac{|A||V_R|^2}{|B|} \angle \theta_B - \theta_A$$

$$S_{R3\phi} = 3 \left(\frac{\frac{|V_{R\,LL}|}{\sqrt{3}} * \frac{|V_{S\,LL}|}{\sqrt{3}}}{|B|} \angle \theta_B - \delta - \frac{|A| \frac{|V_{R\,LL}|^2}{\sqrt{3}}}{|B|} \angle \theta_B - \theta_A \right)$$

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V_{LL}

$$S_{3\phi} = \frac{|V_s||V_R|}{|B|}\angle\theta_B-\delta \;-\; \frac{|A||V_R|^2}{|B|}\angle\theta_B-\theta_A$$

$$P_R + jQ_R = S_{R3\phi}$$

$$P_R = Re\{S_{R3\phi}\}$$

$$P_R = \frac{|V_s||V_R|}{|B|}\cos(\theta_B-\delta) - \frac{|V_R|^2|A|}{|B|}\cos(\theta_B-\theta_A)$$

$$Q_R = Img\{S_{3\phi}\}$$

$$Q_R = \frac{|V_s||V_R|}{|B|}\sin(\theta_B-\delta) - \frac{|A||V_R|^2}{|B|}\sin(\theta_B-\theta_A)$$

* $\angle\theta_B$, $\angle\theta_A$ متغيرات حسب نوع ال T.L .

$$P_R = \frac{|V_s||V_R|}{|B|}\cos(\theta_B-\delta) - \frac{|V_R|^2|A|}{|B|}\cos(\theta_B-\theta_A)$$

* $|V_s|$ و $|V_R|$ ثابتين مع ال power .

* "ما بصير تغير في ال power إلا اذا تغيرت δ "

* lossless $\Rightarrow$

$\theta_B = 90°$

$B = jZ_c \sin\beta L$

$\theta_A = 0$

$$P_R = \frac{|V_s||V_R|}{|B|}\cos(90-\delta) - \frac{|A||V_R|^2}{|B|}\cancel{\sin}\cos(90)$$

0

$$P_R = \frac{|V_s||V_R|}{|B|}\sin\delta$$ " $\cos(90-\delta) = \sin\delta$ "

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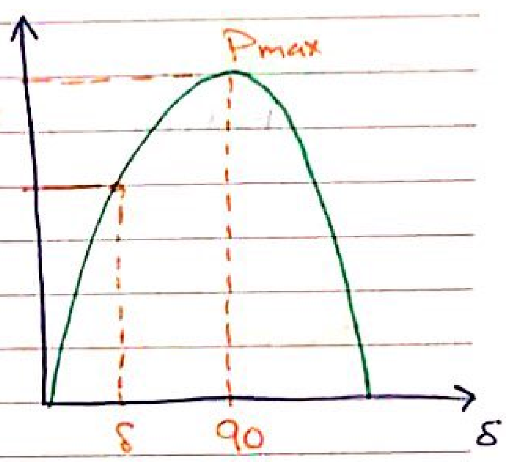
unit of $\beta L = \frac{rad}{Km} \cdot$ length (Km) $\triangleq$ electrical length.

$\lambda \equiv$ wave length.

$\lambda f = v$ $\qquad$ $v \equiv$ velocity.

$$P_R = \frac{|V_S|\,|V_R|}{Z_c \sin\left(\frac{2\pi}{\lambda}\underbrace{\ell}_{\text{length}}\right)} \sin\delta$$



Stability $\Rightarrow$ limitation power

$\delta \approx 30-45^\circ$

حيث اذا لو صار fault للـ System

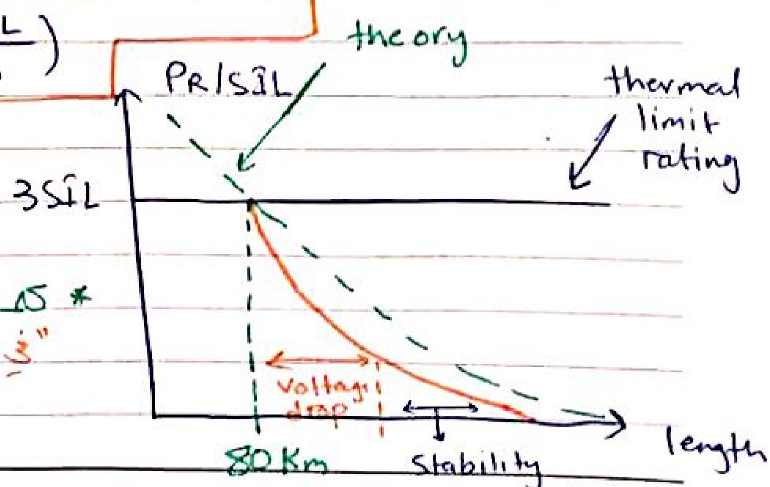
يضل الـ system stable.

$$P_R = \frac{|V_S|\,|V_R|}{Z_c \sin\left(\frac{2\pi L}{\lambda}\right)} * \frac{|V_{rated}|^2}{|V_{rated}|^2} \sin\delta$$

$$P_R = |V_{S\,pu}|\,|V_{R\,pu}| \cdot \frac{SIL \sin\delta}{\sin \frac{2\pi L}{\lambda}}$$

$$\boxed{\frac{|V_{rated}|^2}{Z_c} = SIL}$$

$$\boxed{\frac{P_R}{SIL} = \frac{|V_{S\,pu}|\,|V_{R\,pu}|}{\sin\left(\frac{2\pi L}{\lambda}\right)} \sin\delta}$$



* كلما زاد الـ length الباور بتقل

" في الحقيقة هذا الكلام غير منطقي "

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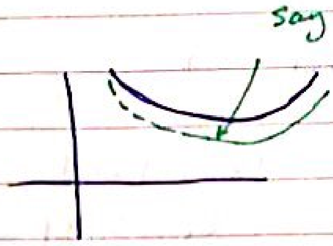
* Max power flow (limits).

* thermal limit (heating)

- over head line (OHL)

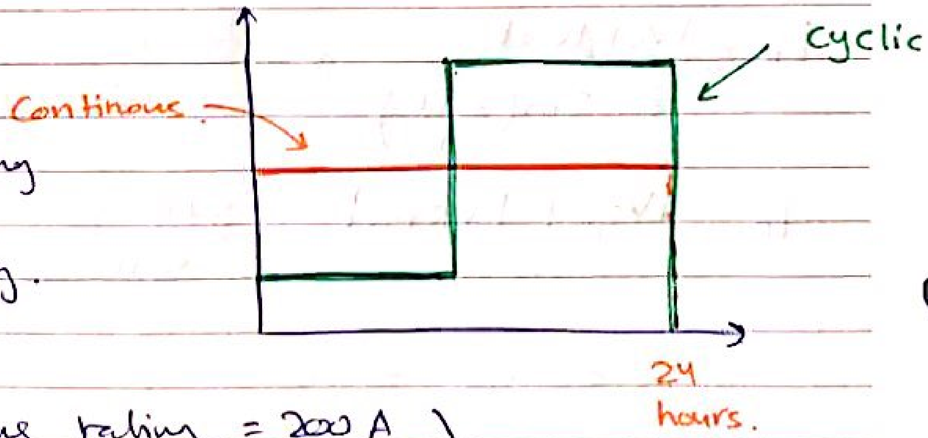
  ↑ heating → Sag
  "ترخي"



- Cables.

  Rating A $\xrightarrow{\text{season}}$ winter (أعلى أكبر)
  └→ Summer

thermal rating → season
└→ temprealure , wind speed.



* continous rating

* cyclic rating.

* line (Continous rating = 200 A
  Cyclic " = 250 A)

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* lossless T.L :-

$$P_R = \frac{|V_s||V_R|}{|B|} \sin\delta$$

$\hookrightarrow Z_c \sin\beta L$

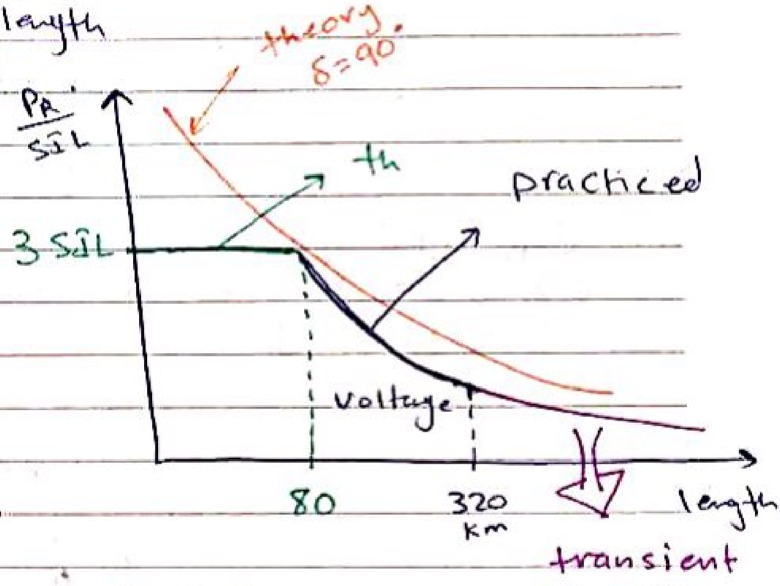
$$= \frac{V_{s\,pu}\; V_{R\,pu}\; SIL\; \sin\delta}{\sin\left(\frac{2\pi L}{\lambda}\right)}$$

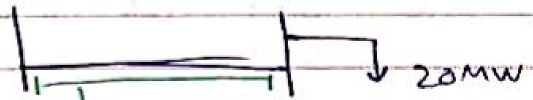
SIL = Surge impedance loading.

$$P \propto V^2 \quad , \quad P \propto \frac{1}{\text{length}}$$

Power flow limits.

- thermal
- voltage.

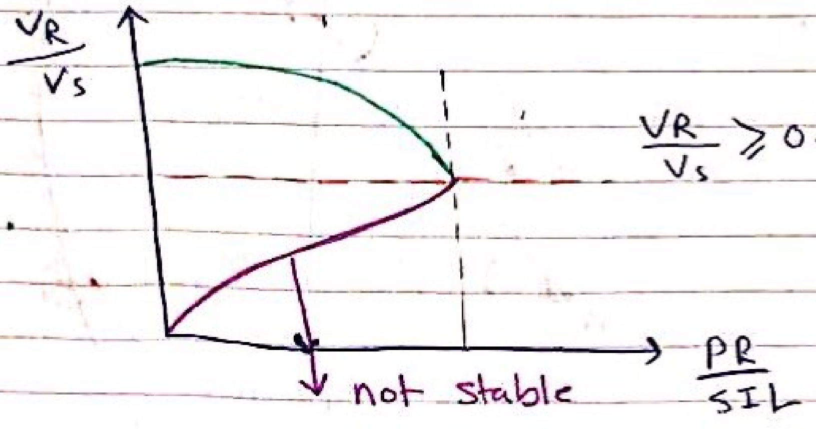




$\hookrightarrow$ line thermal rating $\geq$ 20MW

* voltage.

$\uparrow P_R \longrightarrow Q_R \uparrow \longrightarrow \Delta V.$ (زادت ال P بقل ال V)

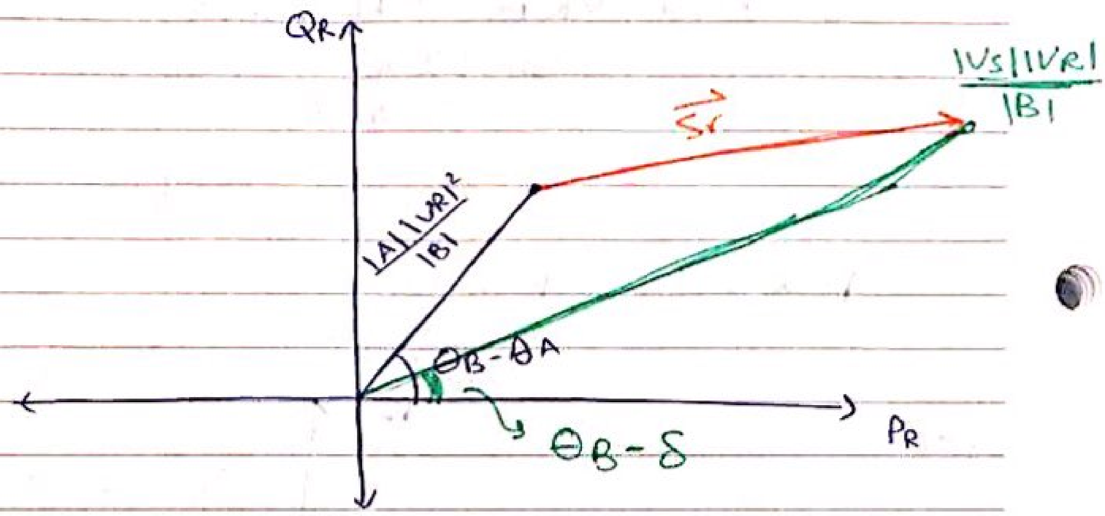


$$\frac{V_R}{V_s} \geq 0.95$$

* Reciving-end power circle diagram :

$$S_R = \frac{|V_S||V_R|}{|B|}\angle \theta_B - \delta - \frac{|A||V_R|^2}{|B|}\angle \theta_B - \theta_A$$

$$S_R = P_R + jQ_R$$

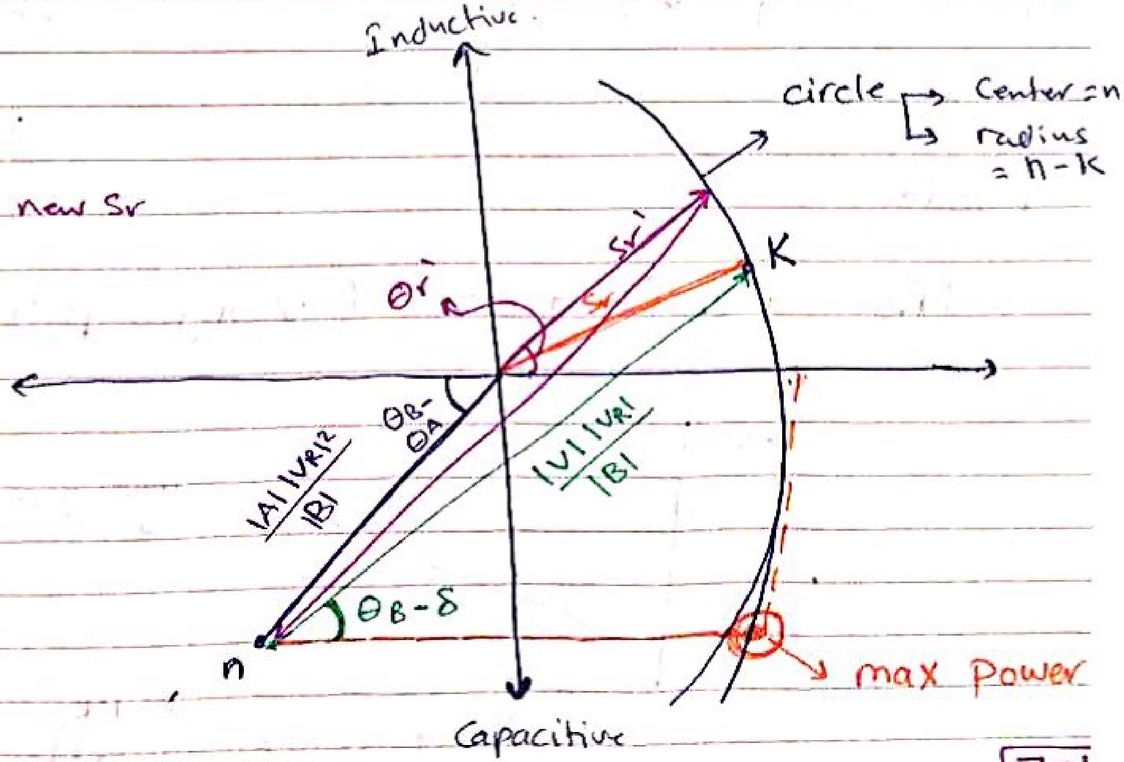


$\theta_B \approx 90°$
$\theta_A \approx 0°$
$\delta \approx 30°$

$\Rightarrow \theta_B - \theta_A > \theta_B - \delta$

* بدي اعمل shift down للرسمة.

$S_r' \equiv$ new S_r



$|V_s| \triangleq$ constant
$|V_R| \triangleq$ constant.

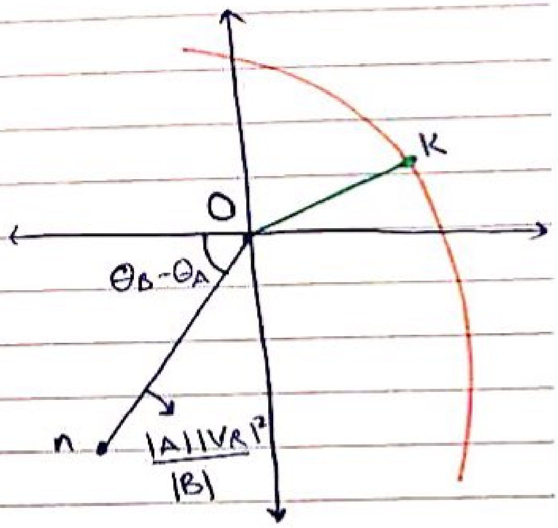
max power. → lossless → $\delta = 90^\circ$
→ lossy → $\delta = \theta_B$

* Step to draw circle diagram $\delta \Delta$ ((single phase ← LL بيرسم))

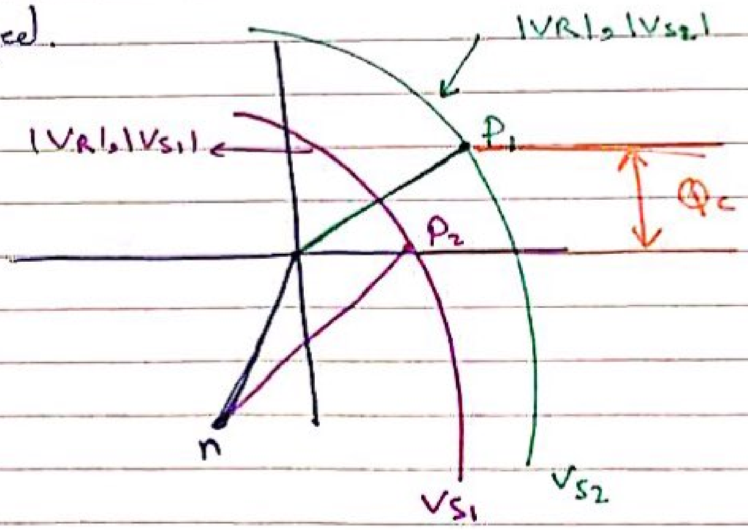
① center.
- angle.
- scale ex(100 M → 1cm)

② Radius.
$\frac{|V_s||V_R|}{|B|}$ → بعدو بالفرجار.

if V_R constant →
(On) fixed



* Vs changed.



P_1 and P_2 have save V_R.
* ممكن احافظ على V_R من غير ما ازيد V_s ⇐ عن طريق
اني اضيف capacitor (Q_c) ⇐ بيكون قيمتها باخذ الفرق بينهم.

$V_{s2} > V_{s1}$
V_{s2} max power > V_{s1} max power.

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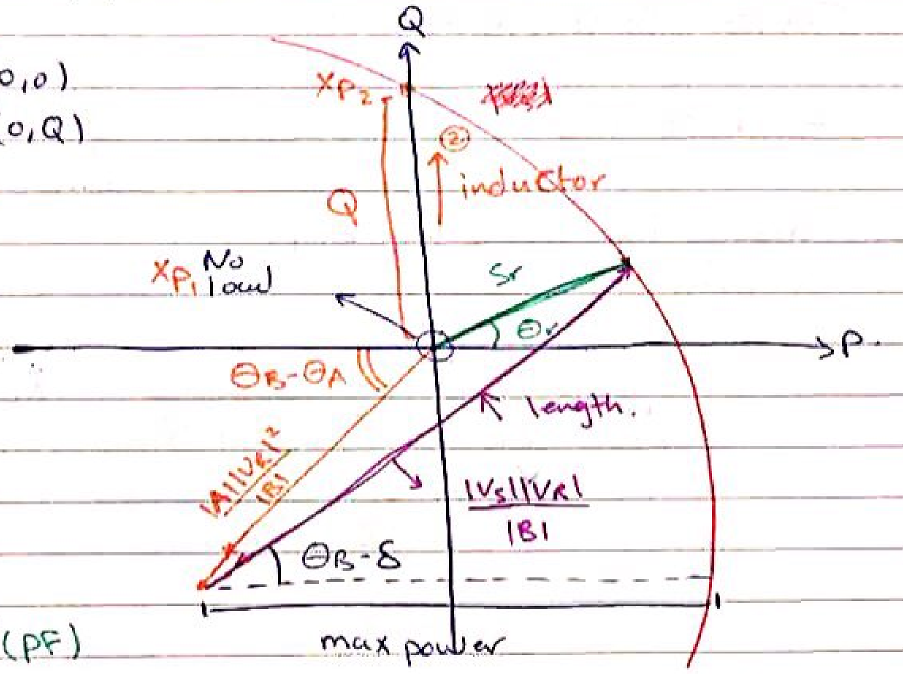
Ex A long T.L $A = 0.88 \angle 2^\circ$
$B = 120 \angle 77^\circ$

load at reciving is 170 MW at 0.85 PF lag
$|V_R|$ is 300 KV , find V_s , δ by using power circle diagram. ?!

Sol: $S_r = \frac{|V_s||V_R|}{|B|} \angle \theta_B - \delta - \frac{|A||V_R|^2}{|B|} \angle \theta_B - \theta_A$

$X_{P_1} (P,Q) = (0,0)$
$X_{P_2} (P,Q) = (0,Q)$

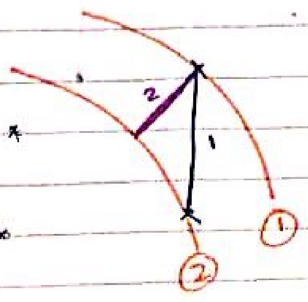


$\theta_r = \cos^{-1}(PF)$

$\frac{|A||V_R|^2}{|B|} = 660$ MVA , scale 1 cm $\rightarrow$ 100 MVA
?? cm $\rightarrow$ 660 MVA

$S_R = 170MW / 0.85$.

length = ?! 1 cm $\rightarrow$ 100 MVA
length $\rightarrow$??



* لما انتقل من 1 إلى 2 بتنقل بطريقة عامودية عشان ما اغير ال power .
* 2 معناه السلك هذا المسار ، بس راح تتغير ال Power تتغير ال Vs .

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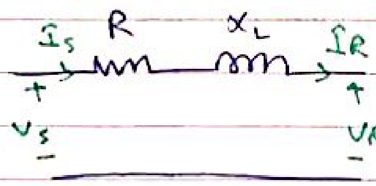
Reactive power compensation :

Series compensation
"heavy load ~~peack~~"
(peak demand)

shunt compensation.
light load.

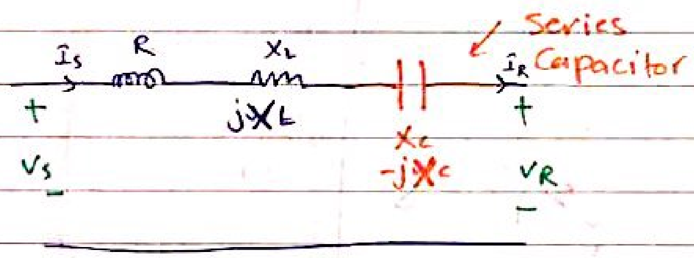
Series compensation :-

- Short T.L

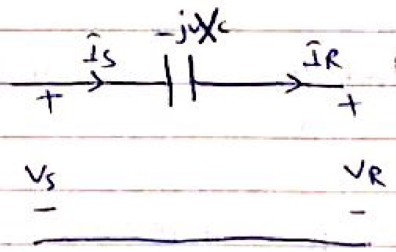


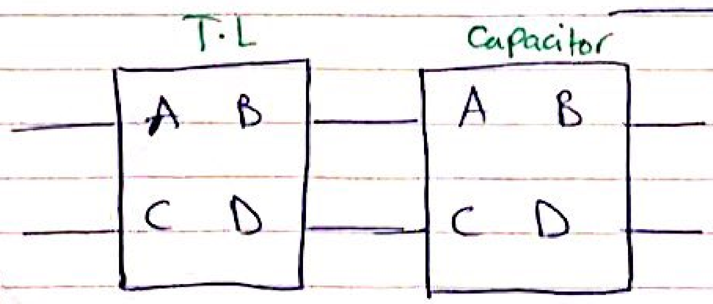
heavy load ⇒ voltage drop.
⇒ solution add capacitor bank

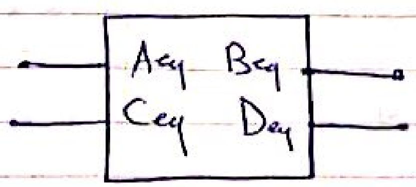
$X_L \gg R$



ABCD constant series capacitor







$V_S = V_R - jX_C I_R$

$I_S = I_R$

$A = 1 \quad , B = -j|X_C| \quad , C = 0 \quad , D = 1$

$$\begin{bmatrix} 1 & -j|X_C| \\ 0 & 1 \end{bmatrix}$$

$$\begin{array}{cc} \text{T.L} & \text{Capacitor} \\ \begin{bmatrix} A & B \\ C & D \end{bmatrix} & \begin{bmatrix} 1 & -j|X_C| \\ 0 & 1 \end{bmatrix} \end{array}$$

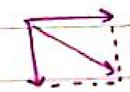
$$= \begin{bmatrix} A & \boxed{\underbrace{-jA|X_C| + B}_{B_{eq}}} \\ C & -jC|X_C| + D \end{bmatrix}$$

* $P_{max} = \frac{|V_S||V_R|}{|B|} \sin\delta$

تقلل ال B زدت ال Pmax.

$|B_{eq}| < B$

$D_{eq} \uparrow$

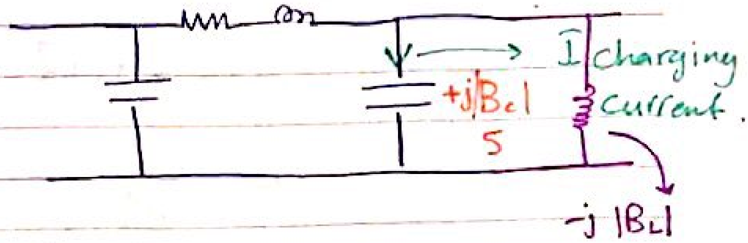


$V_S = A_{eq} V_R + B_{eq} I_R$

$|V_R|$ constant $\Rightarrow$
- without series B $\Rightarrow |V_{S1}|$
- with series B_{eq} $\Rightarrow |V_{S2}|$

$|V_{S2}| < |V_{S1}|$ ← رح يقل ال Voltage drop.

* under light load: * الحكي عن ال voltage rise.



$\boxed{81}$ capacitor → بزيد ال voltage

$I_{\text{charging current}} = |V_{LN}|\, B_c$

$X = jWL \quad , \quad B_L = \dfrac{-j}{X_L}$

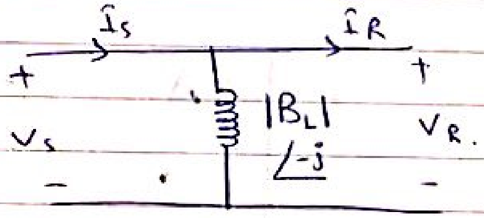
$I_{\text{charging}} = |V_{LN}| \left(|B_c| - |B_L| \right)$

$= |V_{LN}|\,|B_c| \left(1 - \underbrace{\dfrac{|B_L|}{|B_c|}}_{\text{compensation factor}} \right)$

80% compensation factor $\rightarrow B_L = 80\%\, B_c$.

$V_S = V_R$

$I_S = I_R + j|B_L|\, V_R$



$\begin{bmatrix} 1 & 0 \\ -j|B_L| & 1 \end{bmatrix}$

(in light load
A الي بيزيد)

$\begin{bmatrix} A & B \\ C & D \end{bmatrix} \begin{bmatrix} 1 & 0 \\ -jB_L & 1 \end{bmatrix}$

$A_{eq} = A - jB_L\, B \quad \Rightarrow \quad \boxed{A_{eq} > A}$

$\angle 0 \qquad \angle -90 \qquad \angle +90$

$-j \qquad +j \qquad -j * +j = +ve.$

$V_S = AV_R + \cancel{B I_R}^{\,0}$

$\downarrow V_R = \dfrac{V_s}{A \uparrow}$

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Ex A T.L serve a load (400 MVA, 0.8 pF lag 345 KV), reciving voltage 345 KV

T.L $A = D = 0.81 \angle 1.3°$

$B = 172.2 \angle 84.4 \ \Omega$

$C = 0.001933 \angle 90.4 \ S$

$-jX_s = -j\,146.6$

① VR% ?!

② Series capacitor ~~at~~ at mid of T.L
Find VR% ?!

$$\text{mid T.L} \begin{bmatrix} A & B \\ C & D \end{bmatrix} = \begin{bmatrix} 0.9534 \angle 0.3° & 90.33 \angle 84.1 \\ 0.001014 \angle 90.1° & 0.9534 \angle 0.3 \end{bmatrix}$$

sol. ①

$$VR = \frac{|V_{RNL}| - |V_{RFL}|}{|V_{RFL}|} \times 100\%$$

V_s fixed.

$$V_{RFL} = \frac{345}{\sqrt{3}} = 199 \text{ KV}$$

$$V_s = A\,V_R + \underbrace{B\,\hat{I}_R}_{}\ \text{→}\ 0$$

$$V_{RNL} = \frac{V_s}{A}$$

$$V_s = A V_R + B \hat{I}_R$$

at Full load $\quad V_R = 199 \text{ KV} \angle 0$

$$S = \sqrt{3}\, V_L \hat{I}_L$$

$$\hat{I}_L = \hat{I}_R = \frac{S}{\sqrt{3}\, V_L} = \frac{400}{\sqrt{3}\,(345)} = 669.4 \angle -36.87 \text{ A}$$

$$\angle -\cos^{-1}(PF) = \angle -36.87$$

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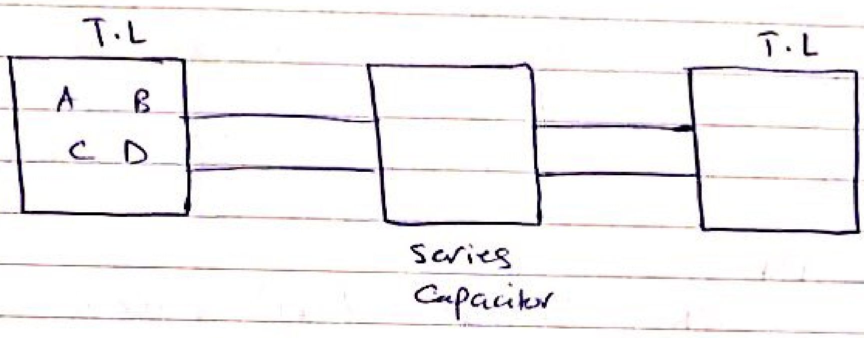
$V_s = 256.8 \angle 20.1 \text{ KV}$

$$V_{RNL} = \frac{V_s}{A} = \frac{256.8}{0.81}$$

$$VR = \frac{\left|\frac{V_s}{A}\right| - |V_{RFL}|}{|V_{RFL}|} \times 100\%$$

$$\boxed{VR\% = 57.6\%}$$

Sol (2)



بدي اطلع ABCD equivalent ⇐ بضرب الثلاث مع بعض.

$$\text{Series Capacitor} = \begin{bmatrix} 1 & -j146.6 \\ 0 & 1 \end{bmatrix}$$

$$\underbrace{\begin{bmatrix} 0.9534 \angle 0.3 & 90.33 \angle 84.1 \\ 0.001014 \angle 90.1 & 0.9534 \angle 0.3 \end{bmatrix}}_{T.L} * \begin{bmatrix} 1 & -j146.6 \\ 0 & 1 \end{bmatrix} * \begin{bmatrix} & \\ & \end{bmatrix}$$

نفسها

$A_{eq} = 0.96 \angle 1.2^\circ = D_{eq}.$

$B_{eq} = 42 \angle 64.8^\circ$

$C_{eq} = 0.002 \angle 90^\circ$

Keshin Color

$V_s = 216.7 \angle 4.5^\circ$

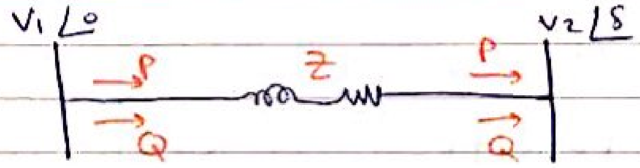
$\boxed{VR\% = 14\ \%}$

* Load flow / Power flow 84

what ?!

- Voltage (magnitude , angle)
- Complex power flow (P , Q , S) ~~throug~~ through T.L

* اذا بعرف قيم V_1 , V_2
بقدر اطلع قيم P , Q .



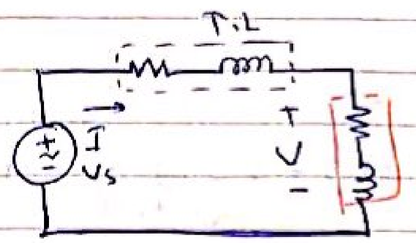
why ?!

- planning .
- operations .

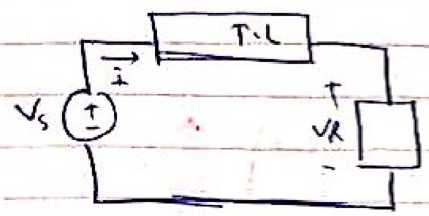
* check Voltage ≤ limits ± → normal
* " power flows ≤ limits → contingency

" loss of line "

CKt :



$I = V_s / Z$, $P = I^2 R$, $Q = I^2 X$.



Pload , constant power , $P = VI$

PF

$\downarrow V , I \uparrow$

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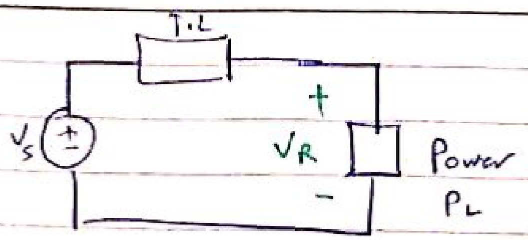
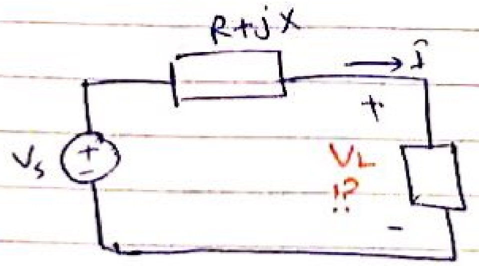


Find V_R :?! using $\boxed{\text{Iterations}}$



$S_L = P_L + jQ_L$

$$S_L = V_L \hat{I}^*$$

$$\hat{I} = \frac{S_L^*}{V_L^*}$$

$$\hat{I} = \frac{P_L - jQ_L}{V_L^*} \quad \ldots \text{①}$$

$$V_L = V_s - \hat{I}(R + jX)$$

$$V_L = V_s - \frac{P_L - jQ_L}{V_L^*}(R + jX)$$

. numircal نحلها بـ

Numerical analysis 8Δ

iteration :-

$$V_L(0) \Rightarrow V_L^{(1)} = V_s - \frac{P_L - jQ_L}{V_L^{*(0)}}(R + jX)$$

initial

$$V_L(1) \Rightarrow V_L^{(2)} = V_s - \frac{P_L - jQ_L}{V_L^*}(R + jX)$$

اكواب الناتج من $V_L(0)$ بعوضها .

tolerance.

$$\left| V_L^{(i+1)} - V_L^{(i)} \right| \leq \varepsilon$$

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load flow → Gauss - Sidel
→ Newton - Raphson.

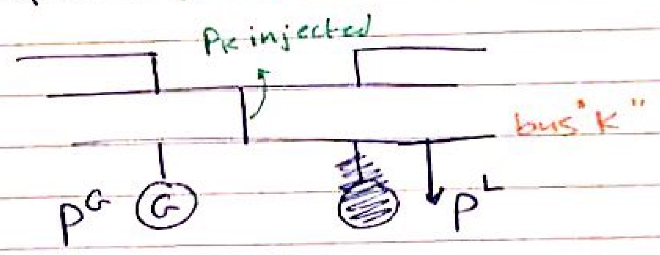
* formulation power flow problem
* Solutions.

* Formulation power flow Problem :-

Inputs :-

* Single line diagram "data" → T.L
→ Generator
→ Load.

* bus. V_K
δ_K
P_K injected
Q_K injected



KCL : $P_K^{injected} = P_K^G - P_K^L$

$Q_K^{injected} = Q_K^G - Q_K^L$

* classification / Bus types :-

* Load bus (PQ) → Known : P_K , Q_K
→ unknown : V_K , δ_K .

* PV bus → Known : P , V_K (magnitude) "control volt"
→ unknown : Q_K , δ_K

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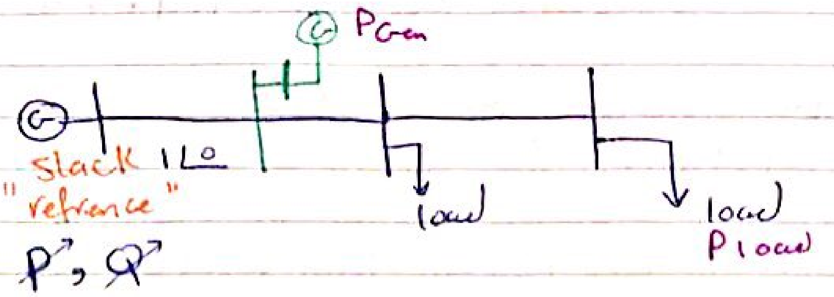
* Slack bus → Known : V_K , δ_K
"buffer" → Unknown : P_K , Q_K.

KCl:



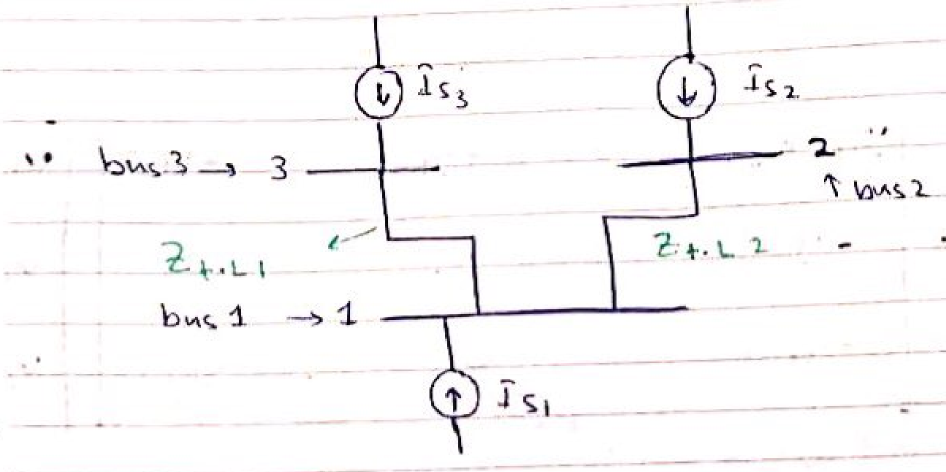
* اذا كان أكثر من Gen بنختار ، اكبر واحد بصير ال refrance.

$$P_{slack} + P_{generation} - P_{load} - P_{losses} = 0$$

P_{slack} → balancing بتعمل

P_{losses} → f (voltage) ↳ unknown

* Addmittance matrix " Y_{bus} "



$V_1, V_2, V_3 = ?!$
⇒ Nodal analysis

at bus 1:

$$\sum I_{in} = \sum I_{out} \quad (KCL)$$

$$I_{s_1} = \frac{V_1 - V_2}{Z_{t.L2}} + \frac{V_1 - V_3}{Z_{t.L1}}$$

$$I_{s_1} = (V_1 - V_2)\, y_{t.L3} + (V_1 - V_3)\, y_{t.L1}$$

$$I_{s_1} = V_1 (y_{t.L2} + y_{t.L1}) - V_2\, y_{t.L2} - V_3\, y_{t.L3}$$

at bus 2:

$$I_{s_2} = (V_2 - V_1)\, y_{t.L2}$$

$$= V_2\, y_{t.L2} - V_1\, y_{t.L2}$$

at bus 3:

$$I_{s_3} = V_3\, y_{t.L1} - V_1\, y_{t.L1}$$

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$$I = Y V$$

↳ injected

كل مشبوك على 1

$$\begin{bmatrix} I_{s1} \\ I_{s2} \\ I_{s3} \end{bmatrix} = \begin{bmatrix} y_{tL1} + y_{tL3} & -y_{tL2} & -y_{tL3} \\ -y_{tL2} & y_{tL2} & 0 \\ -y_{tL3} & 0 & y_{tL3} \end{bmatrix} \begin{bmatrix} V_1 \\ V_2 \\ V_3 \end{bmatrix}$$

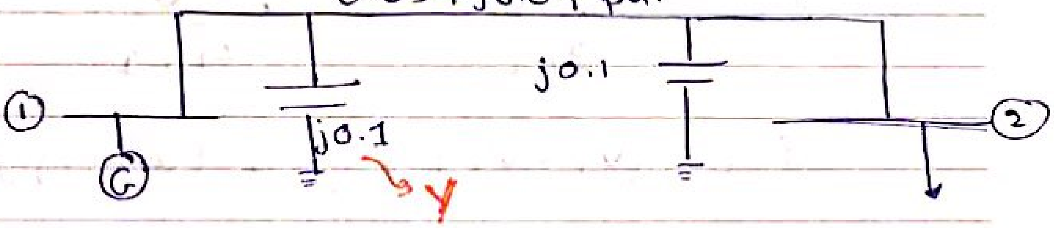
لانه 2 مشبوك مع 3.

كل المشبوك على 3

دائماً الـ diagonal موجب والباقي سالب.

$\boxed{Ex}$

(لانو j موجب) (Z)



(لانو الـ j موجب)

Find Y matrix ?!

$$y_{t.L} = \frac{1}{0.03 + 0.04} = 12 - j16$$

$$Y = \begin{bmatrix} 12 - j16 + j0.1 & -(12 - j16) \\ -(12 - j16) & -12 - j16 + j0.1 \end{bmatrix}$$

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Power Flow Solution :-

"iterative solution"

Gauss sidel :

$f(x) = 0 \rightarrow$ write it as :

$\boxed{X = F(x)}$ Fixed-Point solution

$X^{(0)} \Rightarrow X^{(1)}$

$X^{(1)} \Rightarrow X^{(2)}$

$\vdots$

until $\max |X^{i+1} - X^{i}| \leq \varepsilon$

Ex: Solve $X - \sqrt{X} - 1 = 0$ by using fixed point method?!

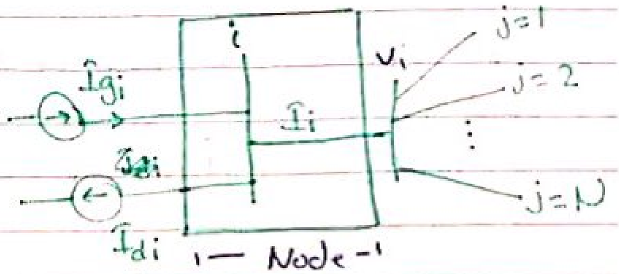
$X^{0} = 1 \Rightarrow$ (inital condition)

Sol: $X = \sqrt{X} + 1$

iteration $\rightarrow$ ν	X^{ν}
0	1 $\rightarrow$ initial condition.
1	2
2	$\vdots$
$\vdots$	
9	~~2.6~~ 2.617

Power flow solution - Gauss Sidel

$X = f(X)$



KCl $\quad \Delta I = 0$

$$I_i = \sum_{j=1}^{N} y_{ij} V_j$$

$$S_i = V_i I_i^*$$

$$I_i = \frac{S_i^*}{V_i^*}$$

$$\frac{S_i^*}{V_i^*} = \sum_{j=1}^{N} y_{ij} V_j$$

j ⇒ كل الـ Bus
الموجود عندي .

$$\frac{S_i^*}{V_i^*} = y_{ii} V_i + \sum_{\substack{j=1 \\ j \neq i}}^{N} y_{ij} V_j$$

$$V_i = \frac{1}{y_{ii}} \left[\overbrace{\frac{S_i^*}{V_i^*}}^{\text{complex}} - \sum_{\substack{j=1 \\ j \neq i}}^{N} \underbrace{y_{ij} V_j}_{\text{complex}} \right]$$

* V لكل اي bus
بحسبه على voltage
إلي بعده .

$X = f(X)$

$$V_i = \frac{1}{y_{ii}} \left[\frac{P_i - jQ_i}{V_i^*} - \sum_{\substack{j=1 \\ j \neq j}}^{N} y_{ij} V_j \right]$$

Let K iteration number.

$$\underset{(K+1)}{V_i} = \frac{1}{y_{ij}} \left[\frac{P_i - jQ_i}{\underset{(K)}{V_i^*}} - \sum_{j=1}^{i-1} y_{ij} \underset{(K+1)}{V_j} - \sum_{j=i+1}^{N} y_{ij} \underset{(K)}{V_j} \right]$$

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PQ bus $\Rightarrow$ P_i, Q_i $\to$ Known
V_i $\Rightarrow$ unknown

* 4 bus, 3 iteration.

iteration

$$\underbrace{V_2}_{\text{bus}}^{(4)} = f\left(V_1^{(4)}, V_2^{(3)}, V_3^{(3)}, V_4^{(3)}\right)$$

$$V_3^{(4)} = f\left(\underbrace{V_1^{(4)}, V_2^{(4)}}_{\text{هدول بكون حاسبهم وطالعهم}}, \underbrace{V_3^{(3)}, V_4^{(3)}}_{\text{هدول بدي احسبهم}}\right)$$

$\boxed{\text{PV bus}}$ $\Rightarrow$ P (Known), Q $\to$ unknown, V $\to$ Known
$\delta \to$ unknown.

* ما بقدر افرض قيمة للـ Q مش عندي زي الـ V.

((ابدي احسب الـ Q من V))
Q $\to$ calculated V

* عندي Q بتحكم فيها عشان اثبت الـ Volt $\Rightarrow$ PV bus

بدي اطلع Q

① $S_i = V_i \, I_i^*$

$$S_i = V_i \left[\sum_{j=1}^{N} y_{ij} V_j\right]^*$$

$$S_i^* = V_i^* \left[\sum_{j=1}^{N} y_{ij} V_j\right]$$

$$P_i - jQ_i = V_i^* \left[\sum_{j=1}^{N} y_{ij} V_j\right]$$

$$Q_i = -\underbrace{\text{Im}}_{\text{Imaginary}} \left\{ V_i^* \left[\sum_{j=1}^{N} y_{ij} V_j\right] \right\}$$

② $$V_i = \frac{1}{y_{ii}} \left[\frac{S_i^*}{V_i^*} - \sum_{\substack{j=1 \\ i \neq j}}^{N} y_{ij} V_j\right]$$

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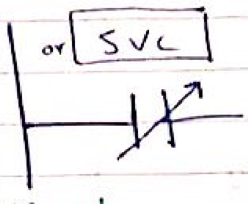
③ Correction V.

$$V_i^{(k+1)} = |V_i^{specified}| * \frac{V_i^{(k+1)}}{|V_i^{(k+1)}|}$$ (* بثبت الـ V وبطلع δ)

④ Check Q:

$Q > Q_{max}.$



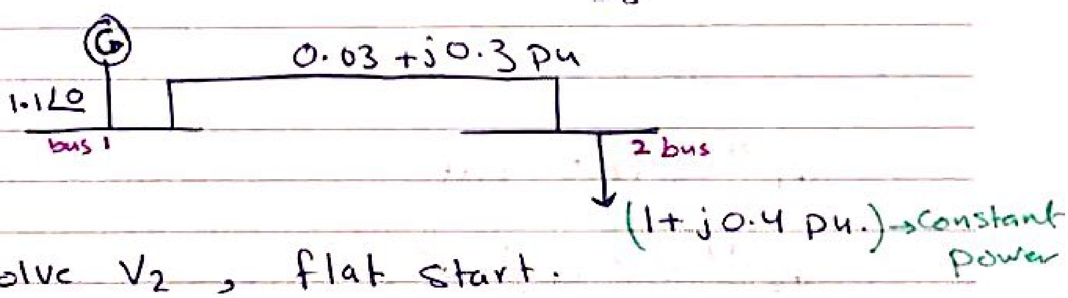
$Q_{min} \leq Q \leq Q_{max}$

⇒ Voltage will not fixed.
⇒ transform PV bus to PQ bus

P_i $\quad Q_i = Q_{max}$.

* ~~[illegible]~~ لا تطلع عند Q كمصدر $Q_{max} <$ ⇐ الـ V ما بثبت فالحل إني احوله من PQ bus ← PV bus

Ex



Solve V_2, flat start.

Sol:

	Known	unKnown
bus 1 : slack	1∠0	P_1, Q_1
bus 2 ⇒ PQ bus	$P_2 = 0 - 1 = -1$ $Q_2 = 0 - 0.4 = -0.4$	

$S_2 = -1 - 0.4j$

① Find Y matrix :-

$$y_{T.L} = \frac{1}{0.03 + j0.3} = 0.33 - j\,3.3003 \text{ pu}$$

$$Y = \begin{bmatrix} 0.33 - j\,3.3003 & -0.33 + j\,3.3003 \\ -0.33 + j\,3.3003 & 0.33 - j\,3.3003 \end{bmatrix}$$

$$V_2 = \frac{1}{y_{22}} \left[\frac{S_2^*}{V_2^*} - \sum_{\substack{j=1 \\ j\neq 2}}^{2} y_{ij}\, V_j \right]$$

$$V_2^{(K+1)} = \frac{1}{0.33 - j\,3.3003} \left[\frac{-1 + j0.4}{(V_2^{K})^*} - y_{21}\, \underbrace{V_1^{K}}_{1\angle 0 \text{ slack}} \right]$$

((* Flat start $\Rightarrow$ Initial condition $V_i^{(0)} = 1\angle 0$))

$V_2^{(0)} = 1\angle 0$ flat.

$V_2^{(1)} = 0.99 \angle -16^\circ$

$V_2^{(2)} = 0.91 \angle -15^\circ$

$S_{1G} = V_1\, I^*$

$I = (V_1 - V_2)\, y_{T.L}$

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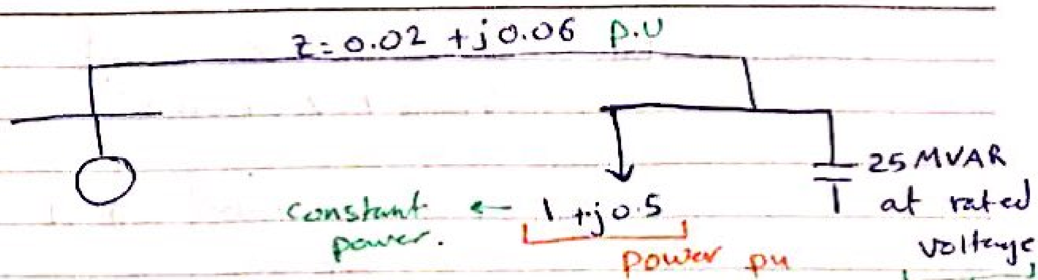
Ex

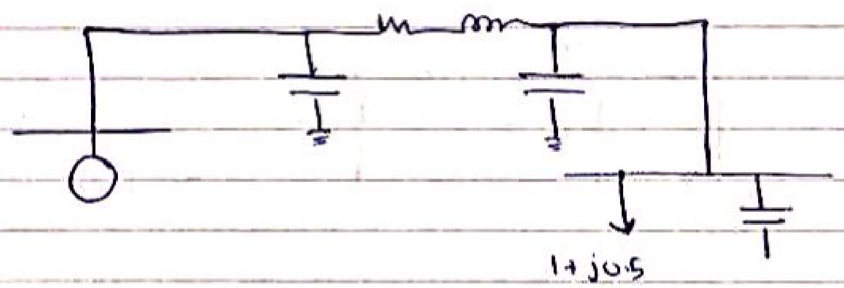


line charging current at each ends 5 MVAR at rated voltage.

1. Find V2 ?! (base 100 MVA)
2. I_1
3. Q capacitor.

* 25MV فمو بتتغير كل ما تغير الـ volt
و 1+j0.5 load ـه قيم بور ثابتة.
فما بقدر اجمعهم مع بعض.

Sol:



$$y_{capacitor\ pu} = \frac{Y_{actual}}{Y_{base}}$$

$$= \frac{Y_{actual}}{S_{base} / (V_{LL\ base})^2}$$

$$Q_{capacitor}\Big|_{\text{rated voltage}} = 3 * (V_{LN\ rated})^2 * Y_{actual}$$

$$= (V_{LL\ rated})^2 * Y_{actual}$$

$$= (V_{LL\ base})^2 * Y_{actual}$$

$$Y_{actual} = \frac{Q_{capacitor}}{(V_{LL\ base})^2}$$

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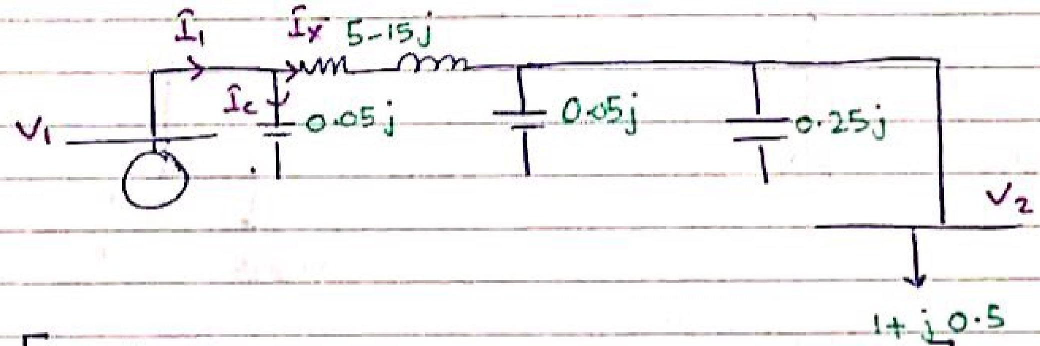
$$Y_{capacitor}\ pu = \frac{Q_{capacitor}/(V_{LL\ base})^2}{S_{base}/(V_{LL\ base})^2}$$

$$= \frac{Q_{capacitor}\ (\text{rated voltage})}{S_{base}}$$

$$Y_{capacitor}\ pu = \frac{25}{100} = 0.25\ pu.$$

$$Y_{E.L} = \frac{5}{100} = 0.05\ pu.$$

$$y_{T.L} = \frac{1}{0.02 + j0.06} = 5 - j15.$$



$$Y = \begin{bmatrix} 5 - j15 + j0.05 & -5 + j15 \\ -5 + j15 & 5 - j15 + j0.05 + j0.25 \end{bmatrix}$$

$$Y = \begin{bmatrix} 5 - j14.95 & -5 + j15 \\ -5 + j15 & 5 - j14.7 \end{bmatrix}$$

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Bus:-

① → slack bus → Known $1\angle 0$
→ unknown: P_1, Q_1

② → load bus PQ → Known ⇒ $P_2 = -1$, $Q_2 = -0.5$
→ unknown ⇒ $|V_2| \angle V_2$ (initial $1\angle 0$)

$$V_2^{(1)} = \frac{1}{y_{22}} \left(\frac{S_2^*}{V_2^*} - \sum_{\substack{i=1 \\ i \neq 2}}^{2} y_{2i} V_i \right) \quad (i \equiv \text{bus } \#)$$

$$V_2^{(1)} = \frac{1}{5 + j14.7} \left(\frac{-1 + j0.5}{1\angle 0} - \underbrace{y_{21}}_{-5+j15} \underbrace{V_1}_{\to 1\angle 0} \right)$$

$$= 0.9687 \angle -3.36^\circ$$

② $I_{\text{injected}} = YV$

$\hat{I}_1 = y_{11} V_1 + y_{12} V_2 = 1.029 \angle -8.979$

OR $I_x = (V_1 - V_2)(5 - j15)$

$I_c = V_1 (0.05j)$

$I_1 = I_x + I_c$

$S_1 = V_1 I_1^*$

③ Q capacitor = ?!

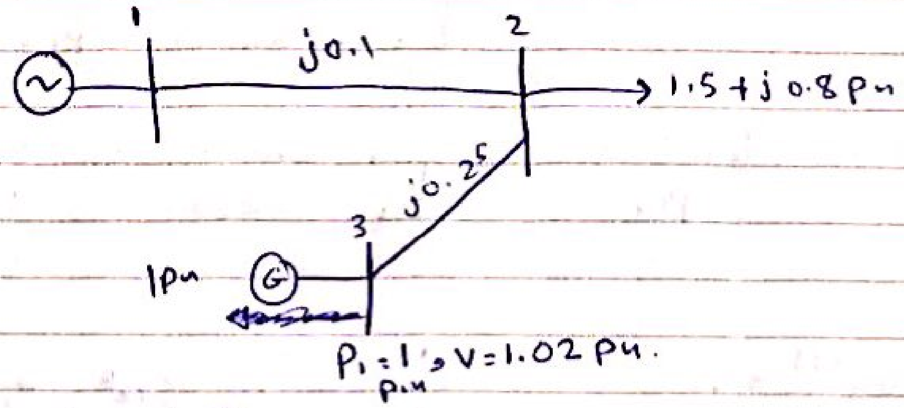
$Q_{\text{capacitor pu}} = |V_{2\,pu}|^2 * y_{\text{capacitor pu}}$

$Q_{\text{capacitor actual}} = |V_{2\,pu}|^2 * y_{\text{capacitor pu}} * S_{\text{base}}$ (100)

98

$Q_{capacitor}$ actual $= 23.2$ MVAR.

$\boxed{Ex:}$



Find V_2, V_3 ?!

Sol: Bus:

$1 \longrightarrow$ slack $\rightarrow$ Known $V_1 = 1\angle 0$

$\rightarrow$ unknown P_1 / Q_1

$2 \longrightarrow$ PQ bus $\rightarrow$ Known $P_2 = -1.5$, $Q_2 = -0.8$

$\rightarrow$ unknown $V_2 \angle V_2$

$3 \longrightarrow$ PV bus. $\rightarrow$ known $P_3 = 1$, $V_3 = 1.02$

$\rightarrow$ unknown Q_3 , V_3

* $P_3^{injected} = 1 - 0 = 1$

$$Y = \begin{bmatrix} -j10 & j10 & 0 \\ j10 & -j14 & j4 \\ 0 & j4 & -j4 \end{bmatrix}$$

$$V_2 = \frac{1}{y_{22}} \left(\frac{-1.5 + j0.8}{1\angle 0} - \left(j10 * 1\angle 0 + 4j * 1.02 \angle 0 \right) \right)$$

$$V_2^{(1)} = 0.95744 \angle -6.4^\circ$$

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$$Q_3 = -\operatorname{Im}\left[V_3^* \sum_{i=1}^{3} y_{3i} V_i \right]$$

$$Q_3 = -\operatorname{Im}\left[V_3^* \left(y_{31} \overset{1\angle 0}{V_1} + y_{32} \overset{0.957\angle -6.4}{V_2} + y_{33} \overset{1.02\angle 0}{V_3} \right) \right]$$

$$Q_3 = 0.32038 \text{ pu.}$$

$$V_3 = \frac{1}{y_{33}} \left(\frac{1 - j0.32038}{1.02\angle 0} - \left(0.957\angle -6.4 * j4 \right) \right)$$

$$V_3^{(1)} = 1.0395 \angle 7.626^\circ \text{ pu.}$$

$V_3^{(1)}$ 1.0395 > $V_3 = 1.02$ => بستخدم ال correct

Correction :

$$V_3^{(1)\,correction} = \frac{|V_3|}{|V_3|^{(1)}} * V_3^{(1)}$$

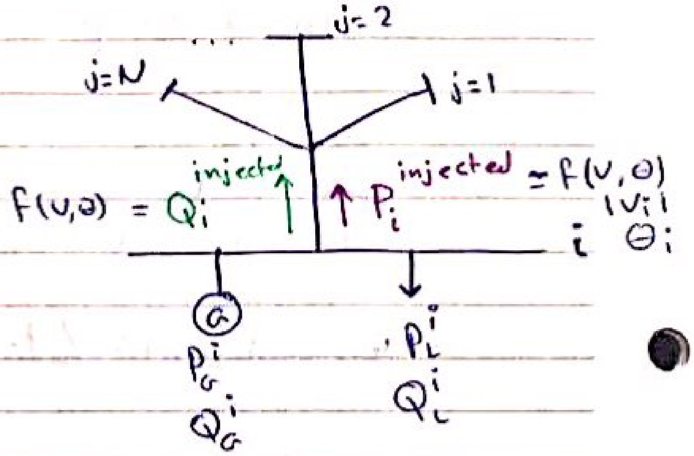
" * بحل load flow عشان احافظ عل voltage "

100

- Newton Raphson :-

- problem formulation → (معادلات) → $P_i = f(V_j, \theta_j)$, $Q_i = f(V_j, \theta_j)$ — Power flow equations
- Solution → (Find V_2, $\angle\theta$)

عبدي اطلع قيم P بدلالة ال V,θ .



$$S_i = V_i \left(I_i^{injected} \right)^*$$

$$= V_i \left[\sum_{j=1}^{N} y_{ij} V_j \right]^*$$

$$V_i = |V_i| \angle \theta_i$$
$$V_j = |V_j| \angle \theta_j$$

$$y_{ij} = g_{ij} + j b_{ij}$$

$$S_i = |V_i| \angle \theta_i \left[\sum_{j=1}^{N} (g_{ij} + j b_{ij})^* |V_j| \angle -\theta_j \right]$$

$$\angle \theta_i - \theta_j = \theta_{ij}$$

$$S_i = \sum_{j=1}^{N} |V_i||V_j| \left[(g_{ij} - j b_{ij})(\cos\theta_{ij} + j \sin\theta_{ij}) \right]$$

$$S_i = P_i + j Q_i$$

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$$P_i = \sum_{j=1}^{N} |V_i||V_j| \left[g_{ij} \cos\theta_{ij} + b_{ij} \sin\theta_{ij} \right]$$

$$Q_i = \sum_{j=1}^{N} |V_i||V_j| \left[g_{ij} \sin\theta_{ij} - b_{ji} \cos\theta_{ij} \right]$$

$$Y = G + jB.$$

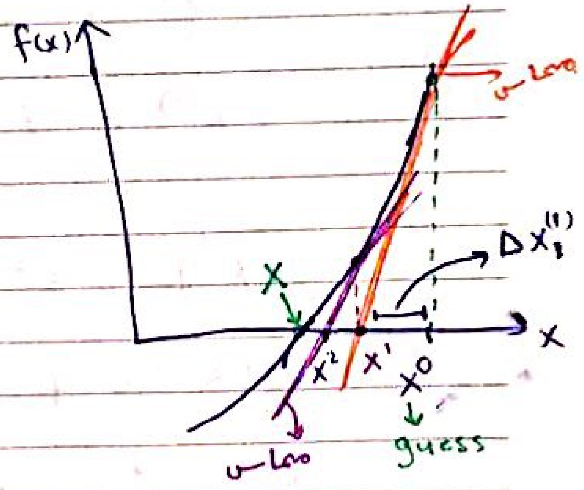
$$P_i^{injected} = P_G^i - P_L^i$$

$$\underbrace{P_i^{injected}}_{f(V,\theta)} - P_G^i + P_L^i = 0$$

Newton Raphson:

«بدي اطلع اصفار الاقتران»

$f(x) = 0 \rightarrow x^*$ (roots)



* بلش من x^0 بتطلع قيم بعيدة كثير فبأخذ مماس بقطع محور السينات ويكون x^1 ⇐ أقرب لل x من x^0.

$f(x^*) = 0$ Taylor series.

$$f(x^{k+1}) = f(x^k) + f'(x^k)(x^{k+1} - x^k) + \cancel{f(x^k)(x^k)} + \underbrace{\cancel{\frac{f''(x^k)(x^{k+1} - x^k)^2}{2!}}}_{0} + \underbrace{\cancel{\frac{f'''(x^k)(x^{k+1} - x^{k+1})^3}{3!}}}_{0}$$

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$$0 = f(x^{k+1}) = f(x^k) + f'(x^k)(x^{k+1} - x^k)$$

input $x^k \longrightarrow x^{k+1}$ next iteration

$$\boxed{(x^{k+1} - x^k) = -[f'(x)]^{-1} f(x^k)}$$

$$\boxed{x^{k+1} = x^k - [f'(x^k)]^{-1} f(x^k)}$$

Ex $f(x) = x^2 - 5x + 4$, $x^{(0)} = 6$

$f(x^*) = 0$, $x^* = ?!$

sol: $f(x) = x^2 - 5x + 4$

$f'(x) = 2x - 5$

$$x^{(1)} = x^{(0)} - \frac{f(x^{(0)})}{f'(x^{(0)})}$$

$f(x^{(0)}) = 6^2 - 5 \times 6 + 4 = 10$

$f'(x^{(0)}) = 7$

$x^{(1)} = 6 - \frac{10}{7} = 4.57$

$x^{(2)} = 4.57 - \frac{f(4.57)}{f'(4.57}$

$= 4.08$

sol using Gaussian:

$x = f(x)$

$x = \frac{x^2 + 4}{5}$

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* Newton Raphson 8Δ
two function of 2 variable.

$$f(x,y)=0$$

$$g(x,y)=0$$

$$f(x^{K+1},y^{K+1}) = f(x^K,y^K) + \frac{\partial f}{\partial x} f(x^K, \cancel{y}^{K}) \Delta x^K + \frac{\partial}{\partial y} f(x^K,y^K)\, \Delta y^K = 0$$

$$g(x^{K+1},y^{K+1}) = g(x^K,y^K) + \frac{\partial}{\partial x} g(x^K,y^K)\, \Delta x^K + \frac{\partial}{\partial y} g(x^K,y^K)\, \Delta y^K = 0$$

$$\underbrace{\begin{bmatrix} \frac{\partial f(x^K,y^K)}{\partial x} & \frac{\partial f(x^K,y^K)}{\partial y} \\ \frac{\partial g(x^K,y^K)}{\partial x} & \frac{\partial g(x^K,y^K)}{\partial y} \end{bmatrix}}_{\text{Jaccobian}} \begin{bmatrix} \Delta x^K \\ \Delta y^K \end{bmatrix} = - \begin{bmatrix} f(x^K,y^K) \\ g(x^K,y^K) \end{bmatrix}$$

$$\boxed{\begin{aligned} \Delta x^K &= x^{K+1} - x^K \\ \Delta y^K &= y^{K+1} - y^K \end{aligned}}$$

Keshia Color

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Newton Raphson:

$$f(x^*) = 0 \Rightarrow x^*$$

$$x^{k+1} = x^k - (f'(x^k))^{-1} f(x^k)$$

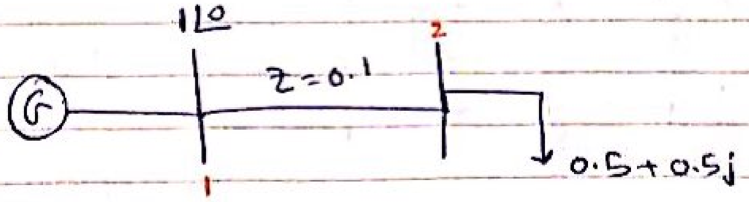
Generalization to multiple variables.

$$f(x) = \begin{bmatrix} f_1(x) \\ f_2(x) \\ \vdots \\ f_n(x) \end{bmatrix}, \quad X = \begin{bmatrix} x_1 \\ x_2 \\ \vdots \\ x_n \end{bmatrix}$$

$$f'(x) = \underbrace{\begin{bmatrix} \frac{\partial f_1(x)}{\partial x_1} & \frac{\partial f_1(x)}{\partial x_2} & \cdots & \frac{\partial f_1(x)}{\partial x_n} \\ \vdots & & & \\ \frac{\partial f_n(x)}{\partial x} & \frac{\partial f_n(x)}{\partial x_2} & \cdots & \frac{\partial f_n(x)}{\partial x_n} \end{bmatrix}}_{\Downarrow \text{ Jaccobian.}}$$

$$x^{(k+1)} = x^k - J^{-1}(x^k) f(x^k)$$

$\boxed{\text{Ex:}}$



$V_2, \theta_2 = ?!$

Bus	Known	unknown
1	$V_1 = 1\angle 0$	P_1, Q_1
2	$P_2 = -0.5$ $Q_2 = -0.5$	V_2, θ_2

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$$P_i = \sum_j |V_i||V_j| \left[G_{ij} \cos\theta_{ij} + B_{ij} \sin\theta_{ij}\right]$$

$$Q_i = \sum_j |V_i||V_j| \left[G_{ij} \sin\theta_{ij} - B_{ij} \cos(\theta_{ij})\right]$$

$$Y = \begin{bmatrix} -10j & j10 \\ j10 & -j10 \end{bmatrix} = \cancel{G}^{0} + jB$$

$$= j\begin{bmatrix} -10 & 10 \\ 10 & -10 \end{bmatrix}$$

$$P_1 = |V_1||V_1| \left[-10 \sin\theta_{11}\right] + |V_1||V_2| \left[10 \sin\theta_{12}\right]$$

$$P_1 = -10 |V_1||V_2| \sin\theta_2$$

$$P_1 = -10 |V_2| \sin\theta_2$$

$$Q_1 = 10 - 10|V_2| \cos\theta_2$$

~~explicit~~ explicit equation

* $\theta_{11} = \theta_1 - \theta_1 = 0$

$\sin(0) = 0$

$\theta_{12} = \theta_1 - \theta_2$

(slack bus $V_1 = 1$, $\theta_1 = 0$)

$\sin(\theta_{12}) = \sin(-\theta_2) = -\sin\theta_2$

$$P_2 = 10 |V_2| \sin\theta_2$$

$$Q_2 = -10 |V_2| \cos\theta_2 + 10 |V_2|^2$$

→ implicit equation.

Newton Raphson.

- Solve implicit equation.

$$f_1(x) = 10 |V_2| \sin\theta_2 + 0.5 = 0$$

$$f_1(x) = P_2 + 0.5$$

$$f_2(x) = -10|V_2| \cos\Theta_2 + 10|V_2|^2 + 0.5 = 0$$

$$f_2(x) = Q_2 + 0.5$$

$$X = \begin{bmatrix} \Theta_2 \\ |V_2| \end{bmatrix}$$

Flat start

$$\begin{bmatrix} 0 \\ 1 \end{bmatrix} \quad 0 \to \text{rad}$$

$$X^{k+1} = X^k - J^{-1}_{(x^k)} \, f(x^k)$$

$$J = \begin{bmatrix} \frac{\partial f_1(x)}{\partial \Theta_2} & \frac{\partial f_1(x)}{\partial |V_2|} \\ \frac{\partial f_2(x)}{\partial \Theta_2} & \frac{\partial f_2(x)}{\partial |V_2|} \end{bmatrix}$$

$$J = \begin{bmatrix} \frac{\partial P_2(x)}{\partial \Theta_2} & \frac{\partial P_2(x)}{\partial |V_2|} \\ \frac{\partial Q_2(x)}{\partial \Theta_2} & \frac{\partial Q_2(x)}{\partial |V_2|} \end{bmatrix}$$

$$J = \begin{bmatrix} 10|V_2| \cos\Theta_2 & 10 \sin\Theta_2 \\ 10|V_2| \sin\Theta_2 & 20|V_2| - 10\cos\Theta_2 \end{bmatrix}$$

first iteration

1. $J(\Theta^{(0)} = 0, \; V^{(0)} = 1) = \begin{bmatrix} 10 & 0 \\ 0 & 10 \end{bmatrix}$

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$$\begin{bmatrix} \Theta^{(0)} \\ V^{(0)} \end{bmatrix} = \begin{bmatrix} 0 \\ 1 \end{bmatrix}$$

② $J^{-1}(\Theta^{(0)}, V^{(0)}) = \begin{bmatrix} 0.1 & 0 \\ 0 & 0.1 \end{bmatrix}$

$f(x^{(0)})$

$$\left.\begin{aligned} f_1(\Theta = 0, |V| = 1) &= 0.5 \\ f_2(\Theta = 0, |V| = 1) &= 0.5 \end{aligned}\right\}$$ Power and reactive power "mis match"

$$x^{(1)} = \begin{bmatrix} 0 \\ 1 \end{bmatrix} - \begin{bmatrix} 0.1 & 0 \\ 0 & 0.1 \end{bmatrix} \cdot \begin{bmatrix} 0.5 \\ 0.5 \end{bmatrix}$$

$$\begin{bmatrix} \Theta^{(1)} \\ V^{(1)} \end{bmatrix} = \begin{bmatrix} 0 \\ 1 \end{bmatrix} - \begin{bmatrix} -0.05 \\ -0.05 \end{bmatrix} = \begin{bmatrix} -0.05 \\ 0.95 \end{bmatrix}$$

$$\begin{bmatrix} \Theta^{(2)} \\ V^{(2)} \end{bmatrix} = \begin{bmatrix} -0.5288 \\ 0.94574 \end{bmatrix}$$

after 2 iterations

$P_1 = -10|V_2| \sin\Theta_2 = 0.4999$ pu

$Q = 10 - 10|V_2| \cos\Theta_2 = 0.5557$ pu

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1 slack + NPQ

$$J = \left[\begin{array}{ccc|ccc}
\frac{\partial P_2(x)}{\partial \theta_2} & \frac{\partial P_2(x)}{\partial \theta_3} \cdots & \frac{\partial P_2(x)}{\partial \theta_N} & \frac{\partial P_2(x)}{\partial |V_2|} & \frac{\partial P_2(x)}{\partial V_3} \cdots & \frac{\partial P_2(x)}{\partial V_N} \\
\vdots & \frac{\partial P_i}{\partial \theta} & & & \frac{\partial P}{\partial V} & \\
\frac{\partial P_N(x)}{\partial \theta_2} & \cdots & \frac{\partial P_n(x)}{\partial \theta_N} & \frac{\partial P_n}{\partial |V_2|} & \cdots & \frac{\partial P_n}{\partial |V_n|} \\
\hline
\frac{\partial Q_2(x)}{\partial \theta_2} & & \frac{\partial Q_2}{\partial \theta_n} & \frac{\partial Q_2}{\partial |V_2|} & \cdots & \frac{\partial Q_{n}}{\partial V_n} \\
\vdots & \frac{\partial Q}{\partial \theta} & & & \frac{\partial Q}{\partial V} & \\
\frac{\partial Q_n}{\partial \theta_2} & \cdots & \frac{\partial Q_n}{\partial \theta_n} & \frac{\partial Q_n}{\partial |V_2|} & & \frac{\partial Q_n}{\partial |V_n|}
\end{array}\right]$$

at PV bus $Q=0 \longrightarrow$

* P_1 ما اشتقنا الها لأنها ← slack.

$$X = \begin{bmatrix} \theta_2 \\ \theta_3 \\ \vdots \\ \theta_n \\ |V_2| \\ \vdots \\ |V_n| \end{bmatrix}$$

* PV bus
P known , Q unknown.
بتكون الـ $Q = 0$.

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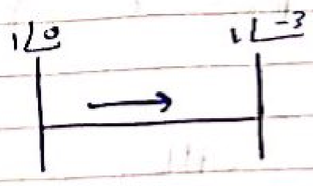
* DC. load flow 84 "linear"

- power.
- Angles unknown.
- Voltage fixed.

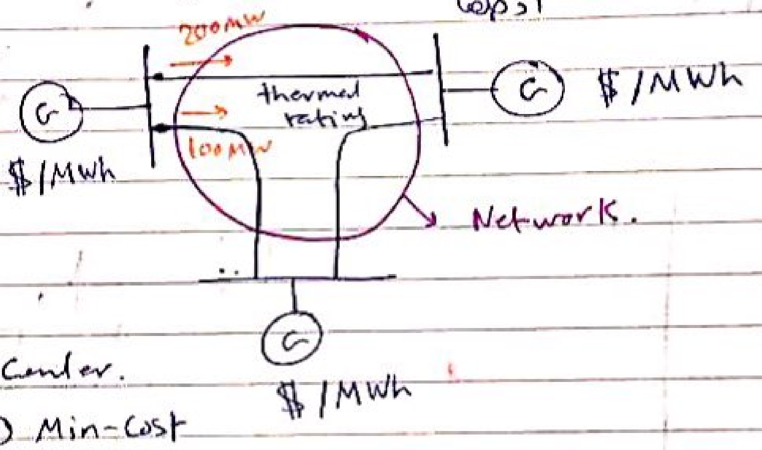
$\Delta p \propto (\Delta \underline{\delta})$

↳ angles.



* economic dispatch.

thermal rating قدرش كمية الـpowr إلي بقدر ادخلها



Control Center.

↳ ① Min-Cost

② Network.

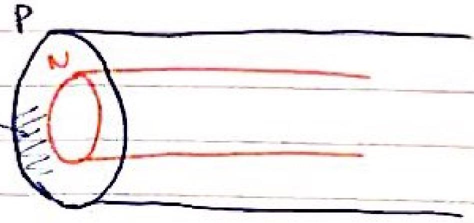
* Fast Decoupled load flow :- اسرع من DC load

$$\begin{bmatrix} \frac{\partial P}{\partial \theta} & \cancel{\frac{\partial P}{\partial |V|}}^{\,0} \\ \cancel{\frac{\partial Q}{\partial \theta}}^{\,0} & \frac{\partial Q}{\partial |V|} \end{bmatrix}$$

transmission $\frac{X}{R} \gg 1$

* Fault analysis 84

يعني insulation breakdown.



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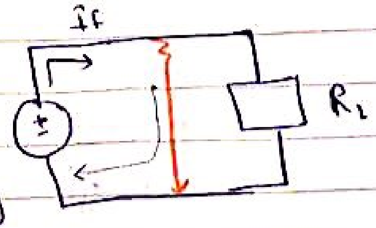
① dangerous
- personal
- facilities
- stability



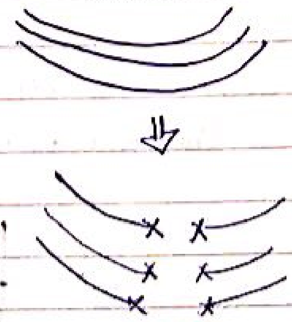
OHL

متى يحصل fault

① يحصل تلامس بين الـ ٣ اسلاك .

② الثلج ← يقطع الاسلاك .

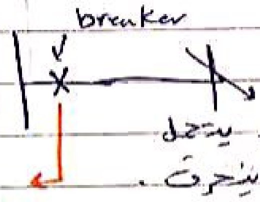
wind . ice.



open

Fault current Calculation:-

1) Design

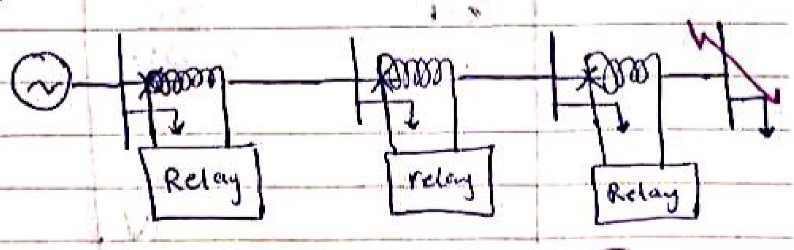


لازم breaker يفصل الـ fault وما يتحرق .

withstand fault current.

" worst - case " → max fault current

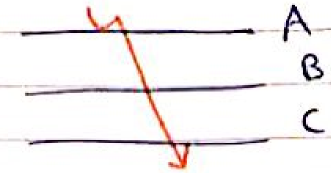
2) protection coordination studies



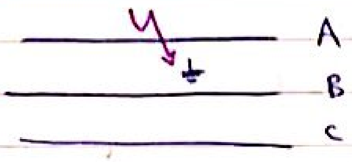
I setting
wait
open

3) Stability.

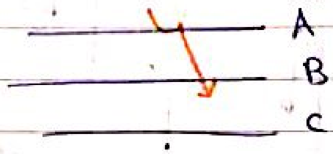
types of fault :- → internal voltage method
→ thevenin.



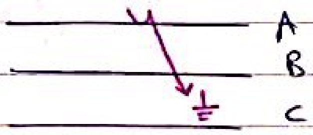
- three-phase short circuit
Symmetrical fault
balanced "per phase analysis"



line to current fault.



line to line fault.



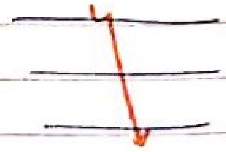
line to line Ground
"LLG"

unbalanced ⇒ Symmetrical componants

-ve seq   +ve seq   Zero seq

Symmetrical fault:

three phase short circuit.



Objective.
- fault current
- contributions to fault current
- voltage.
- effect of load current.

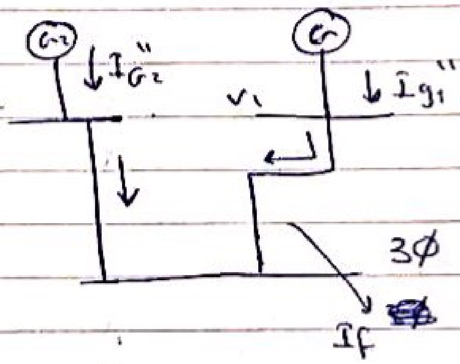
Methods :-

1) Internal voltage method

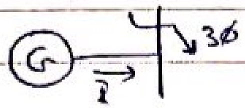
2) thevenin.

3) Superposition

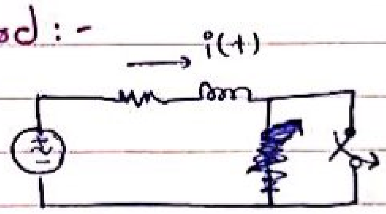
4) impedance matrix. ($Z_{bus} = Y^{-1}_{bus}$)
↳ complex system.

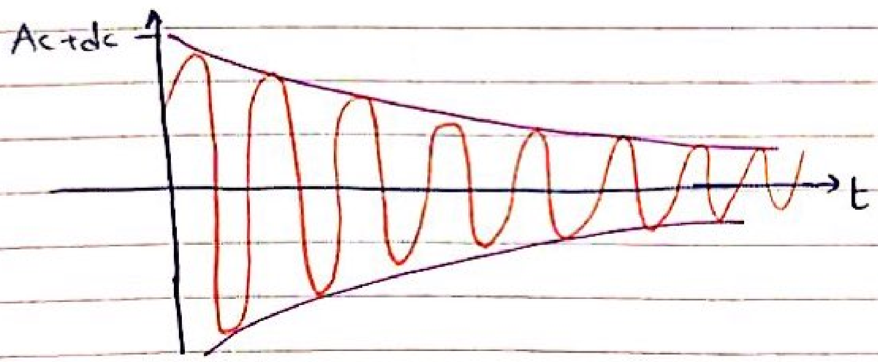


[I] Internal Voltage method :-

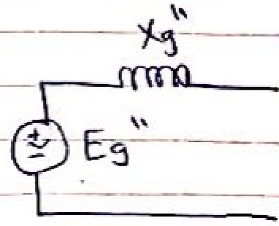


⇒





① sub - transient



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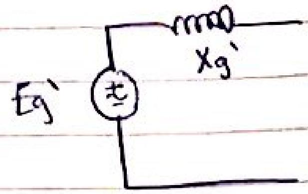
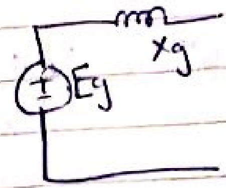
② transient



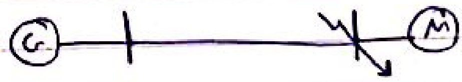
③ steady state.

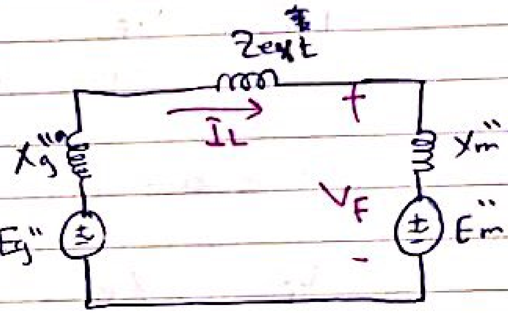


① subtranisient current :-

① E_g'' , E_m'' (internal voltage)

* pre-fault analysis $\Rightarrow$ E_m'' و E_g'' بحول عشان اطلع



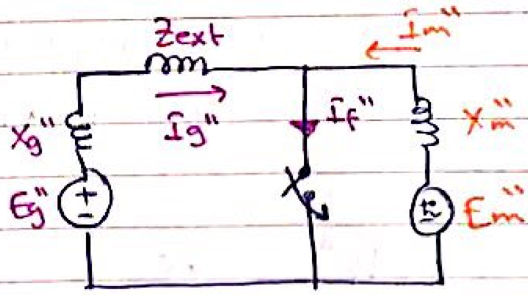


~~Symmetrical fault~~

$$E_g'' = V_F + I_L(Z_{ext} + jX_g'')$$
↓ pre-fault

$$E_m'' = V_F - I_L(jX_m'')$$

Post fault :-



$$I_g'' = \frac{E_g''}{jX_g'' + Z_{ext}}$$

$$= \frac{V_F + I_L(jX_g'' + Z_{ext})}{jX_g'' + Z_{ext}}$$

$$I_g'' = \frac{V_F}{jX_g'' + Z_{ext}} + \underline{\underline{I_L}}$$ → current (pre-fault)

$$I_m'' = \frac{E_m''}{jX_m''} = \frac{V_F - jX_m'' I_L}{jX_m''} = \frac{V_F}{jX_m''} - I_L$$

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$$\hat{I}_f'' = \hat{I}_g'' + \hat{I}_m''$$

$$\hat{I}_f'' = \frac{V_F}{Z_{ext} + jX_g''} + \frac{V_F}{jX_m''}$$

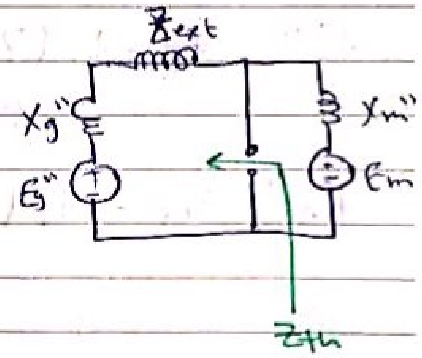
$$\boxed{\hat{I}_f'' = V_F\left(\underbrace{\frac{1}{Z_{ext} + jX_g''} + \frac{1}{jX_m''}}_{\frac{1}{Z_{th}}}\right)}$$

$\frac{1}{Z_{th}}$ => seen from the fault

$$\hat{I}_f'' = \frac{V_F}{Z_{th}}$$ → seen from the fault.

$\boxed{2}$ thevenin :-

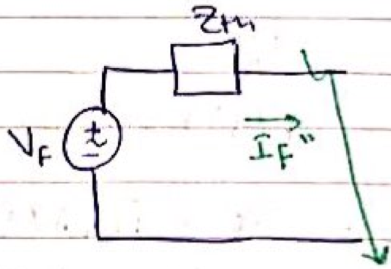
* V_F , Z_{th} = ?



$$Z_{th} = (Z_{ext} + jX''_g) // jX''_m$$

$$Z_{th} = \frac{(Z_{ext} + jX_g'') * jX_m''}{Z_{ext} + jX_g'' + jX_m''}$$

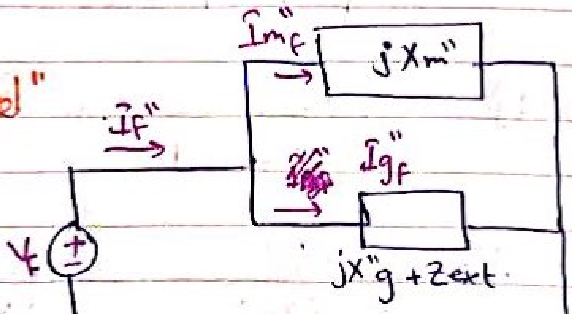
$$\boxed{\hat{I}_f'' = \frac{V_F}{Z_{th}}}$$



$$\hat{I}_{mF}'' = \frac{V_F}{jX_m''}$$

"unloaded"

$$\hat{I}_{gF}'' = \frac{V_F}{jX_g'' + Z_{ext}}$$

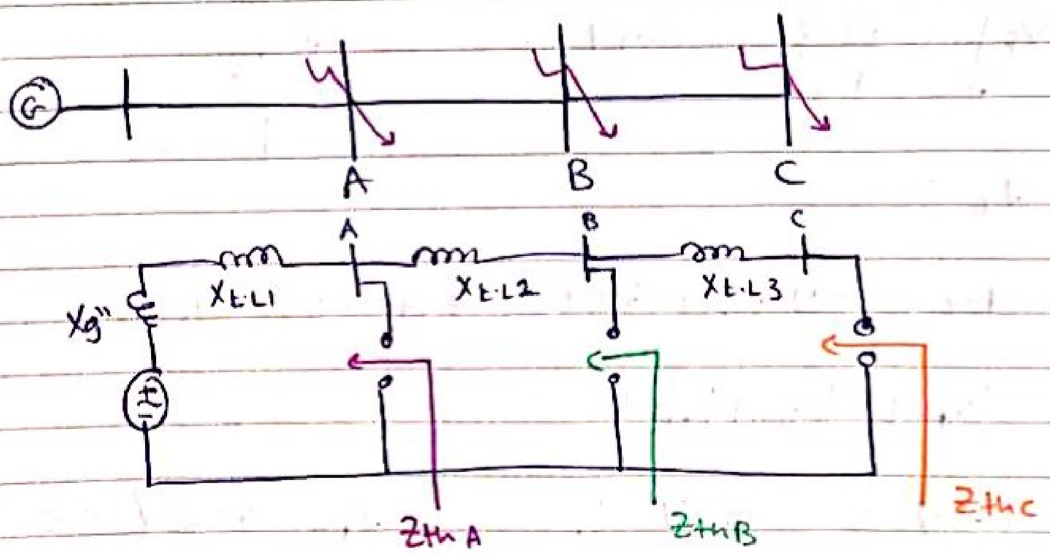


Correction:

$$\hat{I}_m'' = \frac{V_F}{jX_m''} - \hat{I}_L$$

$$\hat{I}_g'' = \frac{V_F}{jX_g'' + Z_{ext}} + \hat{I}_L .$$

Internal	thevenin
Pre fault ($\hat{I}_L$, V_F)	V_F
E_g'', E_m''	Z_{th}
Contributions $\hat{I}_g''$, $\hat{I}_m''$	$\hat{I}_f'' = \frac{V_F}{Z_{th}}$
	contribution "current division"
Fault current $\hat{I}_f'' = \hat{I}_g'' + \hat{I}_m''$	
	Correction ($\mp \hat{I}_L$, $+\hat{I}_L$)



$Z_{th}(A) = X_g'' + X_{t.L1}$

$Z_{th}(B) = X_g'' + X_{tL1} + X_{tL2}.$

$\boxed{I_{f\,B}'' < I_{f\,(A)}''}$

$\uparrow Z_{th} \rightarrow \downarrow I_{Fault}.$

A اعلى اشي لانو قريب ال source.

كلما بعدت بيقل ال Fault.

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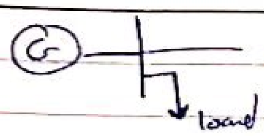
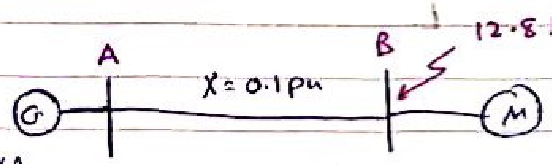


" * اذا عندي load ⟸ بحوله impedance. "

Ex:



30 MVA
13.2 KV
$x'' = 0.2$ pu

20 MW
at 12.8 KV
0.8 PF leading ~~lagging~~
$x'' = 0.2$ pu.

operation

all pu at Generator rating $\left(\frac{30\,MVA}{13.2\,K}\right)$ calculate 3φ subtransient fault current at Bus B contributions from motor and generator

1. internal voltage ?!
2. thevenin method. ?

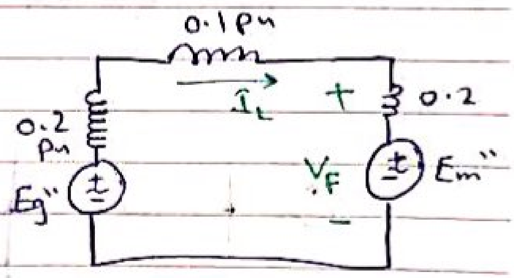
Sol: $V_F = 12.8$ KV

* اذا اعطاني x, x', x"
هنا x" ← subtrans
لانو بهمنا التيار اول اشي

① internal voltage method.

$I_L = ?!$ V_F (before fault).

E_g'', E_m'' ?!



$$V_F\big|_{pu} = \frac{12.8}{13.2} = 0.97$$

I_L ?!

motor (20 MW, 12.8 KV, 0.8 pF leading).

$$|S_{pu}| = |V_{pu}|\,|I_{pu}|$$

$$\frac{20/0.8}{30} = 0.97\, I_{pu} \Rightarrow I_{pu} = 0.86 \angle +\cos^{-1}(0.8)$$

$$\boxed{I_{pu} = 0.86 \angle 36.87 \text{ pu}}$$

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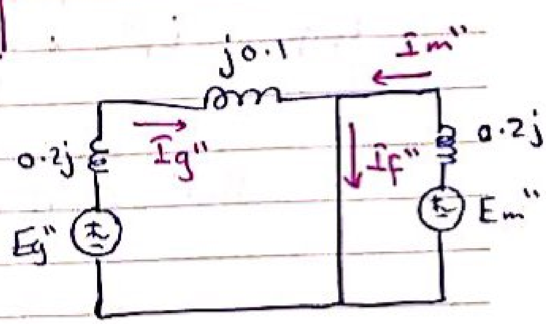
$E_g'' = \hat{I}_L(j0.2 + j0.1) + 0.97\angle 0$

$E_m'' = 0.97\angle 0 - \hat{I}_L \cdot (j0.2)$

$$\boxed{E_g'' = 0.84 + j0.207 \text{ pu}}$$

$$\boxed{E_m'' = 1.074 - j0.138 \text{ pu}}$$



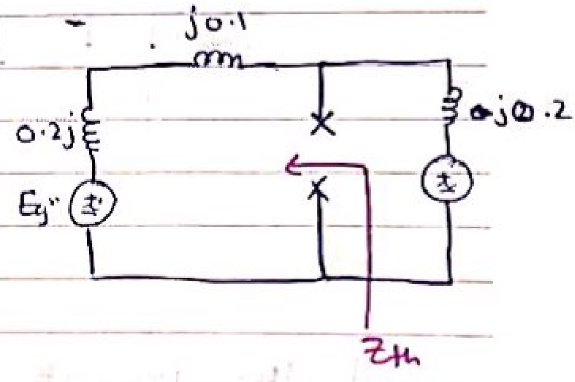
$\hat{I}_g'' = \dfrac{E_g''}{j0.2 + j0.1}$

$\hat{I}_m'' = \dfrac{E_m''}{j0.2}$

$\hat{I}_f'' = \hat{I}_g'' + \hat{I}_m'' = -j8.08 \text{ pu}.$

$\hat{I}_f'' \text{ (actual)} = -j\,8.08 * \dfrac{30M}{\sqrt{3} * 13.2K}$

$$\boxed{\hat{I}_f'' = -j10.6 \text{ KA}}$$

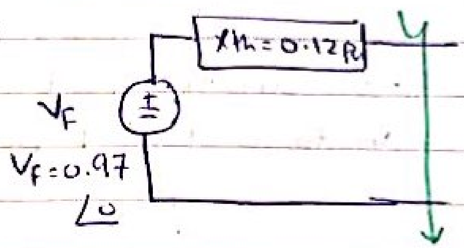


(2) thevenin sol

$X_{th} = (j0.1 + 0.2j) \,//\, (j0.2)$

$= 0.12 \text{ pu}$

$\hat{I}_f'' = \dfrac{V_F}{X_{th}} = \dfrac{0.97}{j0.12} = -j8.08 \text{ pu}$



* نلاحظ انو طلعو نفس الجواب في لانو

* I_L ما الها علاقة بتيار ال fault

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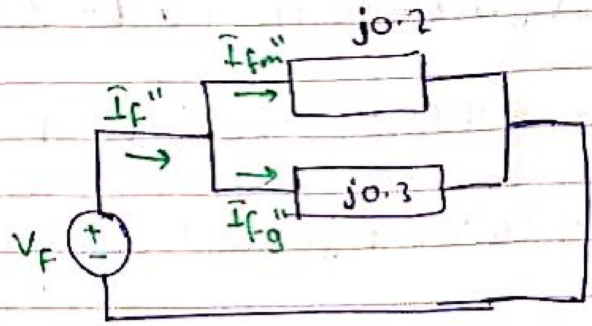
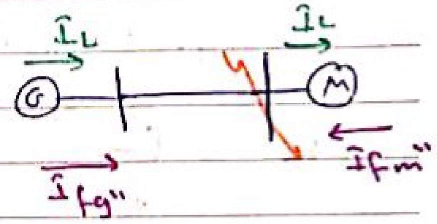


$$\hat{I}_{fm}'' = \hat{I}_f'' * \frac{j0.3}{j0.5} = -j\,3.23\ \text{pu}$$

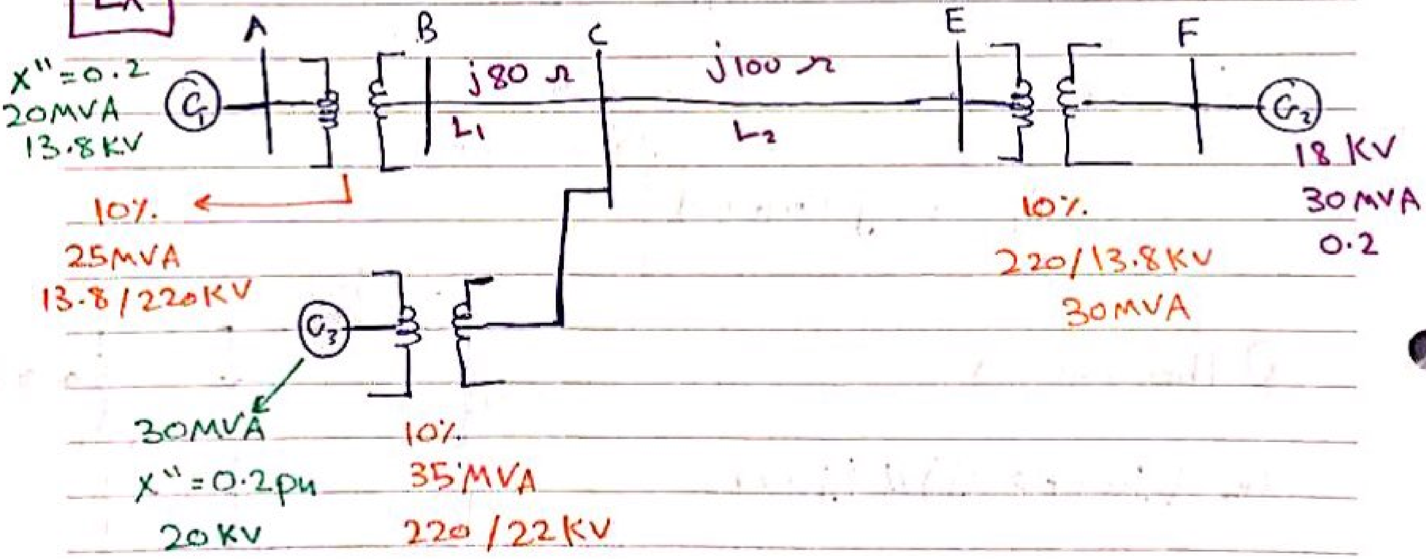
$$\hat{I}_{fg}'' = \hat{I}_f'' * \frac{0.2j}{j0.5} = -j\,4.85\ \text{pu}.$$

Correction. $\hat{I}_g = \hat{I}_{fg}'' + \hat{I}_L$

$\hat{I}_m'' = \hat{I}_{fm}'' - \hat{I}_L$



$\boxed{Ex}$



all the perunit on a common base (50MVA, 13.8KV at generated G_1 side) fault.
Find subtransient current at bus C, pre fault Voltage is 1 pu Neglect load current. ?!

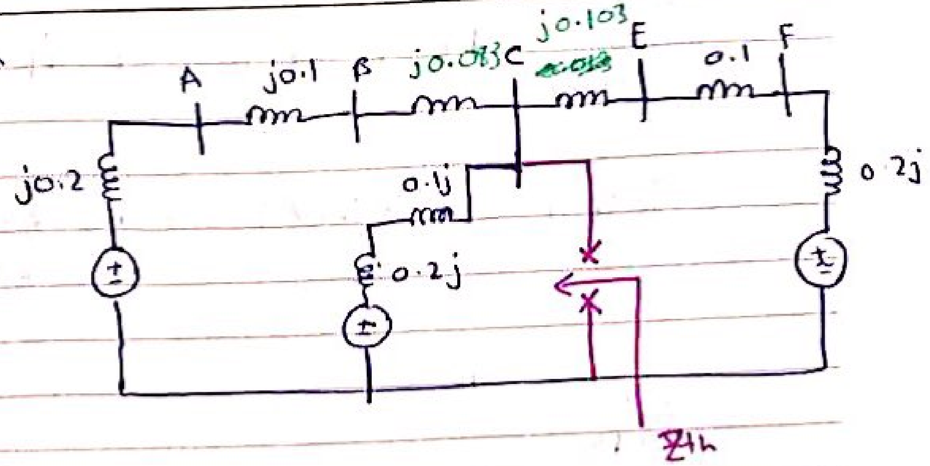
E_{g_1}'', E_{g_2}'', E_{g_3}'' | V_F ✓, $\hat{I}_L = 0$

ال E_{g_3}'', E_{g_2}'', E_{g_1}'' بكونوا نفس قيمة V_F.

اذا طلب ال internal method.

KeshiaColor

sol : using thevenin



$Z_{t.L}(pu) = \frac{80}{(220)^2/50}$

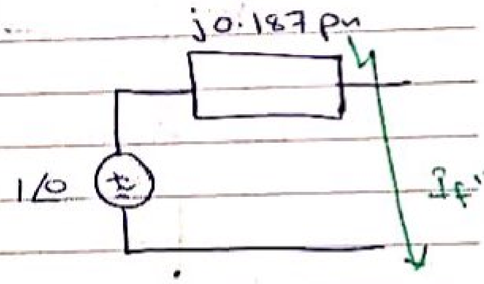
$= 0.083j$

$Z_{t.L} = \frac{100}{(220)^2/50} = 0.103j$

$Z_{th} = (j0.103 + j0.1 + j0.2) \,//\, (j0.1 + j0.2) \,//\, (j0.083 + j0.1 + 0.2) = j0.187.$

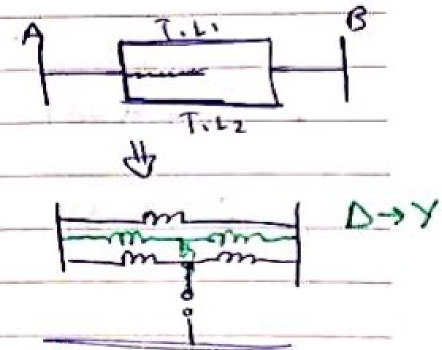
$I_{f\,pu}'' = \frac{1}{Z_{th}}$

$= -j\,5.348$ pu



$I_{f\,actual} = 5.348 * \frac{50M}{\sqrt{3} * 220K}$

$\boxed{I_f \text{ actual} = 702\ A}$



* بيقل ال fault لل اوّل عدد ال Gener.

*

* Fault level , Short circuit Level :-

- express fault interms of MVA.

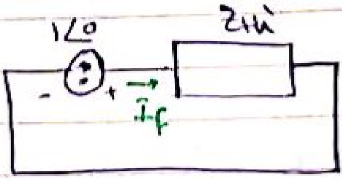
* - easier to compare fault at different voltage level.

16KA	11 KV
16 KA	33 KV

$$\boxed{S_c^{MVA} = \sqrt{3} * V_{LL\,base} * I_F}$$

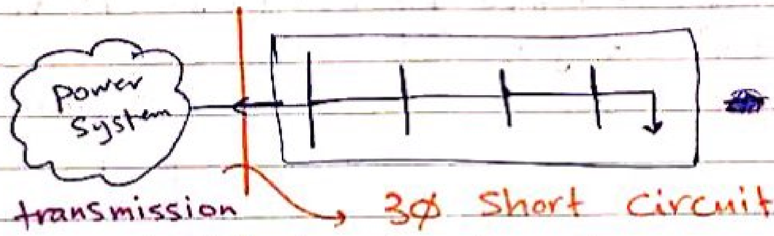
$$S_c(pu) = \frac{S_c(MVA)}{S_{base}} = \frac{\sqrt{3} * V_{LL\,base} * I_F}{\sqrt{3} * V_{LL\,base} * I_{base}} = I_F(pu)$$

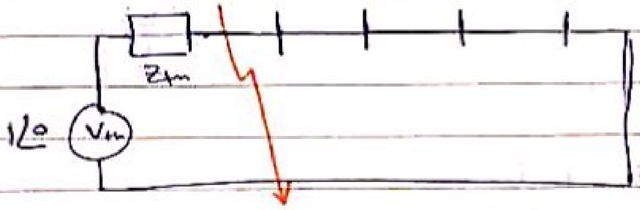
$$I_{f\,pu} = \frac{1}{Z_{th}}$$



$$Z_{th} = \frac{1}{I_{f\,pu}}$$

$V_F = 1\,pu.$



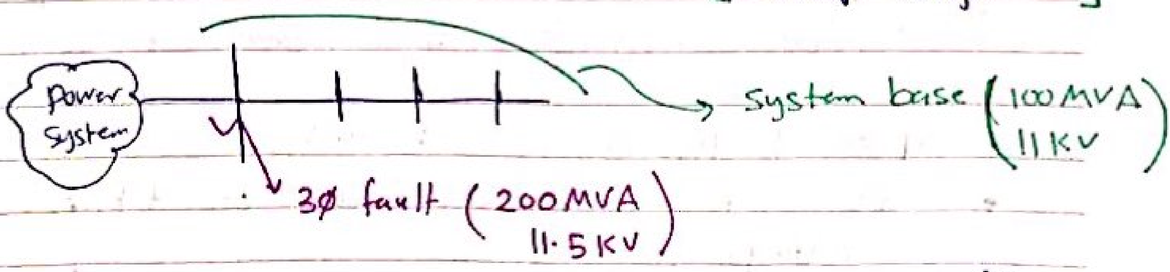


* اذا اعطاني الـ 3ϕ S/C
بقدر اطلع منها Zth
اذا ما اعطاني اياها بفرض
انو قيمتها (Zth = 0)
هي اقل قيمة.

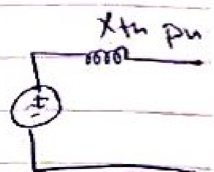
* $S_c(MVA)$ – Large ⇒ strong ⇒ [current ↑ → Z_{th} Small] [→ voltage drop Small]

* $S_c(MVA)$: small ⇒ weak → [Z_{th} large, Voltage drop large]

"fault current ↑"



$$X_{th\,pu} = j1. * \left(\frac{S_{new}}{S_{old}}\right) * \left(\frac{V_{old}}{V_{new}}\right)^2$$



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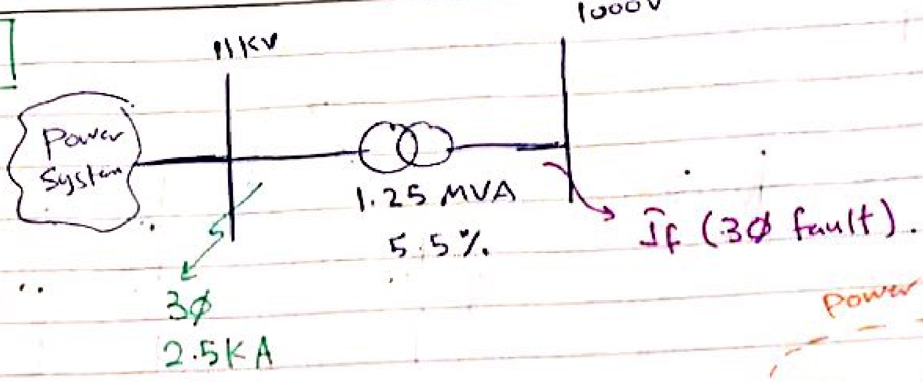
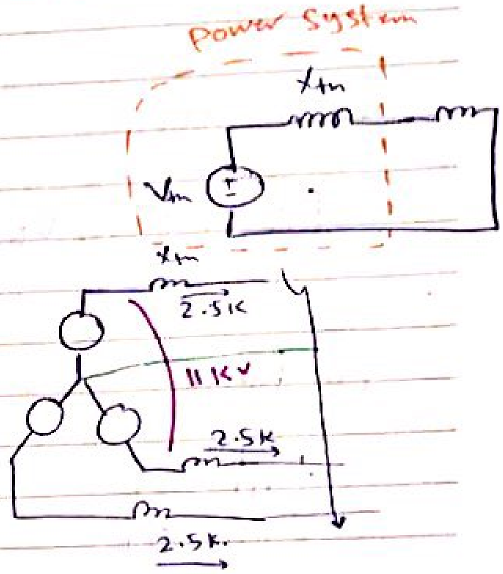
$\boxed{\text{Ex}}$





Sol.

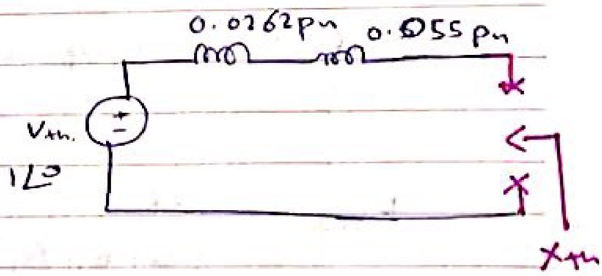
$$Z_{th} = \frac{11/\sqrt{3}}{2.5}$$

$$I_f(pu) = \frac{2.5\,KA}{1.25\,MVA/\sqrt{3} * 11K}$$

$$I_f(pu) = \frac{1}{Z_{th}(pu)}$$

$$Z_{th}(pu) = 0.0262\ pu.$$

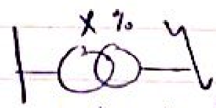
thevenin



$$X_{th} = j0.055 + j0.0262$$

$$I_f \Big|_{1000\,V} pu = 12.315\ pu$$

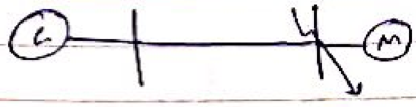
$$I_f(\text{actual}) = 12.315 * \frac{1.25\,M}{\sqrt{3} * 1000} = 8.88\ KA$$

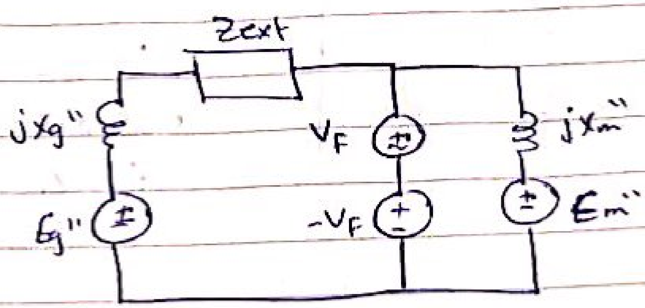


$$\text{max SC current} = \frac{1}{X} * \text{full load current}$$

Kokin Color

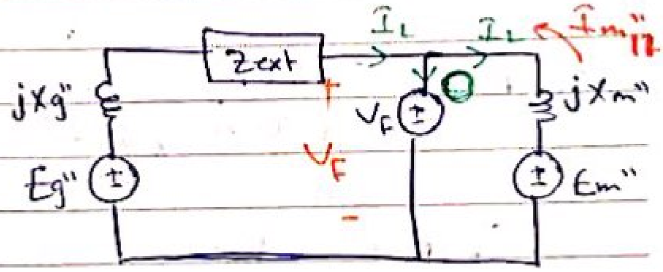
③ Superposition:-





Solution (1):

$\left(\underset{\text{ON}}{E_g'',\ E_m'',\ V_F}\right)$, $-V_F \Rightarrow$ off



Pre fault "load flow"

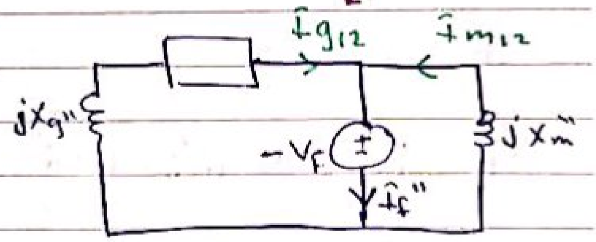
$\hat{I}_{g_{11}} = \hat{I}_L$

$\hat{I}_{m_{11}} = -\hat{I}_L$

Solution (2)

2nd solution.

$\left(\underset{\text{OFF}}{E_g'',\ E_m'',\ V_F}\right)$ $(-V_F$ ON$)$



" Short → source. "

($-V_F$ دة بس ↓
الـ fault

$$\hat{I}_{g_{12}} = \frac{V_F}{Z_{ext} + jX_g''}$$

$$\hat{I}_g'' = \hat{I}_{g_{11}} + \hat{I}_{g_{12}}$$

$$\hat{I}_g'' = \hat{I}_L + \frac{V_F}{Z_{ext} + jX''_g}$$

$$\hat{I}_m'' = -\hat{I}_L + \frac{V_F}{jX_m''}$$

$$\hat{I}_f'' = \hat{I}_g'' + \hat{I}_m''$$

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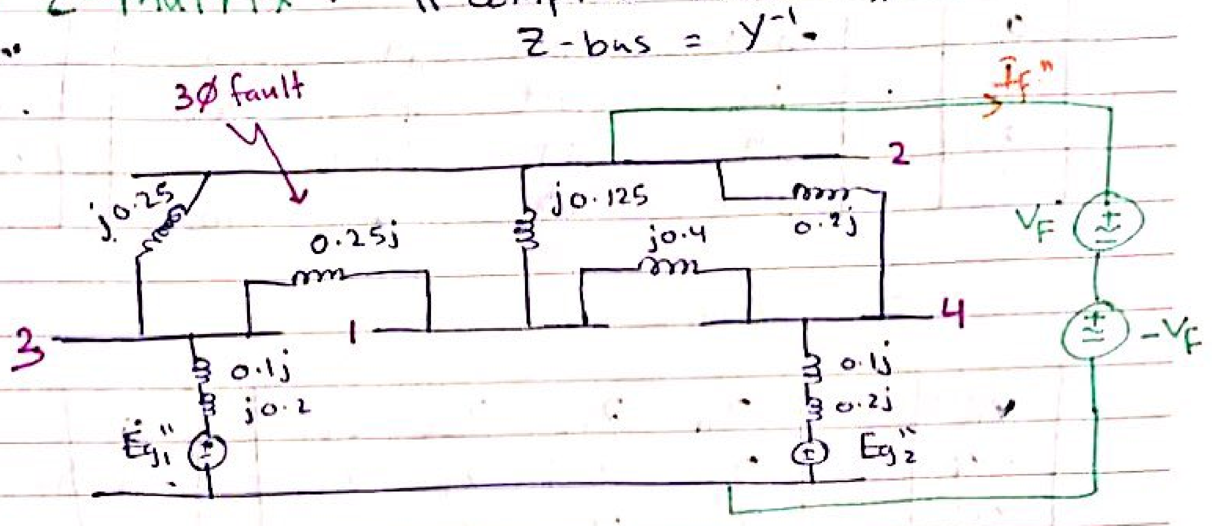
④ Z-matrix :- ((complex network))

$Z\text{-bus} = Y^{-1}$.



Neglect pre fault current. (V_F = pre fault voltage)

(($-V_F$ off)) => (V_F ON , E_{g1}'', E_{g2}'' = ON)

Solution (1) :-

Pre-fault (Neglect load current)

I (branceshes) = 0

$E_{g1}'' = E_{g2}'' = V_1^{(1)} = V_2^{(1)} = V_3^{(1)} = V_4^{(1)}$ (مافي تيار في الـ volt نفس)

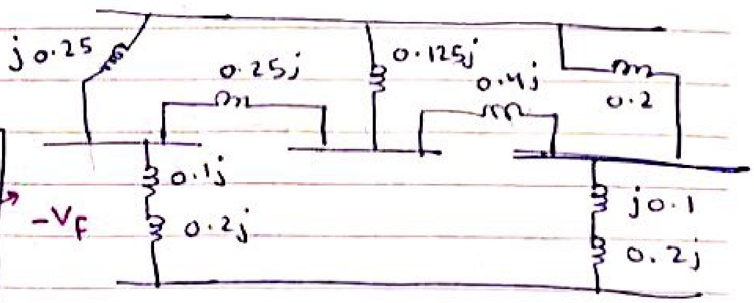
$= V_F$

Solution (2) :-

($-V_F$ ON / V_F, E_{g1}'', E_{g2}'' => off)

$I = YV$

$$\begin{bmatrix} 0 \\ -I_f'' \\ 0 \\ 0 \end{bmatrix} = \begin{bmatrix} Y_{matrix} \end{bmatrix} \begin{bmatrix} V_1^{(2)} \\ V_2^{(2)} \\ V_3^{(2)} \\ V_4^{(2)} \end{bmatrix} \quad V_2^{(2)} \rightarrow -V_F$$



$$\begin{bmatrix} 0 \\ -I_f'' \\ 0 \\ 0 \end{bmatrix} = \begin{bmatrix} -j14.5 & j8 & j4 & j2.5 \\ j8 & -j17 & j4 & j5 \\ j4 & j4 & -j11.33 & 0 \\ j2.5 & j5 & 0 & j10.88 \end{bmatrix} \begin{bmatrix} V_1^{(2)} \\ -V_f \\ V_3^{(2)} \\ V_4^{(2)} \end{bmatrix}$$

$V_1^{(2)} \rightarrow$ secound solution.

$$\begin{bmatrix} V_1^{(2)} \\ -V_F \\ V_3^{(2)} \\ V_4^{(2)} \end{bmatrix} = \underbrace{\begin{bmatrix} Z_{11} & Z_{12} & Z_{13} & Z_{14} \\ Z_{21} & Z_{22} & Z_{23} & Z_{24} \\ Z_{31} & Z_{32} & Z_{33} & Z_{34} \\ Z_{41} & Z_{42} & Z_{43} & Z_{44} \end{bmatrix}}_{Z\text{-bus} = Y^{-1}} \begin{bmatrix} 0 \\ -I_f'' \\ 0 \\ 0 \end{bmatrix}$$

interest

يعني صار العمود لانه fault صار, عند bus 2.

$$-V_F = Z_{21}(-I_f'')$$

$$\boxed{I_f'' = \frac{V_F}{Z_{22}}}$$

$$V_1^{(2)} = -Z_{12}\, I_f'' = -\frac{Z_{12} V_F}{Z_{22}}$$

يقل ال volt.

$$V_1 = V_1^{(1)} + V_1^{(2)}$$

$$V_1 = V_F - \frac{Z_{12} V_F}{Z_{22}} = V_F\left(1 - \frac{Z_{12}}{Z_{22}}\right)$$

$$V_3 = V_F\left(1 - \frac{Z_{32}}{Z_{22}}\right)$$

$$\boxed{I_f'' = \frac{V_F}{Z_{KK}}}$$

$$\boxed{V_i = V_F\left(1 - \frac{Z_{iK}}{Z_{KK}}\right)}$$

$\Rightarrow$ fault at bus K

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$$Z = \begin{bmatrix} j0.2436 & j0.1938 & j0.1544 & j0.1456 \\ & j0.2295 & & \\ & \cancel{j0.1499} & & \\ & j0.1994 & & \\ & j0.1506 & & \end{bmatrix}$$

$V_F = 1\angle 0$ at bus 2.

$$I_f'' = \frac{1\angle 0}{\underbrace{j0.2295}_{Z_{th}}} = -j4.3573 \text{ pu.}$$

طلع تيار بال pu اكبر من 1
لانو عامل fault وقيمتو كبيرة.

$$V_1 = V_F\left(1 - \frac{Z_{12}}{Z_{22}}\right)$$
$$= 0.1556.$$

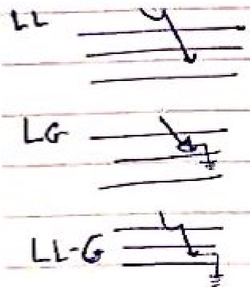
$V_2 = 0 \quad (V_F - V_F = 0)$

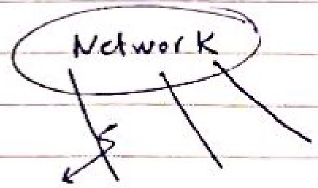
$$V_3 = V_F\left(1 - \frac{Z_{13}}{Z_{22}}\right) = 0.349j$$

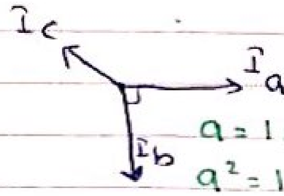
$V_4 = 0.3438$ pu.

$$I_{31} = \frac{V_3 - V_1}{j0.25} = -j0.7736 \text{ pu.}$$

* Symmetrical Components and Asymmetrical faults Δ "un balanced system"

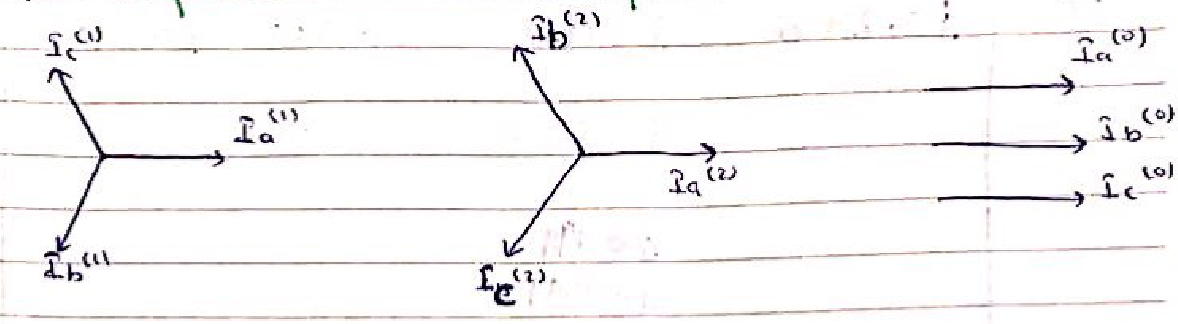






$a = 1\angle 120°$
$a^2 = 1\angle 240°$
unbalanced.
(operator) $a^3 = 1\angle 0$

+ve Sequence | -ve Sequence | Zero Sequence.



$$\hat{I}_a = \hat{I}_a^{(1)} + \hat{I}_a^{(2)} + \hat{I}_a^{(0)}$$

$$\hat{I}_b = \hat{I}_b^{(1)} + \hat{I}_b^{(2)} + \hat{I}_b^{(0)}$$

$$\hat{I}_c = \hat{I}_c^{(1)} + \hat{I}_c^{(2)} + \hat{I}_c^{(0)}$$

$$\begin{bmatrix} \hat{I}_A \\ \hat{I}_B \\ \hat{I}_C \end{bmatrix} = \begin{bmatrix} \text{matrix} \\ A \\ \text{"operator"} \end{bmatrix} \begin{bmatrix} \hat{I}_a^{(0)} \\ \hat{I}_a^{(1)} \\ \hat{I}_a^{(2)} \end{bmatrix}$$

بعبر ال a

↓

Phase current.

Keshin Color

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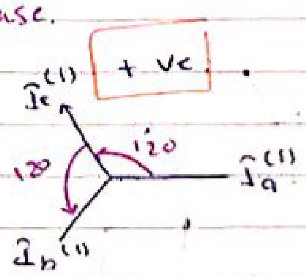
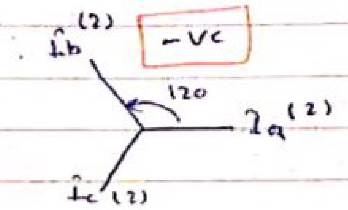
23/4 SUN

Symmetrical components :-

$$\begin{bmatrix} I_a \\ I_b \\ I_c \end{bmatrix} = \underbrace{\begin{bmatrix} 1 & 1 & 1 \\ 1 & a^2 & a \\ 1 & a & a^2 \end{bmatrix}}_{A} \begin{bmatrix} I_a^{(0)} \\ I_a^{(1)} \\ I_a^{(2)} \end{bmatrix}$$

phase. Symmetrical component





$a = 1\angle 120$

$a^2 = 1\angle 240^\circ$

$$I_b = a^2 I_a^{(1)} + a I_a^{(2)} + I_a^{(0)}$$

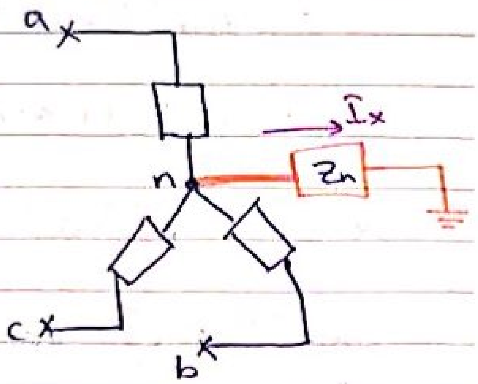
$$I_c = a I_a^{(1)} + a^2 I_a^{(2)} + I_a^{(0)}.$$

$$\begin{bmatrix} I_a^{(0)} \\ I_a^{(1)} \\ I_a^{(2)} \end{bmatrix} = \frac{1}{3} \underbrace{\begin{bmatrix} 1 & 1 & 1 \\ 1 & a & a^2 \\ 1 & a^2 & a \end{bmatrix}}_{A^{-1}} \begin{bmatrix} I_a \\ I_b \\ I_c \end{bmatrix}$$

① Balanced

$I_x = 0$

$V_n = V_E$



② un balanced

$$I_x = I_a + I_b + I_c = 3 I_a^{(0)}$$

* $I_a^{(0)} = \frac{1}{3}(I_a + I_b + I_c) \Rightarrow 3 I_a^{(0)} = I_a + I_b + I_c.$

$$V_n = 3 I_a^{(0)} * Z_n$$

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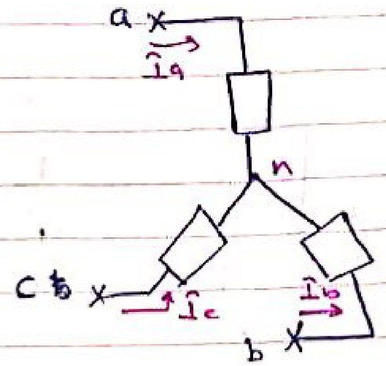
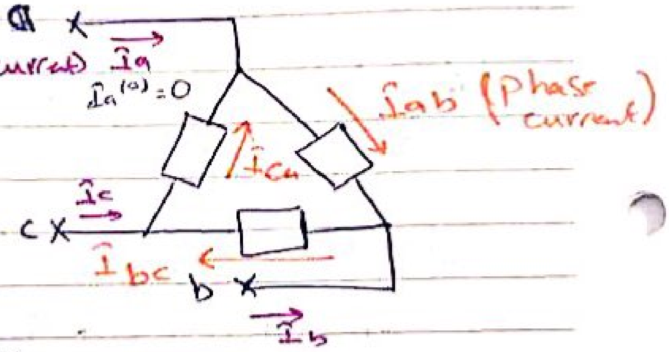
$\hat{I}_a^{(0)} = 3(\hat{I}_a + \hat{I}_b + \hat{I}_c) = 0$

لانو ما في Ground تفرغ فيه .



$\hat{I}_a = \hat{I}_{ab} - \hat{I}_{ca}$ (line current) $\hat{I}_a$

$\hat{I}_a^{(0)} = 0$



$$= (\hat{I}_{ab}^{(0)} + \hat{I}_{ab}^{(1)} + \hat{I}_{ab}^{(2)})$$

$$- (\hat{I}_{ca}^{(0)} + \hat{I}_{ca}^{(1)} + \hat{I}_{ca}^{(2)})$$

$$= \hat{I}_{ab}^{(0)} + \hat{I}_{ab}^{(1)} + \hat{I}_{ab}^{(2)}$$

$$\cancel{-(\hat{I}_{ab}^{(0)} + a^2 \hat{I}_{ab}^{(2)} + a \hat{I}_{ab}^{(1)})}$$

$$- (\hat{I}_{ab}^{(0)} + a\, \hat{I}_{ab}^{(1)} + a^2 \hat{I}_{ab}^{(2)})$$

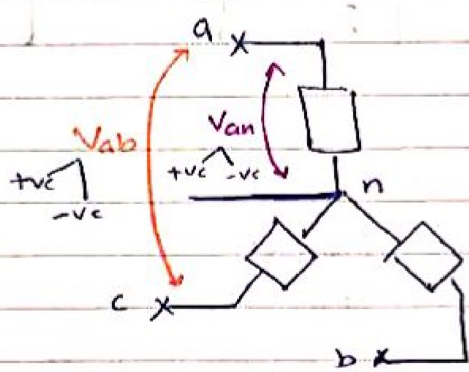
$$\hat{I}_a = \hat{I}_{ab}^{(1)} (1-a) + \hat{I}_{ab}^{(2)} (1-a^2).$$

$$\hat{I}_a = \hat{I}_{ab}^{(1)} (\sqrt{3}) \angle -30^\circ + \sqrt{3}\, \hat{I}_{ab}^{(2)} \angle +30^\circ$$

$$V_{ab}^{(1)} = V_{an}^{(1)} - V_{bn}^{(1)}$$

$$= V_{an}^{(1)} - a^2 V_{an}^{(1)}$$

$$= V_{an}^{(1)} (1-a^2)$$



$$V_{ab}^{(1)} = \sqrt{3}\, V_{an}^{(1)} \angle +30$$

$$V_{ab}^{(2)} = \sqrt{3}\, V_{an}^{(2)} \angle -30^\circ$$

$1 - a$

$(1 - 1\angle 120 = \sqrt{3})$

Δ in delta $\Rightarrow$ $\hat{I}_a^{(1)} = \sqrt{3}\, \hat{I}_{ab}^{(1)} \angle -30$

$$\hat{I}_a^{(2)} = \sqrt{3}\, \hat{I}_{ab}^{(2)} \angle +30^\circ$$

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3ϕ complex Power :-

$S_{3\phi} = 3\, V_a\, I_a^*$ "balanced"

$S_{3\phi} = V_a I_a^* + V_b I_b^* + V_c I_c^*$ "unbalanced"

$S_{3\phi} = 3 V_a^{(0)} I_a^{*(0)} + 3 V_a^{(1)} I_a^{*(1)} + 3 V_a^{(2)} I_a^{*(2)}$

↳ symmetrical Compoment.

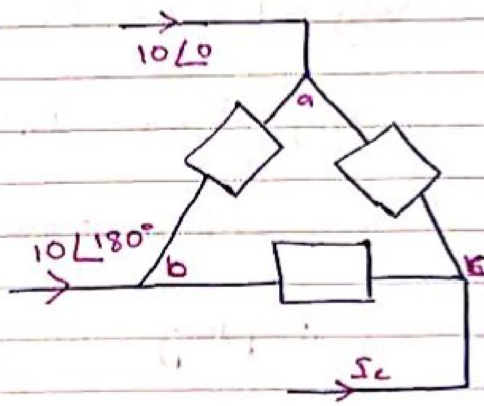
$$S_{3\phi} = \begin{bmatrix} V_a & V_b & V_c \end{bmatrix} \begin{bmatrix} I_a^* \\ I_b^* \\ I_c^* \end{bmatrix}$$

symmetrical

$3V_a^{(0)} I_a^{*(0)} = 0$ when → Δ connect load
↳ Y load un grounded

Ex :

Find I_c ?!



$\frac{1}{3}(10\angle 0 + 10\angle 180 + I_c) = 0$

line
$I_a^{(0)} = 0$

$I_a^{(0)}, I_a^{(1)}, I_a^{(2)} = ?!$

$$\begin{bmatrix} I_a^{(0)} \\ I_a^{(1)} \\ I_a^{(2)} \end{bmatrix} = \frac{1}{3} \begin{bmatrix} 1 & 1 & 1 \\ 1 & a & a^2 \\ 1 & a^2 & a \end{bmatrix} \begin{bmatrix} I_a \\ I_b \\ I_c \end{bmatrix}$$

$I_a^{(0)} = 0$
$I_a^{(1)} = 5.78 \angle -30°$
$I_a^{(2)} = 5.78 \angle +30°$

Kashin Color

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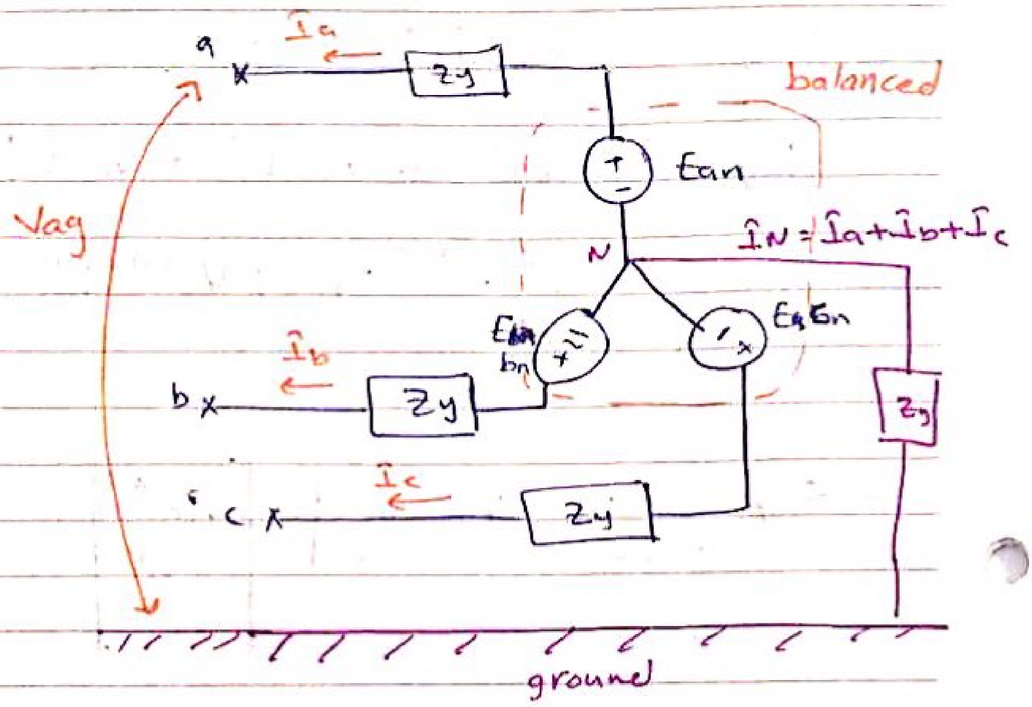
Sequence Network :-



$$-V_{ag} - I_a Z_y + E_{an} - I_n Z_n.$$

$$-V_{ag} - I_a Z_y - E_{an} - (I_a + I_b + I_c) Z_n = 0$$

$$V_{ag} = E_{an} - I_a (Z_y + Z_n) - I_b Z_n - I_c Z_n.$$

$$V_{bg} = E_{bn} - I_a (Z_n) - I_b (Z_y + Z_n) - I_c Z_n.$$

$$V_{cg} = E_{cn} - I_a Z_n - I_b (Z_n + Z_y)$$

coupling in phase.

Symmetrical Components :-

p ≙ phase.
s ≙ symmtrical.

$$V_p = E_p - Z_p I_p$$

$$A V_s = E_p - Z_p A I_s$$

$$V_s = A^{-1} E_p - A^{-1} Z_p A I_s$$

$$A^{-1} E_p = \begin{bmatrix} E_a^{(0)} \\ E_a^{(1)} \\ E_a^{(2)} \end{bmatrix}$$

generator balanced
→ current un balanced

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generator balanced. $\begin{bmatrix} 0 \\ E_a^{(1)} \\ 0 \end{bmatrix}$

$A^{-1} Z_P A$

$$\frac{1}{3}\begin{bmatrix} 1 & 1 & 1 \\ 1 & a & a^2 \\ 1 & a^2 & a \end{bmatrix}\begin{bmatrix} Z_y+Z_n & Z_n & Z_n \\ Z_n & Z_y+Z_n & Z_n \\ Z_n & Z_n & Z_y+Z_n \end{bmatrix}\begin{bmatrix} 1 & 1 & 1 \\ 1 & a^2 & a \\ 1 & a & a^2 \end{bmatrix}$$

$$= \begin{bmatrix} Z_y+3Z_n & 0 & 0 \\ 0 & Z_y & 0 \\ 0 & 0 & Z_y \end{bmatrix}$$

$$V_s = A^{-1} E_P - A^{-1} Z_P A \hat{I}_s$$

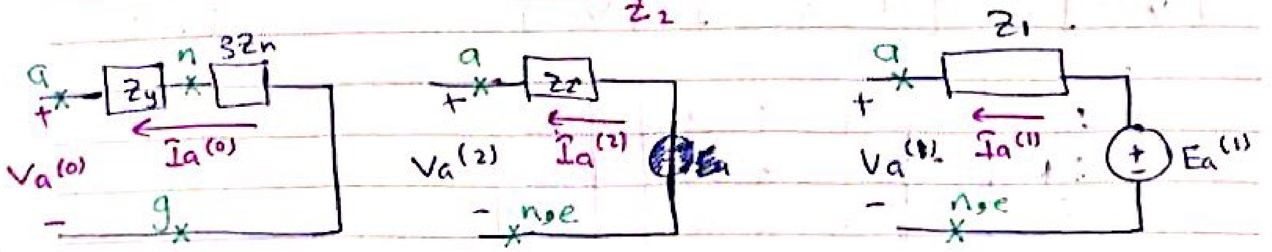
$$\begin{bmatrix} V_a^{(0)} \\ V_a^{(1)} \\ V_a^{(2)} \end{bmatrix} = \begin{bmatrix} 0 \\ E_a^{(1)} \\ 0 \end{bmatrix} - \begin{bmatrix} Z_y+3Z_n & 0 & 0 \\ 0 & Z_y & 0 \\ 0 & 0 & Z_y \end{bmatrix}\begin{bmatrix} \hat{I}_a^{(0)} \\ \hat{I}_a^{(1)} \\ \hat{I}_a^{(2)} \end{bmatrix}$$

* كل ال Symmetrical افضل لانو ال zeroV بيعتمد ع $\hat{I}_a^{(0)}$ فما في Coupling.

$$V_a^{(0)} = -\hat{I}_a^{(0)} \underbrace{(Z_y + 3Z_n)}_{Z_0}$$

$$V_a^{(1)} = E_a^{(1)} - \hat{I}_a^{(1)} \underbrace{Z_y}_{Z_1}$$

$$V_a^{(2)} = -\hat{I}_a^{(2)} \underbrace{Z_y}_{Z_2}$$



zero seq g = ground

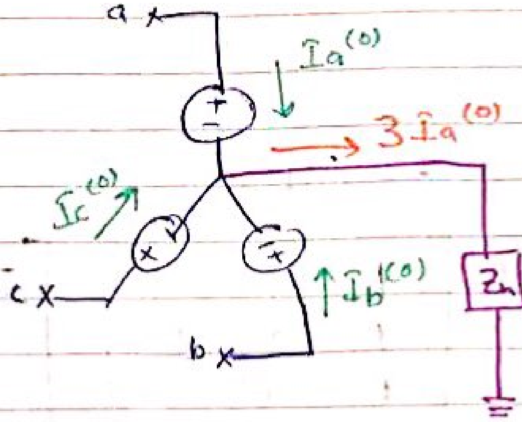
−ve seq

+ve seq n = nutral e = earth

* اذا ما كان عندي مسار للأرض بكون الـ zero seq ← O.C .

المقاومة بين n و e = ٣ اضعاف المقاومة .

$$V_n = 3Z_n \hat{I}_a^{(0)}$$



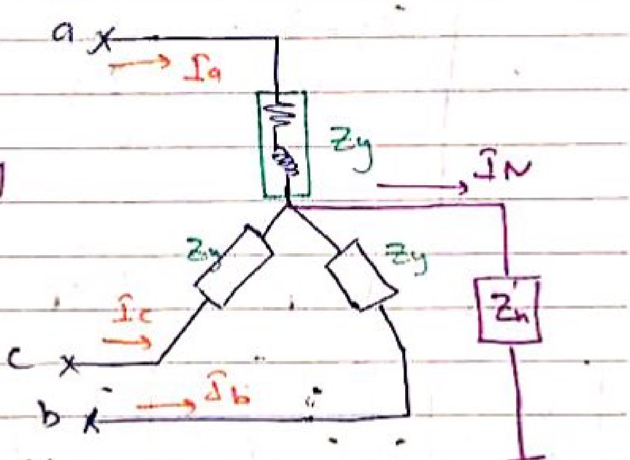
Sequence network with loads :-

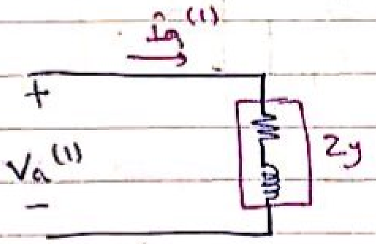
input $\begin{bmatrix} V_a \\ V_b \\ V_c \end{bmatrix}$, Z_y

$\hat{I}_a, \hat{I}_b, \hat{I}_c = ?!$

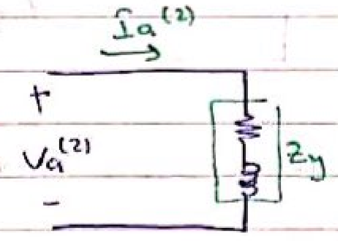
unbalanced

$V_a \equiv V_{ag}$

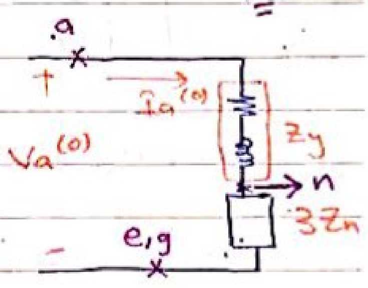




+ve seq



-ve seq



Zero seq

$$\begin{bmatrix} V_a^{(0)} \\ V_a^{(1)} \\ V_a^{(2)} \end{bmatrix} = \frac{1}{3} \begin{bmatrix} 1 & 1 & 1 \\ 1 & a & a^2 \\ 1 & a^2 & a \end{bmatrix} \begin{bmatrix} V_a \\ V_b \\ V_c \end{bmatrix}$$

circuit → $\hat{I}_a^{(0)}$, $\hat{I}_a^{(1)}$, $\hat{I}_a^{(2)}$

$$\begin{bmatrix} \hat{I}_a \\ \hat{I}_b \\ \hat{I}_c \end{bmatrix} = \begin{bmatrix} 1 & 1 & 1 \\ 1 & a^2 & a \\ 1 & a & a^2 \end{bmatrix} \begin{bmatrix} \hat{I}_a^{(0)} \\ \hat{I}_a^{(1)} \\ \hat{I}_a^{(2)} \end{bmatrix}$$

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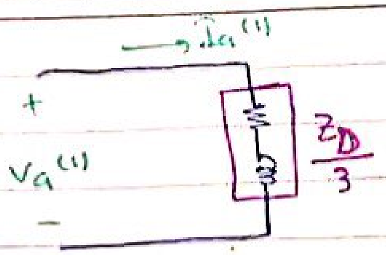
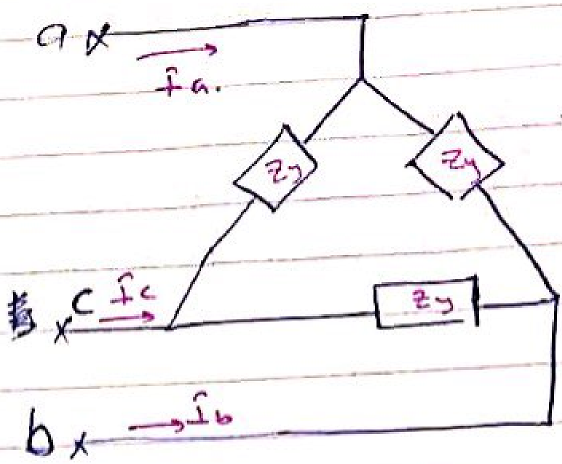
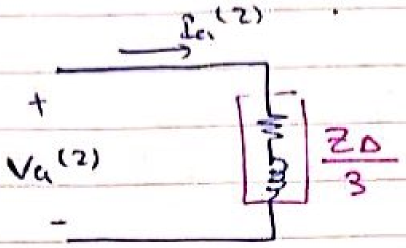
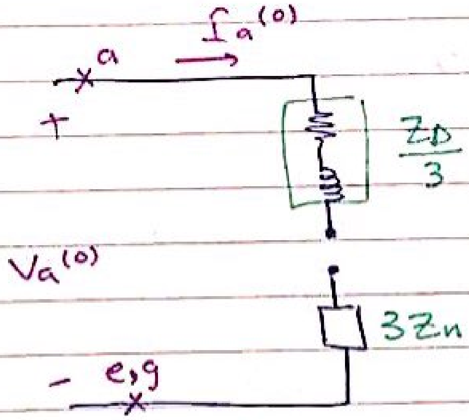


+ve Seq.





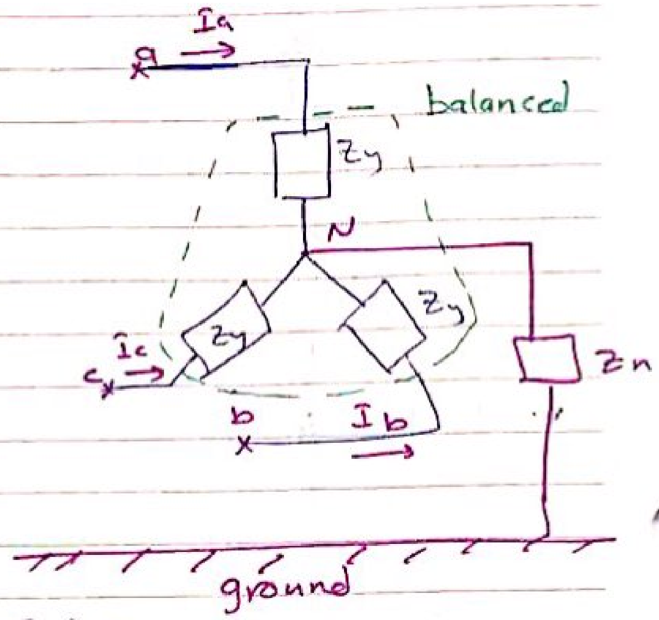
-ve Sequence.



zero Sequence.

Sequence Networks of impedance Y & Δ

load → balanced
I_a, I_b, I_c → unbalanced.
→ voltage unbalanced.



$$V_a = I_a Z_y + (I_a + I_b + I_c) Z_n$$

$$V_a = I_a (Z_y + Z_n) + I_b Z_n + I_c Z_n$$

$$V_b = I_a Z_n + I_b (Z_y + Z_n) + I_c Z_n$$

$$V_c = I_a Z_n + I_b Z_n + I_c (Z_y + Z_n)$$

$$Z_p = \begin{bmatrix} Z_y + Z_n & Z_n & Z_n \\ Z_n & Z_y + Z_n & Z_n \\ Z_n & Z_n & Z_y + Z_n \end{bmatrix}$$

$$V_p = Z_p I_p$$

$$A V_s = Z_p A I_s$$

$$V_s = A^{-1} Z_p A I_s$$

$$\boxed{\begin{aligned} a + a^2 &= -1 \\ 1 + a + a^2 &= 0 \end{aligned}}$$

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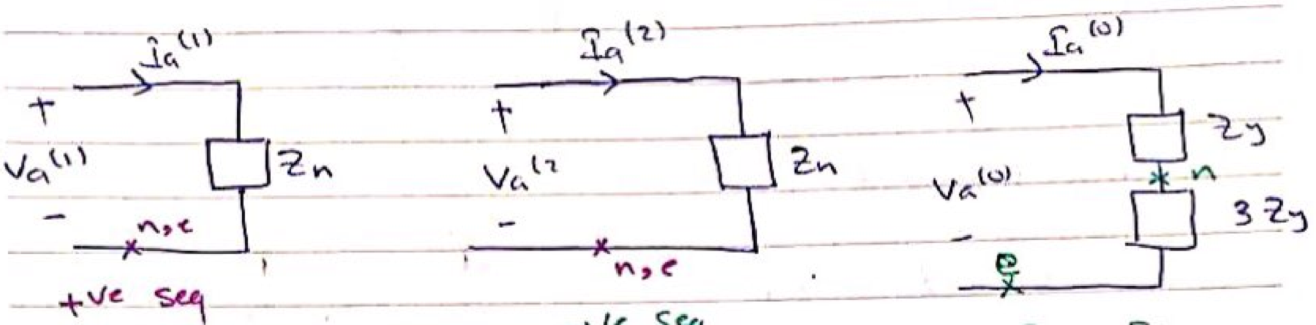
$$\begin{bmatrix} V_a^{(0)} \\ V_a^{(1)} \\ V_a^{(2)} \end{bmatrix} = \begin{bmatrix} Z_y+3Z_n & 0 & 0 \\ 0 & Z_y & 0 \\ 0 & 0 & Z_y \end{bmatrix} \begin{bmatrix} I_a^{(0)} \\ I_a^{(1)} \\ I_a^{(2)} \end{bmatrix}$$



+ve seq — −ve seq — Zero seq

$$V_{an} = V_{an}^{(0)} + V_{an}^{(1)} + V_{an}^{(2)}$$

$$V_{ae} = V_{ae}^{(0)} + V_{ae}^{(1)} + V_{ae}^{(2)}$$

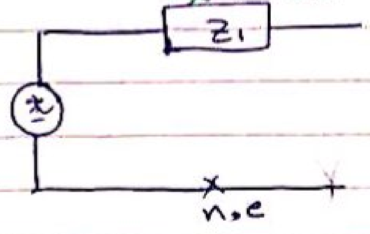
* sequence diagram 8∆ :

Power system → Generator
→ transformer
→ T.L
→ loads

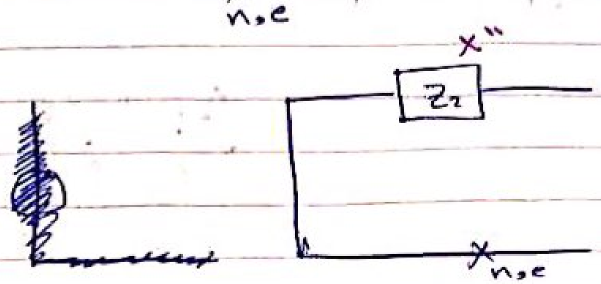
⇒ Generator :-

$X'', X', X \Rightarrow X > X' > X''$

+ve Sequence :-



−ve Sequence :



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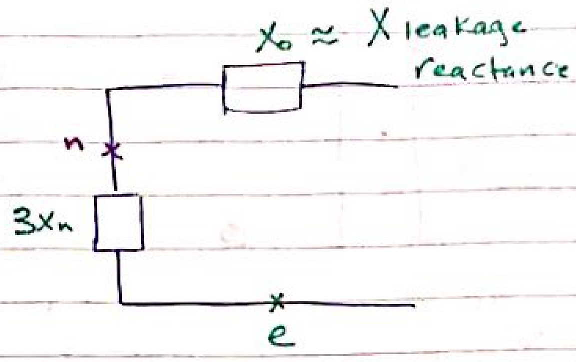
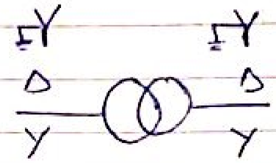
Zero sequence :

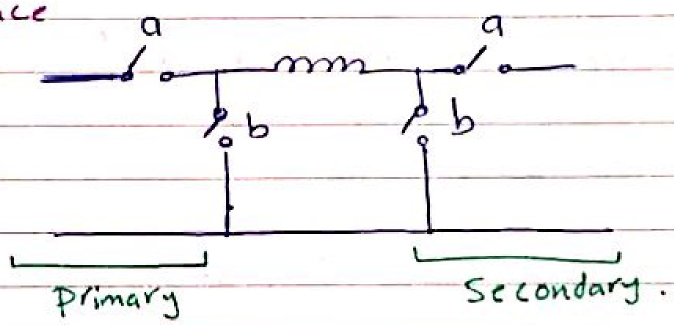


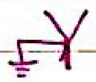
* transformer 8Δ

$X_1 = X_2 = X_0$



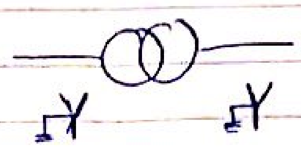
zero sequence



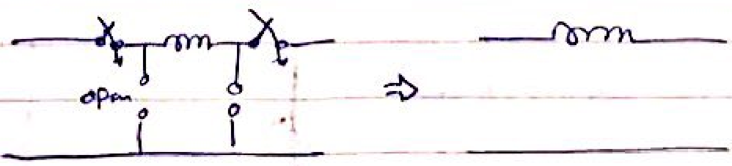
 close a
open b

Δ open a
close b

Y open a
open b



Zero sequence



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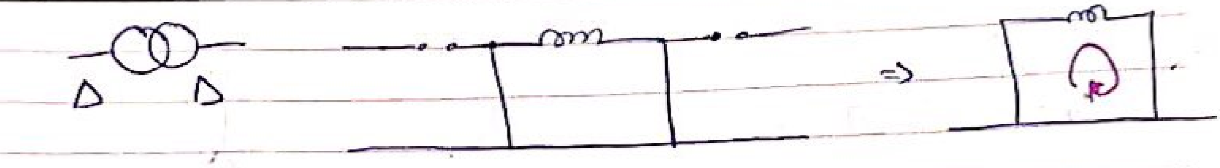
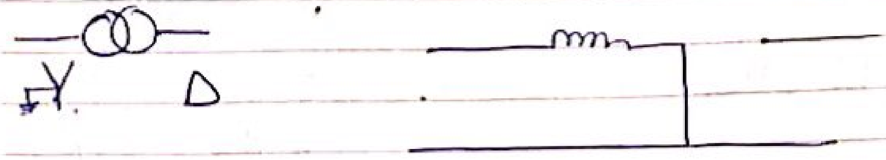
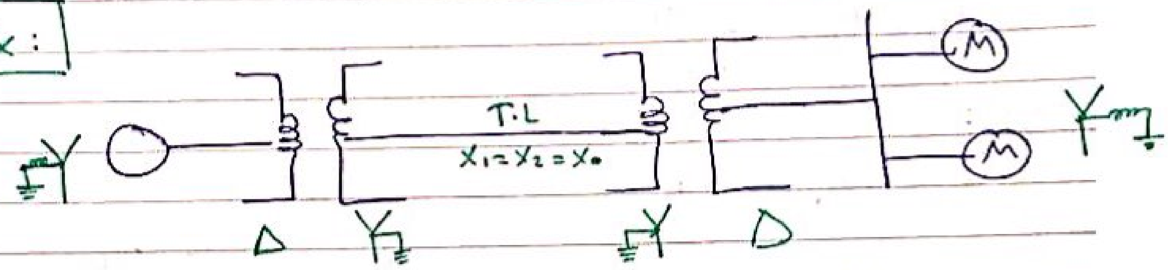
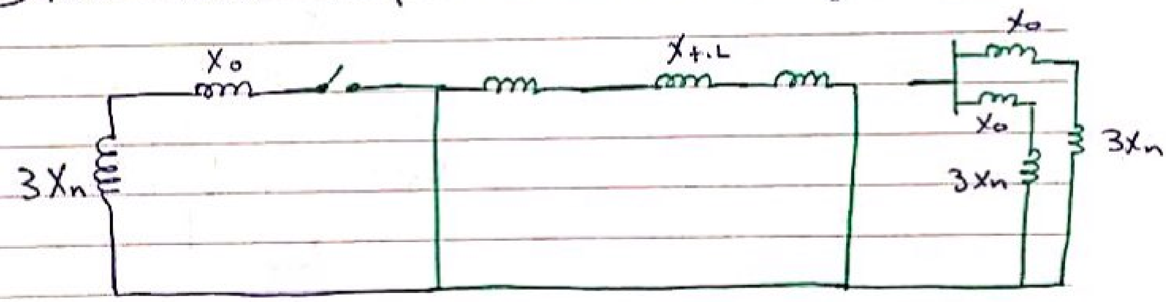




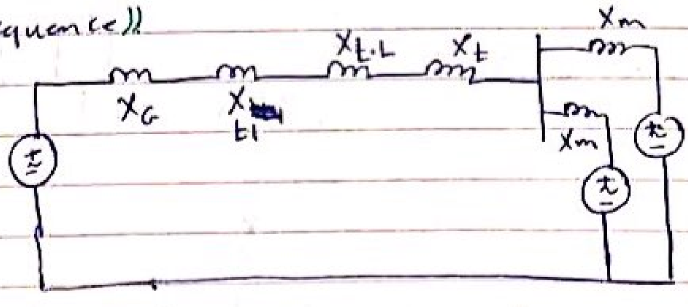
Ex:



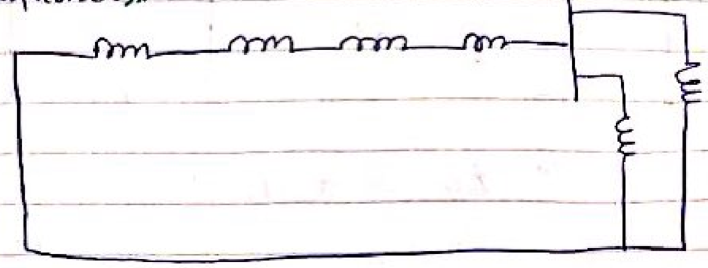
Draw zero sequence networks?



((+ve sequence))



((-ve sequence)):



KashinColor

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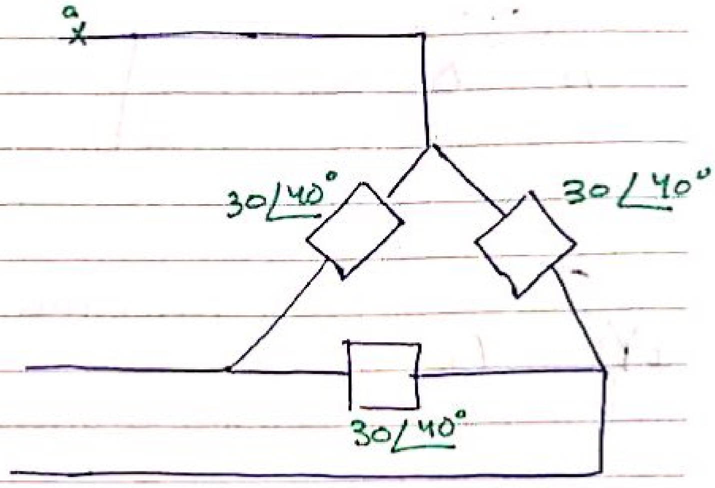
$\boxed{Ex}$



$V_{ag} = 277\angle 0$

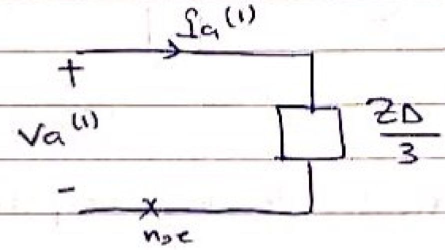
$V_{bg} = 260\angle -120°$

$V_{cg} = 295\angle 115°$

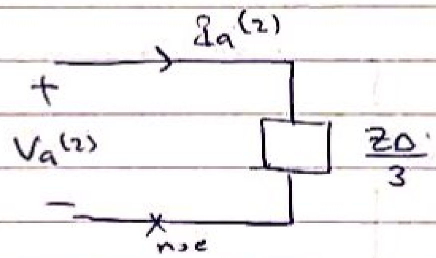
I_a, I_b, I_c ?!

Sol:

+ve sequence :-

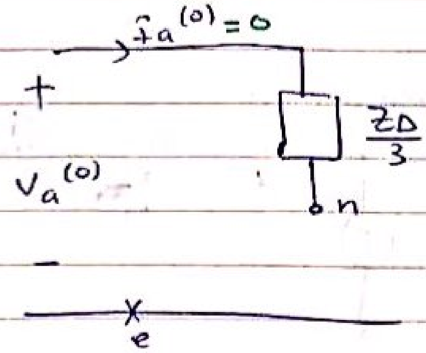


−ve sequence:



Zero sequence:

(($V_a \rightarrow g$ لل الفولت بالنسبة))



$$\begin{bmatrix} V_a^{(0)} \\ V_a^{(1)} \\ V_a^{(2)} \end{bmatrix} = \frac{1}{3}\begin{bmatrix} 1 & 1 & 1 \\ 1 & a & a^2 \\ 1 & a^2 & a \end{bmatrix} \begin{bmatrix} V_a \\ V_b \\ V_c \end{bmatrix}$$

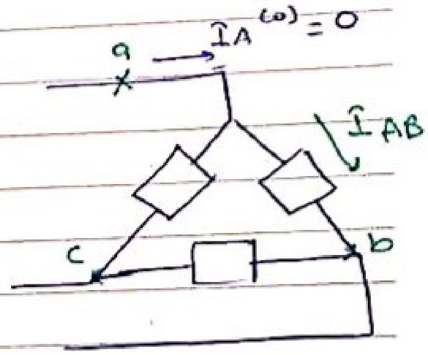
$V_a^{(0)} = I_a^{(0)} Z_0 \longrightarrow I_a^{(0)}$

$$V_a^{(1)} = I_a^{(1)} \frac{Z_\Delta}{3} \Rightarrow I_a^{(1)}$$

$$V_a^{(2)} = I_a^{(2)} \frac{Z_\Delta}{3} \Rightarrow I_a^{(2)}$$

$$\begin{bmatrix} I_a \\ I_b \\ I_c \end{bmatrix} = \begin{bmatrix} 1 & 1 & 1 \\ 1 & a^2 & a \\ 1 & a & a^2 \end{bmatrix} \begin{bmatrix} I_a^{(0)} \\ I_a^{(1)} \\ I_a^{(2)} \end{bmatrix}$$

$$I_{AB} = I_{AB}^{(0)} + I_{AB}^{(1)} + I_{AB}^{(2)}$$

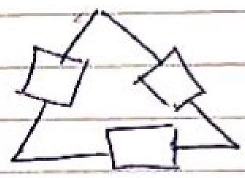


$$I_A^{(1)} = I_{AB}^{(1)} \sqrt{3} \angle -30^\circ$$

$$\underbrace{I_A^{(2)}}_{\text{line}} = \underbrace{I_{AB}^{(2)}}_{\text{phase}} * \sqrt{3} \angle +30^\circ$$

$$I_{AB}^{(0)} = ?!$$

$$V_{ab}^{(1)} = \sqrt{3}\, V_1^{(1)} \angle +30$$



V_a, V_b, V_c.

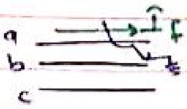
$$V_{ab} = V_a - V_b$$

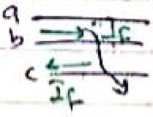
$$I_{ab} = \frac{V_{ab}}{Z_\Delta}$$

$$* \quad S_{3\phi} = 3 V_a^{(0)} * I_a^{(0)*} + \dots + \dots$$

2/5 Tue

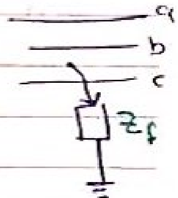
* Unsymmetrical fault analysis :-

LG 

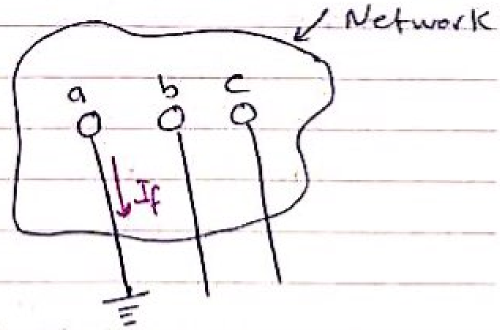
LL 

LLG 

* Analysis current
* Analysis voltage.
* Sequence network
  (+ve, -ve, zero)
* $\hat{I}_f$
* impact of Z_f (impedance of fault)



Single line to Ground :-



$\hat{I}_f = \hat{I}_a$

$\hat{I}_b = \hat{I}_c = 0$ (unloaded)

$$\begin{bmatrix} \hat{I}_a^{(0)} \\ \hat{I}_a^{(1)} \\ \hat{I}_a^{(2)} \end{bmatrix} = \frac{1}{3} \begin{bmatrix} 1 & 1 & 1 \\ 1 & a & a^2 \\ 1 & a^2 & a \end{bmatrix} \begin{bmatrix} \hat{I}_a \\ \cancel{\hat{I}_b}\ 0 \\ \cancel{\hat{I}_c}\ 0 \end{bmatrix}$$

$$\hat{I}_a^{(0)} = \frac{1}{3} \hat{I}_a = \frac{1}{3} \hat{I}_f$$

$$\hat{I}_a^{(1)} = \frac{1}{3} \hat{I}_a = \frac{1}{3} \hat{I}_f$$

$$\hat{I}_a^{(2)} = \frac{1}{3} \hat{I}_a = \frac{1}{3} \hat{I}_f$$

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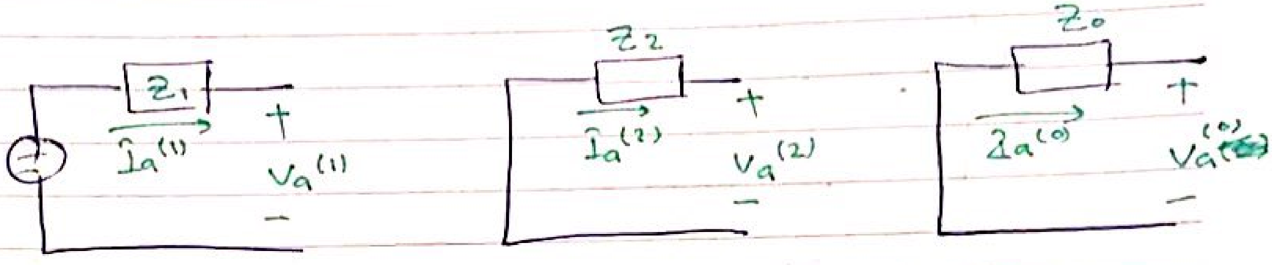
$$I_a^{(0)} = I_a^{(1)} = I_a^{(2)}$$

$$V_a = 0$$

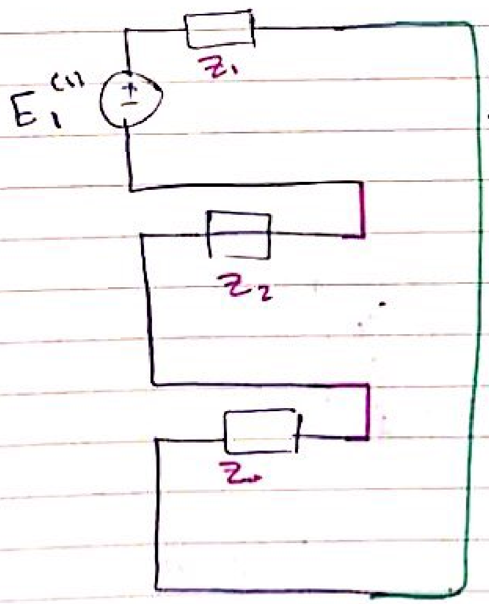
$$V_a^{(0)} + V_a^{(1)} + V_a^{(2)} = 0$$

$$I_a^{(0)} = I_a^{(1)} = I_a^{(2)}$$



+ve seq — −ve seq — zero seq

$Z_0, Z_1, Z_2 \Rightarrow Z_{th}$ thevenin from fault.



$I_a^{(0)}$
$I_a^{(1)}$
$I_a^{(2)}$

برضهم نفس تيار

in series مشبوكين ⇐

$$\underline{I_f = 3I_a^{(0)}}$$

$$I_f = 3\,I_a^{(0)} = \frac{3\,E^{(1)}}{Z_1 + Z_2 + Z_0}$$

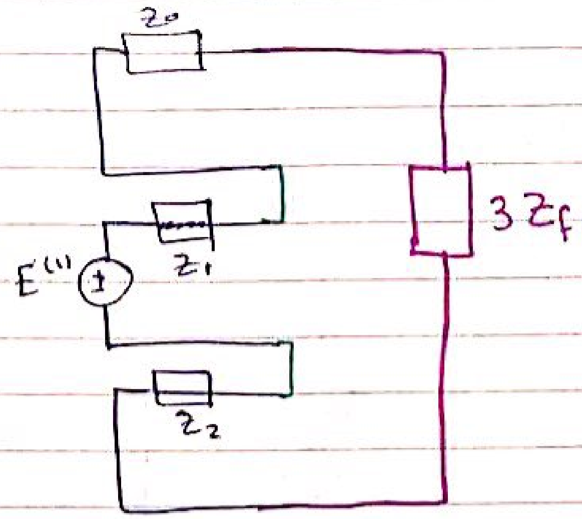
$Z_0 > Z_1, Z_2$

لانها مقاومة الأرض.

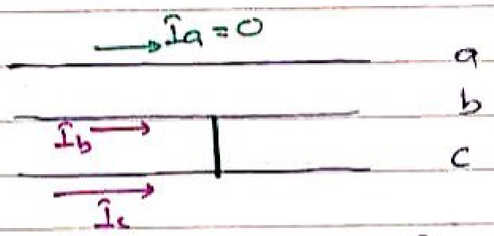
Impact of Z_f 84

$$V_a = I_f\,Z_f = 3I_a^{(0)}\,Z_f = I_a^{(0)}\,3Z_f$$

$$V_a^{(0)} + V_a^{(1)} + V_a^{(2)} = I_a^{(0)}(3Z_f)$$



Line to Line fault :-



$I_a = 0 \qquad I_b = I_f \quad , \quad I_c = -I_b$
$= -I_f$

$$\boxed{I_b = -I_c}$$

$$\begin{bmatrix} I_a^{(0)} \\ I_a^{(1)} \\ I_a^{(2)} \end{bmatrix} = \frac{1}{3}\begin{bmatrix} 1 & 1 & 1 \\ 1 & a & a^2 \\ 1 & a^2 & a \end{bmatrix}\begin{bmatrix} \cancel{I_a} \rightarrow 0 \\ I_b \\ \cancel{I_c} \rightarrow -I_b \end{bmatrix}$$

$I_a^{(0)} = 0$

$I_a^{(1)} = \frac{1}{3}(a I_b - a^2 I_b)$

$I_a^{(2)} = \frac{1}{3}(a^2 I_b - a I_b)$

$$\boxed{\begin{aligned} I_a^{(0)} &= 0 \\ I_a^{(1)} &= -I_a^{(2)} \end{aligned}}$$

$V_b = V_c$

$V_a^{(0)} + a^2 V_a^{(1)} + a V_a^{(2)} = V_a^{(0)} + a V_a^{(1)} + a^2 V_a^{(2)}$

$V_a^{(1)}(a^2 - a) = V_a^{(2)}(a^2 - a)$

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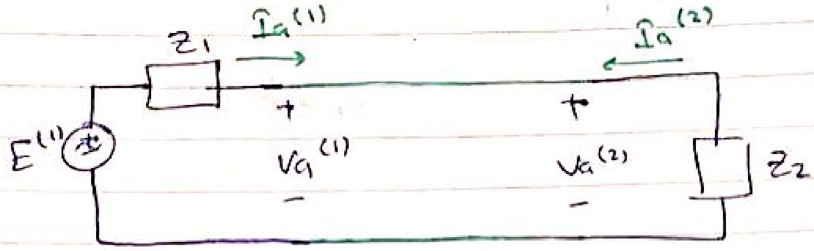
$\boxed{V_a^{(1)} = V_a^{(2)}} \Rightarrow$ parallel.



$-\hat{I}_a^{(1)} = +\hat{I}_a^{(2)}$

$$\hat{I}_a^{(1)} = \frac{E}{Z_1 + Z_2}$$

~~$\hat{I}_b = a^2 \hat{I}_a^{(1)} - a \hat{I}_a^{(1)}$~~

$\hat{I}_f = \hat{I}_b$

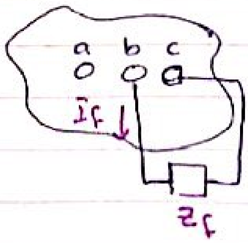
$$\begin{bmatrix} \hat{I}_a \\ \hat{I}_b \\ \hat{I}_c \end{bmatrix} = \begin{bmatrix} 1 & 1 & 1 \\ 1 & a^2 & a \\ 1 & a & a^2 \end{bmatrix} \begin{bmatrix} \cancel{\hat{I}_a^{(0)}} \to 0 \\ \hat{I}_a^{(1)} \\ \cancel{\hat{I}_a^{(2)}} \to -\hat{I}_a^{(1)} \end{bmatrix}$$

$$\hat{I}_b = a^2 \hat{I}_a^{(1)} - a \hat{I}_a^{(1)}$$

$$\hat{I}_f = \hat{I}_b = \hat{I}_a^{(1)} (a^2 - a)$$

$$|\hat{I}_f| = \sqrt{3} \left| \frac{E^{(1)}}{Z_1 + Z_2} \right|$$

impact Z_f :-



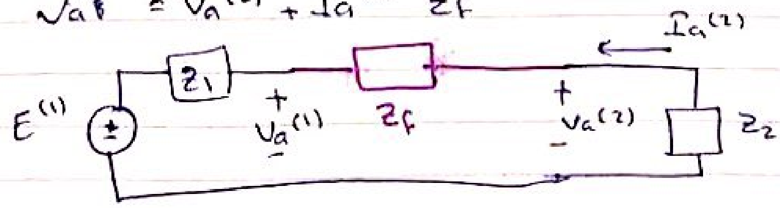
$$V_b - V_c = \hat{I}_f Z_f$$

$$V_b = V_c + \hat{I}_f Z_f$$

$$V_a^{(1)}(a^2 - a) = V_a^{(2)}(a^2 - a) + (\hat{I}_a^{(0)} + a^2 \hat{I}_a^{(1)} + a \hat{I}_a^{(2)}) Z_f$$

$$V_a^{(1)}(a^2 - a) = V_a^{(2)}(a^2 - a) + \hat{I}_a^{(1)}(a^2 - a) Z_f$$

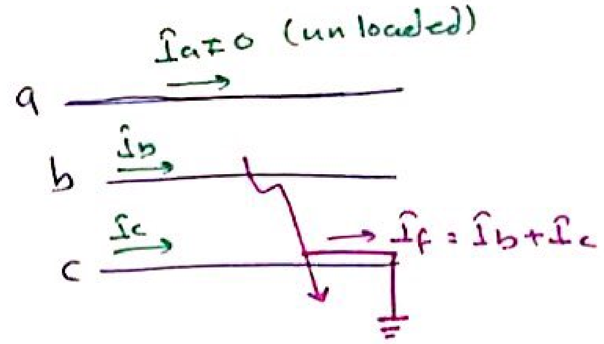
$$V_a^{(1)} = V_a^{(2)} + \hat{I}_a^{(1)} Z_f$$



4/5 Thur

Double line to ground fault:-

1) Analysis of current
2) " Voltage
3) Sequence networks.
4) impact of Z_f.



$\hat{I}_a = 0$

$\hat{I}_a^{(0)} + \hat{I}_a^{(1)} + \hat{I}_a^{(2)} = 0$, KCL

$V_b = V_c$

$V_a^{(0)} + a^2 V_a^{(1)} + a V_a^{(2)} = V_a^{(0)} + a V_a^{(1)} + a^2 V_a^{(2)}$

$V_a^{(1)} (a^2 - a) = V_a^{(2)} (a^2 - a)$

$\boxed{V_a^{(1)} = V_a^{(2)}}$

$V_b = 0$

$a^2 + a = ?!!$

$1 + a^2 + a = 0$

$a^2 + a = -1$

$V_a^{(0)} + a^2 V_a^{(1)} + a V_a^{(2)} = 0$

$V_a^{(0)} + a^2 V_a^{(1)} + a V_a^{(1)} = 0$

$V_a^{(0)} + V_a^{(1)} (a^2 + a) = 0$

$V_a^{(0)} + V_a^{(1)} (-1) = 0$

$\boxed{V_a^{(0)} = V_a^{(1)}}$

$\hat{I}_a^{(0)} + \hat{I}_a^{(1)} + \hat{I}_a^{(2)} = 0$

$V_a^{(1)} = V_a^{(2)}$

$V_a^{(1)} = V_a^{(0)}$

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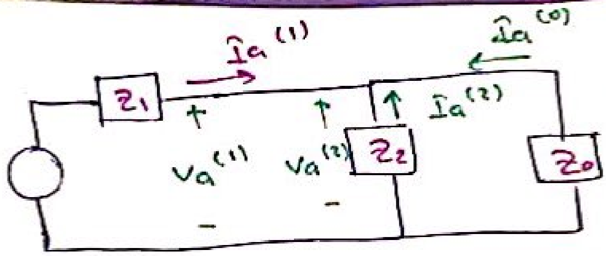
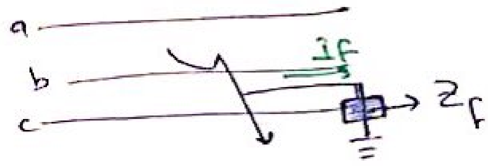


$\hat{I}_a^{(0)}, \hat{I}_a^{(1)}, \hat{I}_a^{(2)} \rightarrow \hat{I}_b, \hat{I}_f \rightarrow \hat{I}_f.$

* impact Z_f :-



$V_b = V_a^{(0)} - V_a^{(1)}$,

$V_b = \hat{I}_f Z_f$

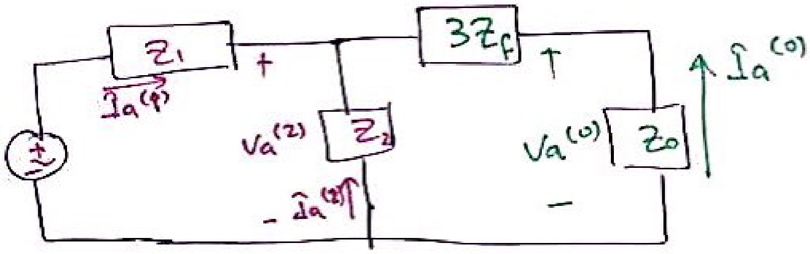
$V_b = 3(\hat{I}_a^{(0)}) Z_f$

$V_b = \hat{I}_a^{(0)} \, 3Z_f$

$V_a^{(0)} - V_a^{(1)} = \hat{I}_a^{(0)}(3Z_f)$

$V_b \neq 0$

V_b ساوي تيار ال fault مضروب بالمعاوقة .

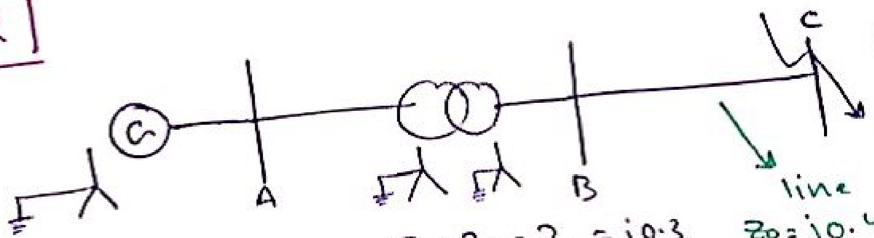


$$\hat{I}_f = \hat{I}_b + \hat{I}_c$$

$$= \left(\hat{I}_a^{(0)} + a^2 \hat{I}_a^{(1)} + a \hat{I}_a^{(2)}\right) + \left(\hat{I}_a^{(0)} + a \hat{I}_a^{(1)} + a^2 \hat{I}_a^{(2)}\right)$$

$$\boxed{\hat{I}_a^{(0)} + \hat{I}_a^{(1)} + \hat{I}_a^{(2)} = 0}$$

Ex



LG "on a common base"

$Z_0 = j1$ pu
$Z_1 = j0.5$ pu
$Z_2 = j0.6$ pu

$Z_1 = Z_2 = Z_0 = j0.3$

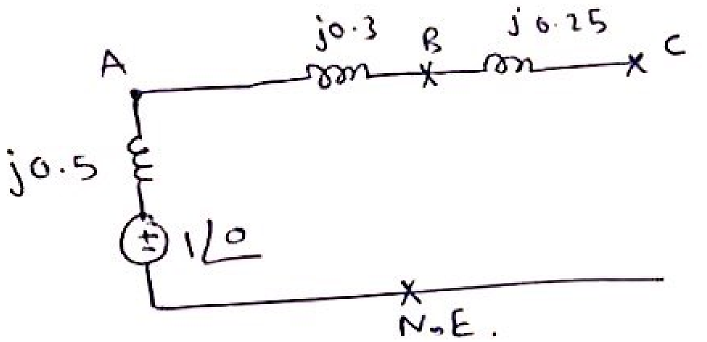
line
$Z_0 = j0.45$ pu
$Z_1 = j0.25$ pu
$Z_2 = j\,0.25$ pu.

Neglect load current,
$V_f = 1$ pu

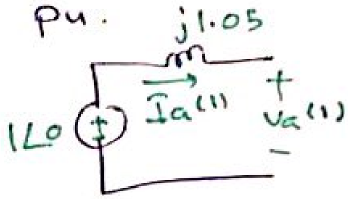
① find LG fault at bus C ?!

② Line to fault at bus B ?!

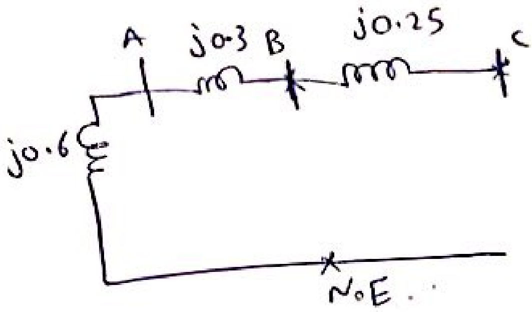
+ve Sequence :



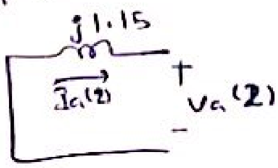
$Z_1 = j1.05$ pu.



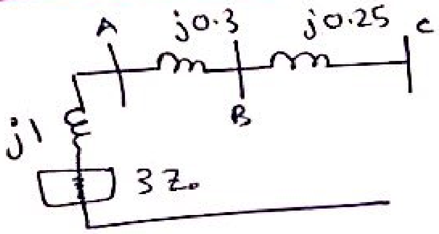
-ve Sequence :



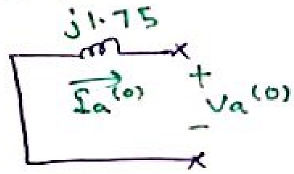
$Z_2 = j1.15$ pu

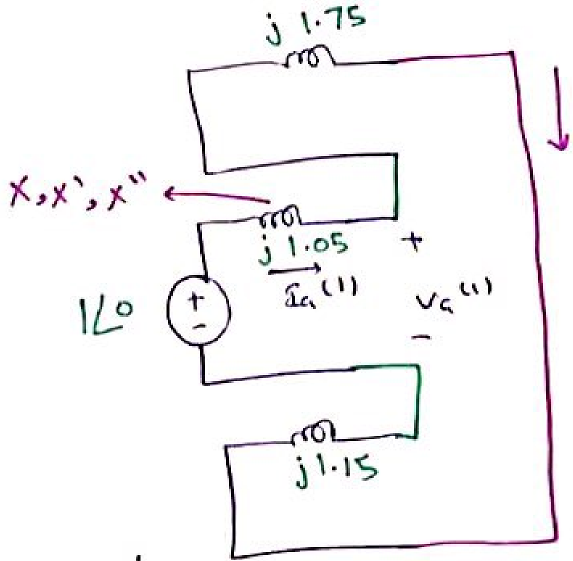


Zero sequence :



$Z_0 = j1.75$ pu





$\downarrow I_a^{(0)}$

$I_a^{(1)} = I_a^{(0)} = I_a^{(2)}$

$I_{LG} = 3 I_a^{(0)}$

$$I_a^{(0)} = \frac{1}{j1.75 + j1.05 + j1.15}$$

$$\boxed{I_f = 3 I_a^{(0)} = 0.759 \text{ pu}}$$

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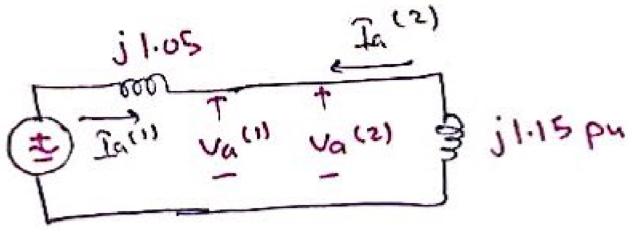
② line to line fault . at bus C



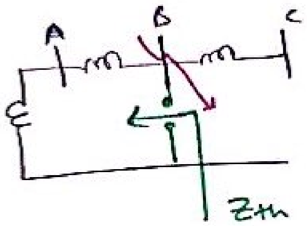
$$\boxed{\hat{I}_a^{(1)} = -\hat{I}_a^{(2)}}$$

$$\hat{I}_a^{(1)} = \frac{1\angle 0}{j1.05 + j1.15}$$

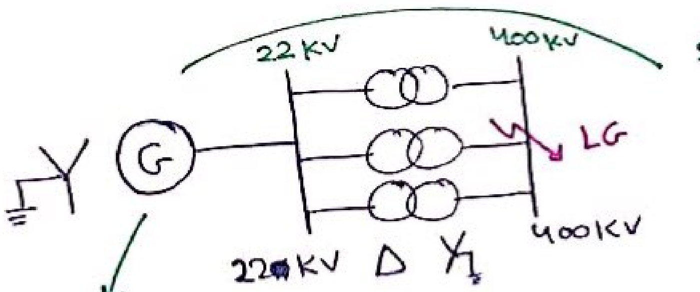
$$\hat{I}_a^{(2)} = -\hat{I}_a^{(1)}$$

$$\boxed{\hat{I}_f = \sqrt{3}\ \hat{I}_a^{(1)}}$$

* لوحطو عندي fault ع bus B بتغير عندي قيم ال Zth .



Ex



$S_b = 1000$ MVA

* V_b باخدو نفس ال ratio for transformer

22KV
825 MVA.
$X_1 = 0.14$ pu.
$X_2 = 0.13$ pu
$X_0 = 0.15$ pu

each transformer
300MVA
$X_1 = X_2 = X_0 = 0.14$ pu

LG fault
at bus 2?!
((base 1000MVA))
$V_f = 1\angle 0$ pu

Sol:

Generator ⇒

$$X_1 = 0.14 * \left(\frac{1000}{825}\right) = 0.17 \text{ pu}$$

$$\boxed{X_2 = 0.158 \text{ pu}} \qquad \boxed{X_0 = 0.182 \text{ pu}}$$

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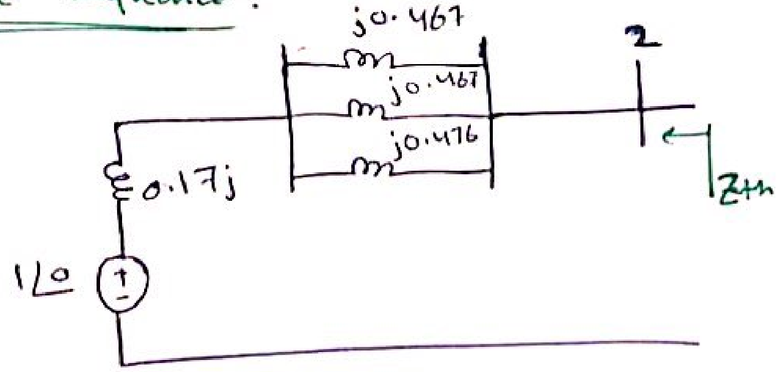
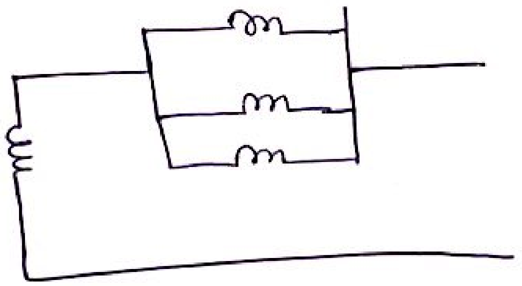
transformer: $X_1 = X_2 = X_0 = 0.14 * \left(\frac{1000}{300}\right) = 0.467\,pu$

+ve Sequence:



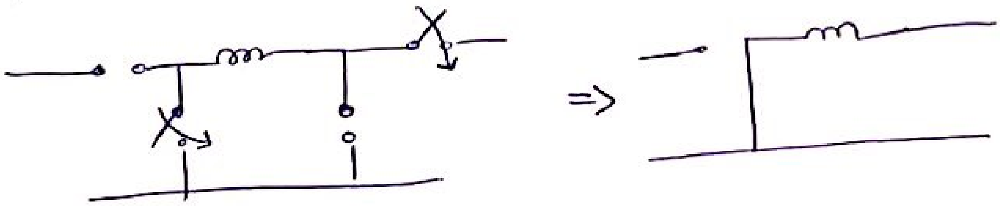
$Z_{th} = j\left(\frac{j0.467}{3} + 0.17\right)$

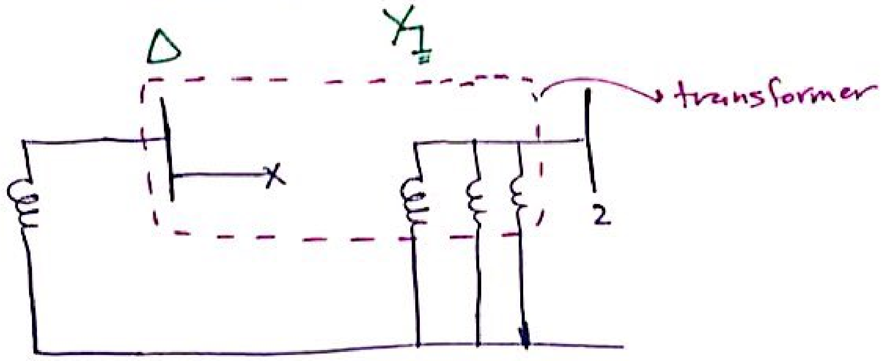
-ve sequence:



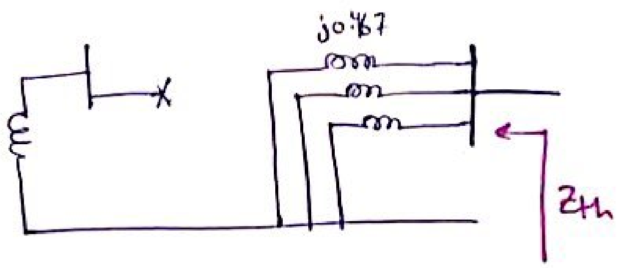
$Z_2 = j\left(\frac{0.467}{3} + j0.158\right)$

Zero sequence :-





$\equiv$



* لما $Y_{\perp}$ $Y_{\perp}$ بتزيد ال Z_{th} .

$Z_0 = \frac{j0.467}{3}$

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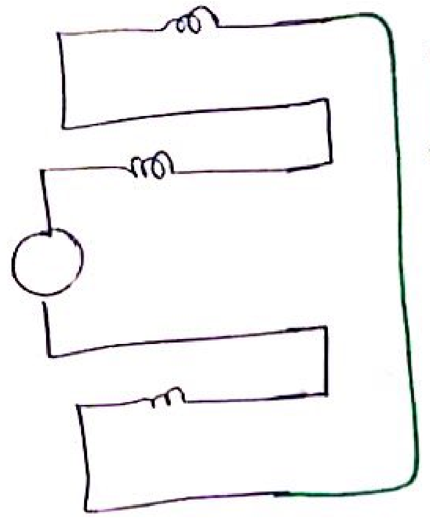
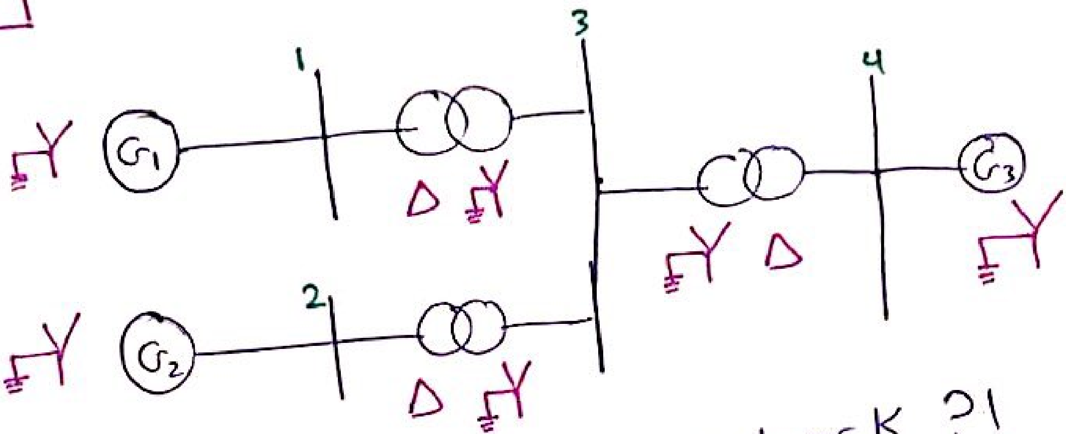
LG



$\downarrow I_a^{(0)}$

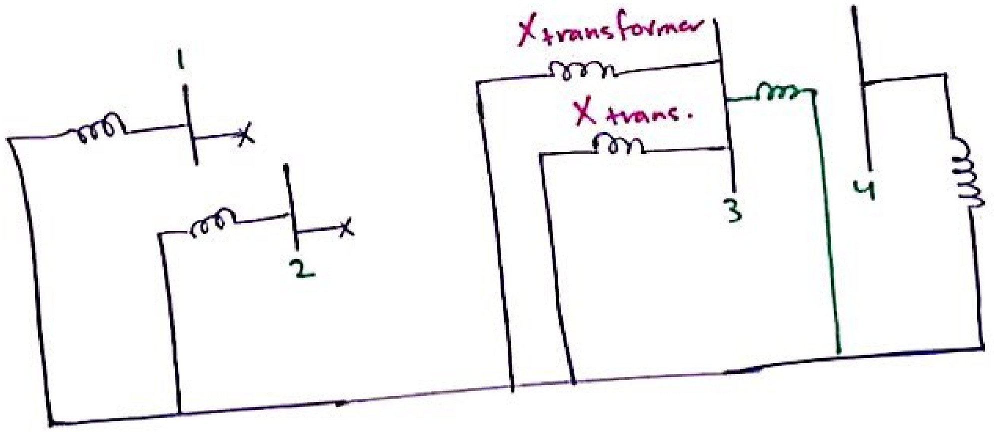
$I_f = 3 I_a^{(0)}$

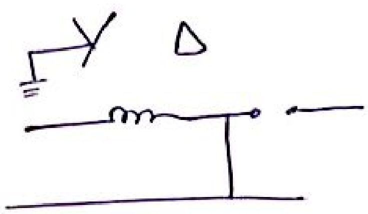
Ex



Draw zero sequence. network ?!

Sol:





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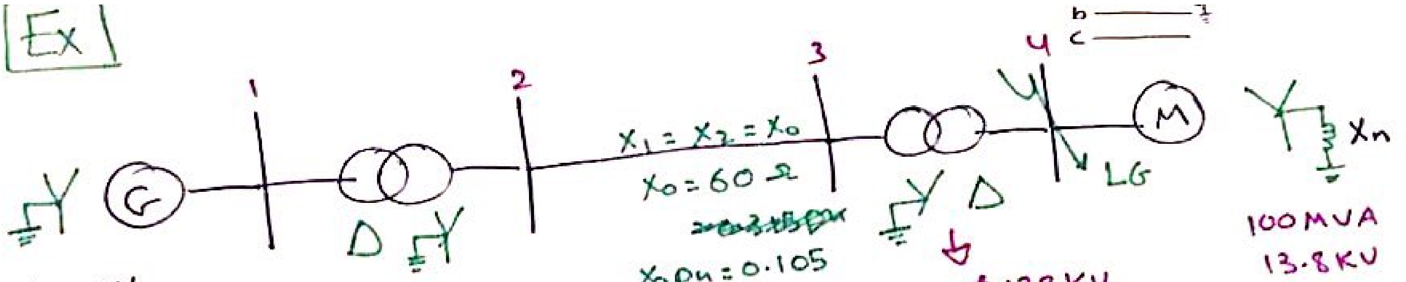
Ex



Generator: 100MV, 13.8 KV, $X'' = 0.15$ pu, $X_2 = 0.17$ pu, $X_0 = 0.05$ pu., $X_n = 0$

Transformer (1–2): 100 MVA, 13.8 / 138 KV, $X = 0.1$ pu

Line (2–3): $X_1 = X_2 = X_0$, $X_0 = 60\ \Omega$, $X_0\,pu = 0.105$

Transformer (3–4): 13.8 / 138 KV, $X = 0.1$

Motor: 100 MVA, 13.8 KV, $X'' = 0.2$ pu, $X_2 = 0.21$ pu, $X_0 = 0.1$ pu, $X_n = 0.05$ pu

Pre fault voltage 1.05 pu

Determine phase voltage at bus 4 LG fault ?!

Sol:

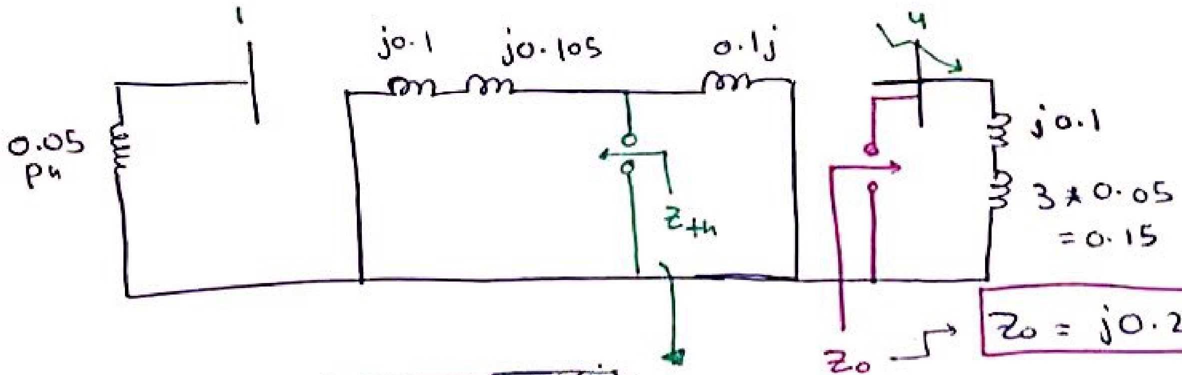
$$\begin{bmatrix} I_a^{(0)} \\ I_a^{(1)} \\ I_a^{(2)} \end{bmatrix} \longrightarrow \begin{bmatrix} V_a^{(0)} \\ V_a^{(1)} \\ V_a^{(2)} \end{bmatrix} \longrightarrow \begin{matrix} V_a\ ?! \\ V_b\ ?! \\ V_c\ ?! \end{matrix}$$

① ② ③

بطلعهم من model LG fault

$E \begin{cases} +ve \\ -ve \\ zero \end{cases}$

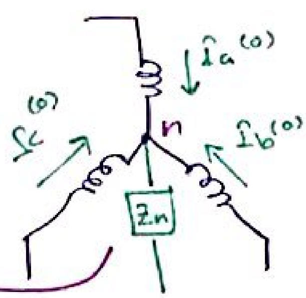
* zero sequence:



$\boxed{Z_0 = j0.25}$

* لو كان ال fault ← عند (bus 3)

$Z_{th} = ((0.1j + 0.105j) \,//\, j0.1)$



current $= 3 I_a^{(0)}$

$V_n = 3 I_a^{(0)} Z_n$

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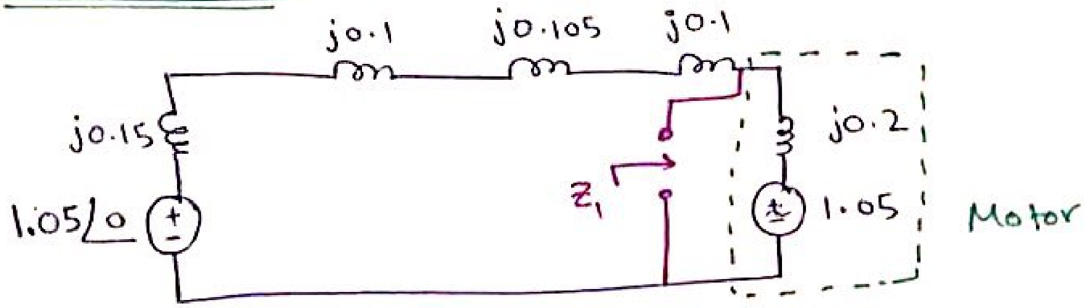
+ve Sequence :-

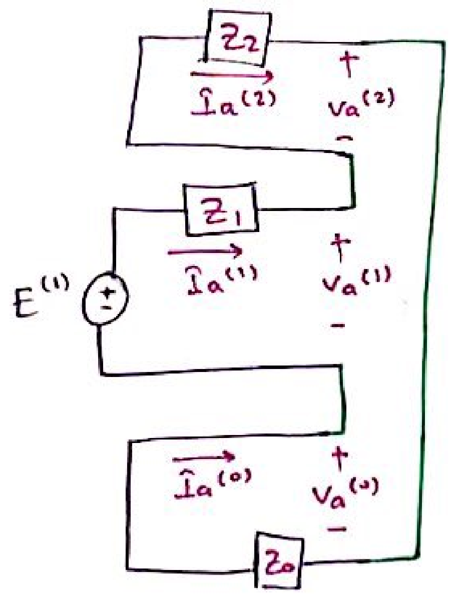


$$Z_1 = (j0.15 + j0.1 + j0.105 + j0.1) // (j0.2) = j0.13893$$

$$Z_2 = j0.14562$$

$$\boxed{E^{(1)} = 1.05 \ pu}$$

LG fault :



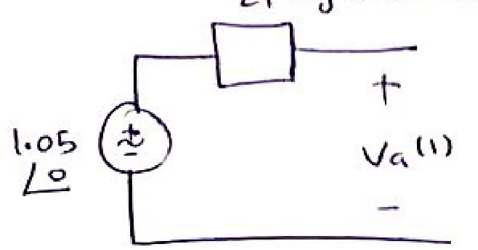
$$I_a^{(0)} = I_a^{(1)} = I_a^{(2)}$$

$$= \frac{1.05\angle 0}{Z_1 + Z_2 + Z_0}$$

$$\boxed{I_a^{(0)} = -j1.96427 \ pu}$$

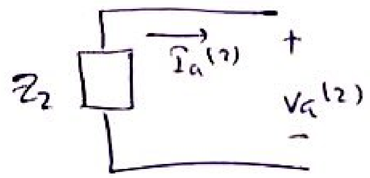
$$V_a^{(1)} = 1.05\angle 0 - I_a^{(1)}(Z_1)$$

$$= 1.05\angle 0 - I_a^{(1)}(0.13893)$$



$$V_a^{(2)} = -I_a^{(2)} Z_2$$

$$V_a^{(0)} = -I_a^{(0)} Z_0$$



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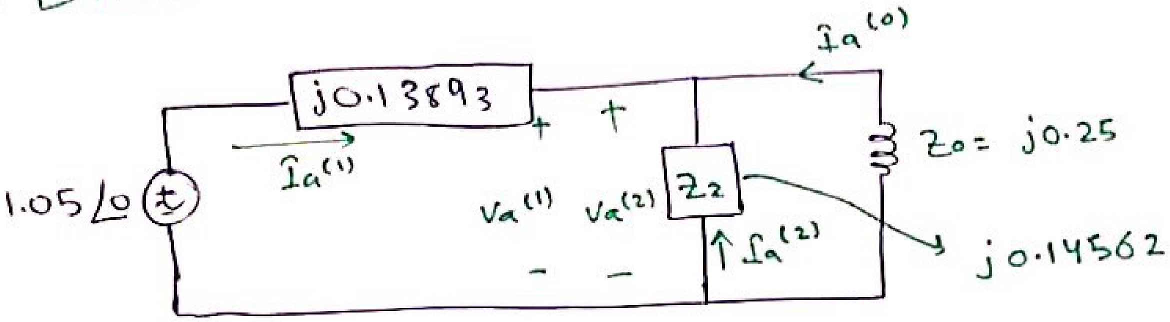
$$\begin{bmatrix} V_a \\ V_b \\ V_c \end{bmatrix} = \begin{bmatrix} 1 & 1 & 1 \\ 1 & a^2 & a \\ 1 & a & a^2 \end{bmatrix} \begin{bmatrix} V_a^{(0)} \\ V_a^{(1)} \\ V_a^{(2)} \end{bmatrix}$$

$$\boxed{V_a = 0 \text{ pu}}$$

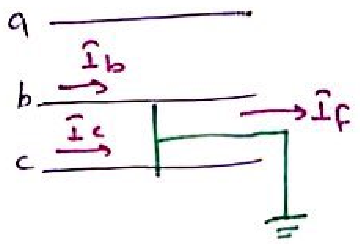
$$\boxed{V_b = 1.179 \angle 231.3^\circ \text{ pu}}$$

$$\boxed{V_c = 1.179 \angle 128.7^\circ \text{ pu}}$$

* Double line to Ground fault :



1) Fault current (LLG)
2) neutral fault current
3) contribution to the fault from the motor ?!



① $I_a^{(1)} = \dfrac{1.05 \angle 0}{Z_1 + (Z_2 // Z_0)}$

$$\boxed{I_a^{(1)} = -j\,4.5464 \text{ pu}}$$

$$I_a^{(2)} = -I_a^{(1)} * \frac{Z_0}{Z_0 + Z_2}$$

$$\boxed{I_a^{(2)} = j\,2.873 \text{ pu}}$$

$$I_a^{(0)} = -I_a^{(1)} * \frac{Z_2}{Z_0 + Z_2}$$

$$\boxed{I_a^{(0)} = j\,1.6734 \text{ pu}}$$

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② neutral current ?!

$$I_N = I_A + I_B + I_C$$

$$\begin{bmatrix} I_A \\ I_B \\ I_C \end{bmatrix} = \begin{bmatrix} 1 & 1 & 1 \\ 1 & a^2 & a \\ 1 & a & a^2 \end{bmatrix} \begin{bmatrix} I_a^{(0)} \\ I_a^{(1)} \\ I_a^{(2)} \end{bmatrix}$$

$\boxed{I_A = 0}$

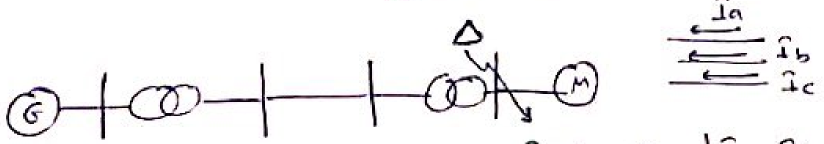
$\boxed{I_B = 6.89 \angle 158^\circ \text{ pu}}$

$\boxed{I_C = 6.89 \angle 21^\circ \text{ pu}}$

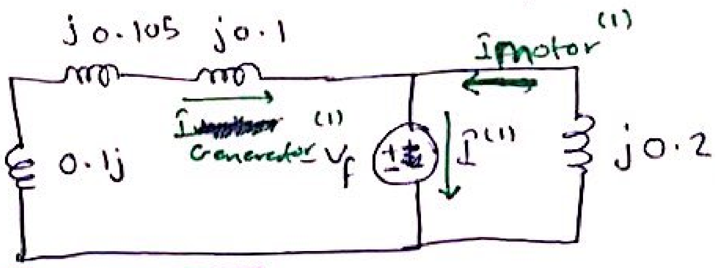
$\boxed{I_N = 21 \angle 90^\circ \text{ KA}}$ → base = 4.18 KA

③

Motor contribution
- +ve
- −ve
- zero.



I_f (تحصل تيار G , تيار M)



بحل current devision

لل zero, −ve, +ve

$$\boxed{\begin{aligned} I_{motor}^{(0)} &= 0 \\ I_{motor}^{(1)} &= 1.9813 \angle 172.643^\circ \text{ pu} \\ I_{motor}^{(2)} &= 1.9813 \angle 7.357^\circ \text{ pu.} \end{aligned}}$$

$$\begin{bmatrix} I_{motor\,a} \\ I_{motor\,b} \\ I_{motor\,c} \end{bmatrix} = \begin{bmatrix} 1 & 1 & 1 \\ 1 & a^2 & a \\ 1 & a & a^2 \end{bmatrix} \begin{bmatrix} I_{motor}^{(0)} \\ I_{motor}^{(1)} \\ I_{motor}^{(2)} \end{bmatrix}$$

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Zbus - matrix

$$Z^{(1)} = Y^{(1)-1}$$
$$Z^{(2)} = Y^{(2)-1}$$
$$Z^{(0)} = Y^{(0)-1}$$

$$I_n^{(1)} = \frac{V_F}{Z_{nn}^{(1)}}$$ → location fault at bus n

LG:

$$I_n^{(0)} = I_n^{(1)} = I_n^{(2)}$$

$$= \frac{V_F}{Z_{nn}^{(0)} + Z_{nn}^{(1)} + Z_{nn}^{(2)} + 3Z_f}$$

$$* \ LG \Rightarrow I_a^{(0)} = \frac{E^{(1)}}{\underbrace{Z_1 + Z_2 + Z_0}_{\text{thevenion}}}$$

LL:

$$I_n^{(1)} = -I_n^{(2)} = \frac{V_F}{Z_1 + Z_2} = \frac{V_F}{Z_{nn}^{(1)} + Z_{nn}^{(2)}}$$

LLG:

$$I_n^{(1)} = \frac{V_F}{Z_{nn}^{(1)} + \left[Z_{nn}^{(2)} \,//\, Z_{nn}^{(0)}\right]}$$

$$I_n^{(2)} = -I_n^{(1)} * \frac{Z_{nn}^{(0)}}{Z_{nn}^{(0)} + Z_{nn}^{(2)}}$$

$$I_n^{(0)} = -I_n^{(1)} * \frac{Z_{nn}^{(2)}}{Z_{nn}^{(0)} + Z_{nn}^{(2)}}$$

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$$Z = \begin{bmatrix} & & \end{bmatrix}$$

coulom n

(fault at bus n)

fault flow:

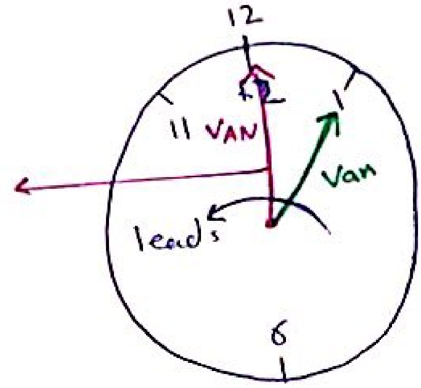
$$\begin{bmatrix} V_K^{(0)} \\ V_K^{(1)} \\ V_K^{(2)} \end{bmatrix} = \begin{bmatrix} 0 \\ V_f \\ 0 \end{bmatrix} - \begin{bmatrix} Z_{Kn}^{(0)} & 0 & 0 \\ 0 & Z_{Kn}^{(1)} & 0 \\ 0 & 0 & Z_{Kn}^{(2)} \end{bmatrix} \begin{bmatrix} I_n^{(0)} \\ I_n^{(1)} \\ I_n^{(2)} \end{bmatrix}$$

Impact of vector group on fault ~~cu~~ current :-

* vector group of transformers :-

HV	LV	X → clock number
Ex: D	y	1 → angle between equivalent Y at HV side and LV side.

refrence HV side.

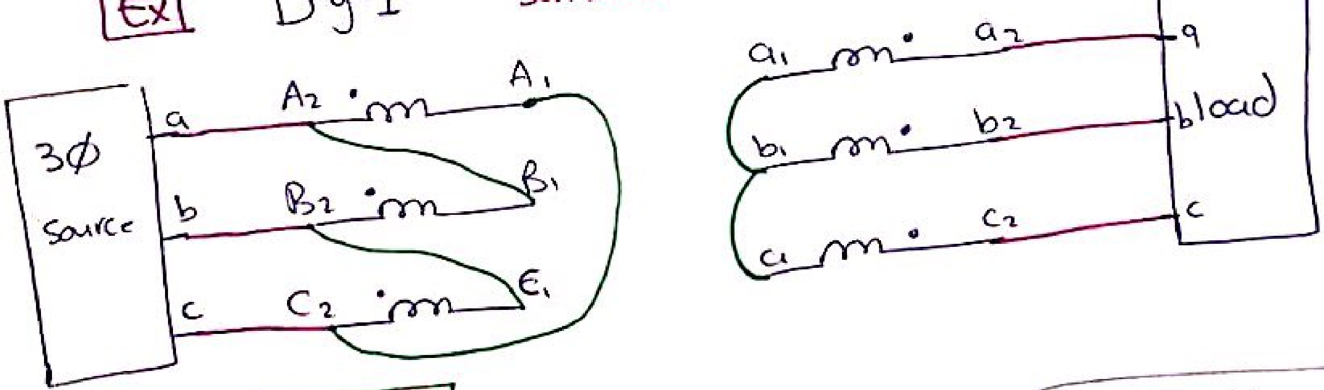


V_{AN} leads Van by 30°

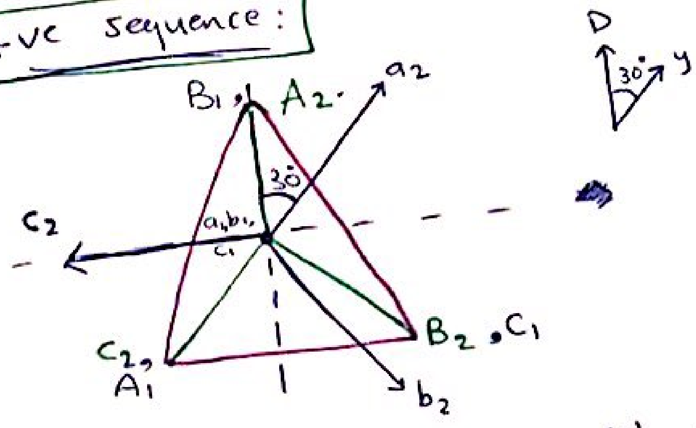
I_A leads I_c by 30°

$S = V I^*$

$\boxed{Ex}$ Dy 1 schematic representation:-



+ve sequence:



⇒

$V_{A_2A_1} \parallel V_{a_2a_1}$
$V_{B_2B_1} \parallel V_{b_2b_1}$
$V_{C_2C_1} \parallel V_{c_2c_1}$

1. HV side.
2. ~~clock~~ clock a_2
3. b_2, c_2

A_1, B_1, C_1 ?!

$$V_A^{(1)} = V_a^{(1)} \angle +30°$$

$$I_A^{(1)} = I_a^{(1)} \angle +30°$$

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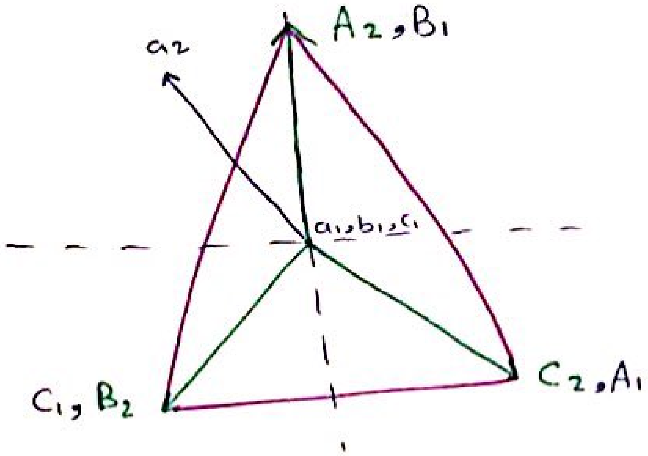
$-ve$ sequence:

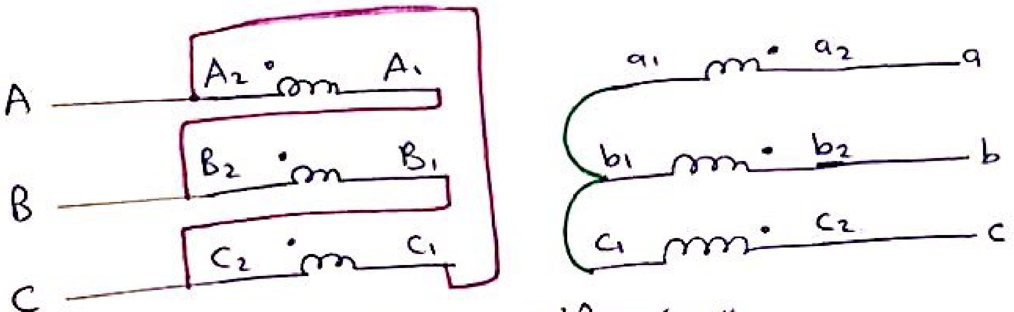


$V_{A_2 A_1} \parallel V_{a_2 a_1}$

$V_A^{(2)} = V_a^{(2)} \angle -30^\circ$

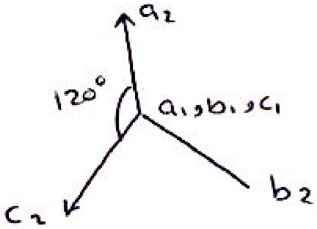
$I_A^{(2)} = I_a^{(2)} \angle -30^\circ$

Ex $Dy11$



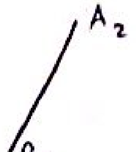
* حـــد ~ احدد الـ vector group

① Draw $+ve$ Sequence. Y winding.

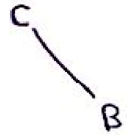


* $V_{A_2 A_1} \parallel V_{a_2 a_1} \Rightarrow V_{A_2 B_2} \parallel V_{a_2 a_1}$

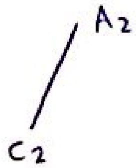
* A_1 مشبوكة مع B_2 فاستبدلت الـ A_1 بـ B_2.



* $V_{B_2 B_1} \parallel V_{b_2 b_1} \Rightarrow V_{B_2 C_2} \parallel V_{b_2 b_1}$



* $V_{C_2 C_1} \parallel V_{c_2 c_1} \Rightarrow V_{C_2 A_2} \parallel V_{c_2 c_1}$



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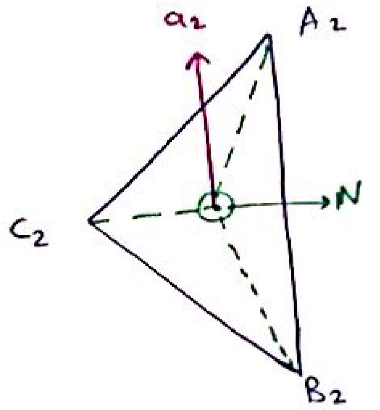
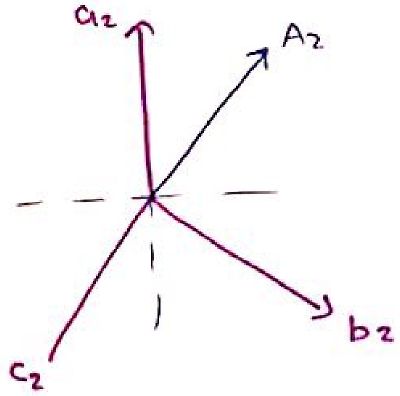
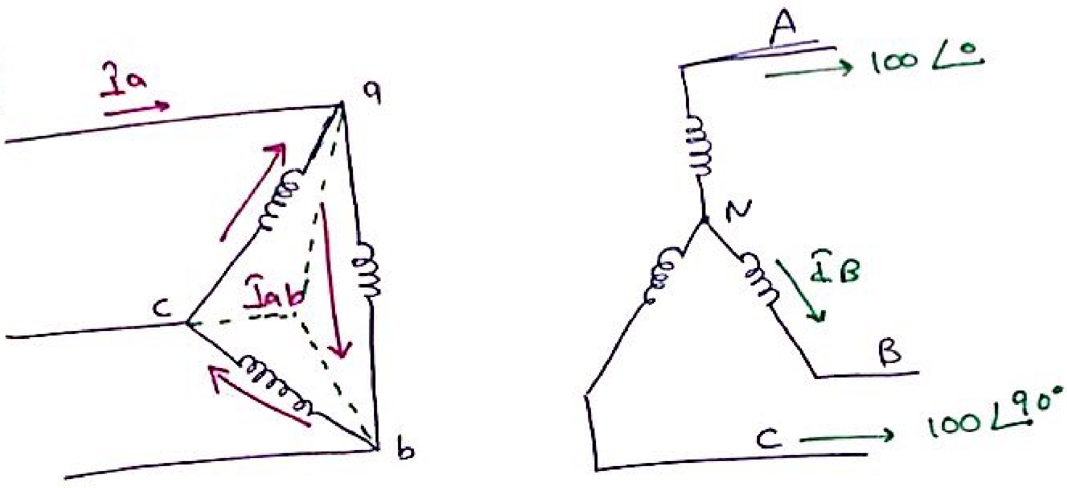




Ex



13.2/66 KV
10 MVA

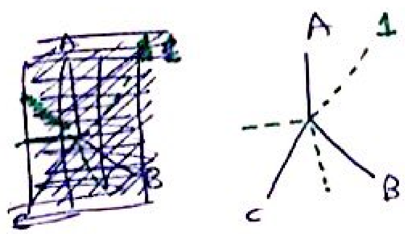
Find

1. $\hat{I}_B$?!
2. Vector group ?!
3. $\hat{I}_{ab}$
4. $\hat{I}_a$.

Sol: 1) $\hat{I}_A + \hat{I}_B + \hat{I}_C = 0$

$$\boxed{\hat{I}_B = 141\angle -135 \text{ A}}$$

2) vector group : Yd 1



3) $\hat{I}_{ab} = \hat{I}_A * \left(\frac{66/\sqrt{3}}{13.2}\right)$

$$\boxed{\hat{I}_{ab} = 289\angle 0 \text{ A}}$$

$\hat{I}_{ca} = \hat{I}_C * \left(\frac{66/\sqrt{3}}{13.2}\right) = 289\angle 90°$

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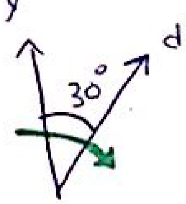
$$\boxed{I_a = 408.71 \angle{-45^\circ}}$$

$$I_a = \cancel{I_a^{(0)}}^{\,0} + I_a^{(1)} + I_a^{(2)}$$



« عندي تيار Y بدي تيار d
طرح 30° »
في ‎-ve‎ بالعكس.

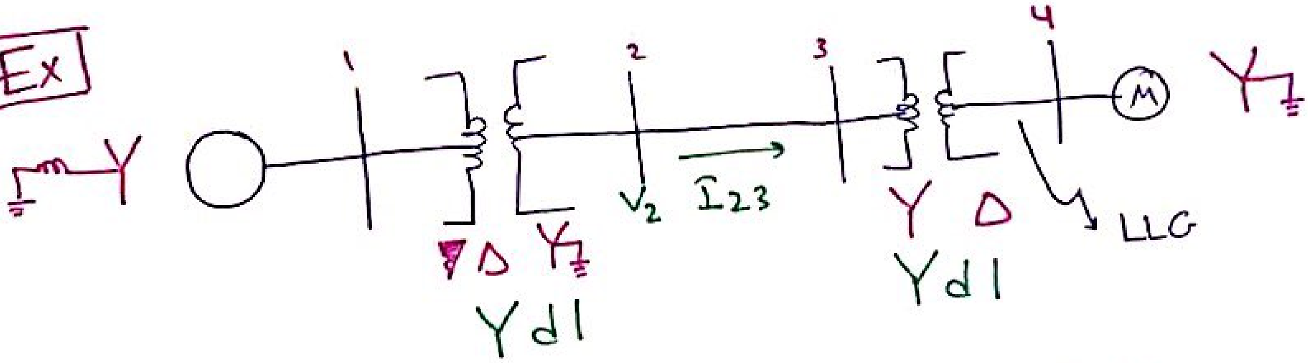
$$I_{a\,pu}^{(1)} = I_{A\,pu}^{(1)} * \angle{-30^\circ}\ pu$$

$$I_{a\,pu}^{(2)} = I_{A\,pu}^{(2)} \angle{+30^\circ}\ pu$$

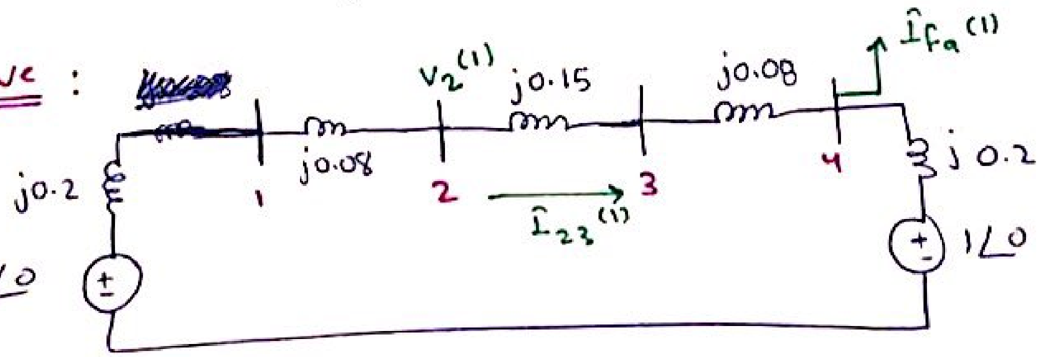
$$\begin{bmatrix} I_A^{(1)} \\ I_A^{(2)} \\ I_A^{(0)} \end{bmatrix} \longrightarrow A \begin{bmatrix} I_A \\ I_B \\ I_C \end{bmatrix}$$

$$\frac{I_A^{(1)}}{I_{base}} \qquad I_{base} \longrightarrow \frac{S_{base}}{\sqrt{3}\, V_L}$$

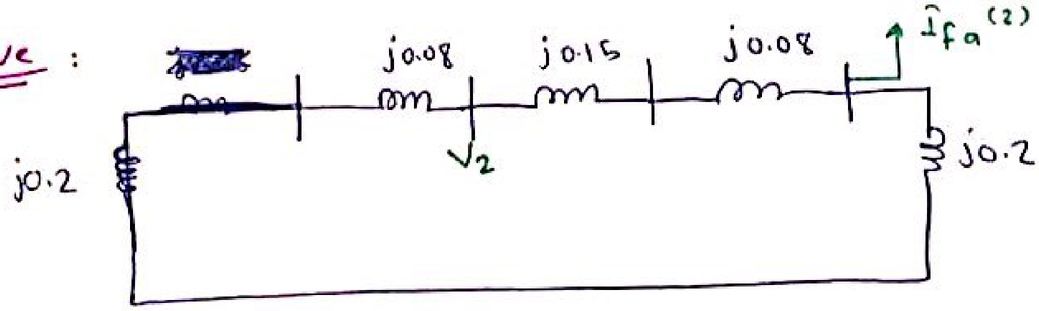
Ex



Sol. **+ve :**



−ve :



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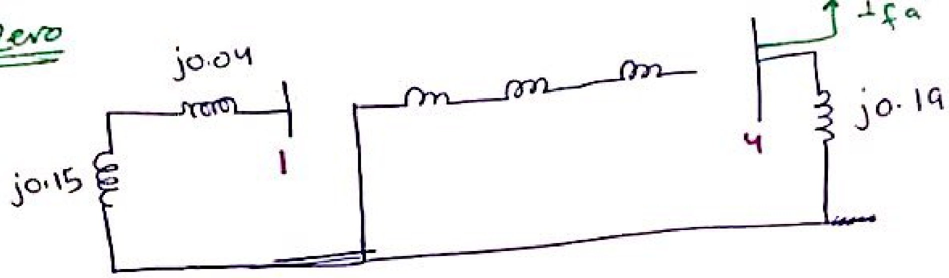
Zero



fault current :

Z_1 $\quad Z_{44}^{(1)} = 0.1437$

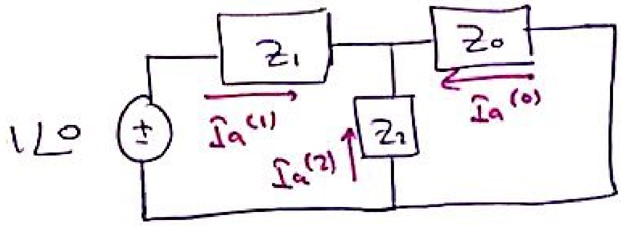
Z_2 $\quad Z_{44}^{(2)} = 0.1437$

Z_0 $\quad Z_{44}^{(0)} = 0.19$

$\hat{I}_a^{(1)} = -j\,4.437$ pu.

$\hat{I}_a^{(2)} = j\,2.547$ pu.

$\hat{I}_a^{(0)} = j\,1.9$



$\hat{I}_a = 0$

$\hat{I}_b = 6.67 \angle 154^\circ$ pu.

$\hat{I}_c = 6.67 \angle 24.4$ pu.

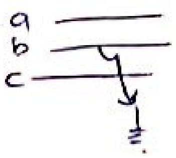
$V_4 = V_{4a}^{(1)} + V_{4a}^{(2)} + V_{4a}^{(0)}$

$V_{4a}^{(1)} = V_{4a}^{(2)} = V_{4a}^{(0)} = 0.30$ pu.

$V_{4,a}$

$V_{4,b} = 0$

$V_{4,c} = 0.$



$\hat{I}_{23} = ?!$

$$\begin{bmatrix} \hat{I}_{23,a} \\ \hat{I}_{23,b} \\ \hat{I}_{23,c} \end{bmatrix} \longrightarrow \begin{matrix} \hat{I}_{23a}^{(1)} \\ \hat{I}_{23a}^{(2)} \\ \hat{I}_{23a}^{(0)} \end{matrix}$$

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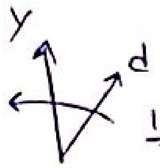
without phase shift:

$$\hat{I}_{23a}^{(1)} = -j\,4.437 * \frac{0.2}{0.71} = -j1.249$$

$$\hat{I}_{23a}^{(2)} = j\,2.547 * \frac{0.2}{0.71} = +j\,0.718$$

$$\hat{I}_{23a}^{(0)} = 0$$

with phase shift:



lead

عندي تيار d وبدي
تيار ال y .

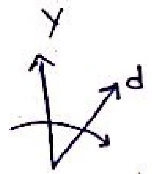
$$\hat{I}_{23,a}^{(1)} = -j1.249 \angle +30^\circ$$

$$\hat{I}_{23a}^{(2)} = j\,0.7118 \angle -30^\circ$$

$$\hat{I}_{23a}^{(0)} = 0$$

$\hat{I}_{23,a}$, $\hat{I}_{23b}$, $\hat{I}_{23c}$ ..

$V_2 = ?!$ → $V_{2a}^{(1)}$, $V_{2a}^{(2)}$, $V_{2a}^{(0)}$



بطرح 30°

Lag

$$V_{2a}^{(1)} = \left(1\angle 0 - \hat{I}_{23}^{(1)} \angle -30 * j\,0.28\right) * \angle 30^\circ$$

$$V_{2a}^{(1)} = 1\angle 30 - \hat{I}_{23}^{(1)} * j0.28 .$$

$$V_{2a}^{(2)} = 0 - \hat{I}_{23}^{(2)} * j0.28$$

$$V_{2a}^{(0)} = 0$$

$V_{2,a}$
$V_{2,b}$!?
$V_{2,c}$

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