FAULT ANALYSIS

[redacted]

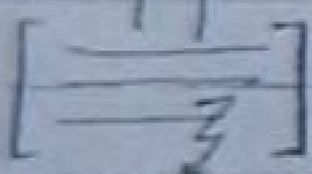
* Main purpose of fault analysis is design circuit breaker. (switch gear)

$I_f \rightarrow$ fault current

$I_f \times V_f$ = fault MVA (circuit Breaker rating).

Fault Analysis

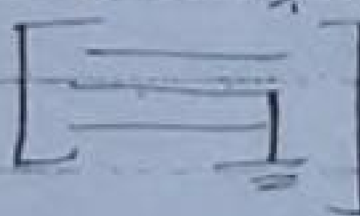
- Symmetrical fault Analysis
  - balanced condition during fault
  - 3ϕ phase fault



- Unsymmetrical fault Analysis
  - under fault unbalanced condition
  - Single line to Ground (SLG)

  - Double line fault (L-L)

  - Double line to ground (LLG)



* Most severe fault is 3ϕ fault and least is SLG.

* During design of circuit breaker 3ϕ fault is counted.

SLG fault is used in relay design (proper setting)

The unsymmetrical fault analysis is also an important

Single line diagram:- indicates that original P.S is 3ϕ and working at balanced condit^n.

study since coz the knowledge of all types of fault is important to provide proper setting for the relay.

PER UNIT Analysis:-

Per unit value is unitless value.

$$\boxed{\text{P.U value} = \frac{\text{Actual value in some unit}}{\text{Base/reference value in same unit}}}$$

Advantage of P.U Method:-

→ It simplifies power s/m calculation.

→ It avoids the discontinuity problem posed by presence of xmer in power system n/w. (Chief advantage)

* Single line diagram:

R

Y

B

N (no significance)

$I_N = I_R + I_Y + I_B = 0$

$V_n = I_n Z_n = 0$

$S_n = V_n I_n^* = 0$

neutral of single line diagram is called as zero power bus

finally we have

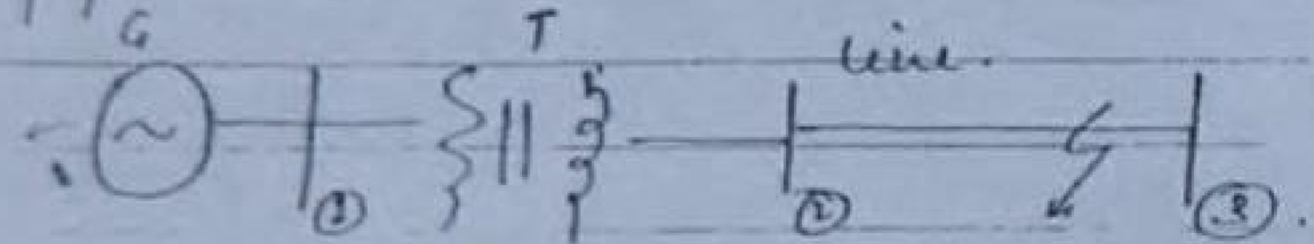
R, Y, B = R

* Single line diagram: the single line diagram. representat^n of

* Circuit Breaker rating should be high.

power system indicates that original per system is 3ϕ and its working under balanced condition. When c/ct work under balanced condition, the advantage is by working on single phase basis (by adopting PU method), we can claim that we have completed 3ϕ analysis.

Explanation of point ③:-



Assumption 4 short circuit calculation:

① Capacitance of circuit neglected (MVA → KV)

② resistance of individual equipment neglected.

Note: By neglecting the resistance and capacitance the only parameter which limit S.C current is the inductance.

* Fault current is inductive, ↑ lagging current, lagging reactive power. Fault demands ↑ lagging reactive power.

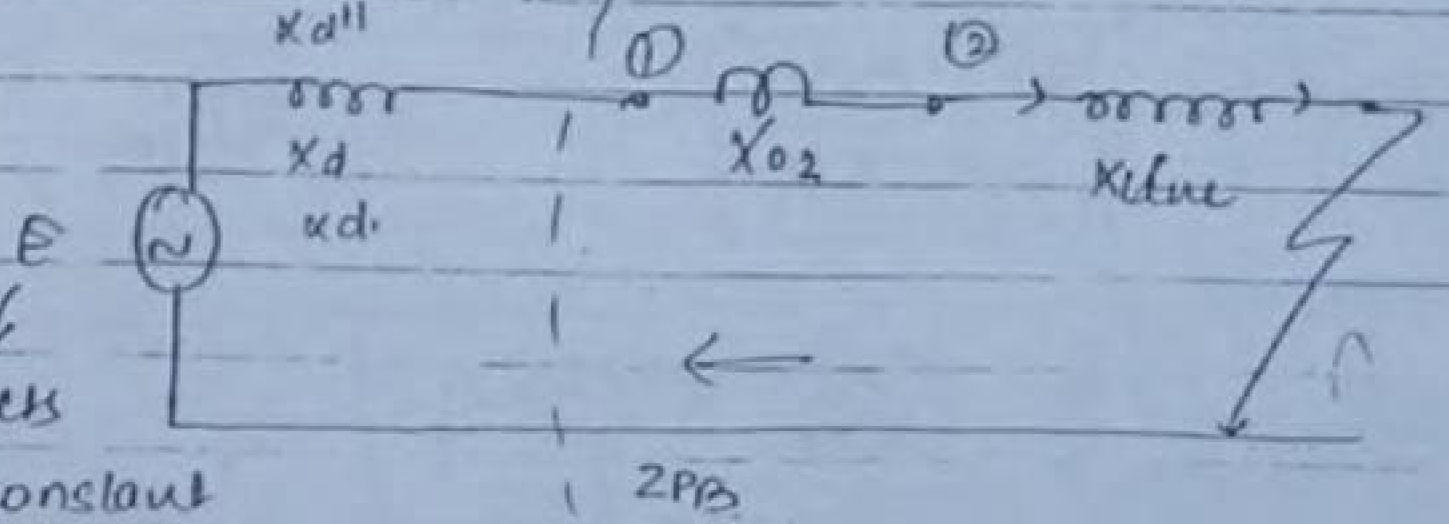
* Whenever fault occurs, the voltage of other phase decreases due to armature reaction (demagnetization - low magnetic field).

* Fault current is maxm in subtransient state as minimum reactance.

③ Effect of saliency (salient pole) is neglect; the effect of non-uniform air of salient pole is neglected.

* → During S.C the voltage is effected, frequency constant (Active power not change whereas reactive)

* → In load analysis the frequency prominently changes



g/r acts as constant voltage source

← 2nd ckt → ← 1 circuit →

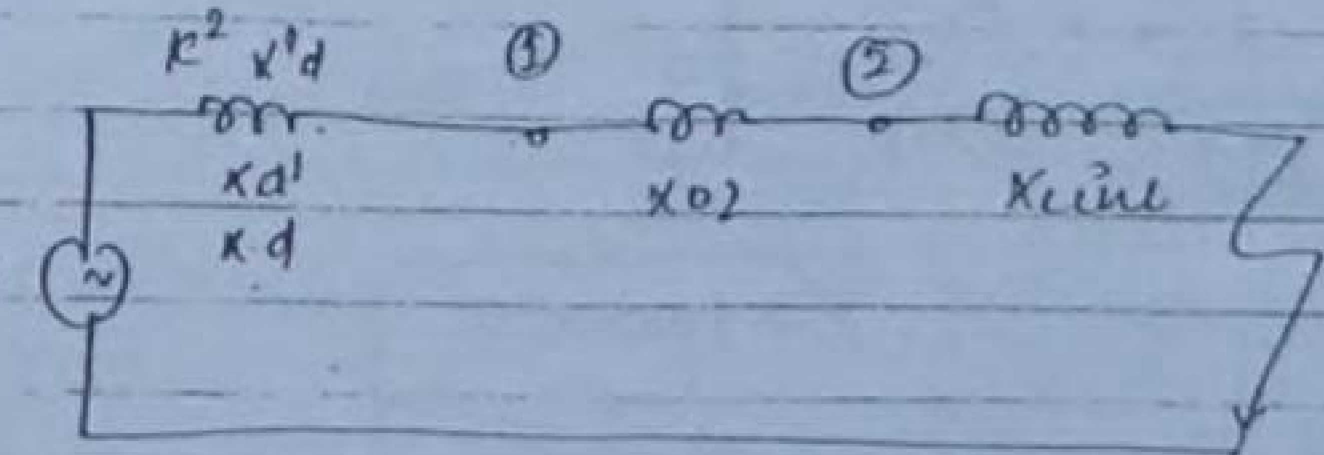
(Low voltage) side (High voltage side)

→ X^{mer} can be represented as:

X_{01} (primary)

X_{02} (secondary)

<u>So</u>



converting g/r to high voltage side (K → turn ratio)

This method is practically impossible. So pu method is used.

- $Z_{eq}(LV) \neq Z_{eq}(HV)$
- $Z_{eq}\,LV_{(pu)} = Z_{eq}\,HV_{(pu)}$

In pu method - X^{mer} are represented as * the <u>series reactance</u> and discontinuity is removed as the value of impedance, current remain same at both ends LV - HV

Selection of base values :- (only 4 P, V, I Z)

(1) We select base value for Power and voltage.

→ Base voltage :- KV_b. Base voltage = 100 kV

→ Base power : KVA_b or MVA_b. Base power = 200 MVA

→ Base current in (Ampere) = $\boxed{I_b = \frac{KVA_b}{KV_b}}$. 200/100 = 2 × 100 = 2000 A

$$\boxed{I_b = \frac{MVA_b}{KV_b} \times 1000 \text{ A}}$$

acts as conversion factor

→ Base impedance (in Ω) =

$$\boxed{Z_b = \frac{KV_b^2}{MVA_b} \Omega}$$

objective

$$\boxed{Z_b = \frac{KV_b^2}{KVA} \times 1000 = \Omega}$$

conversion factor.

objective

→ Base values considered when for calculation of 3ϕ.

→ 3ϕ power, line voltage.

$$\boxed{Z_{b,1\phi} = \frac{KV_{b\,1\phi}^2}{MVA_{b\,1\phi}}}$$

$$\boxed{Z_{b,3\phi} = \frac{KV_{b,line}^2}{MVA_{b\,3\phi}}}$$

$$\Rightarrow \quad \frac{(\sqrt{3} \times KV_{b\,1\phi})^2}{3 \times MVA_{b\,3\phi}} = \frac{K^2V_{b\,1\phi}}{MVA_{1\phi}}$$

$$\boxed{Z_{b\,3\phi} = Z_{b,1\phi}}$$

② whenever we change base values, pu value change (not actual values.

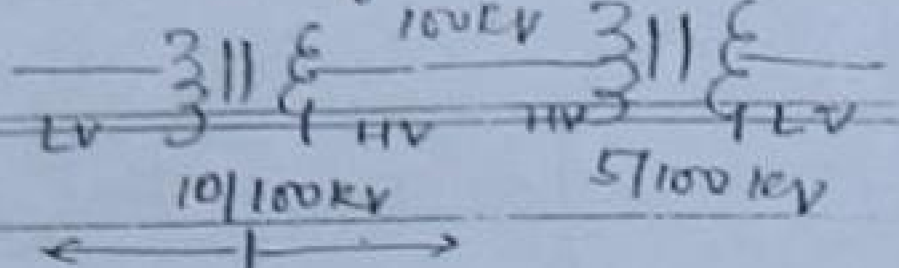
$$Z_{pu,old} = \frac{Z_{actual}}{Z_{b,old}} = \frac{Z_{actual}}{KV_b^2 old / MVA, old}$$

$$Z_{pu,res} = \frac{Z_{actual}}{Z_{b,res}} = \frac{Z_{actual}}{KV_b^2 res / MVA_b res}$$

*

$$\boxed{Z_{pu,res} = Z_{pu,old} \times \left(\frac{KV_{b\,old}}{KV_{b,res}}\right)^2 \times \left(\frac{MVA_{b,res}}{MVA_{b,old}}\right)}$$

:→ If two xmer are connected in series no of base value is 3
one common, LV T_1, HV(T_1, T_2), LV T_2



Example:

Q) An equipment is having 10 pu impedance on 100 MVA, 10kV. Its pu impedance on ~~for~~ 10 MVA, 100kV is ___

$$Z_{pu.new} = 10 \times \left(\frac{10}{100}\right)^2 \times \left(\frac{10}{100}\right)$$

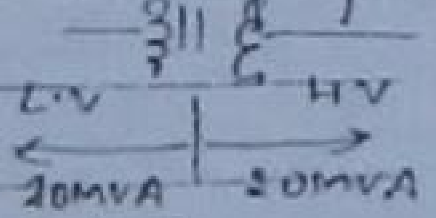
$$10 \times \frac{100}{10000} \times \frac{10}{100}$$

$$= 0.01 \text{ pu.}$$

Rules of selecting base values when xmer is present in n/w:

1) In circuit containing xmer, we have to select two set of base values one for LV and another for HV side.

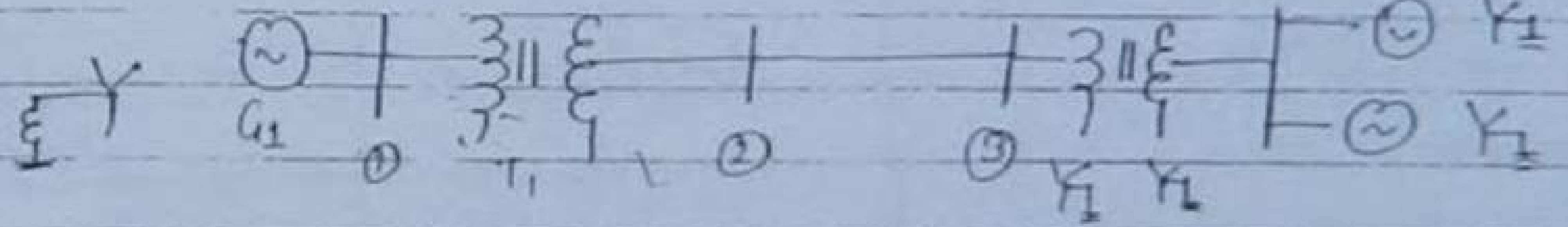
2) Common base power is selected for both sets or for entire n/w.



3) two different base voltages must be selected for LV and HV in such a way their ratio must be equal to transformation ratio of original xmer.

Example:-

Obtain the pu equivalent reactance diagram for the power s/m shown below



G1: 30 MVA, 10.5 kV, $X'' = 1.6$ p.u

G2: 15 MVA, 6.6 kV X''_d 1.2 p.u

G3: 25 MVA, 6.6 kV $X''_d = 0.56$

$T_1 = 15$ MVA, 33/11 kV, $X = 15.2\,\Omega$ p.ph on HV.

$T_2 = 15$ MVA, 33/6.2 kV, $X = 16\,\Omega$/ph on HV side

T.L = 20.5 Ω/ph

Initial values (reactance)	LV side of T_1	HV side of T2 and T2	L.V side T2	
G_1	1.6 pu on 30 MVA, 10.5 kV	—	—	
G_2	—	—	1.2 pu on 15 MVA, 6.6 kV	
G_3	$15.2 \times \frac{11}{33}$ = 1.69 Ω	15.2 pu.	0.56 pU on 25 MVA 6.6 kV	
T_1				
T_2		16 Ω/ph	0.56 Ω/ph	0.56 Ω/ph
L		20.5 Ω/ph		

Base value:-

	LV side of T_1	HV side of $T1/T_2$	LV side of T_2
MVA_b	30 MVA	30 MVA	30 MVA
KV_b	11 KV	33 KV	6.2 KV
Z_b	$\frac{11^2}{30} = 4.03\,\Omega$	$33^2/30 = 36.33\,\Omega$	$\frac{6.2^2}{30} = 1.28\,\Omega$

formula used = $\frac{KV_b^2}{MV_b}$.

G1: 1.6 pu on 30MVA, 10.5 KV

$$Z_{pu}\, new = 1.6 \times \left(\frac{30}{30}\right) \times \left(\frac{10.5}{11}\right)^2$$

$$\boxed{Z_{pu}\, new = 1.46\, pu.}$$

$$\boxed{V_{G_1} = \frac{10.5}{11} = 0.96\, pu}$$

$\frac{Actual}{Base}$.

G2:- 1.2 pu on 15MVA, 6.6 KV

$$Z_{pu}(new) = 1.2 \times \left(\frac{30}{15}\right) \times \left(\frac{6.6}{6.2}\right)^2$$

$$= \boxed{Z_{pu(new)} = 2.72\ p.u}$$

$$V_{G2} = \frac{6.6}{6.2} = 1.06\,pu. \qquad \boxed{V_{G2} = 1.06\,pu}$$

G3:. 0.56pu on 2.5MVA 6.6kV

$$Z_{pu(new)} = 0.56 \times \left(\frac{30}{2.5}\right) \times \left(\frac{6.6}{6.2}\right)^2$$

$$\boxed{Z_{pu(new)} = 0.76\,pu.}$$

$$V_{G3} = \frac{6.6}{6.2} = 1.06\,pu.$$

T1: 1.69 p.Ω w.r.t LV side

base impedence on LV side of T1 = 4.03Ω

$$X_{T.p.u} = \frac{1.69\,\Omega}{4.03\,\Omega} = 0.41\,p.u.$$

1.52Ω/ph w.r.t HV side

base impedence = 36.33Ω

$$X_{Tpu} = \frac{15.2}{36.33} = 0.41\,p.u.$$

$$\boxed{X_{Tpu} = 0.41\,p.u}$$

T2

0.56Ω/ph w.r.t ~~1.28~~ LV side of T2

base impedence on LV side of T2 = 1.28Ω

$$X_{Tpu} = \frac{0.56}{1.28} = 0.434\,p.u$$

$16\,\Omega$/ph w.r.t to H.V side of T2

Base value $= 36.33\,\Omega$

$$X_{T_2} = \frac{16}{36.33} = 0.434\,p.u.$$

$$\boxed{X_{T_2} = 0.434\,p.u}$$

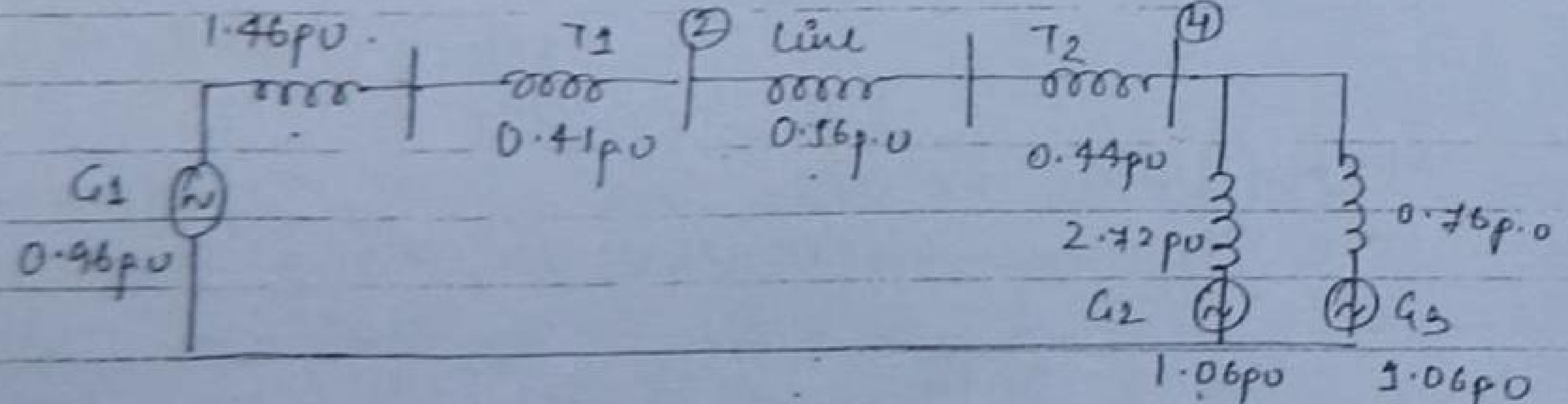
Line

$X_L = 20.5$ on HV side T2 and T1

base value $= 36.33\,\Omega$

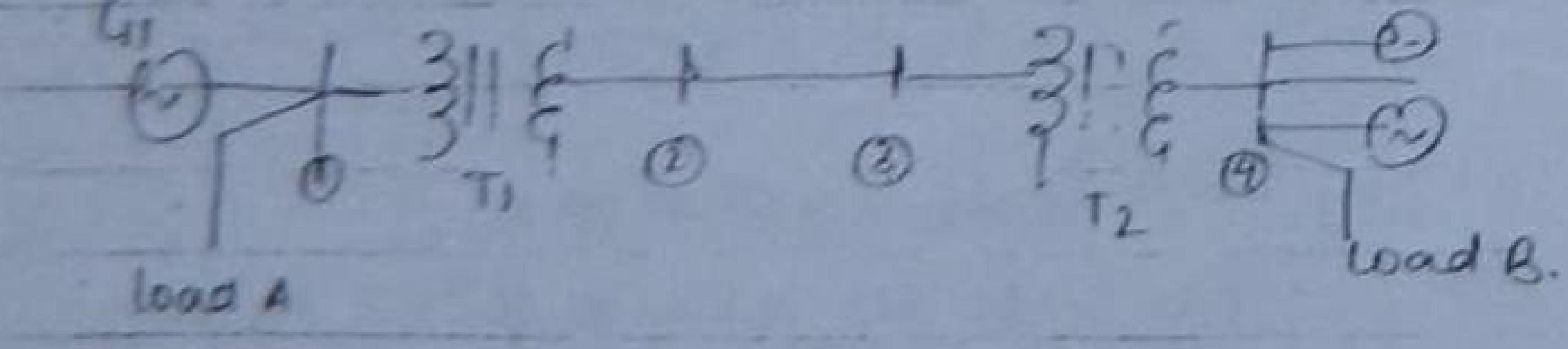
$$X_{line} = \frac{20.5}{36.33} = 0.56\,p.u.$$

$$\boxed{X_{line} = 0.56\,pu}$$



Per unit reactance diagram.

b) Two loads (A) and (B) are connected to bus 1 and bus 4 respectively



load A is 40MW, 11KV, 0.9 pf lag.

represent them in reactance diagram

Solution:

Load A

$$V = \frac{11\,kV}{11\,kV} = 1\ p.u.$$

$$\cos\phi = 0.9 \Rightarrow \sin\phi = 0.43$$

$$P = \frac{40\,MW}{30\,MVA} = 1.33\ p.u.$$

$$P = 1.33\ p.u \Rightarrow S = \frac{1.33}{0.9} = 1.48\ pu$$

$$Q = S\sin\phi = 1.48 \times 0.43 = 0.64\ pu$$

$$R_{load\,A} = V^2/P = 1^2/1.33 = 0.75\ pu$$

$$X_{load} = V^2/Q = 1.56\ pu$$

Load B

$$V = 40 \times \frac{1}{1}\ \frac{66}{62} = 1.06\ p.u.$$

$$\cos\phi = 0.5$$

$$P = \frac{40}{30} = 1.33\ p.u$$

$$S = \frac{1.33}{0.5} = 2.66\ p.u.$$

$$Q = S\sin\phi = 2.26\ pu$$

represent them in reactance diagram

Solution:

Load A
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$$\cos\phi = 0.9 \Rightarrow \sin\phi = 0.43.$$

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$$P = 1.33\ p.u \Rightarrow S = \frac{1.33}{0.9} = 1.48\ p.u.$$

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$$= 0.64\ p.u$$

$$R_{load\,A} = V^2/P = 1^2/1.33 = 0.75\ p.u$$

$$\cancel{X_{load} = V^2/Q = 1.56\ p.u}$$

Load B

$$V = 40 \times \frac{1.1 \times 66}{62} = 1.06\ p.u.$$

$$\cos\phi = 0.5$$

$$P = \frac{40}{30} = 1.33\ p.u$$

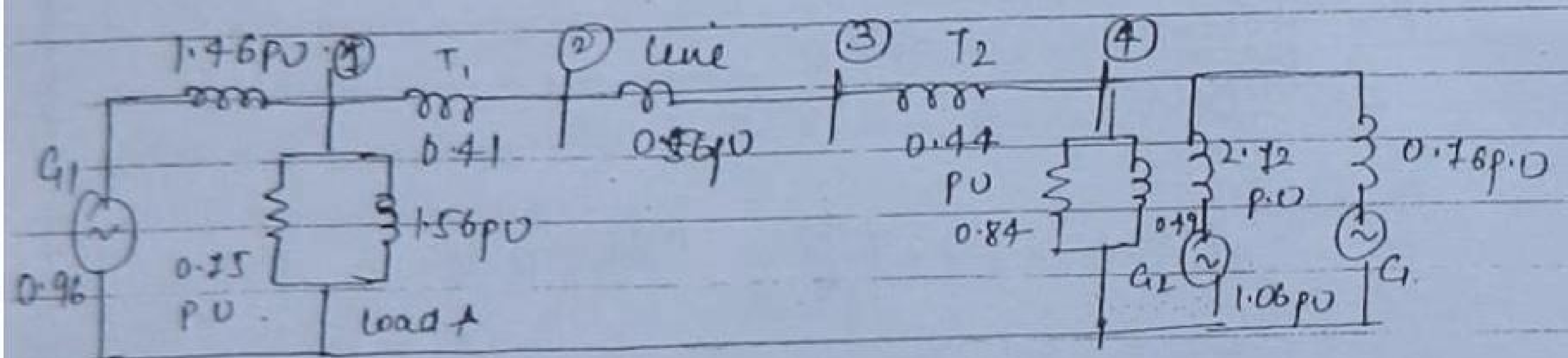
$$S = \frac{1.33}{0.5} = 2.66\ p.u.$$

$$Q = S\sin\phi = 2.26\ p.u$$

* load in S.C → constant impedence
load in stability → constant admittance.

$$R_{load\,A} = V^2/P = \frac{1.06^2}{1.33} = 0.84\ p.u$$

$$X_{load\,B} = \frac{V^2}{Q} = \frac{1.06\ p.u}{2.28} = 0.49\ p.u$$



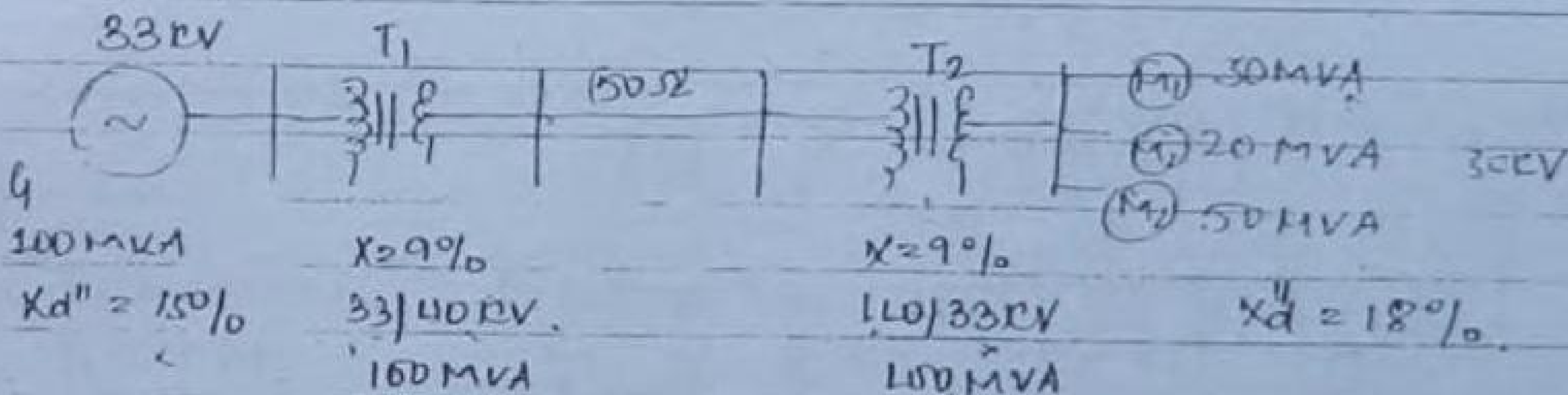
$R_{load\,A} = V^2/P = \frac{1.06^2}{1.33}$

$X_{load\,B} = V^2/Q = \frac{1.06\ p.u}{2.28}$

$\frac{1.06^2}{1.33} = 0.84\ p.u$

Example:-

A 100 MVA, 33kV 3-ϕ g/r has sub-trasient reac of 15% the g/r is connected to the m/r name rate I/P 30MVA, 20, 50 MVA. At 30kV with 18% subtransient reactan the 3-ϕ T/F's are rated at 100 MVA, 33/110kV with leakage reactance of 9%. the line has a reactance of 50Ω obtain pu equivalent reac. diagram.



1) Common base MVA : 100 MVA
Base voltage of LV side of T_1/T_2 = 33kV
" " of HV side of T_1 & T_2 = 110kV

1) $X_{G1} = 0.15\,pu$ (Related value of equipment & selected base value are same).

2) $X_{T_1} = 0.09\,pu$ (" " ")

3) $Z_b = \frac{(kV_b)^2}{MVA_b} = \frac{(110)^2}{100} = 121\,\Omega$

$Z_b = 121\,\Omega$

$X_{line}(pu) = \frac{50}{121} = 0.41\,pu$

$\boxed{X_{line}(pu) = 0.41\,pu}$

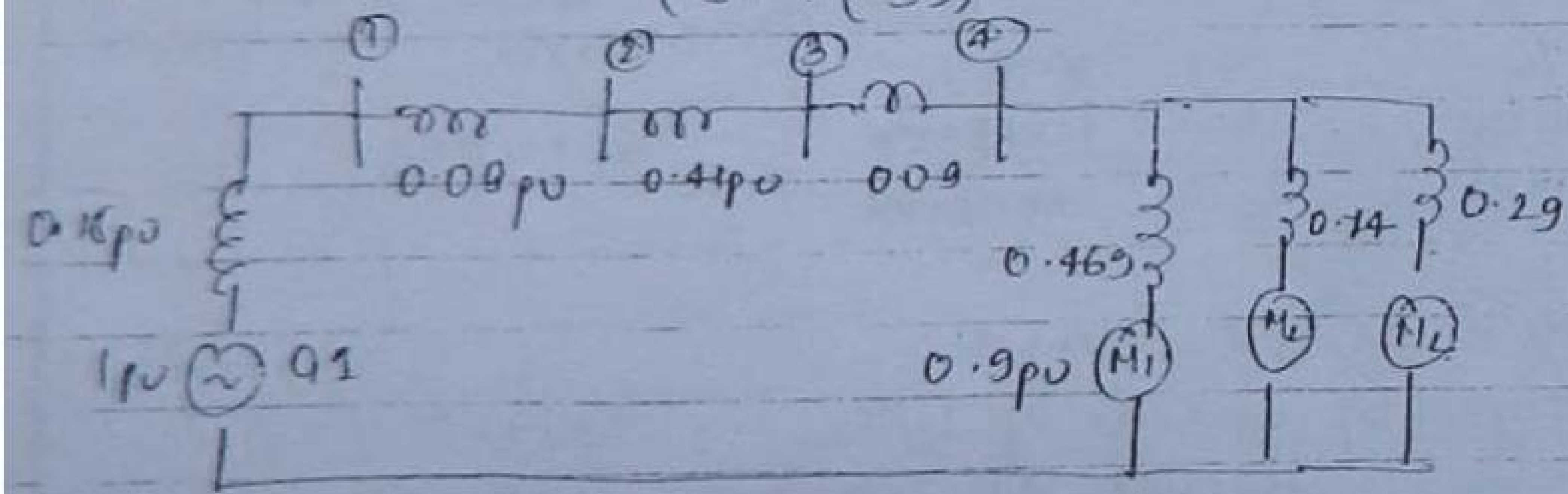
$X_{T_2} = 0.09\,pu$

$$X_{m_1} = X_m \left(\frac{MVA_b(new)}{MVA_b\,old}\right)\left(\frac{KV_{base}\,old}{KV_{base}(new)}\right)^2$$

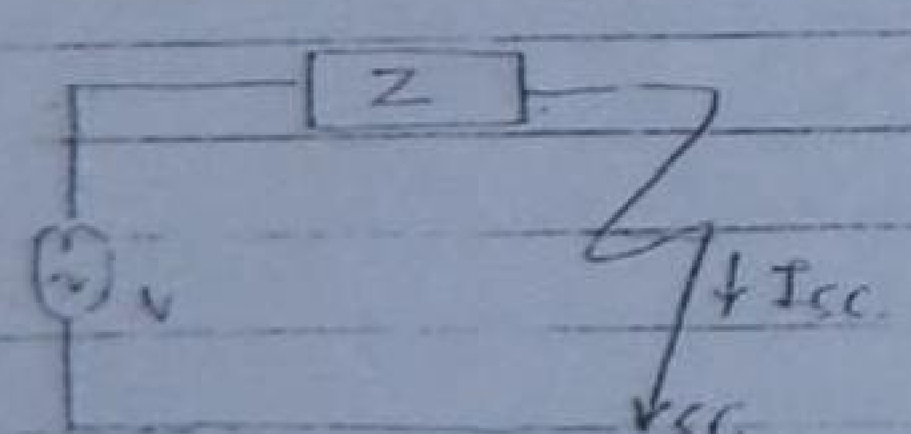
$$= 0.18\left(\frac{100}{500}\right)\left(\frac{30}{33}\right)^2 = 0.496\,p.u$$

$$X_{m_2} = 0.18\left(\frac{100}{20}\right)\left(\frac{30}{33}\right)^2 = 0.74\,p.u$$

$$X_{m_3} = 0.18\left(\frac{100}{50}\right)\left(\frac{30}{33}\right)^2 = 0.24\,p.u$$



Short circuit KVA:-



V = Rated voltage
I = Rated current
Z = internal impedance

$$\boxed{I_{sc} = V/Z} \quad \text{—(1)}$$

Note: Ratio of rated current to short ckt current of equipment given p.u impedance.

$Z_{base} = V/I$

$Z_{pu} = Z/Z_{base} = \frac{Z}{V/I}$

$$\boxed{Z_{p.u} = \frac{I}{V/Z} = \frac{I}{I_{sc}}}$$

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

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

$$V I_s = \frac{VI \times 100}{\% Z}$$

$$\boxed{\text{Short ckt KVA} = \text{Rated or base KVA} \times \frac{100}{\% Z}}$$

Procedure of short circuit calculation :

1) Convert the given single line diagram of power s/m. N/w into p.u equivalent impedence diagram.

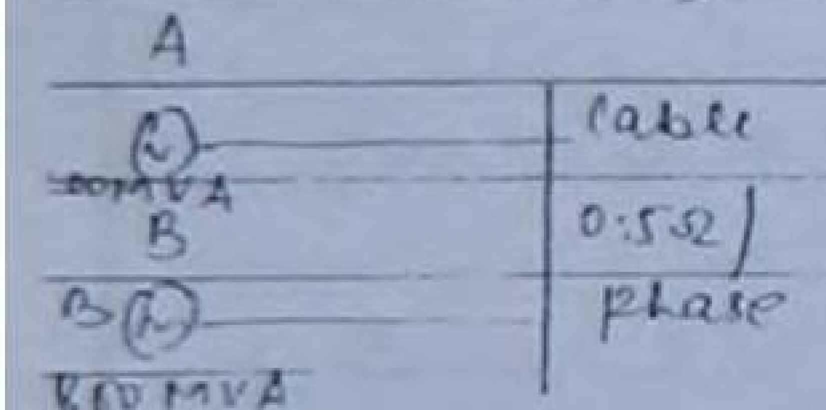
2) Identify the fault terminal. Across the fault terminals reduce the n/w into thevenins equivalent ckt.

3). Using the %age thevenins equivalent impedence short ckt KVA can be calculated using the following formulae.

$$\boxed{\text{Short ckt KVA} = \text{Common base KVA} \times \frac{100}{Z \text{ in } \%}}$$

Example:-

A, 2 generating station having S.C capacities of 1200MVA, 800 MVA resp. & operating at 11 kV or linked by an interconnected cable having a reactance of 0.5Ω/phase. Determine short ckt capacities of each statn. (how much power flows when SC occurs)



Let the rated base MVA = 1200

∴ for station A, the %X is

$$1200 = \frac{1200 \times 100}{\%X}$$

$$\Rightarrow \%X_A = 100$$

station B %age Reactance is

$$800 = \frac{1200 \times 100}{\%X_B}$$

$$\%X_B = 150\%$$

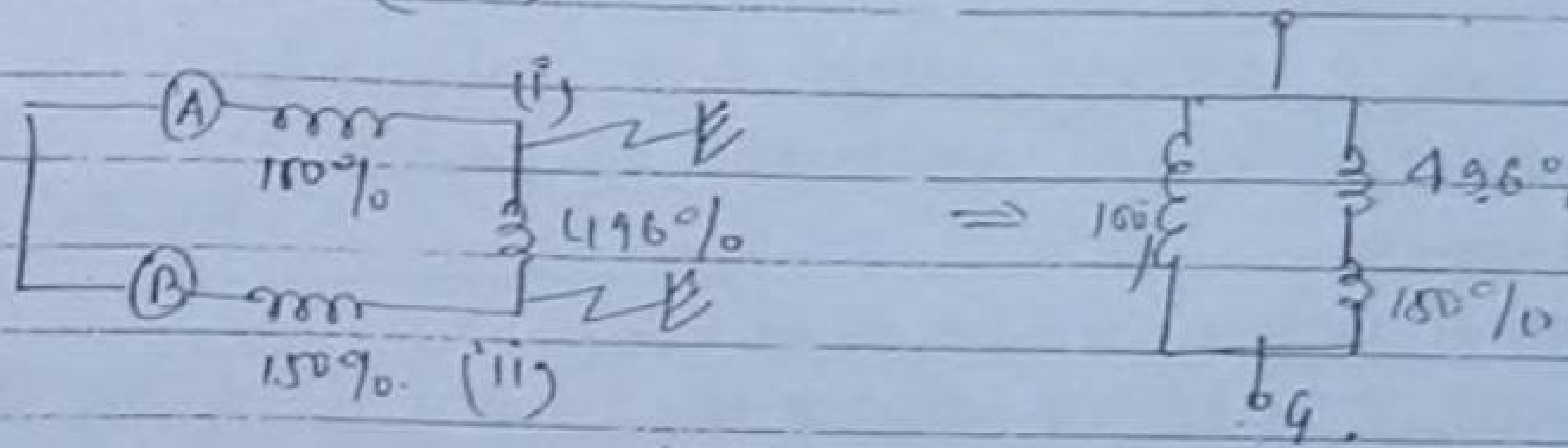
$$Z_{base} = \frac{KV_b^2}{MVA_b} = \frac{(11)^2}{1200} = 0.1008\,\Omega$$

$$X_{cable} = \frac{0.5}{0.1008} = 4.96\,p.u.$$

$$\boxed{\%X_{cable} = 496\%}$$

Now we can calculate short ckt capacities of each statn when fault occurs on the terminal of statn (A-)

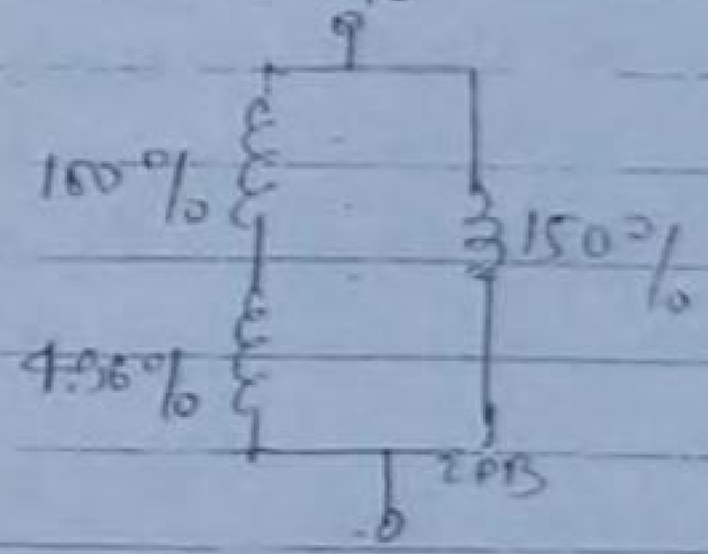
and sect^n (B-ii).



$\% Z_{th} = 86.59\%$.

Short circuit MVA of stat^n A $= 1200\,MVA \times \frac{100}{86.59} = 1385\,MVA$

When fault occurs on terminal of stat^n B short ckt MVA of stat B, $X_{th} = 119.84\%$



Short circuit MVA $= \frac{1200 \times 100}{119.84}$

1001 MVA

→ If we want to keep the ckt breaker at P & Q shown, then they must have braking capacities of 1385 & 1001 MVA resp.

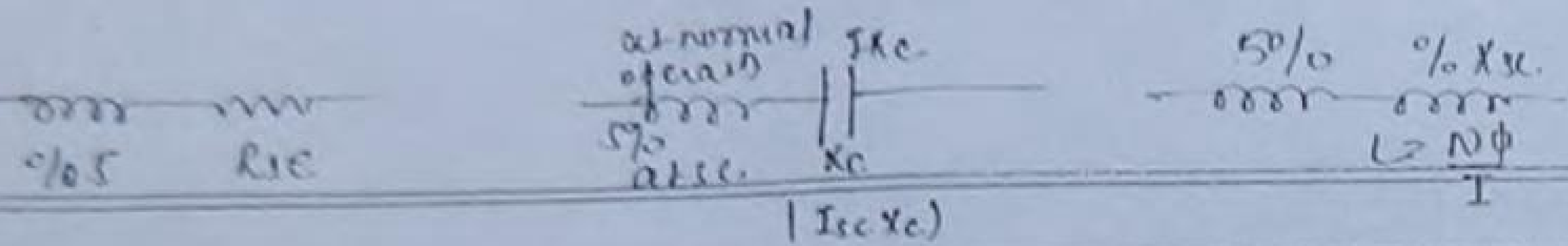
Questn

→ If we have ckt breaker of lesser capacity then how can it be effectively used?

Answer

1) To limit the short ckt current, resistance is not used due to continous power loss.

2) Series capacitors are not used due to break down of dielectric during short ckt (At SC it has high voltage $I_{sc} X_c$ across & act as punctured dielectric)



3) Series Reactors are widely used but they are designed with no core material to avoid saturation problem.
(As the current starts to rise, φ also rises but after certain time, even increment of SC current, φ becomes saturated thus the value of L keeps on ↓sing with ↑sing Isc & thus behaves as a short ckt path. This is becoz air core is used as φ in airgap is never saturated).

→ Purpose of using series Reactor – to limit SC current

Purpose of using shunt reactors – to avoid ferranti effect

Series capacitors – to ↑ steady state power limit
(As when we have inductance then power delivered is less)

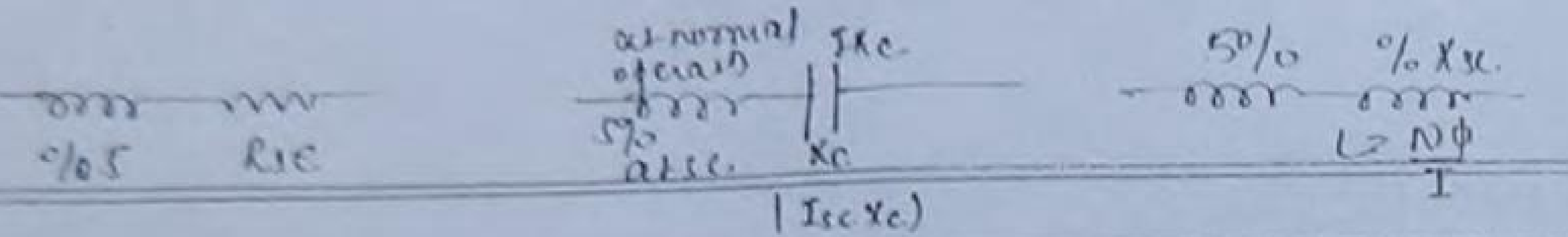
Shunt capacitor – → to improve P.F

✱ Feeder reactors are very commonly used compared to generator & bus bar reactors.

Example:-

100 KVA equipment is having 5% reactance, To limit the short ckt KVA to 500 KVA the value of % Reactance used for series reactors is –

$$500 = 100 \times \frac{100}{5\% + X_{sc}\%}$$



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Example:-

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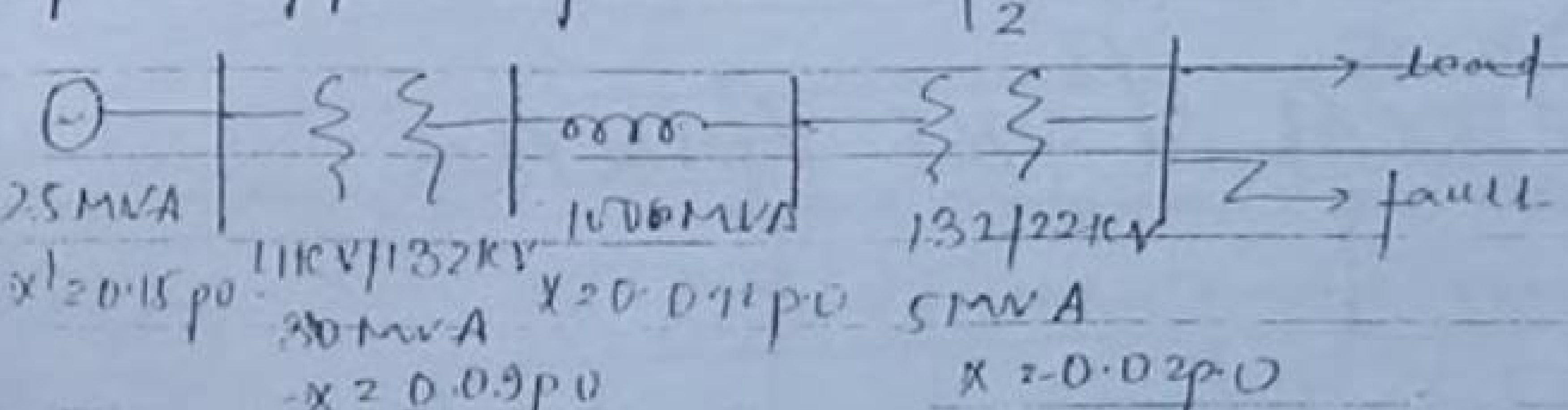
$$500 = 100 \times \frac{100}{5\% + X_{sc}\%}$$

$5\% + X_{se} = 20$

$\% X_{se} = 15\%$

Example:-

A symmetrical 3φ short ckt occur on the 22kV busbar as shown in the fig. Calculate fault current the fault apparent power.



Let the common base MVA = 100MVA

$$X_{G_1} = 0.15 \times \left(\frac{100}{25}\right)\left(\frac{11}{11}\right)^2 = 0.6 p.u$$

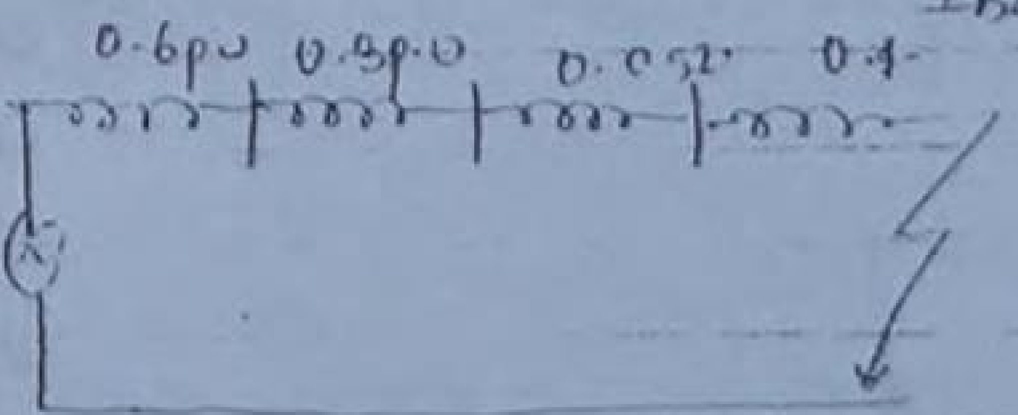
$$X_{T_1} = (0.09) \times \left(\frac{100}{30}\right) = 0.3 p.u$$

$$X_{line} = 0.092 p.u$$

$$X_{T_2} = 0.02 \times \frac{100}{5} = 0.4 p.u$$

Base current on LV side of T_2 is

$$I_{base} = \frac{100 \times 10^6}{\sqrt{3} \times 22 \times 10^6} = 2624.51 \text{ Amp}$$



2PB

$$I_f = \frac{1\angle 0^\circ}{j(0.6 + 0.3 + 0.92 + 0.14)} = \frac{V_{pu}}{\text{Total pu X}}$$

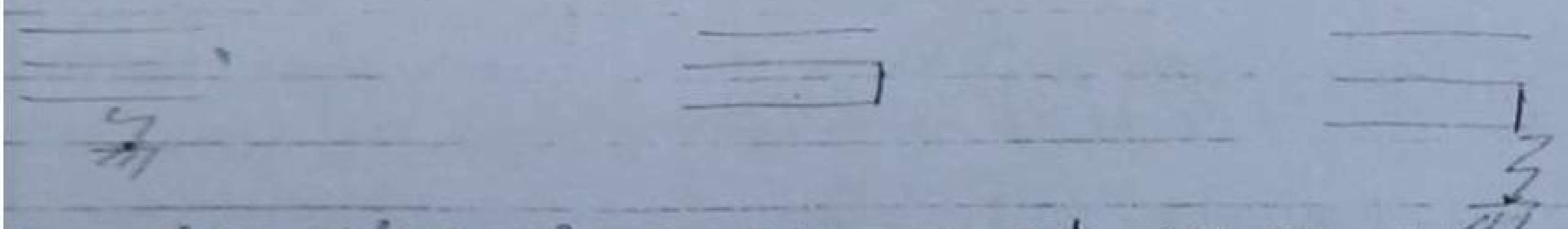
I_f (actual) = I_f (p.u) × I_f (base)

I_f (actual) = 0.718 × 26424.3 = 18874.27 Amp.

Fault MVA = 0.718 pU
= 0.718 × 100 MVA
= 71.8 MVA

UNSYMMETRICAL FAULT ANALYSIS

LG Fault | LL Fault | LLG Fault



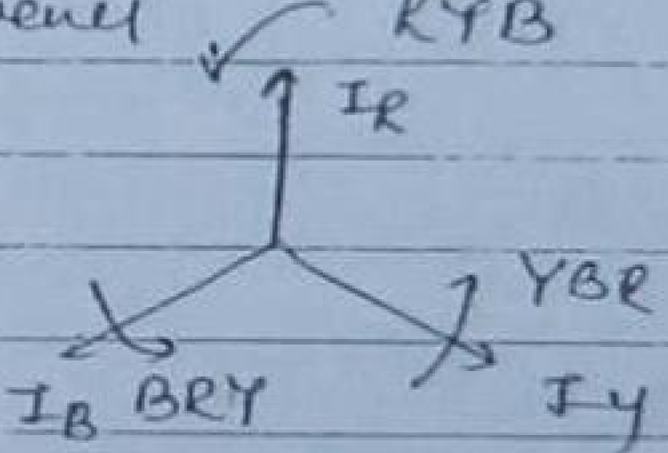
In symmetrical fault all the 3ϕ are at different condition

∴ By working on 1-ϕ base, we can't claim that we have complete 3ϕ analysis

$$\begin{bmatrix} I_R \\ I_Y \\ I_B \end{bmatrix} = \begin{bmatrix} \\ \\ \end{bmatrix} + \begin{bmatrix} \\ \\ \end{bmatrix} + \begin{bmatrix} \\ \\ \end{bmatrix}$$

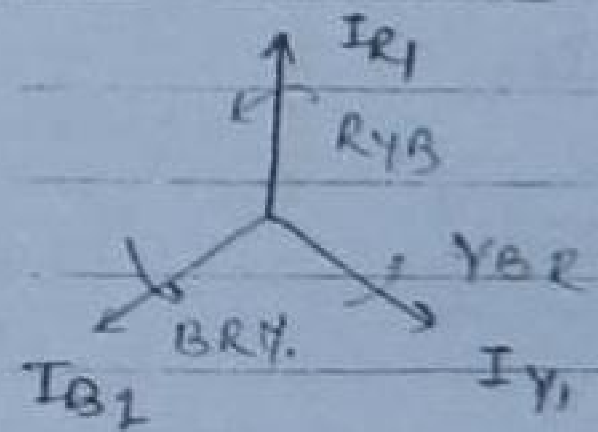
$$\begin{array}{l} I_R = \\ I_Y = \\ I_B = \end{array} \begin{bmatrix} I_{R_1} \\ I_{Y_1} \\ I_{B_1} \end{bmatrix} + \begin{bmatrix} I_{R_2} \\ I_{Y_2} \\ I_{B_2} \end{bmatrix} + \begin{bmatrix} I_{R_0} \\ I_{Y_0} \\ I_{B_0} \end{bmatrix}$$

+ve sequence   -ve seq.   zero sequence

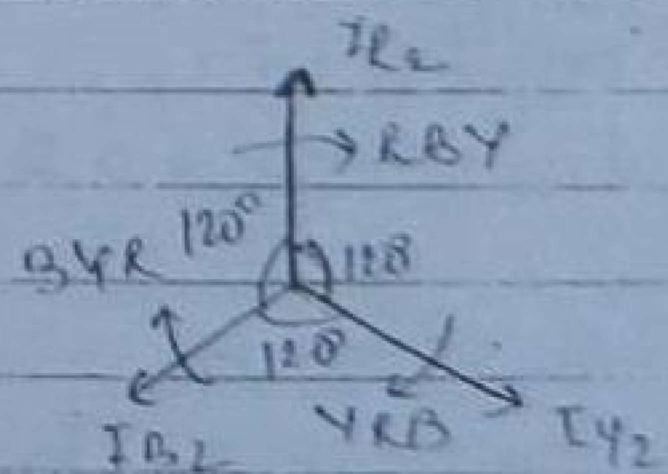


Sequence Components:

+ve sequence – these component are having exactly same as the original unbalanced vectors.

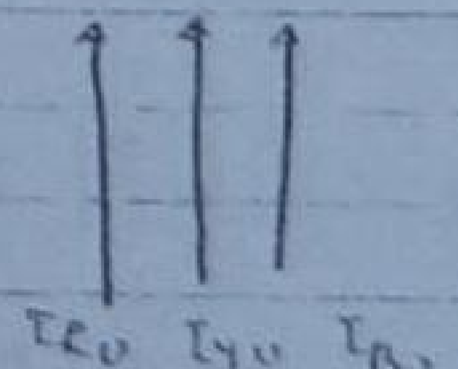


-ve sequence: these component have a sequence exactly opposite to that of original unbalance vector.



Zero Sequence –

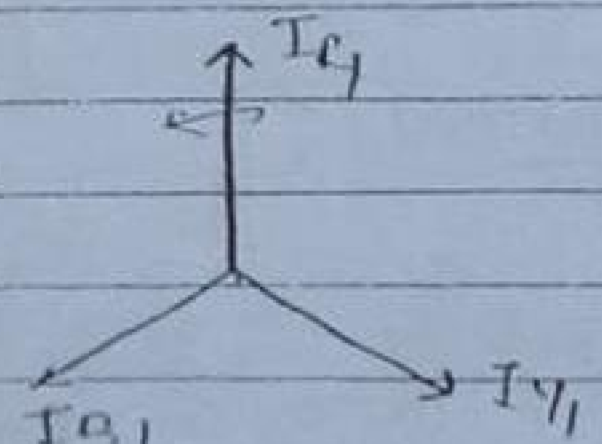
these components have no sequence. (equal magnitude)



→ If we want to convert B, Y component component then we have 'a' operator

$$\boxed{\begin{aligned} a &= 1\angle 120^\circ \\ a^2 &= 1\angle 240 \end{aligned}}$$

$I_{R_1} = I_{R_1}\angle 0^\circ$



$I_{Y_1} = I_{R_1}\angle 240^\circ$
$\quad a^2 I_{R_1}$

$I_{B_1} = I_{R_1}\angle 120$
$\quad a I_{R_1}.$

$$\boxed{I_{R_0} = I_{Y_0} = I_{B_0}}$$

$$\boxed{\begin{aligned} I_{R_2} &= I_{R_2}\angle 0^\circ \\ I_{Y_2} &= I_{R_2}\angle 120^\circ \\ &\quad a I_{R_2} \\ I_{B_2} &= I_{R_2}\angle 240^\circ \\ &\quad a^2 I_{R_2} \end{aligned}}$$

$I_R = I_{R_0} + I_{R_1} + I_{R_2}$

$I_Y = I_{Y_0} + I_{Y_1} + I_{Y_2}$
$\quad I_{R_0} + a^2 I_{R_1} + a I_{R_2}$

$I_B = I_{B_0} + I_{B_1} + I_{B_2}$
$\quad I_{R_0} + a I_{R_1} + a^2 I_{R_2}$

$$\boxed{\begin{bmatrix} I_R \\ I_Y \\ I_B \end{bmatrix} = \begin{bmatrix} 1 & 1 & 1 \\ 1 & a^2 & a \\ 1 & a & a^2 \end{bmatrix} \begin{bmatrix} I_{R_0} \\ I_{R_1} \\ I_{R_2} \end{bmatrix}}$$

$$\boxed{\begin{aligned} [I]_{RYB} &= [A][I]_{012} \\ [V]_{RYB} &= [A][V]_{012} \end{aligned}}$$

Relation of operator 'a' →

('a') → also known as transformation

→ $a = 1\angle 120^\circ = 1(\cos 120 + j\sin 120)$
$= -0.5 + j0.866$

→ $a^2 = 1\angle 240^\circ = 1(\cos 240 + j\sin 240)$
$-0.5 - j0.866$

→ $a^3 = 1\angle 360^\circ = 1$

→ $a^4 = a^3 . a = a$

→ $a^5 = a^3 a^3 = a^2$

→ $1 + a^2 + a = 0$

→ $1 - a^2 = 1 - (-0.5 - j0.866) = \frac{3}{2} + j\frac{\sqrt{3}}{2} = \sqrt{3}\left(\frac{\sqrt{3}}{2} + j\,\frac{1}{2}\right)$

$\sqrt{3}\angle 30^\circ$

→ $1 - a = \sqrt{3}(\angle -30^\circ)$

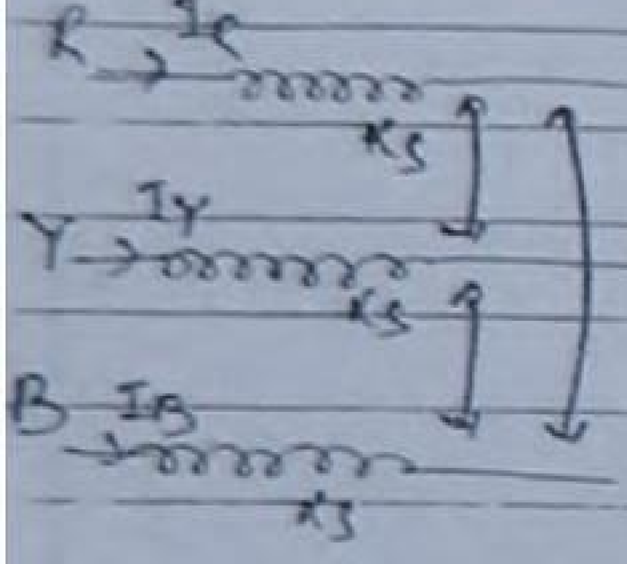
→ $[I]_{RYB} = [A][I]_{012}$

→ $[I]_{012} = [A^{-1}][I_{RYB}]$

where $[A]^{-1} = \frac{1}{3}\begin{bmatrix} 1 & 1 & 1 \\ 1 & a^2 & a^2 \\ 1 & a & a \end{bmatrix}$

* The original N/W are mutually fixed.

* The three sequence N/w +ve, -ve, zero sequence N/w's are mutually disjoined



$$\begin{bmatrix} V_R \\ V_Y \\ V_B \end{bmatrix} = \begin{bmatrix} X_s & X_M & X_m \\ X_M & X_s & X_M \\ X_M & X_m & X_s \end{bmatrix} \begin{bmatrix} I_R \\ I_Y \\ I_B \end{bmatrix}$$

$$\boxed{[V]_{RYB} = [X]_{RYB}[I]_{RYB}}$$

$$[A][V]_{012} = [X]_{RYB}[A][I]_{012}$$

$$[V]_{012} = [A]^{-1}[X]_{RYB}[A][I_{012}]$$

$$[X]_{012} = \begin{bmatrix} X_s+2X_m & 0 & 0 \\ 0 & X_s-X_m & 0 \\ 0 & 0 & X_s-X_m \end{bmatrix}$$

The off diagonal elements are zero in the above matrix, we can conclude that the -ve, zero sequence N/w's are mutually disjoined.

Example:-

A transmission line has self reactance of $j0.6\Omega$/phase & mutual reactance of $j0.1\Omega$ b/w any 2 phase. Find +ve, -ve & zero sequence reactance of the transmission line

$X_0 = X_s + 2X_m$

$j0.6 + 2(j0.1)$

$= j0.8\,\Omega$

$X_1 = X_s - X_m$

$= j0.6 - j0.1$

$= j0.5\,\Omega$

$X_2 = X_s - X_m$

$= j0.6 - j0.1$

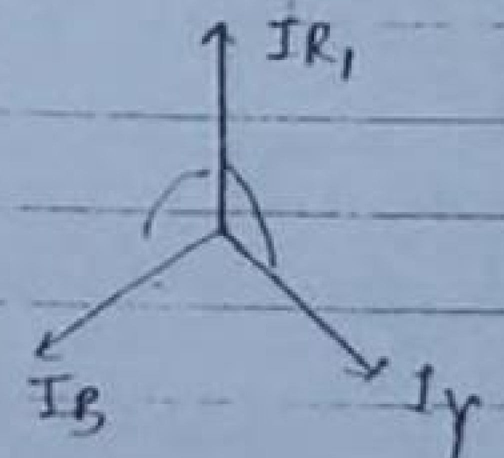
$= j0.5\,\Omega$

→ for static devices phase sequence is not imp.

Example:

In a 3-ϕ balanced s/m, the current in each phase is 10 Amp. The phase sequence is RYB. Find the sequence current. Find the sequence components.

Soln:-



$I_R = 10\angle 0^\circ$

$I_Y = 10\angle 240^\circ = a^2 10$

$I_B = 10\angle 120^\circ = a10$

$[I]_{RYB} = [A][I]_{012} \Rightarrow [I]_{012} = [A^{-1}][I]_{RYB}$

$$\begin{bmatrix} I_{R0} \\ I_{R_1} \\ I_{R_2} \end{bmatrix} = \frac{1}{3}\begin{bmatrix} 1 & 1 & 1 \\ 1 & a & a^2 \\ 1 & a^2 & a \end{bmatrix}\begin{bmatrix} 10 \\ a^2 10 \\ a10 \end{bmatrix}$$

$$I_{R_0} = \frac{1}{3}(10 + a^2 10 + a10) = 0$$

$$I_{R_1} = \frac{1}{3}(10 + a^3 10 + a^3 10) = 10.$$

$$I_{R_2} = \frac{1}{3}(10 + a^4 10 + a^2 10) = 0$$

→ By this we can say that in a balanced s/m the only current in the M/C is +ve sequence current.

Example:-

The fuse in Y & B are removed find seq component

Sol^n = $I_R = 10\angle 0^\circ$ $I_Y = I_B = 0$

$$\begin{bmatrix} I_{R_0} \\ I_{R_1} \\ I_{R_2} \end{bmatrix} = \frac{1}{3}\begin{bmatrix} 1 & 1 & 1 \\ 1 & a & a^2 \\ 1 & a^2 & a \end{bmatrix}\begin{bmatrix} 10 \\ 0 \\ 0 \end{bmatrix}$$

$$I_{R_1} = I_{R_2} = I_{R_0} = 10/3\ A$$

SEQUENCE IMPEDENDEES:

[strictly speaking X_{a_2} is slightly less than X_{a_1}]

Generator:- $\boxed{X_{G_1} \simeq X_{G_2}}$

+ve seq Reactance (-ve seq Reactance)

$$X_{a_1} \begin{cases} \rightarrow X_{a_1} = \dfrac{X_d'' + X_q''}{2}, \ \dfrac{X_d' + X_q'}{2}, \ \dfrac{X_d + X_q}{2} \\ \rightarrow X_{a_1} = X_d'', \ X_d', \ X_d. \end{cases}$$

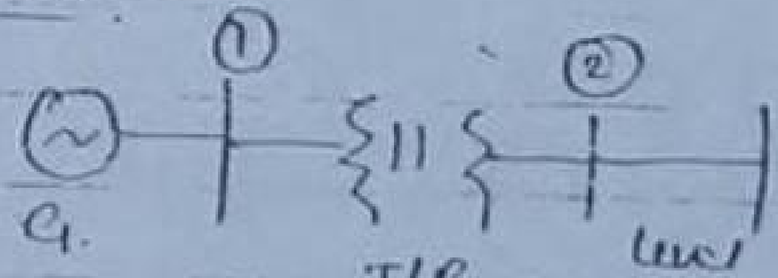
(cylindrical r/r)

$$\boxed{X_{G_0} << X_{a_1}}$$

- For static devices like (T/F & Transmission line)

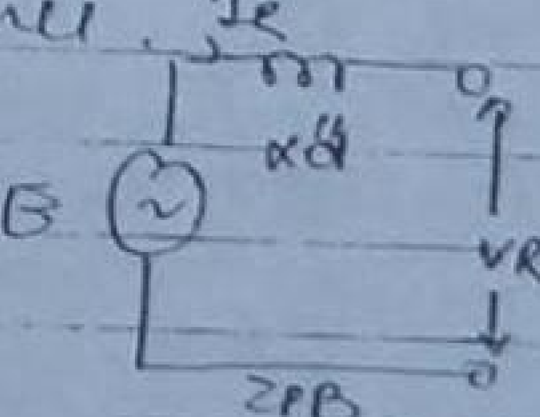
$$X_1 = X_2$$
$$X_0 >> X_1$$

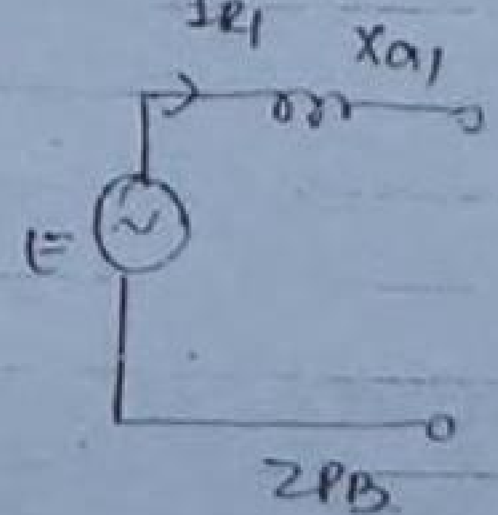
Sequence N/W :-



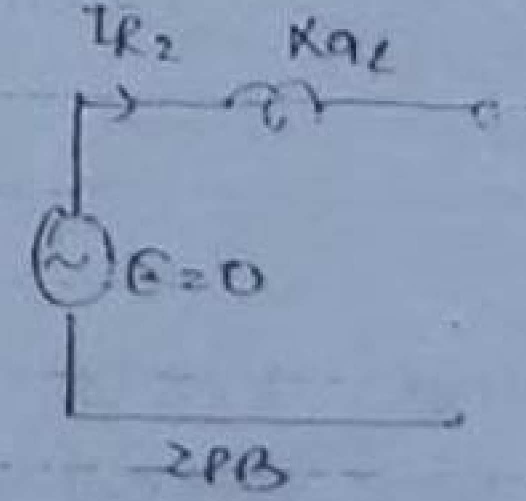
Generator Representation:-

In original N/W with symmetrical fault analysis Gen. is used as const voltage element behind the reactance.

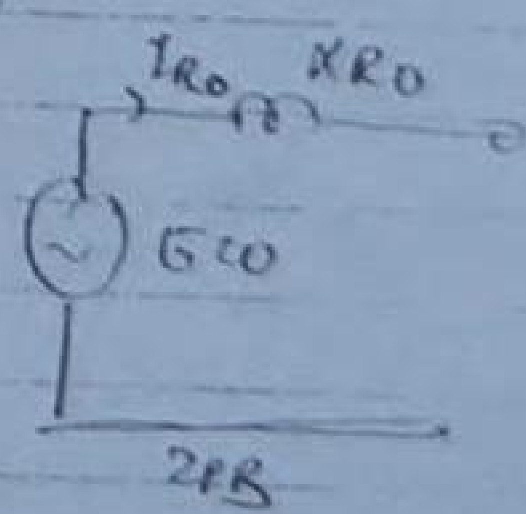




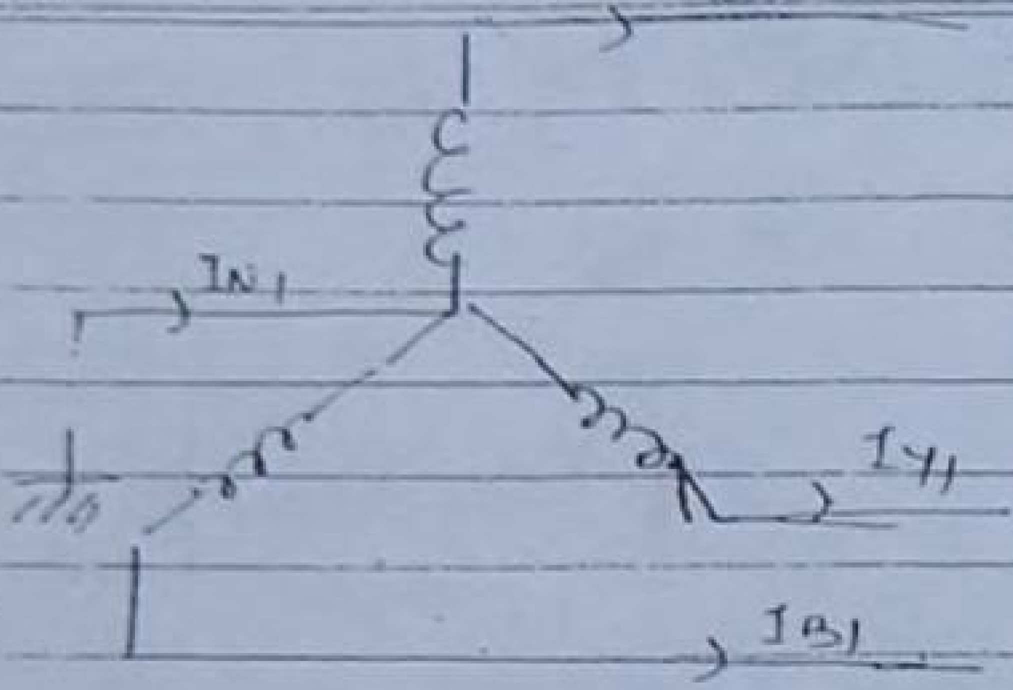
(positive)



(Negative)



(Zero)



$I_R = I_{n_1} + I_{n_2} + I_{n_0}$

$= (I_{R_1} + I_{Y_1} + I_{B_1}) + (I_{R_2} + I_{Y_2} + I_{B_2}) + (I_{R_0} + I_{Y_0} + I_{B_0})$

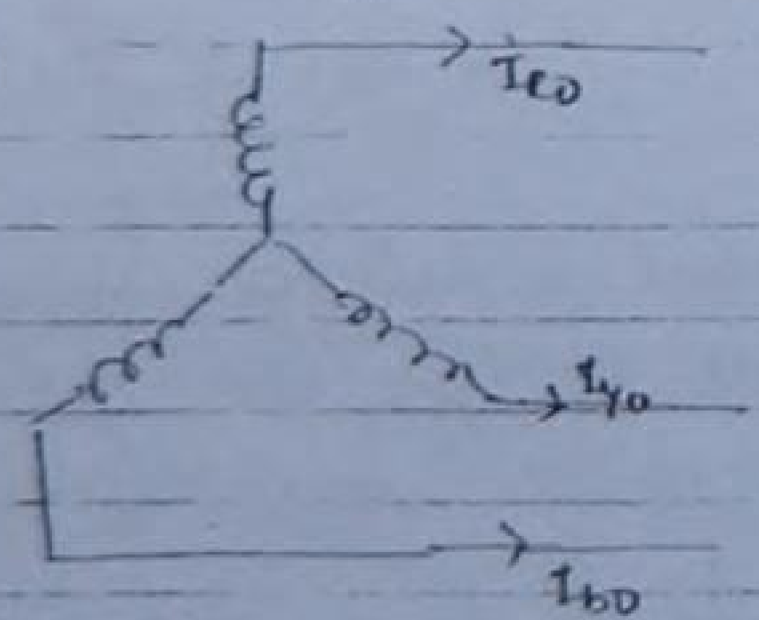
I_{n_0} = sum of outgoing current $= 0$

$\boxed{I_N = 3I_{R_0}}$

∴ positive seq current will flow whether neutral is ground or not

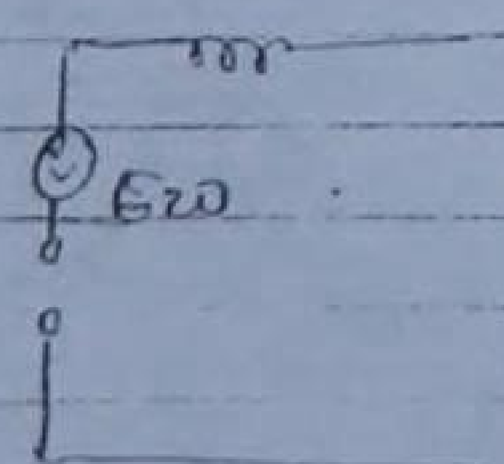
→ If neutral grounded with inductor then:

1)

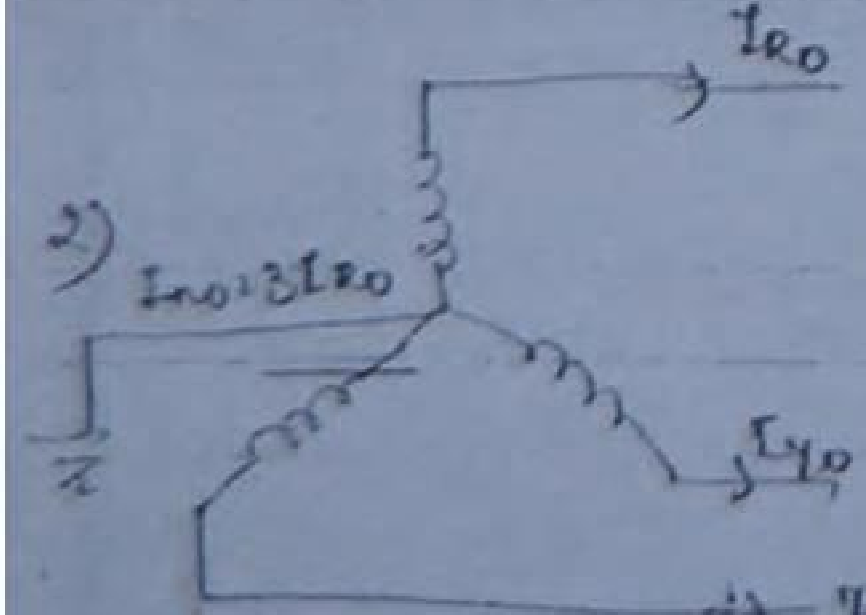


sum of incoming current = 0
Sum of out going current = $3I_{R_0}$
KCL not satisfied.
So such current doesnot exist

∴ Open circuit

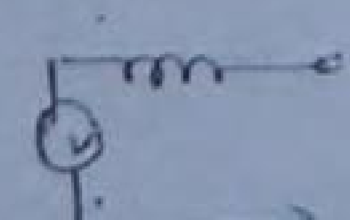


2)

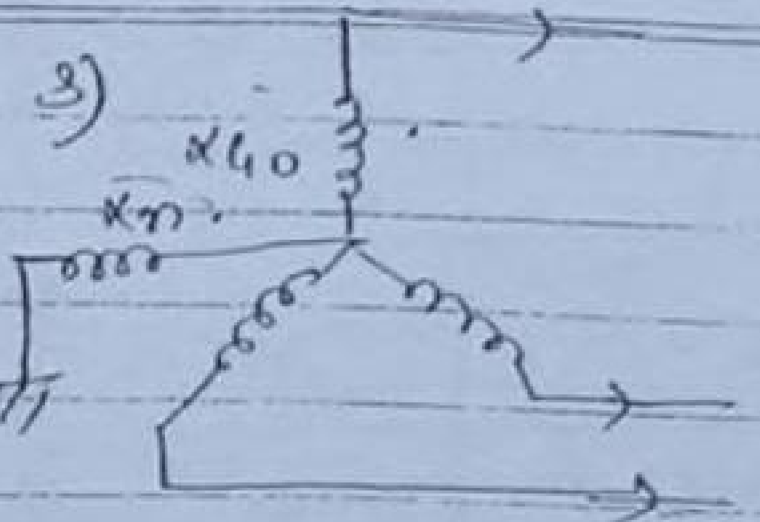


Here KCL is satisfied so now current can flow

So



3)



Now neutral is not ZPB

∴ has drop of $3 I_{n0} X_n$.

∴ unbalanced condn.

$V_{R_1} = 3 I_{R0} X_{n0} + I_{n0} X_{G0}$.

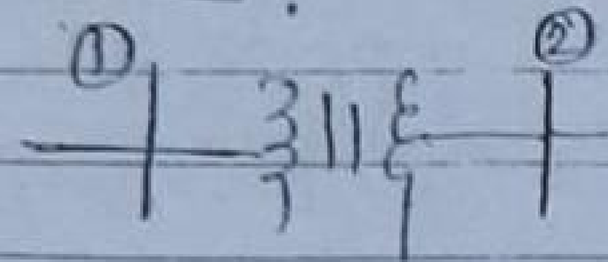
$$\boxed{X_0 = (X_{G0} + 3X_n)}$$

Notes

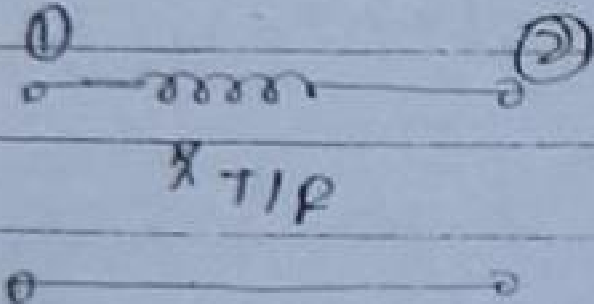
1) Only positive seq n/w contain voltage source
2) Negative & zero seq donot contain voltage source
3) Condition of neutral has got no effect in the representatn of gen. both in +ve & -ve seq N/w
4) However, conditn of neutral has got effect in the representatn of gen, in the zero seq N/w If neutral is unloaded show open ckt. If neutral is solidly grounded show a S.C. If the neutral is grounded with reactance X_n, $3X_n$ must be added to zero sequence reactance of g/r X_{G0} to get total zero sequence reactance

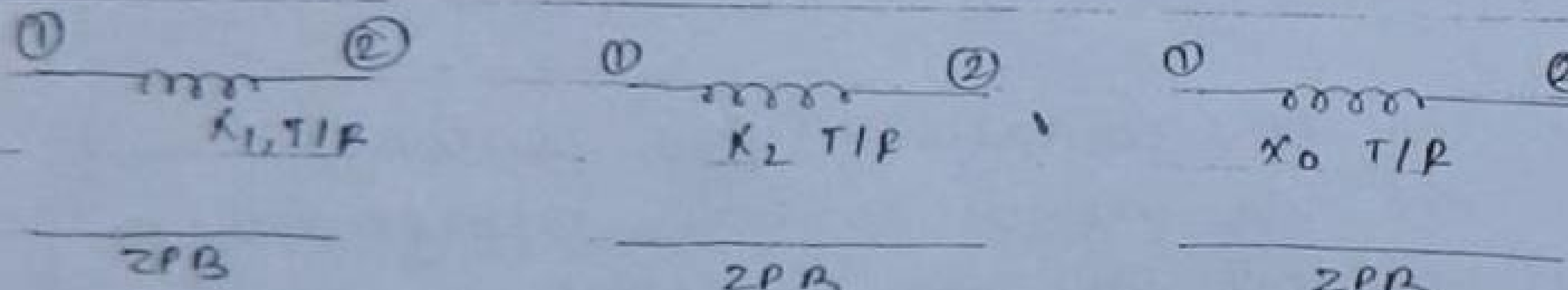
$$\boxed{X_0 = X_{G0} + 3X_n}$$

Transformer Representatⁿ:



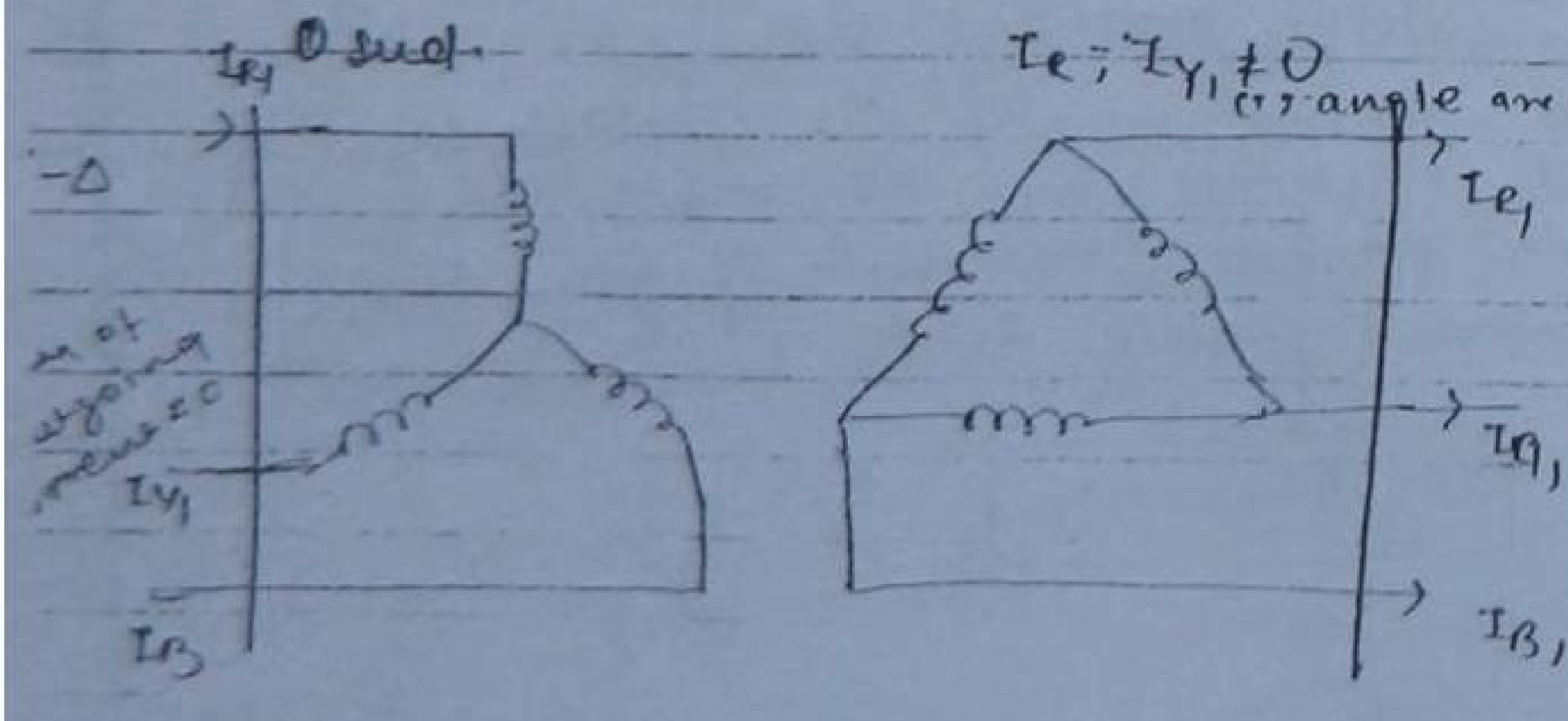
→ In original n/w T/F is shown as series reactance.





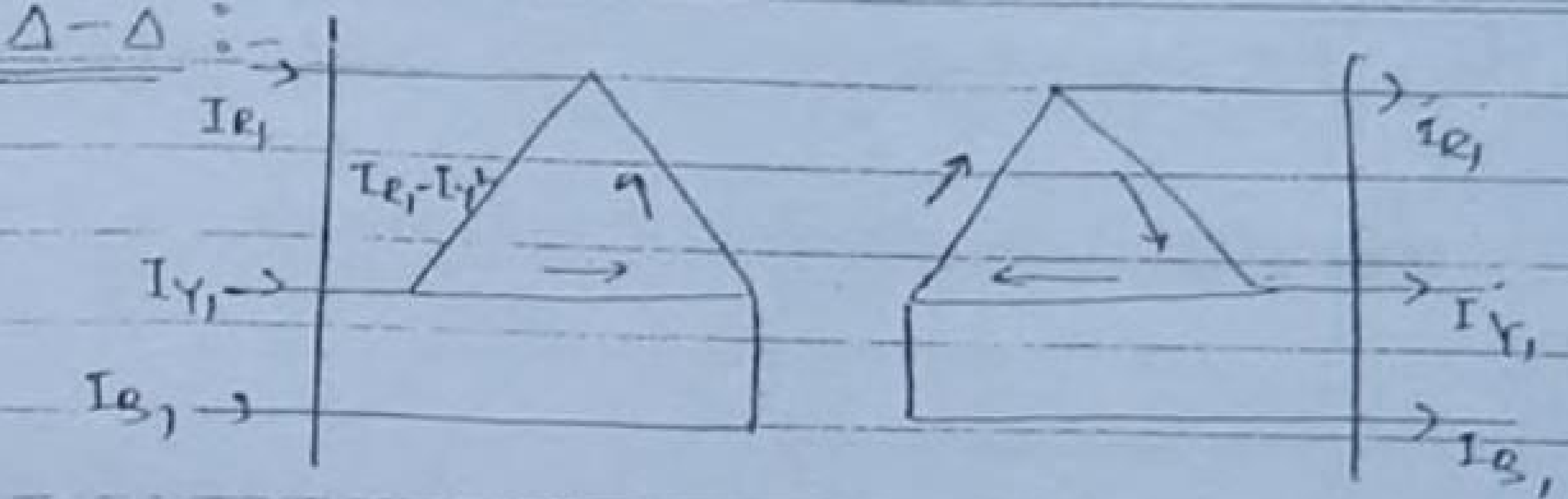
positive Seq   Negative Seq   Zero Seq

→ Power Xmer primary & secondary can be connected in both star & delta.



∴ type of windg has no meaning of T/F

Δ-Δ :-



Conclusion:

xmer has no effect of type of n/w whether Y or Δ

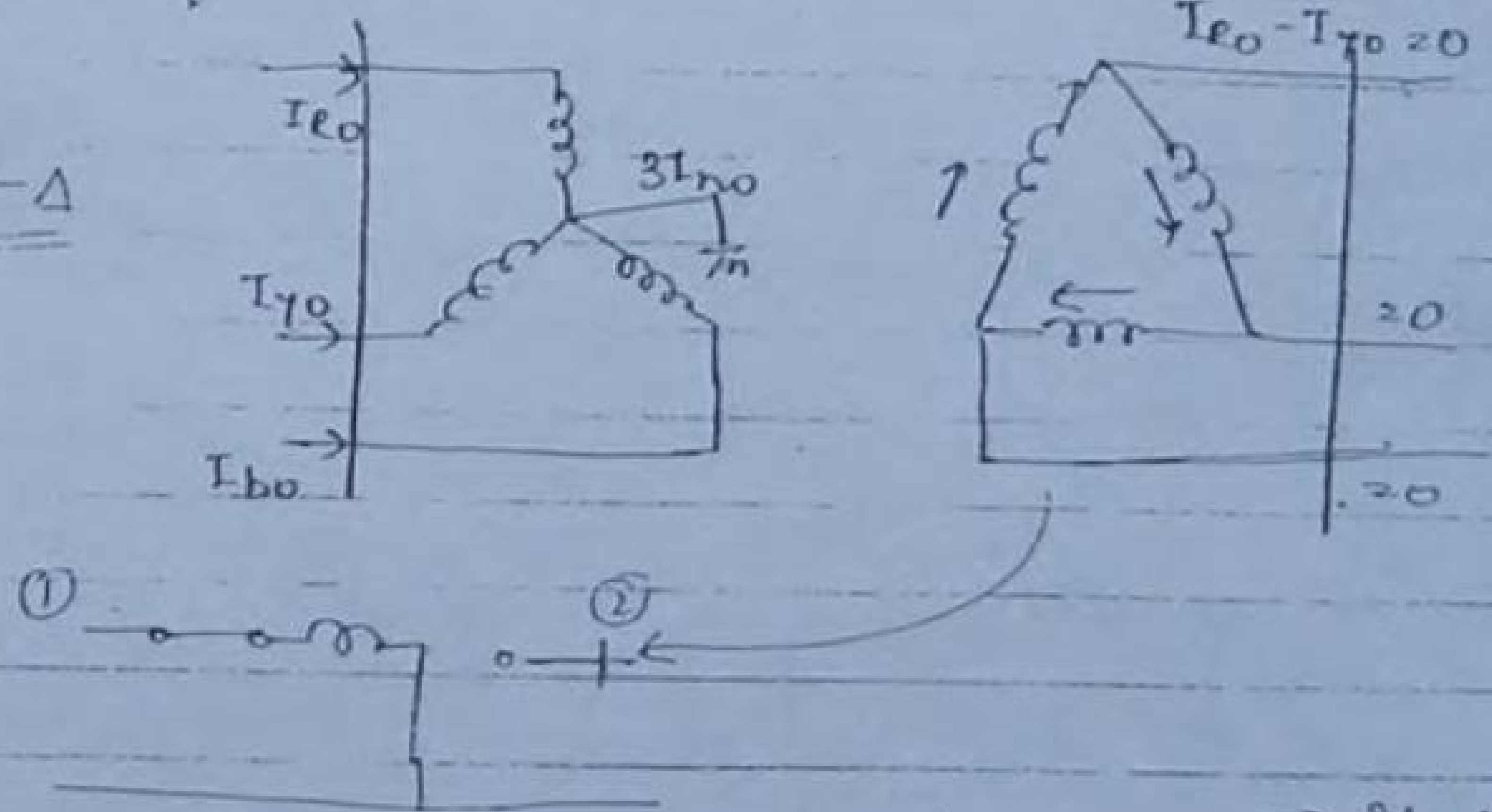
no effect due to neutral ground

$I_{R_1} - I_{Y_1} \neq 0$

∵ mag is same but phase angle = 120°

Zero Sequence:

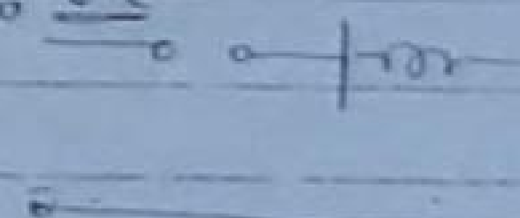
1) Y-Δ



KCL is not satisfied

∵ incoming = $3I_R$, outgoing = 0

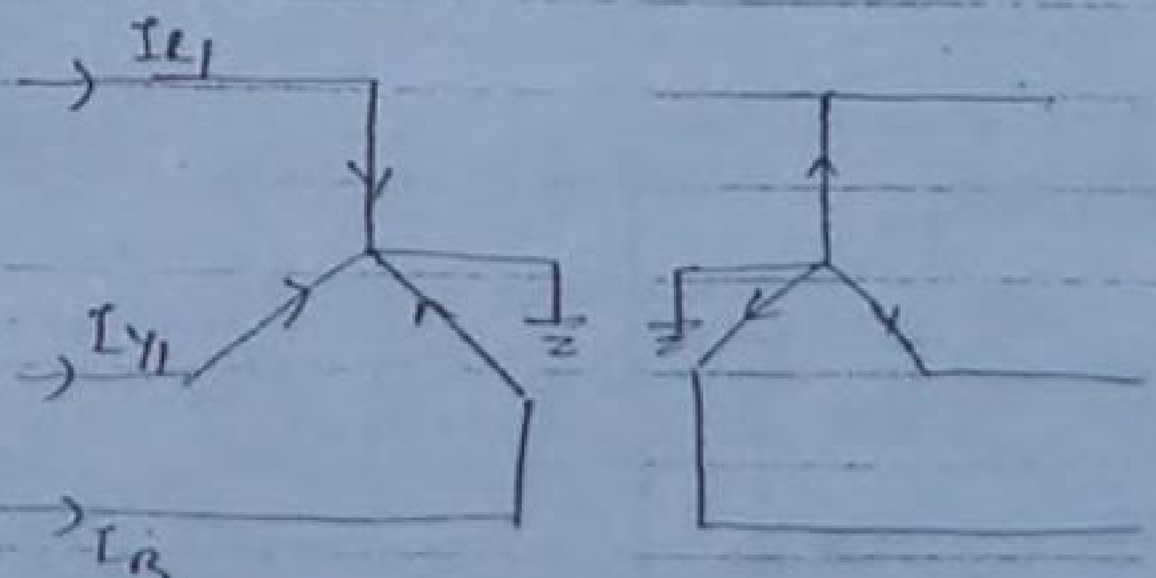
∴ O.C



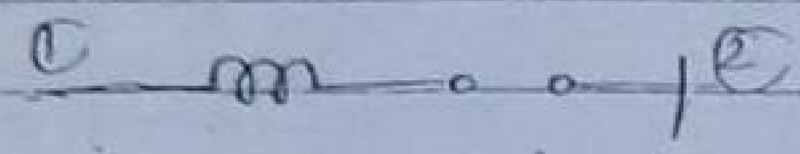
→ If star point is grounded then KCL is satisfied

SC

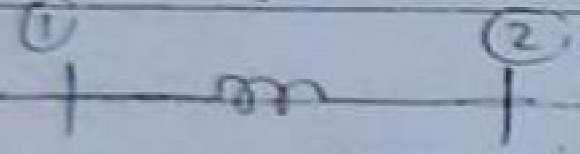
2) Y-Y



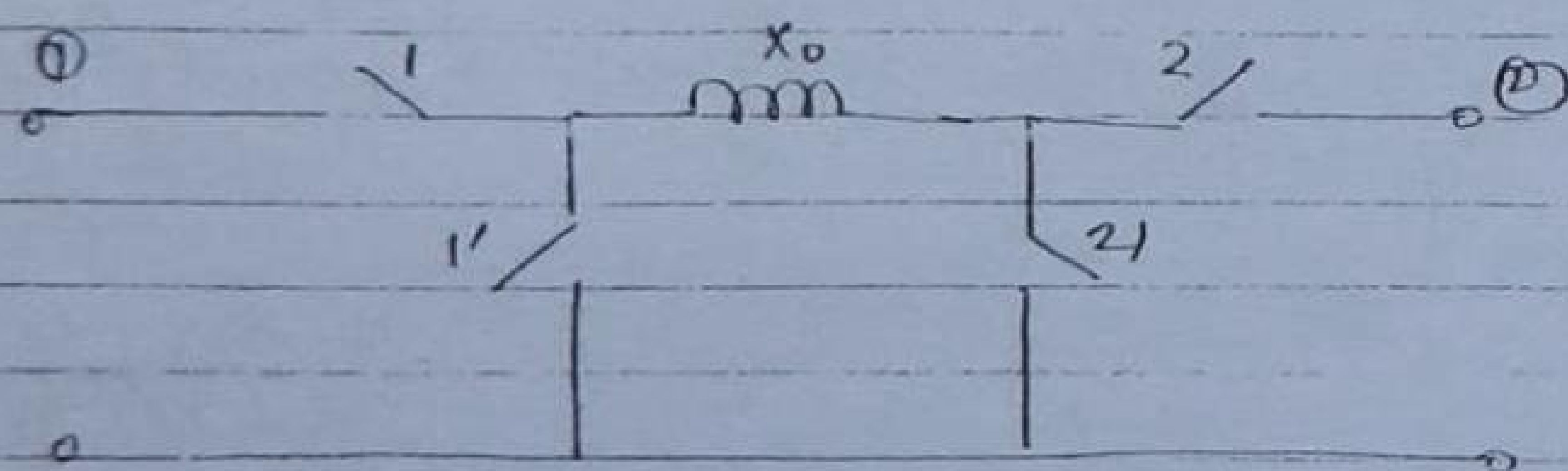
→ If secondary is ungrounded.



→ If it is grounded.



SWITCH DIAGRAM:



1, 1' →	Primary
2, 2' →	Secondary
1, 2 →	Series switches
1', 2' →	Shunt switches

Representatⁿ of Transmission Line :-

In symmetrical fault represented as series reactance.

① ②

X_{Tx}

① +ve sequence

X_1, Tx

ZPB

→ No conditⁿ for T.L

② -ve sequence

X_2, Tx

ZPB

③ Zero sequence

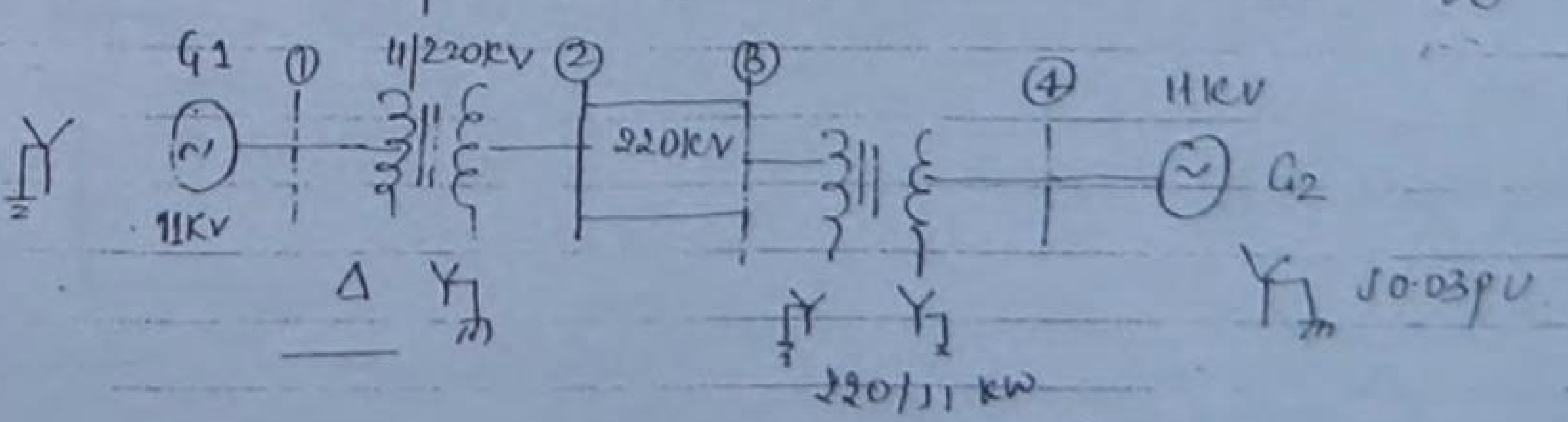
X_0, Tx

ZPB.

* Without verifying any conditⁿ a T.L can be simply represented as series reactance element in all 3-sequen n/w

Problem:-

Obtain the 3-sequence n/w for the n/w shown in figure



→ G1 → $X_1 = X_2 = j0.25$; $X_0 = j0.05$ pu.

G2 → $X_1 = X_2 = j0.2$; $X_0 = j0.05$ pu.

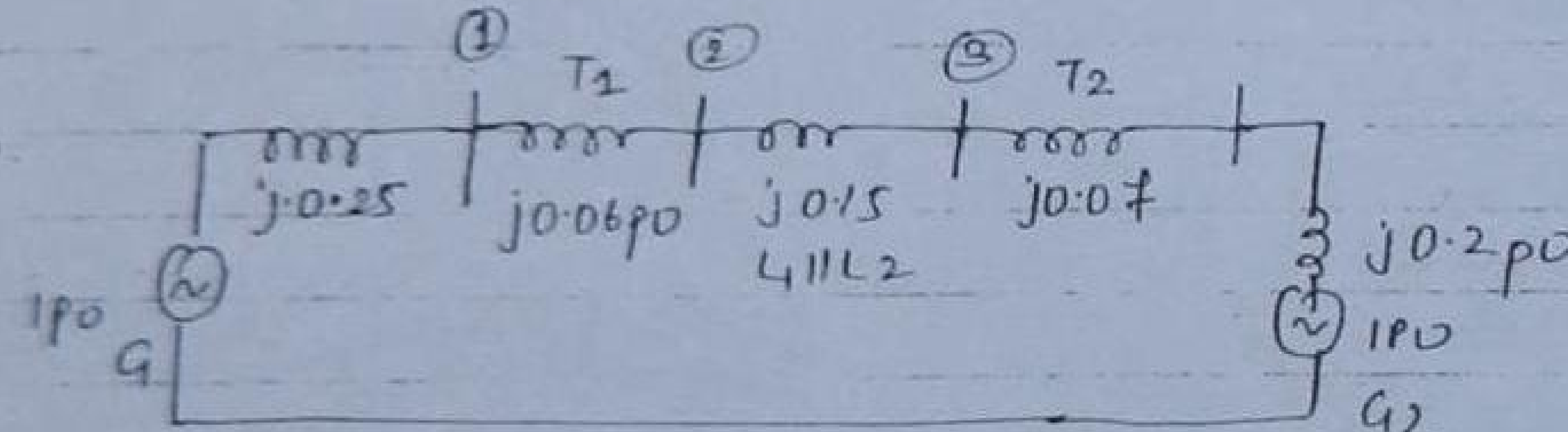
T1 → $X_1 = X_2 = X_0 = j0.06$ p.u.

T2 → $X_1 = X_2 = X_2 = j0.07$ p.u

L1, L2 → $X_1 = X_2 = X_0 = j0.3$.

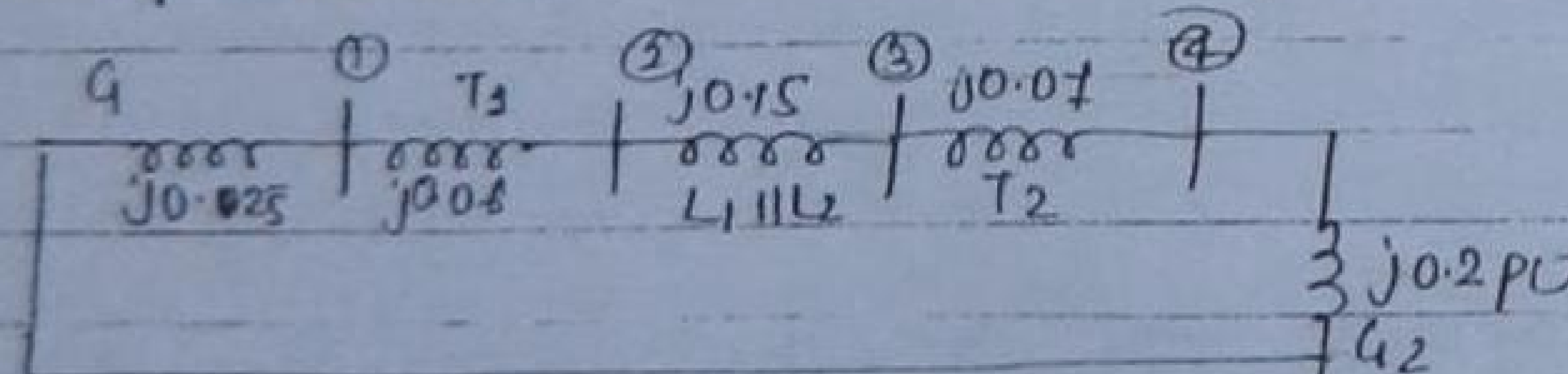
Common base MVA = 100.

Solution: ↓

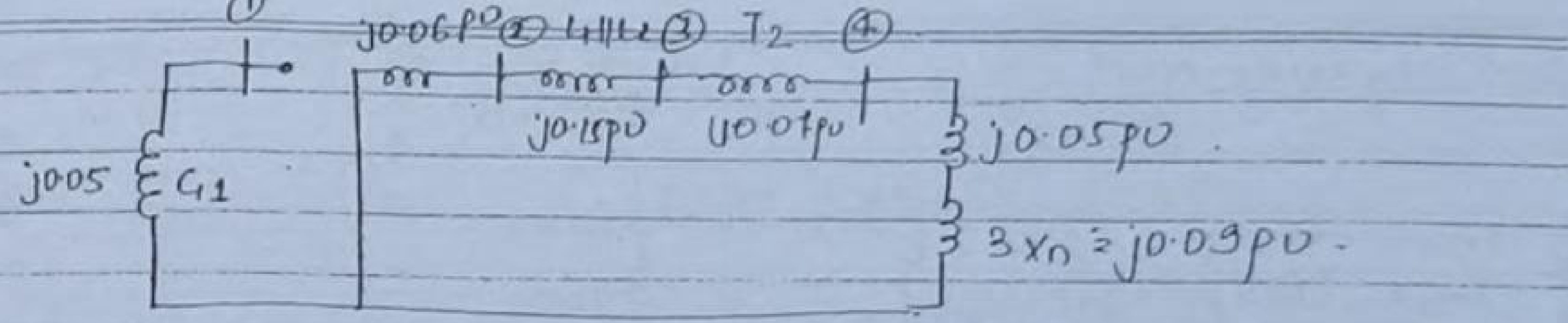


↳ Positive sequence N/W.

→ Negative sequence N/W: (without voltage source rest same)



→ Zero sequence N/W:

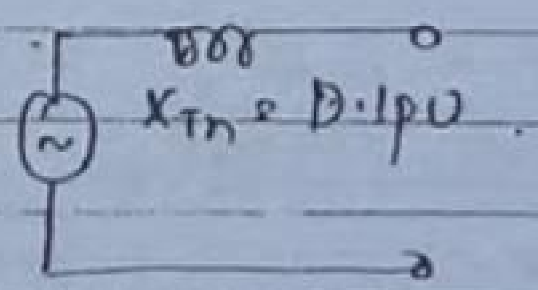


Part B.

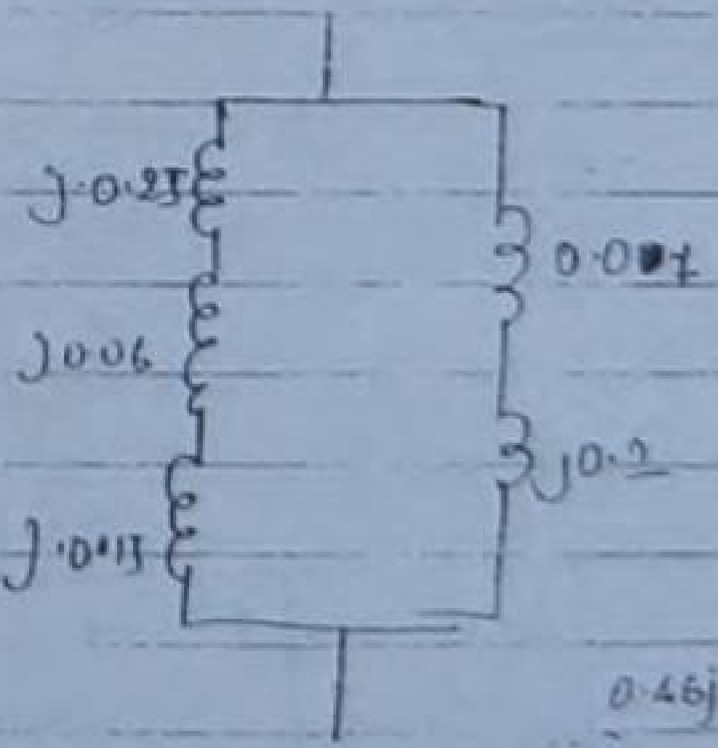
Let the fault is occurred on bus ③, reduce the 3-sequence n/w into thevenin equivalent n/w.

∴ as the voltage on both side is same so circulating current is zero, so drop is also zero, so the same voltage 1pu appears across bus ②. (parallel).

Thevenin's ~~equa~~ equivalent V_{th} = 1pu ; X_{Th} = j0.17pu.



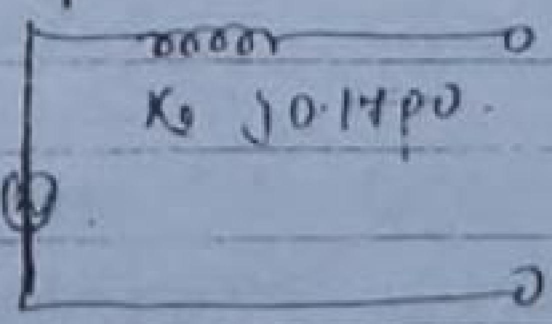
Positive sequence.



0.46j =

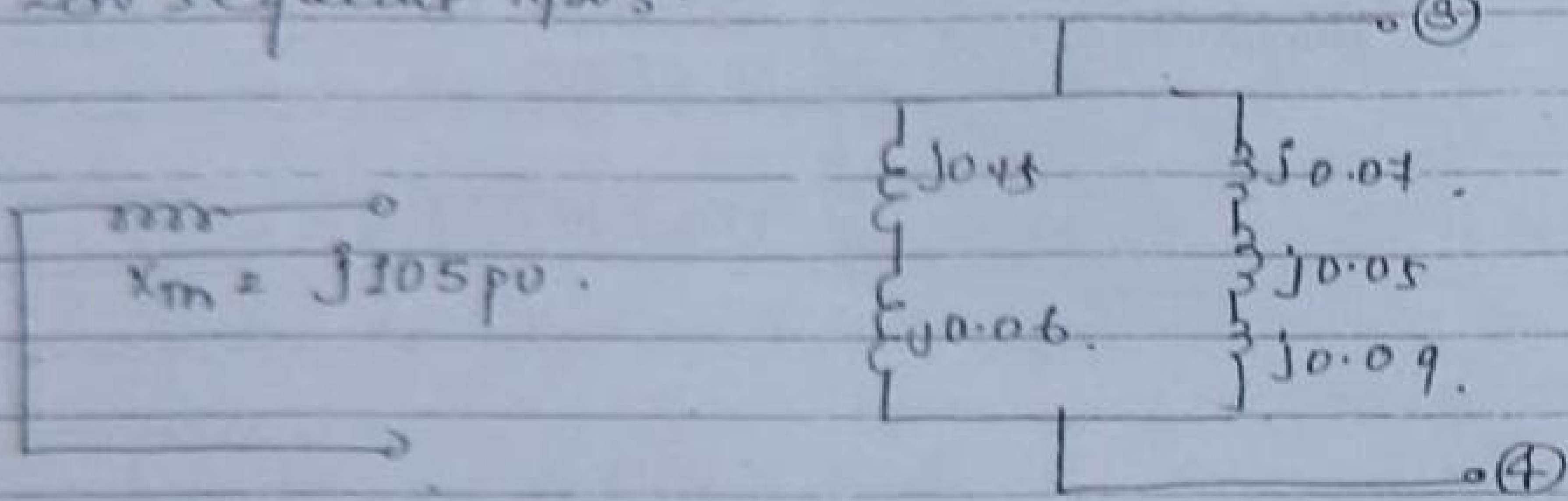
0.23j

-ve sequence n/w same c̄ no voltage



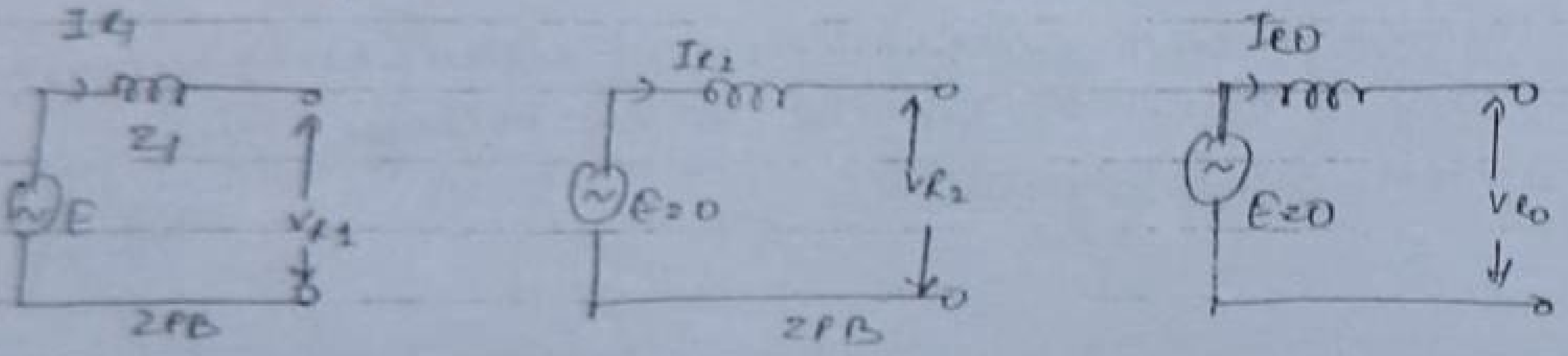
Zero sequence n/w from fm (4.2)

→ Zero sequence n/w :-



0.21P

Voltage Sequence :-



$\boxed{V_{R1} = E - I_{R1}Z_1}$ $\qquad$ $V_{R2} = E - I_{R2}Z_2$ $\qquad$ $V_{R0} = E - I_{R0}Z_0$

$\boxed{V_{R2} = -I_{R2}Z_2}$ $\qquad$ $\boxed{V_{R0} = -I_{R0}Z_0}$

Positive S. $\qquad$ Negative $\qquad$ Zero

$$\begin{bmatrix} V_R \\ V_Y \\ V_B \end{bmatrix} = \begin{bmatrix} 1 & 1 & 1 \\ 1 & a^2 & a \\ 1 & a & a^2 \end{bmatrix} \begin{bmatrix} V_{R0} \\ V_{R1} \\ V_{R2} \end{bmatrix}$$

→ Power s/c not connected to s/m is distributed s/m

Single line Ground fault:

R $I_R = I_f$ · Z_f

Y

B

Before fault:-

$$\boxed{I_R = I_B = I_Y = 0}$$

During fault

$$\boxed{I_R = I_F}$$

$$\boxed{I_Y = I_B = 0}$$

$$\begin{bmatrix} I_{R0} \\ I_{R1} \\ I_{R2} \end{bmatrix} = \frac{1}{3}\begin{bmatrix} 1 & 1 & 1 \\ 1 & a & a^2 \\ 1 & a^2 & a \end{bmatrix}\begin{bmatrix} I_f \\ 0 \\ 0 \end{bmatrix}$$

$$\boxed{I_{R0} = 1/3\, I_f = I_{R1} = I_{R2}}$$

$$\boxed{I_{R1} = I_{R2} = I_{R0} = I_F/3 = I_R/3} \longrightarrow (1)$$

→ All sequence current are equal 4 LG fault.

$$V_R = V_f = I_f Z_f = I_R Z_f = 3 I_{R1} Z_f$$

$$V_{R1} + V_{R2} + V_{R0} = 3 I_{R1} Z_f$$

substituting value of V

$$\Rightarrow (E - I_{R1} Z_1) - I_{R2} Z_2 - I_{R0} Z_0 = 3 I_{R1} Z_f$$

current are equal.

$$\Rightarrow E - I_{R1} Z_1 - I_{R1} Z_2 - I_{R1} Z_0 = 3 I_{R1} Z_f$$

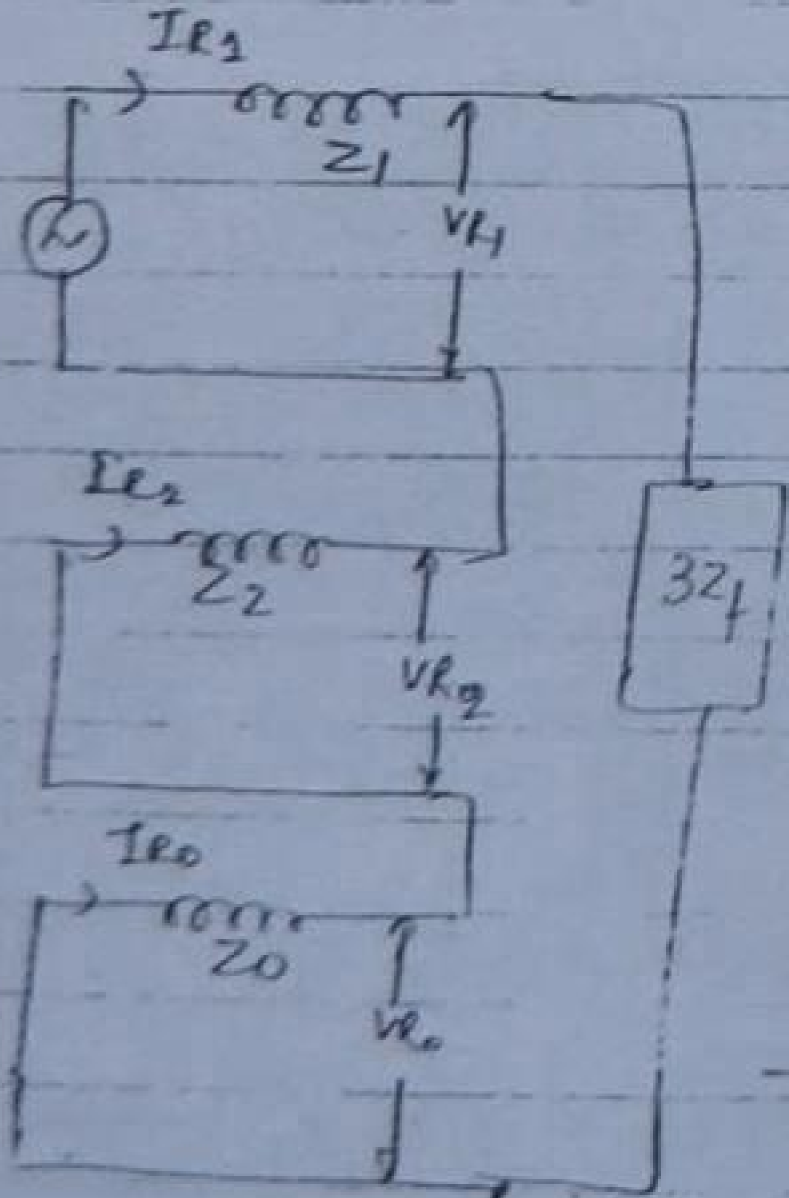
$$\boxed{I_R = \frac{E}{Z_1 + Z_2 + Z_0 + 3Z_f} = I_{R_2} = I_{R_0}} \quad (2)$$

$$\boxed{I_{f_{LG}} = I_R = 3I_{R_1}}$$

$$\therefore \boxed{I_{f_{LG}} = \frac{3E}{Z_1 + Z_2 + Z_0 + 3Z_f}}$$

Objective :-

→ Particular fault for all sequence current equal → LG fault.



→ for LG fault

§ Comments

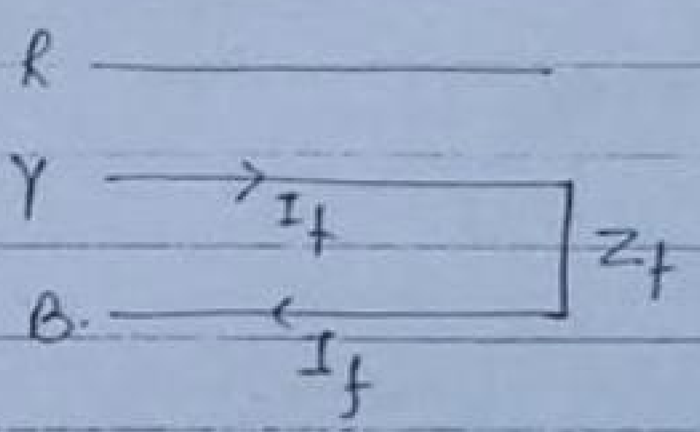
For LG fault :-

→ All sequence n/w are connected in series

→ All sequence currents are equal.

→ $I_{f_{LG}} = 3I_{R_1} = 3I_{R_2} = 3I_{R_0} = \dfrac{3E}{Z_1 + Z_2 + Z_0 + 3Z_f}$.

Line to line fault :-

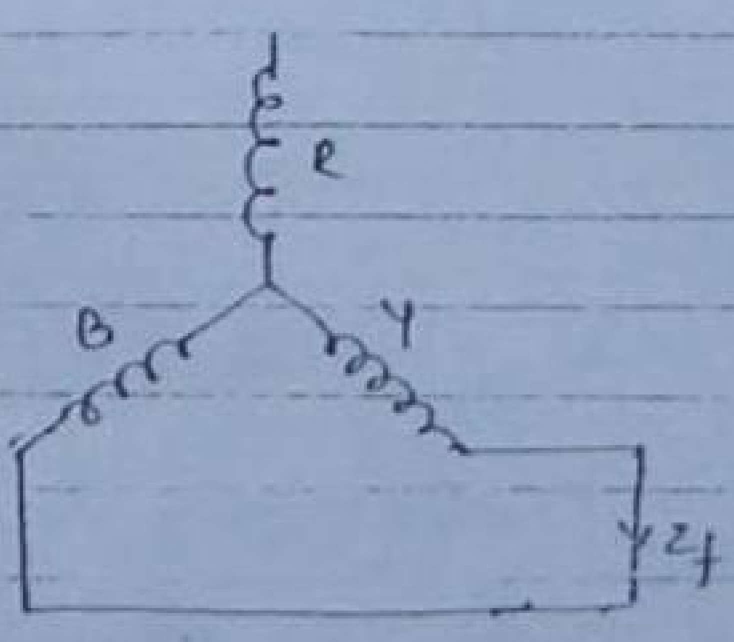


Before fault

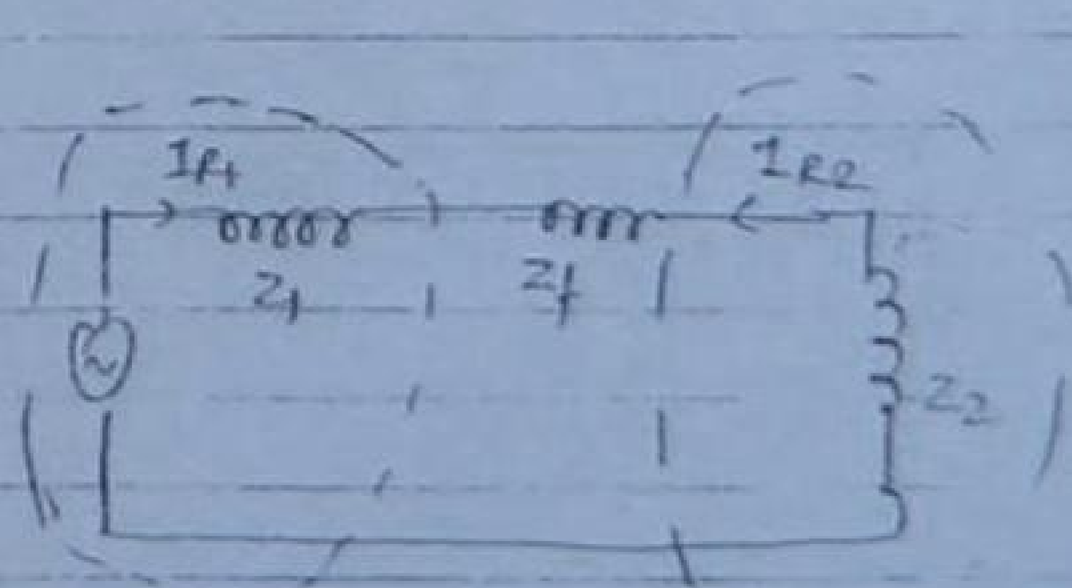
$I_R = I_Y = I_B = 0$

During fault :-

$I_f = I_Y = -I_B$



(Current circulate as shown)



→ Fault in which fault current is $\sqrt{3} I_{R_1}$ or $\sqrt{3} I_{R_2}$ → LL Fault.
a^2-a

$$\boxed{I_{R_1} = -I_{R_2}} \quad \& \quad \boxed{I_{R_0} = 0}$$

two sequences are connected in series opposition

Magnitude :-

$$\boxed{I_{R_1} = -I_{R_2} = \frac{E}{Z_1 + Z_2 + Z_f}}$$

Calculating I_Y

$$I_{f,LL} = I_Y = I_{R_0} + a^2 I_{R_1} + a I_{R_2}$$

$$= (a^2 - a) I_{R_1}$$

$$\therefore (a^2 - a) = (-0.5 - j.866 + 0.5 - j0.866)$$

$$= -j1.732 = -j\sqrt{3}$$

$$I_{f_{L-L}} = -j \frac{\sqrt{3} E}{Z_1 + Z_2 + Z_f}$$

$$\boxed{|I_{f_{L-L}}| = \frac{\sqrt{3} E}{Z_1 + Z_2 + Z_f}}$$

Comments :-

for Line to Line fault :-

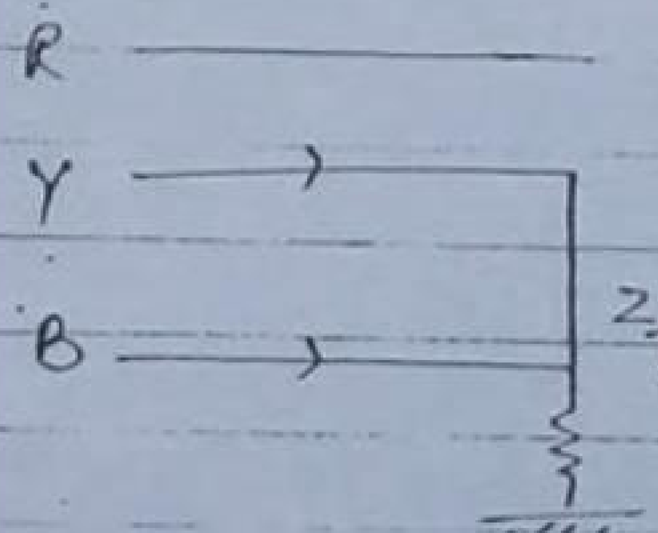
→ Positive and negative sequence n/w are connected in series opposition.

→ $\boxed{I_{R_1} = -I_{R_2}}$ and $\boxed{I_R = 0}$

→ Magnitude of fault current is

$$\boxed{I_{fL} = \sqrt{3} I_{R_1} = \sqrt{3} I_{R_2} = \frac{\sqrt{3}E}{Z_1 + Z_2 + Z_f}}$$

Double line Ground fault :-



Before fault

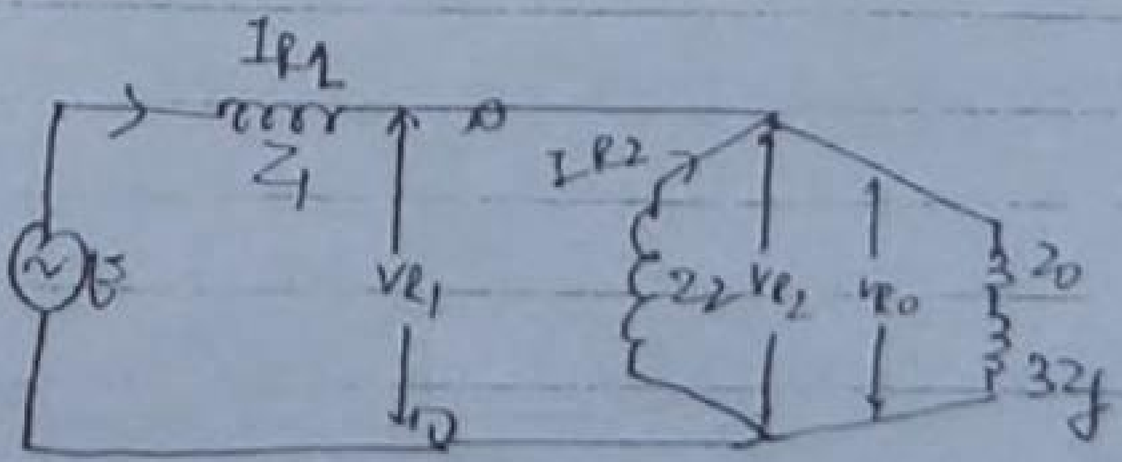
$I_R = I_B = I_Y = 0.$

During fault

$$\boxed{I_f = I_Y + I_B}$$

$$\boxed{V_f = V_Y = V_B = I_f Z_f}$$

Derivation :-



All sequences are in parallel. so

$$\rightarrow \boxed{V_{R_1} = V_{R_2} = V_{R0}}$$

$$\boxed{I_{R_1} = -(I_{R_2} + I_{R0})} \rightarrow \text{objective}$$

Magnitude:

$$\boxed{I_{R_1} = \frac{E}{Z_1 + (Z_2 \parallel (Z_0 + 3Z_f))}}$$

$$\boxed{I_{R2} = -I_{R1} \times \frac{Z_0 + 3Z_f}{Z_2 + Z_0 + 3Z_f}}$$

$$\boxed{I_{R0} = -I_{R1} \times \frac{Z_2}{Z_2 + Z_0 + 3Z_f}}$$

using sequence current find I_Y and I_B

$\cancel{I_{Y/2}}$

$$\boxed{I_f = I_Y + I_B}$$

$\cancel{I_{Y/2}}$

Magnitude of double line fault is 3 times the zero fault.

$$I_R = 0$$

$$I_{R_1} + I_{R_2} + I_{R0} = 0$$

$$I_{fLLG} = I_Y + I_B$$

$$= (I_{R0} + a^2 I_{R1} + a I_{R2}) + (I_{R0} + a I_{R1} + a^2 I_{R2})$$

$$I_{fLL-G} = [2I_{R0} + (a^2+a) I_{R1} + (a^2+a) I_{R2}]$$

$$I_{fLG} = 2I_{R0} - I_{R1} - I_{R2} \qquad \because a^2 + a = -1$$

$$2I_{R0} - (I_{R1} + I_{R2})$$

** $\boxed{I_{fLG} = 3I_{R0}}$ $\qquad \because I_{R1} + I_{R2} = -I_{R0}$

Problem:-

For a balanced 3-φ s/m.

Comment:→

→ All sequence n/w are connected in parallel.

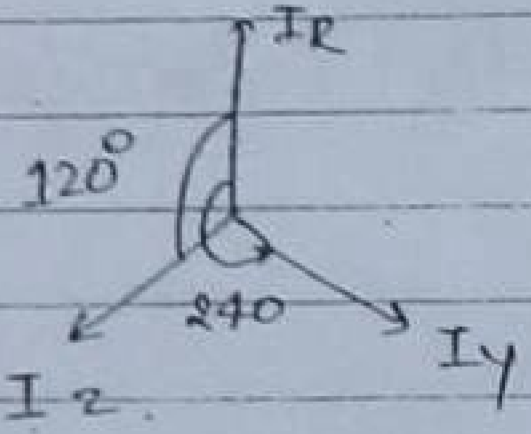
→ $V_{R1} = V_{R2} = V_{R0}$.

→ $I_{R1} = -(I_{R2} + I_{R0})$

Problem:-

The current in each phase of a balanced 3φ s/m is 10 the phase sequence is RYB. Find the resultant sequence current.

Solution:



$I_R = 10\angle 0^\circ = 10.$

$I_Y = 10\angle 240 = a^2 10$

$I_B = 10\angle 120^\circ = a10$

$$\begin{bmatrix} I_{R_0} \\ I_{R_1} \\ I_{R_2} \end{bmatrix} = \frac{1}{3}\begin{bmatrix} 1 & 1 & 1 \\ 1 & a & a^2 \\ 1 & a^2 & a \end{bmatrix}\begin{bmatrix} 10 \\ 10a^2 \\ 10a \end{bmatrix}$$

$I_{R_0} = \frac{1}{3}[10 + 10a^2 + 10a] = 10/3 \times 0 = 0\ A$

$I_{R_1} = \frac{1}{3}[10 + a^3 + a^3] = \frac{1}{3} \times 30 = 10A$

$I_{R_2} = \frac{1}{3}[10 + a^4 + a^3] = \frac{1}{3}[10 + a10 + a^2 10] = 0A.$

Problem 2:

In above s/m the fuses in Y and B phase are removed

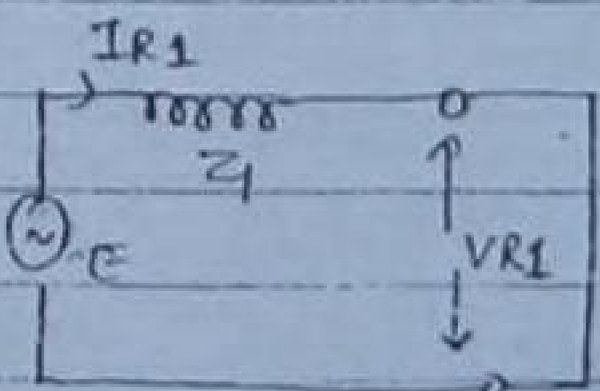
$I_y = I_b = 0$; $I_R = 10$

$$\begin{bmatrix} I_{R_0} \\ I_{R_1} \\ I_{R_2} \end{bmatrix} = \frac{1}{3}\begin{bmatrix} 1 & 1 & 1 \\ 1 & a^2 & a \\ 1 & a & a^2 \end{bmatrix}\begin{bmatrix} 10 \\ 0 \\ 0 \end{bmatrix}$$

$$I_{R_0} = I_{R_1} = I_{R_2} = 10/3$$

* Under balanced condition we only have +ve sequence curr

3-ϕ fault using sequence N/W (+ve sequence):-



EPB

$$\begin{bmatrix} I_R \\ I_Y \\ I_B \end{bmatrix} = \begin{bmatrix} 1 & 1 & 1 \\ 1 & a^2 & a \\ 1 & a & a^2 \end{bmatrix}\begin{bmatrix} 0 \\ I_{R_1} \\ 0 \end{bmatrix}$$

$$\boxed{I_{f,3\phi} = I_{R_1} = E/Z_1}$$

$I_R = I_{R_1}$

$I_Y = a^2 I_{R_1}$

$I_B = a I_{R_1}$

→ In phase fault the fault current with not is not

not limited by impedance Z_f, hence Z_f is not considered in 3ϕ fault.

→ Ground also donot effect the 3ϕ fault current. Also no difference b/w 3ϕ fault and ground fault.

→ All the 3ϕ voltage including +ve sequence. voltage is zero.

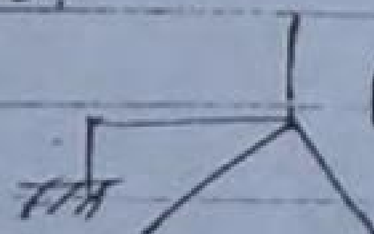
Comparison:

<u>3-ϕ fault</u> | <u>Line to ground fault.</u>

$I_{f\text{-}3\phi} = \frac{E}{Z_1}$; $Z_f = 0$

→ $I_{fLG} = \frac{3E}{Z_1 + Z_2 + Z_0}$

<u>Case: 1</u> Solidly grounded alternator:



$\boxed{Z_n = 0}$

$Z_0 = Z_{a0} + 3Z_n$

$= Z_{a0}.$

∵ -ve alternal sequence current

$Z_2 \simeq Z_1$

$Z_0 >> Z_1$

$I_{f3\phi} = \frac{E}{Z_1}$ — ①

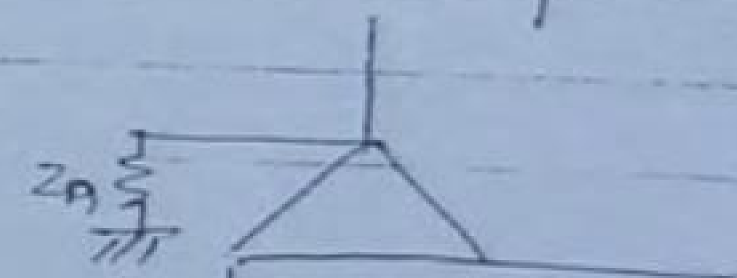
$I_{fLG} = \frac{3E}{Z_1 + (\simeq Z_1) + (<< Z_1)}$

$$= \frac{3E}{2Z_1} \simeq 1.5 \times \frac{E}{Z_1}$$

$\boxed{I_{f_{LG}} > I_{f3\phi}}$ $\qquad = \boxed{1.5 \times I_{f3\phi}}$

- For solidly grounded alternator LG fault is more severe.

Case 2: Alternator neutral grounded with the impedance Z



$\boxed{Z_0 = Z_{n0} + 3Z_n}$

Z_0 depends on Z_n.

$$I_{f3\phi} = \frac{E_1}{Z_1} \qquad I_{f_{LG}} = \frac{3E}{Z_1 + Z_0 + Z_{g0} + 3Z_n}$$

- Here severity of fault is decided by Z_n

If $Z_n = \frac{1}{3}(Z_1 - Z_0)$

then $I_{f_{LG}} = \dfrac{3E}{Z_1 + (\simeq Z_1) + Z_{g0} + 3\left[\frac{1}{3}(Z_1 - Z_0)\right]}$

$$\simeq \frac{3E}{3Z_1} \simeq I_{f3\phi}$$

*

$\boxed{I_{f3\phi} = I_{f_{LG}} \quad \text{for } Z_n = 1/3(Z_1 - Z_0)}$

If Z_n

$\rightarrow < \frac{1}{3}(Z_1 - Z_{g0})$; $I_f LG > I_f 3\phi$

~~$I_f LG > I_f 3\phi$~~

$\rightarrow = \frac{1}{3}(Z_1 - Z_0) \Rightarrow I_f LG = I_f 3\phi$

$\rightarrow > \frac{1}{3}(Z_1 - Z_{g0}) \Rightarrow I_f 3\phi > I_f LG$.

Objectives.

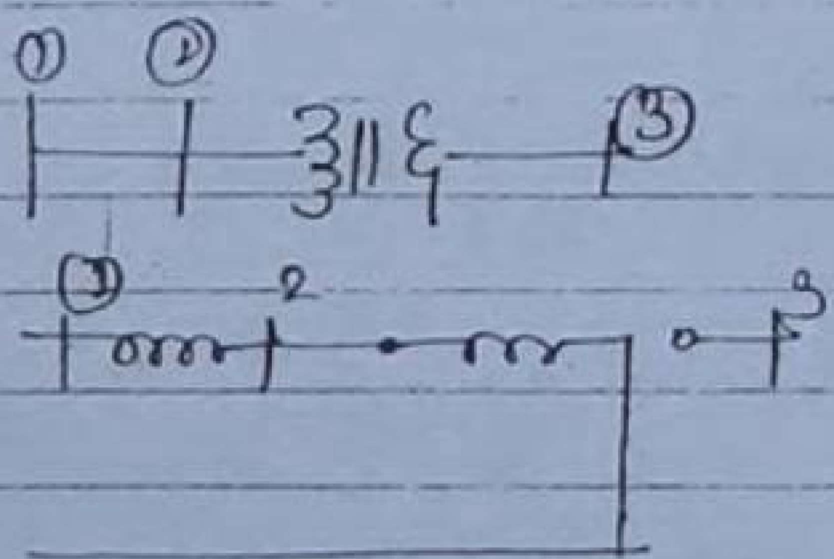
(1) zero sequence current can flow from a line into a xmer bank if the winding of xmer are.

a) $Y_n - \Delta$

b) $\Delta - Y$

c) $Y - Y$

d) $\Delta - \Delta$.



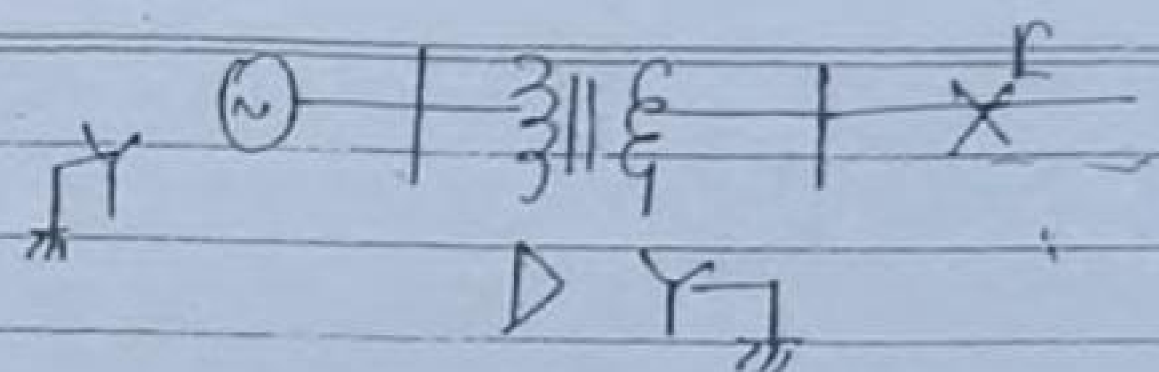
(2) for s/m shown in figure what is the L-G fault on the ~~right~~ side of xmer equivalent to

a) L-G fault on G/r side of xmer

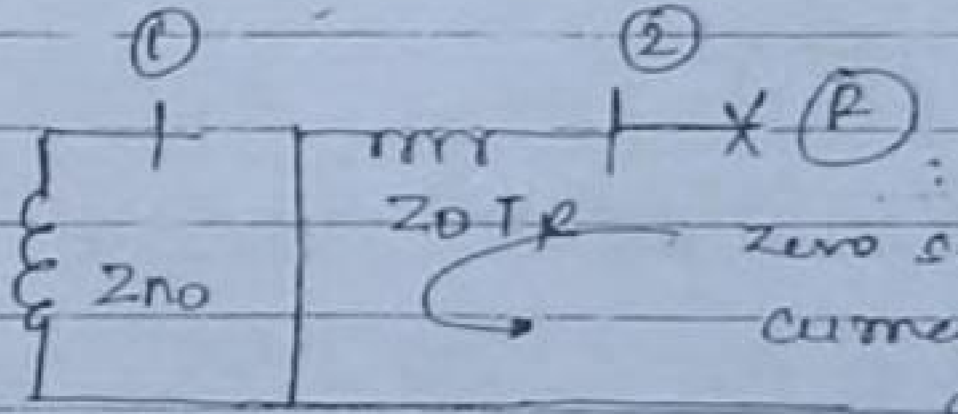
b) L-L fault on G/r of xmer

c) LLG fault on G/r side of xmer

d) 3ϕ fault on G/r xmer.



zero sequence diagram.



zero sequence current comes from delta side

ZPB.

not supplying the zero sequence current so L-L fault on G'r side

(3) ~~T~~

The L-G fault and the 3φ fault at the terminal of unloaded synchronous G/r is to be same. ~~It~~ If terminal voltage is 1pu, $Z_1 = Z_2 = Z_{1} \; j0.1$ and $Z_0 = j0.05$ p.u ~~of~~ for the alternator, then the required inductive reactance 4 nodal grounding is _

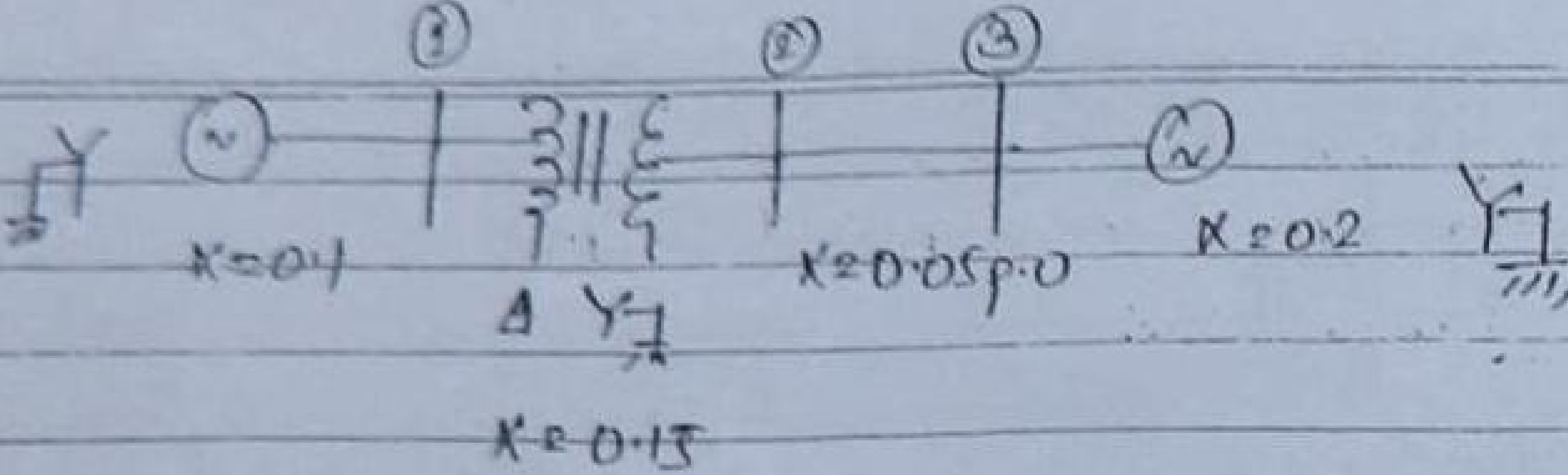
~~0.066~~
~~0.05~~
0.01
0.015

$$Z_n = \frac{1}{3}(Z_f - Z_{g0})$$

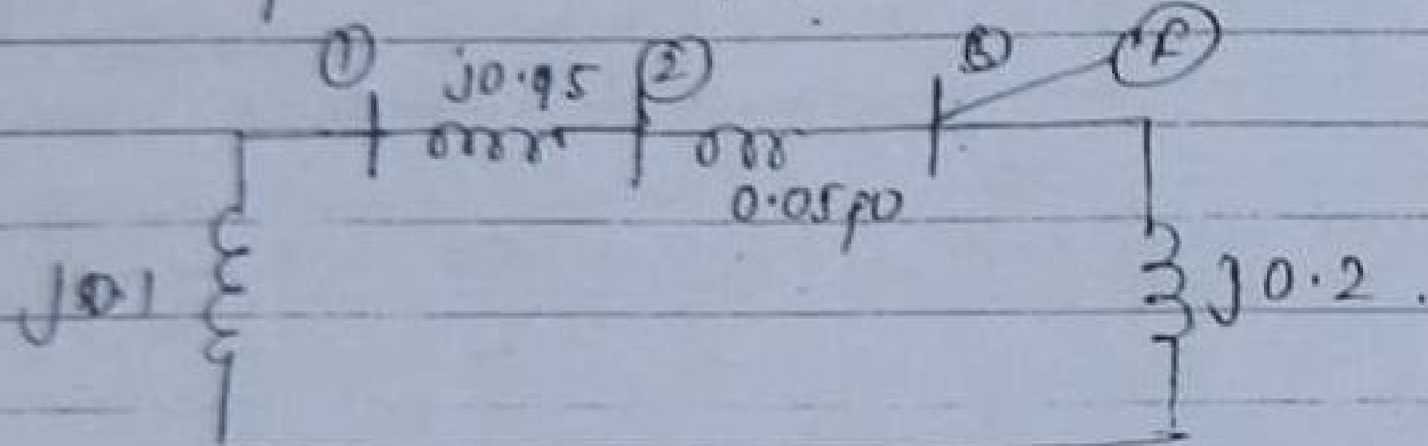
$$\frac{1}{3}(j0.1 - 0.05j)$$

$$\Rightarrow 0.0166j$$

(4) The ~~zero~~ sequence reactances are indicated in n/w shown below. All the equipment have equal sequence impedences, if L-G fault occurs on bus 3 φ the p.u fault current is



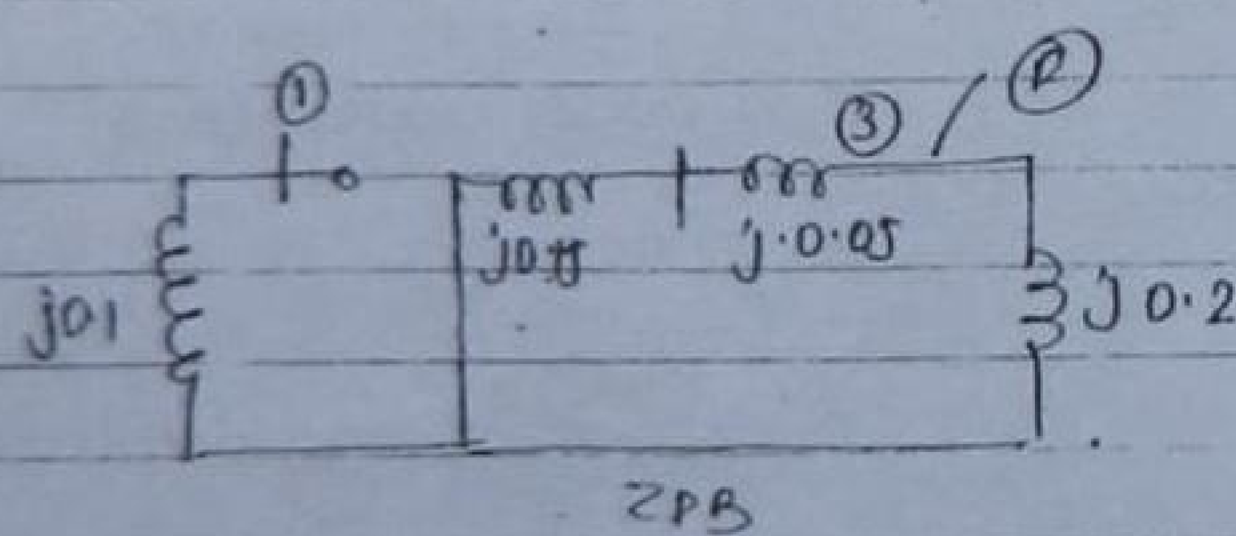
→ Reducing two sequence reactance :-



(+ve and -ve)

$$\Rightarrow (0.1j + j0.15 + j0.05) \,||\, j0.2$$

$$= Z_{1Th} = Z_{2Th} = j0.12\,pu$$



$$(j0.15 + j0.05) \,||\, j0.2$$

$$Z_{0Th} = j0.1\,pu$$

$$I_f = \frac{3E}{Z_1 + Z_2 + Z_0} = \frac{3 \times 1}{j0.12 + j0.12 + j0.1} = 8.823\angle -90^\circ\,p.u$$

4. In an unbalanced $3\text{-}\phi$ s/m the currents are measured as $I_R = 0$, $I_Y = 6\angle 60^\circ$; $I_B = 6\angle -120^\circ$. The corresponding sequence currents will be.

a) 0 $\quad 3 - j\sqrt{3}$ $\quad -3 + j\sqrt{3}$

b) 0 $\quad -3 - j\sqrt{3}$ $\quad 3 - j\sqrt{3}$

c) 0 $\quad -9 + j\sqrt{3}$ $\quad 9 - j3\sqrt{3}$

d) 0 $\quad 9 - j\sqrt{3}$ $\quad -9 + j3\sqrt{3}$

$$\begin{bmatrix} I_{R_0} \\ I_{R_1} \\ I_{R_2} \end{bmatrix} = \frac{1}{3}\begin{bmatrix} 1 & 1 & 1 \\ 1 & a^2 & a \\ 1 & a & a^2 \end{bmatrix}\begin{bmatrix} 0 \\ 6\angle 60^\circ \\ 6\angle -120^\circ \end{bmatrix}$$

$$I_{R_0} = \frac{1}{3}\left[0 + 6\angle 0^\circ + 6\angle -120^\circ\right]$$

$$I_{R_1} = \frac{1}{3}\left[0 + a^2 6\angle 60^\circ + a 6\angle -120^\circ\right]$$

$$I_{R_2} = \frac{1}{3}\left[0 + a 6\angle 60^\circ + a^2 6\angle -120^\circ\right]$$

5) A Star connect 3ϕ, 11KV, 25MVA alternator with it nodal grounded with 0.033p.u reactance and +ve, -ve, and zero reactances of 0.2, 0.1, 0.1 repectively. A SLG fault on one of its terminals would result a fault MVA of

25^2 0.033 p.u

a) 150 MVA
b) 125 MVA
c) 100 MVA
d) 50 MVA

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

$$\frac{I}{I_{sc}} = Z_{p.u.}$$

$$\boxed{I_{sc} = \frac{1}{Z_{pu}}}$$

$$I_{fLG} = \frac{3E}{Z_1 + Z_2 + Z_0 + 3Z_n} = \frac{3 \times 1}{0.2 + 0.1 + 0.1 + 3 \times 0.033} = -j6\,p.u.$$

$\therefore$ $I_{fLG} = 6\,p.u$

Since MVA = 6p.u.

Base MVA = 25MVA

Since MVA = 6×25 = 150MVA.