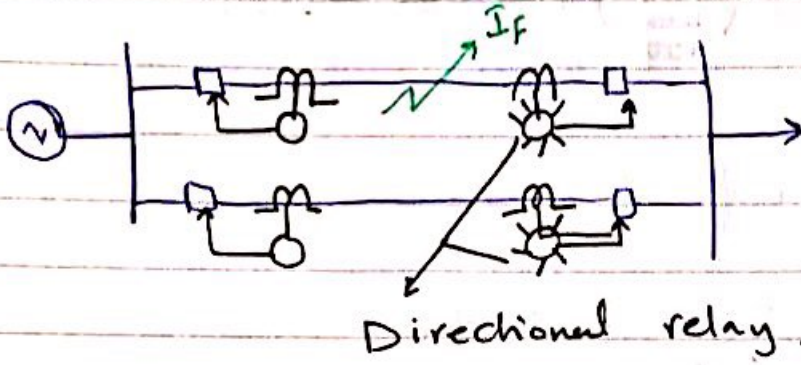
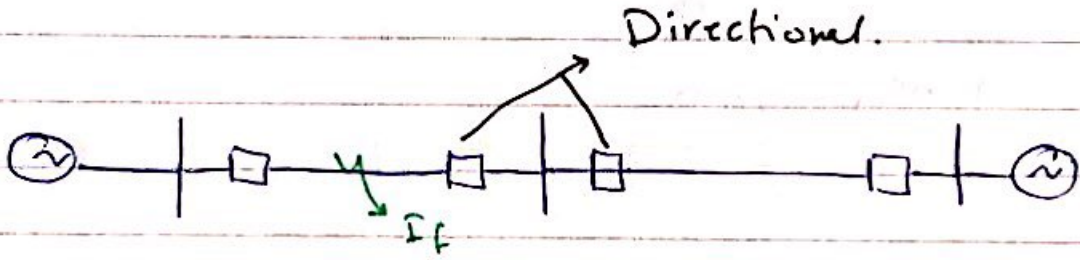


# Directional over current protection:-

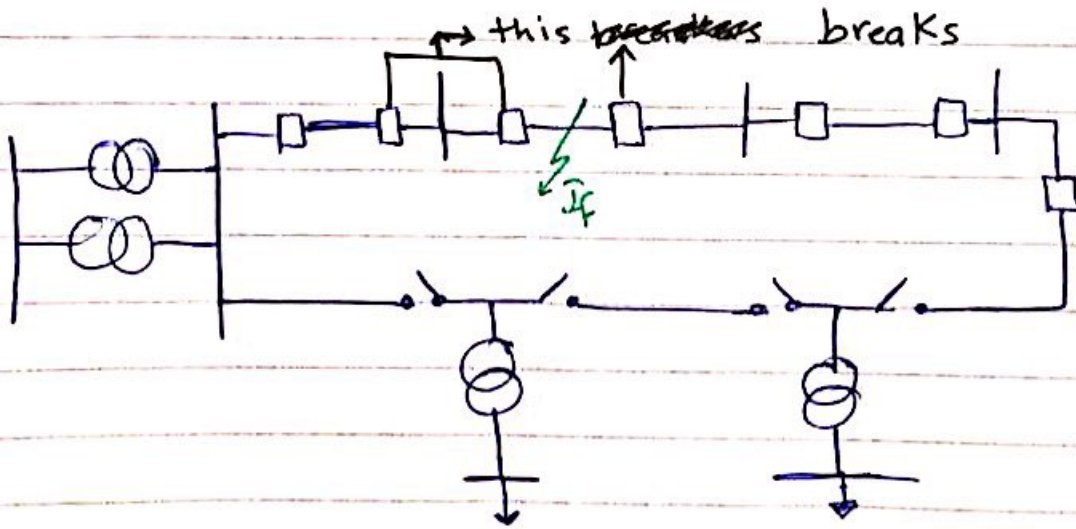
↳ has PT



Directional relay.

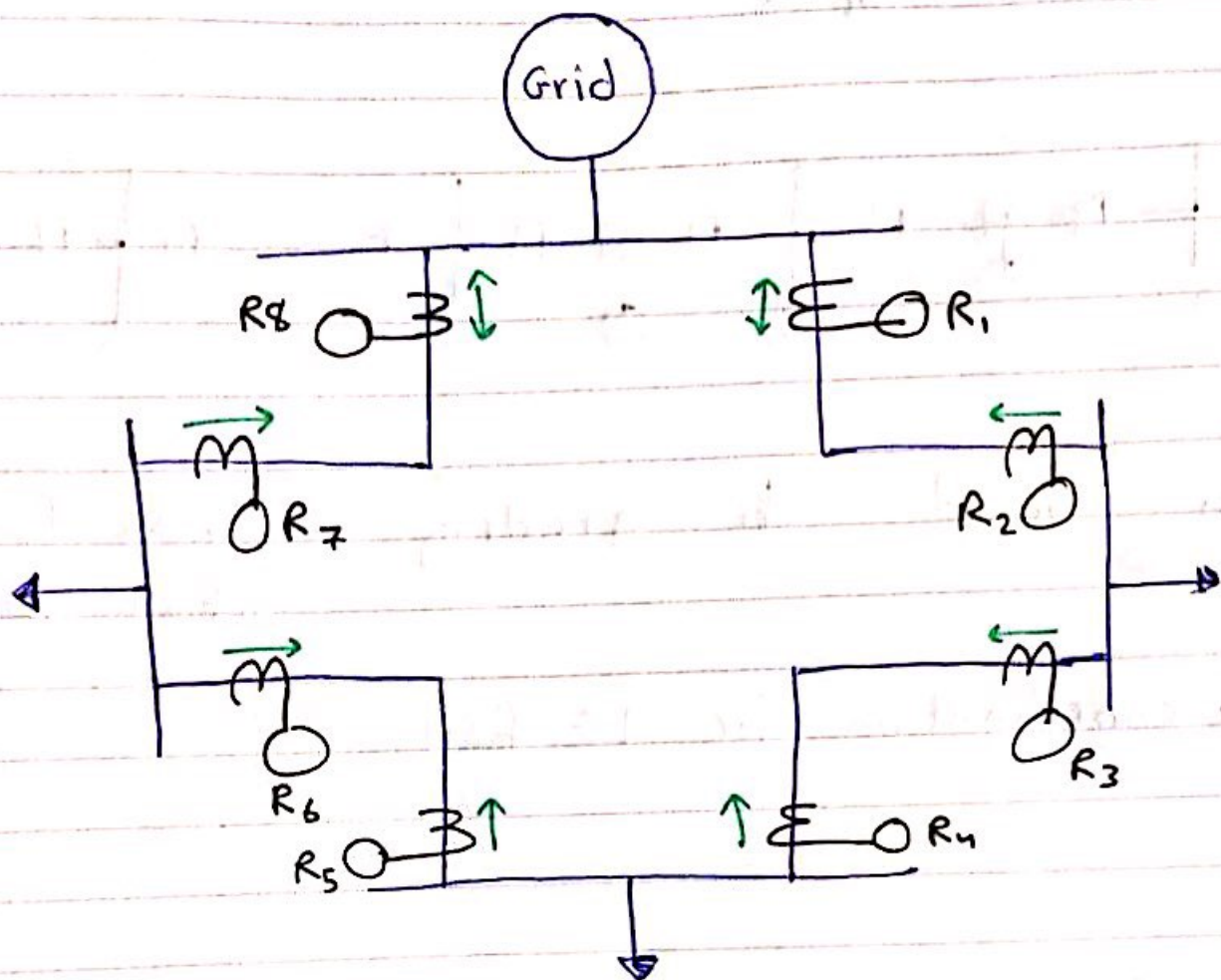


Directional.

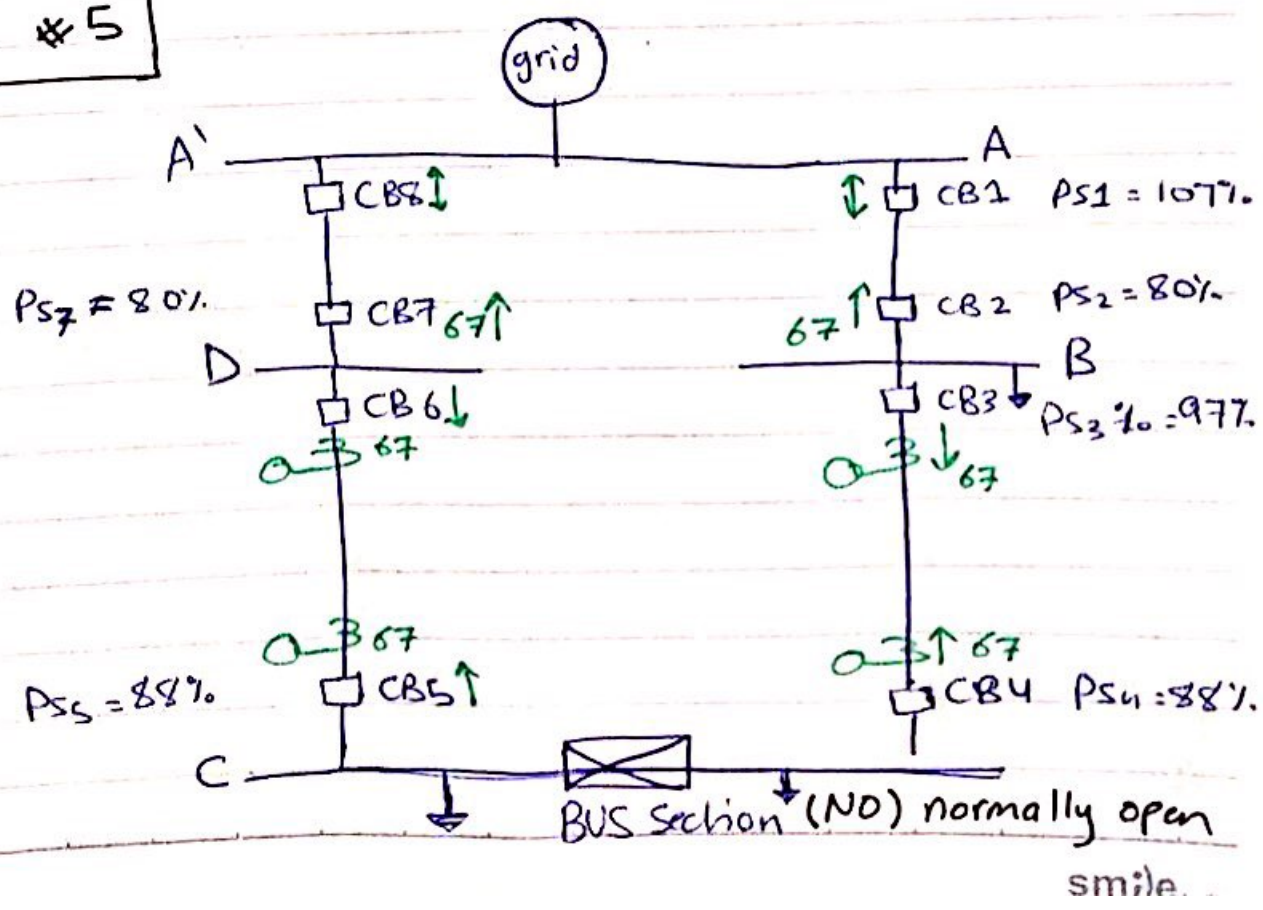


this breaker breaks

RMU (Ring Main Unit)



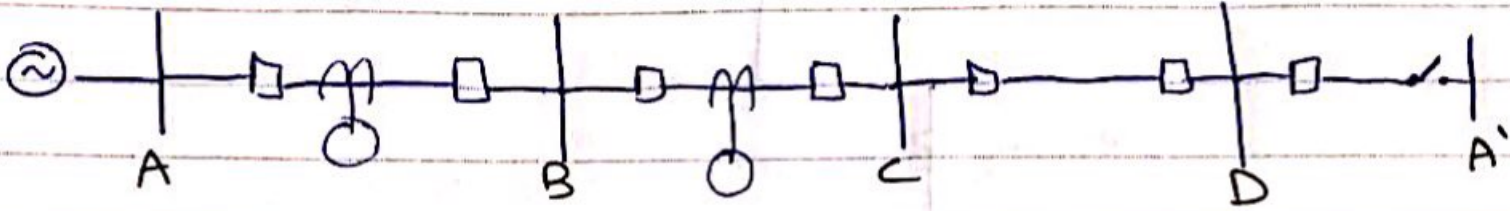
**Problem #5**



35

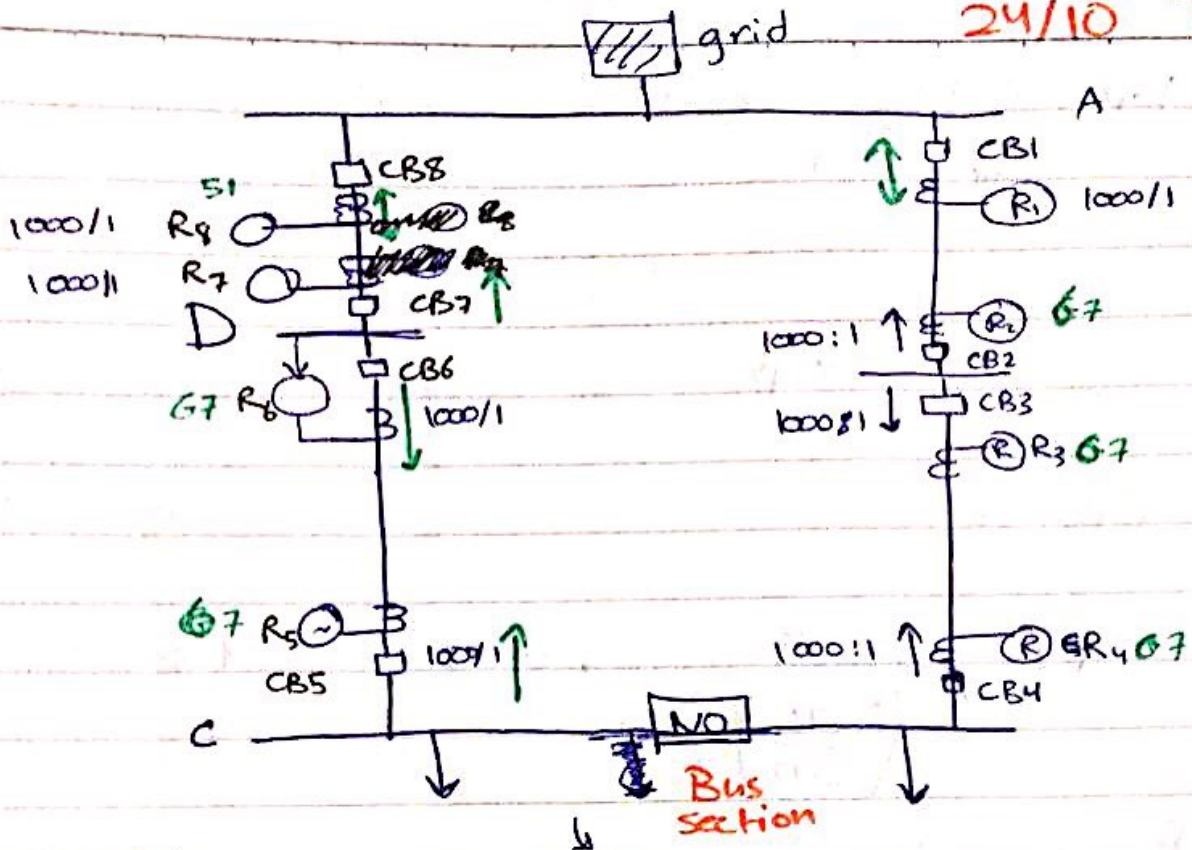


(A) CBs open.



You should do grading ab max fault.  
((fault > 1))

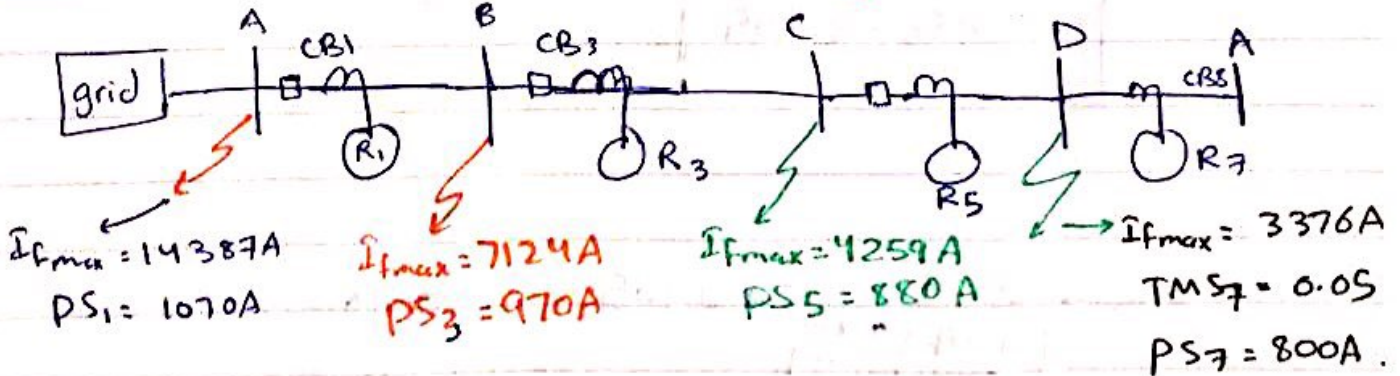
\* coordination for LG fault  $\begin{matrix} +ve \\ -ve \\ Zero \end{matrix}$  Sequence.



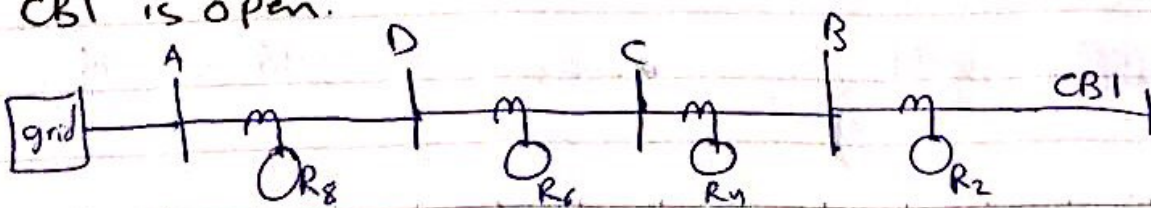
$PS_7 = 80\%$   
 $PS_5 = 88\%$   
 $PS_1 = 107\%$   
 $PS_3 = 97\%$

max fault (← grading لکھیں  
 ← جیسے ~ لکھیں  
 (( max ← fault لکھیں ))

CB8 is open.



CB1 is open.





$$t_{op} = \frac{0.14}{(I_r)^{0.02} - 1} * TMS$$

$$I_r = \frac{I_F}{I_{Pickup}}$$

⇒  $t_{op7} = ?!$

$$\text{Main } t_{op7} = \frac{0.14}{\left(\frac{3376}{800}\right)^{0.02} - 1} * 0.05 = 0.24 \text{ s}$$

Backup :-

$$t_{op5} = 0.3 + 0.24 = 0.54$$

$$0.54 = \frac{0.14}{\left(\frac{3376}{880}\right)^{0.02} - 1} * TMS_5$$

$$TMS_5 = 0.105$$

• R5 Main ⇒

$$t_{op5} = \frac{0.14}{\left(\frac{4259}{880}\right)^{0.02} - 1} * 0.105 = 0.46 \text{ s}$$

R3 Backup :-

~~$$t_{op3} = \frac{0.14}{\left(\frac{4259}{880}\right)^{0.02} - 1} * 0.22$$~~

$$t_{op3} = 0.3 + 0.46 = 0.76 \text{ s}$$

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$$0.76 = \frac{0.14}{\left(\frac{4259}{970}\right)^{0.02} - 1} * TMS_3$$

$$TMS_3 = 0.163$$

R<sub>3</sub> Main :-

$$top_3 = \frac{0.14}{\left(\frac{7124}{970}\right)^{0.02} - 1} * 0.163 \Rightarrow$$

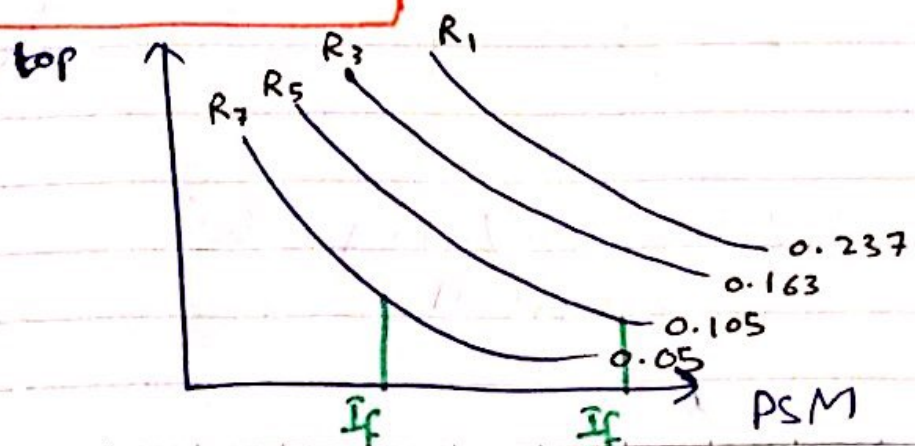
$$top_3 = 0.56 \text{ s}$$

R<sub>1</sub> Backup :-

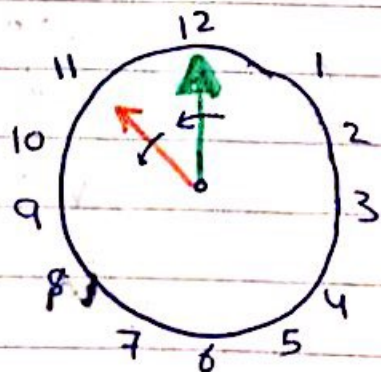
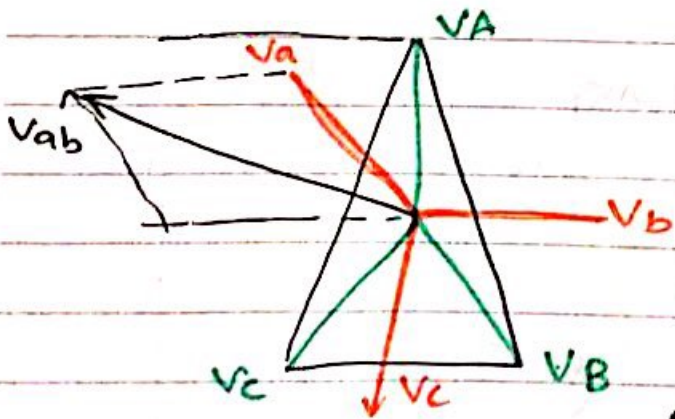
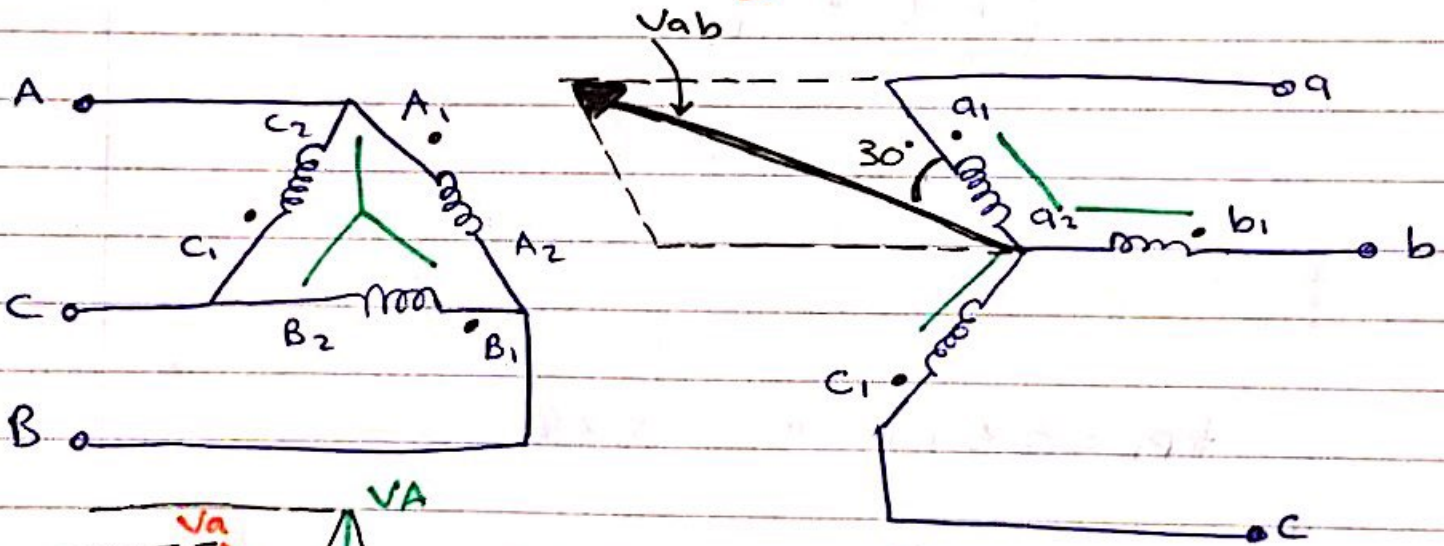
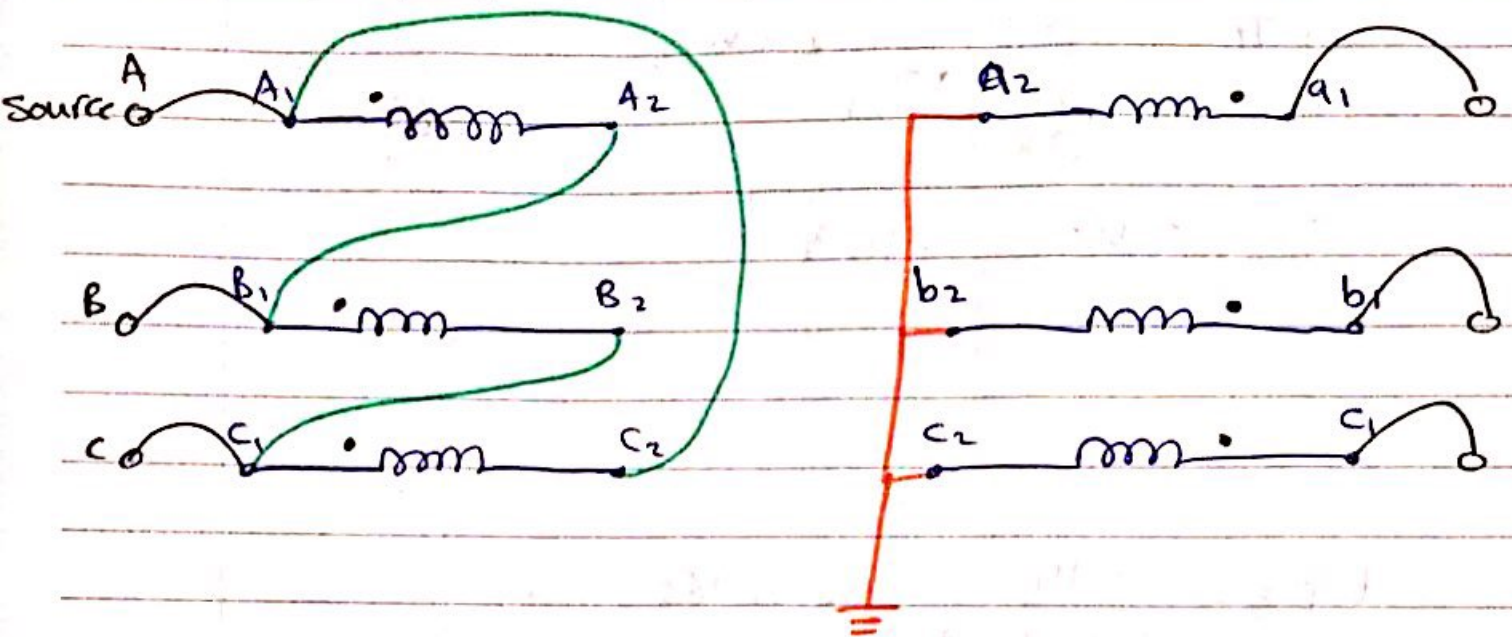
$$top_1 = 0.3 + 0.56 = 0.86 \text{ s.}$$

$$0.86 = \frac{0.14}{\left(\frac{7124}{1070}\right)^{0.02} - 1} * TMS_1$$

$$TMS_1 = 0.237$$





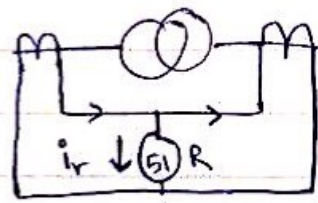
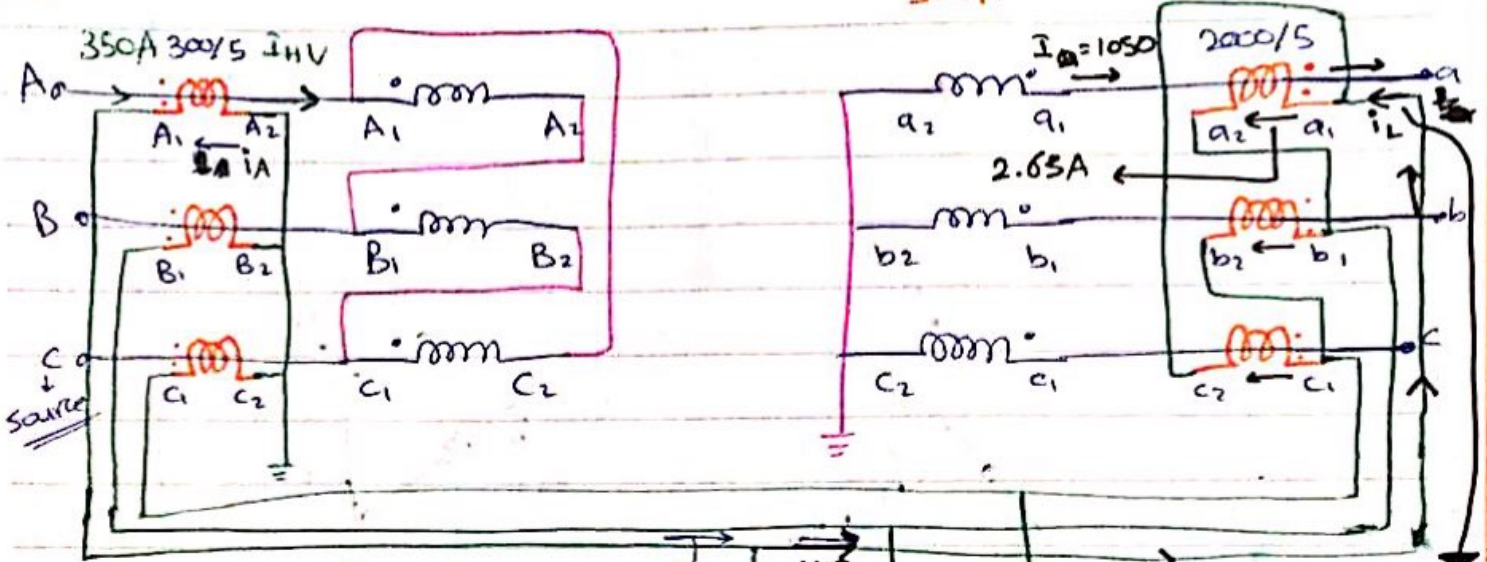


LV lead HV by  $30^\circ$   
Dyn II

Tutorial # 5:- "Transformer"

Q1 20 MVA 33kV/11kV

phasor shift in CT type shift.

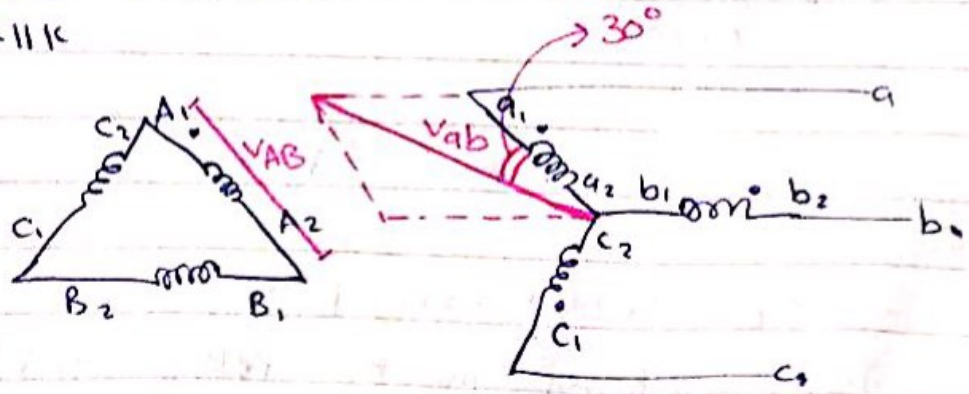


$$i_L = 2.63 \times \sqrt{3} = 4.5 \text{ A}$$

line current, phase shift in CT type shift.

$$I_{HV} = \frac{20 \times 10^6}{\sqrt{3} \times 33k} = 350 \text{ A}$$

$$I_{LV} = \frac{20 \times 10^6}{\sqrt{3} \times 11k} = 1052 \text{ A}$$

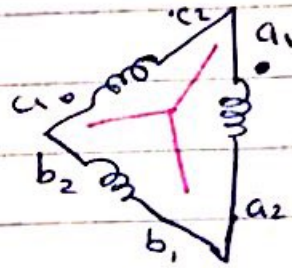
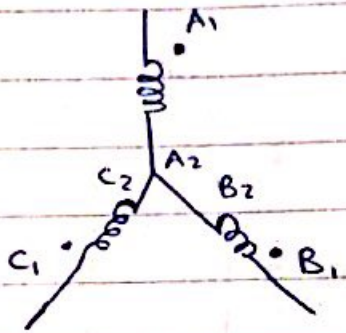
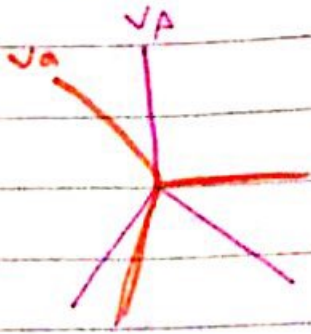


Dyn11

Voltage



Connect the CTS in  $Yd1$  "transverse"



$$I_A = 350 \text{ A}$$

$$i_A = \frac{350}{300/5} = 5.83 \text{ A}$$

$$I_a = 1050 \text{ A}$$

$$i_a = \frac{1050}{2000/5} = 2.63 \text{ A}$$

$$i_r = 5.83 - 4.5 = 1.33 \text{ A}$$

$$i_{rVL} = 1.25 \times 1.33 = 1.6 \text{ A}$$

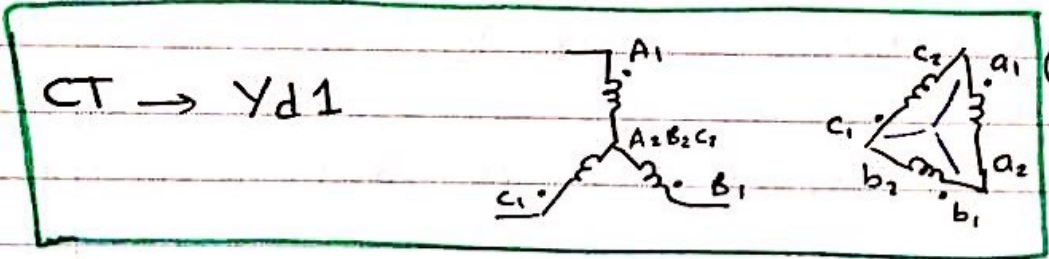
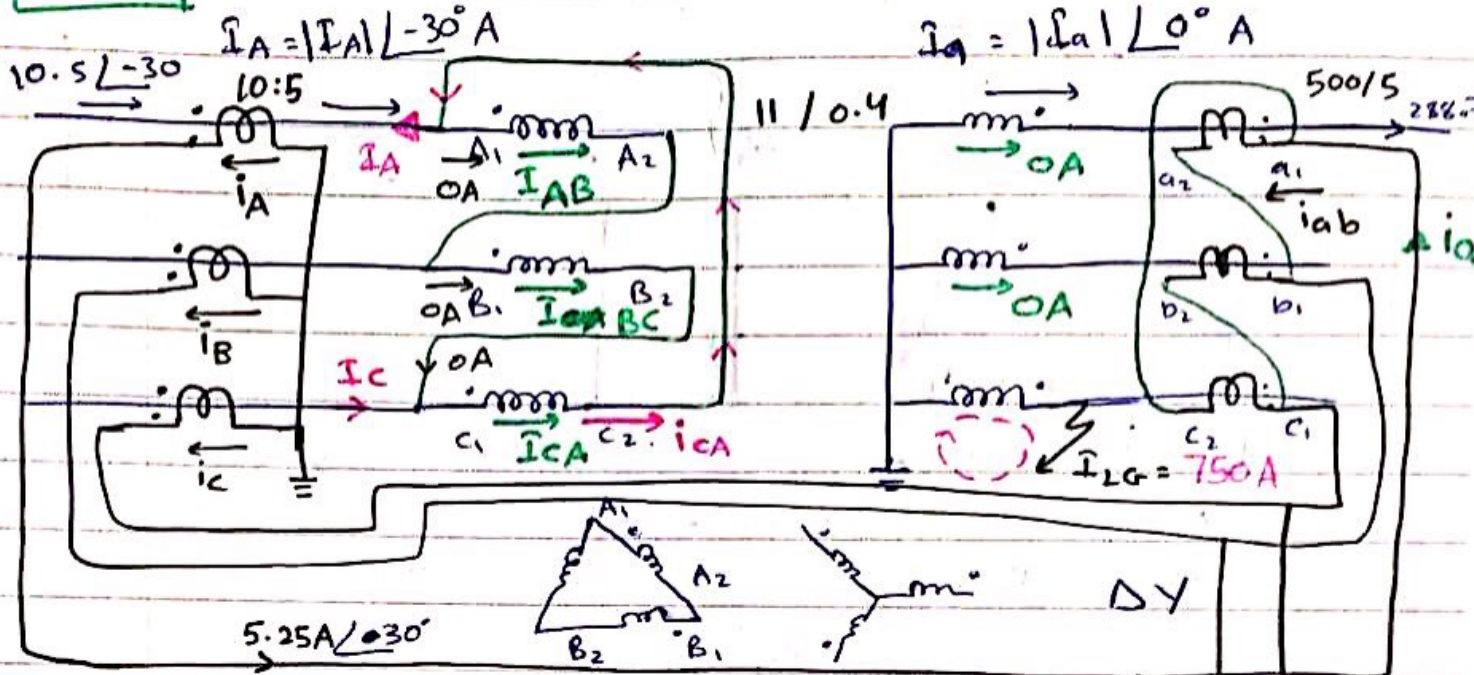
Setting in the relay = 1.6 A

42





Q4



$Yd1 \equiv$  LV lag by  $30^\circ$

$$|I_{aFL}| = \frac{200 \times 10^3}{\sqrt{3} \times 0.4 \times 10^3} = 288.7 \text{ A}$$

$$I_{AFL} = \frac{288.7}{11/0.4} = 10.5 \text{ A}$$

$$|I_{AB}|_{FL} = |I_{BC}| = |I_{CA}| = \frac{10.5}{\sqrt{3}} = 6.06 \text{ A}$$

turn ratio 2:1  
 $v_p \sim v_s$   
 phase  $\rightarrow$   
 $I_{AB}$   
 $I_{CA}$   
 $I_{BC}$

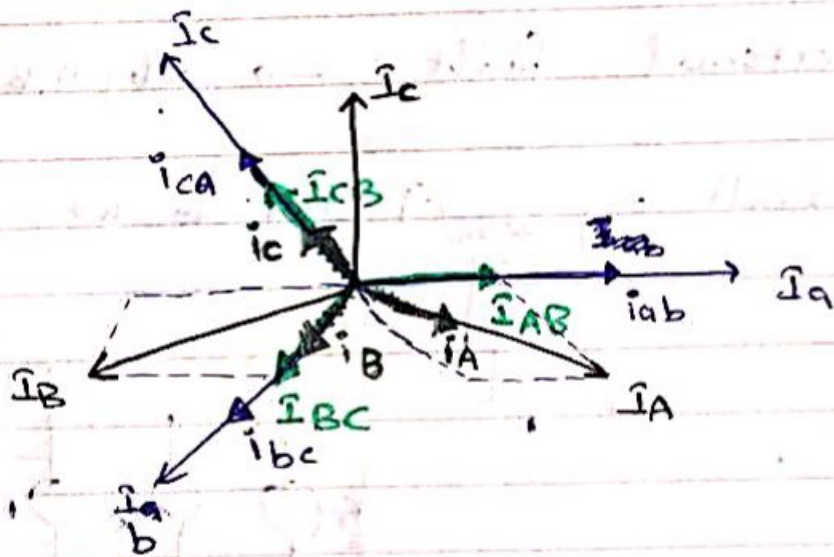
44

$$i_A = \frac{10.5}{2 (10/2)} = 5.25 \text{ A}$$

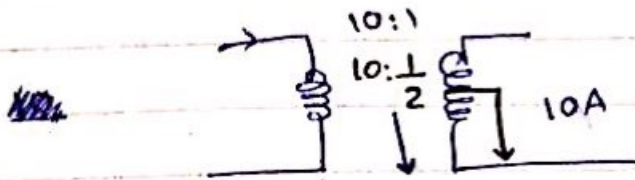
$$i_{ab} = \frac{288.7}{100} = 2.9 \text{ A } \angle 0$$

$$i_a = \sqrt{3} * 2.9 = 5.02 \text{ A } \angle -30^\circ$$

Phaser diagram:



$\uparrow N \rightarrow \uparrow$  induced volt  $\rightarrow \uparrow$  fault current.  
 winding 1 volt  $\leftarrow$   
 $\frac{1}{2}$  volt  $\leftarrow$



winding 1 volt  $\leftarrow$  fault 1, to 1/2  
 turn ratio 1 volt  $\rightarrow$  1 volt

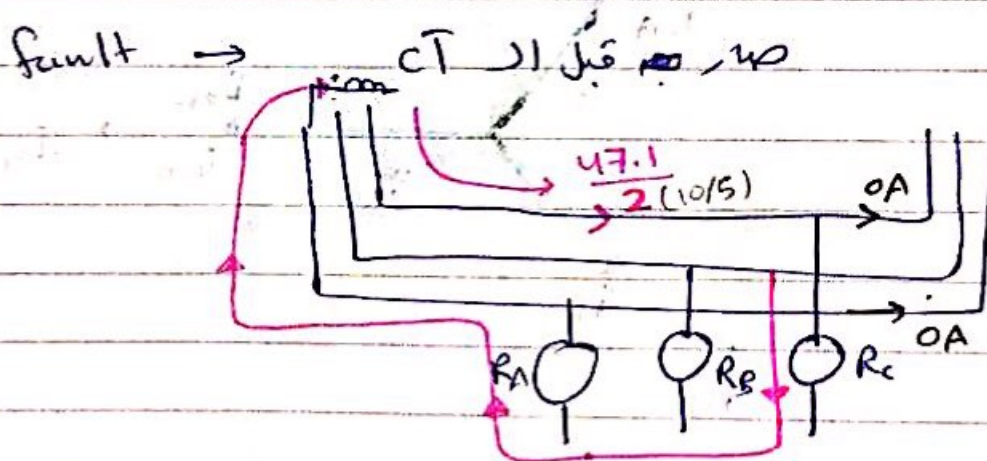


$$\frac{N_1}{N_2} = \frac{V_{ph1}}{V_{ph2}} = \frac{11000/\sqrt{3}}{400} = 15.9$$

$$I_{CA} = \frac{750}{15.9} = 47.1 \text{ A}$$

$$\begin{aligned} I_C &= 47.1 \text{ A} \\ I_A &= 47.1 \angle 180^\circ \end{aligned}$$

\* external fault  $\rightarrow$  relay قبل از CT



**Ex** A 3-ph 5MVA 11/3.3KV Dy1 transformer is subjected to L-L-L, L-L and L-G fault at the LV side of the Tx.

**Q** for a 3-ph fault

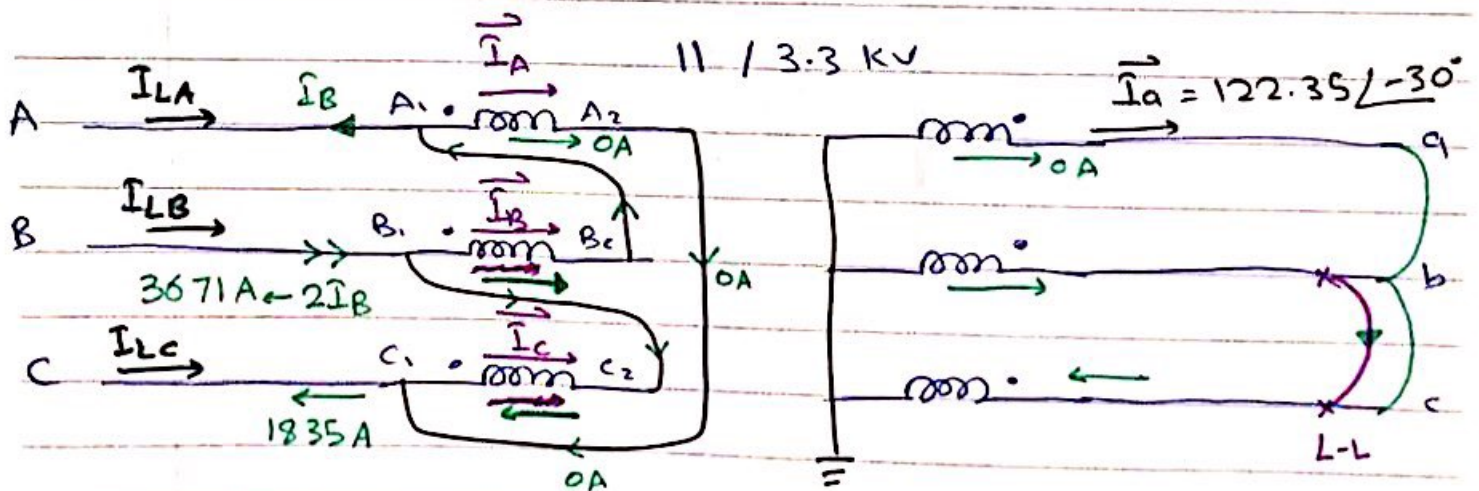
$$\vec{I}_a = 122.35 \angle -30^\circ \text{ A} \quad \vec{I}_b = 122.35 \angle -150^\circ$$

$$\vec{I}_c = 122.35 \angle +90^\circ \text{ A}$$

Find the phaser phase current  $\Rightarrow$

$[\vec{I}_A, \vec{I}_B, \vec{I}_C]$  and phaser line current.

$\Rightarrow [\vec{I}_{LA}, \vec{I}_{LB}, \vec{I}_{LC}]$  at the HV side of the Tx.

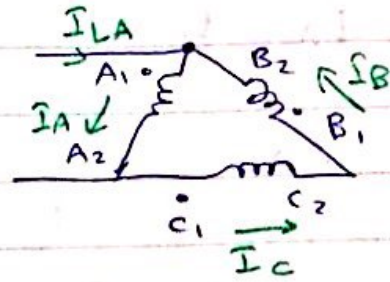
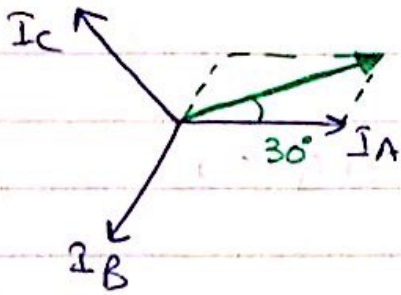


$$\vec{I}_{LA} = \frac{122.35 \angle -30^\circ + 30}{11/3.3} = 36.71 \angle 0^\circ \text{ A}$$

$$\vec{I}_A = \frac{3671}{\sqrt{3}} \angle -30^\circ = 2119 \angle -30^\circ \text{ A}$$

**47**





$$\vec{I}_B = 2119 \angle -150^\circ$$

$$\vec{I}_C = 2119 \angle +90$$

b) \* L-L s-

$$\vec{I}_a = 0 \angle 0, \vec{I}_b = 10596 \angle 0^\circ, \vec{I}_c = -\vec{I}_b = 10596 \angle 180^\circ \text{ A}$$

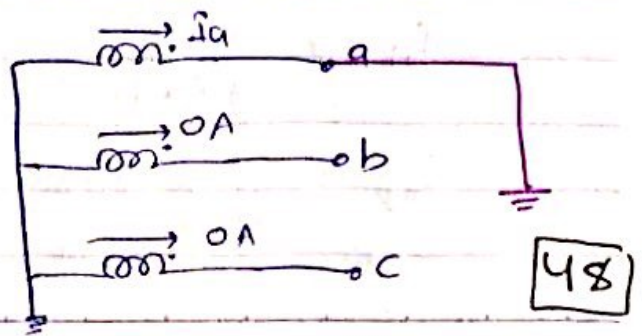
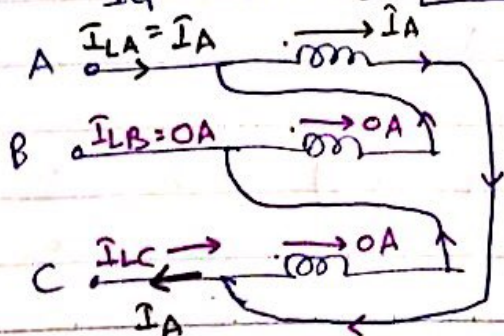
$$\frac{N_1}{N_2} = \frac{11000}{3300/\sqrt{3}} = \frac{\sqrt{3} * 11000}{3300} = 5.8$$

$$\vec{I}_B = \frac{\vec{I}_b}{5.8} = \frac{10596 \angle 0}{5.8} = 1835 \angle 0$$

$$\vec{I}_C = \frac{\vec{I}_c}{5.8} = 1835 \angle 180^\circ$$

c) L-G fault :-

$$\vec{I}_a = 12235 \angle -30^\circ, \vec{I}_b = 0 \angle 0, \vec{I}_c = 0 \angle 0 \text{ A}$$



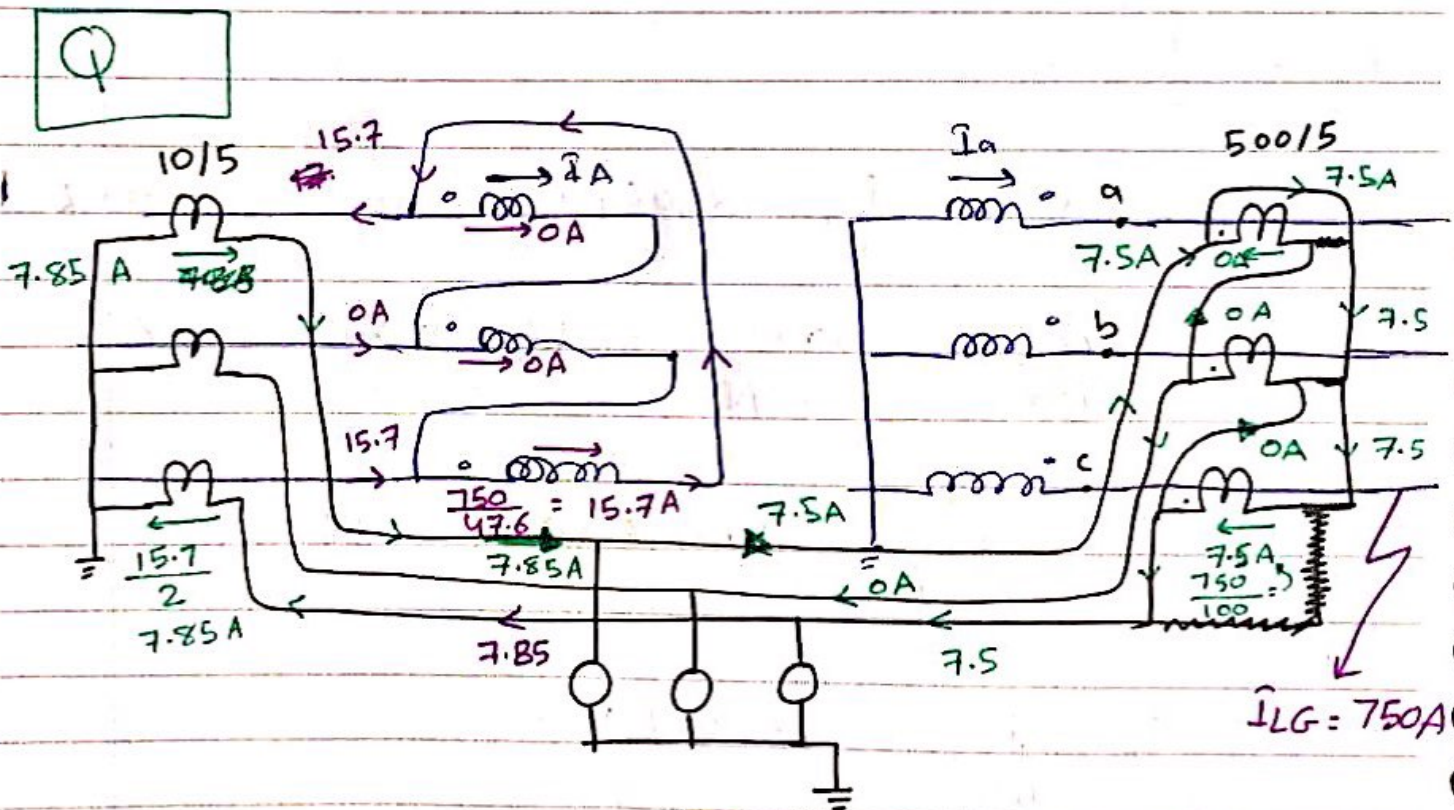
48

$$\vec{I}_A = \vec{I}_{LA}$$

$$\vec{I}_A = \frac{\vec{I}_a}{5.8} \angle -30^\circ = 2119 \angle -30^\circ$$

$$\vec{I}_{LB} = 0$$

$$\vec{I}_{LC} = -\vec{I}_{LA} = 2119 \angle 150^\circ$$



$$\frac{N_1}{N_2} = \frac{11000}{400/\sqrt{3}} = 47.6$$

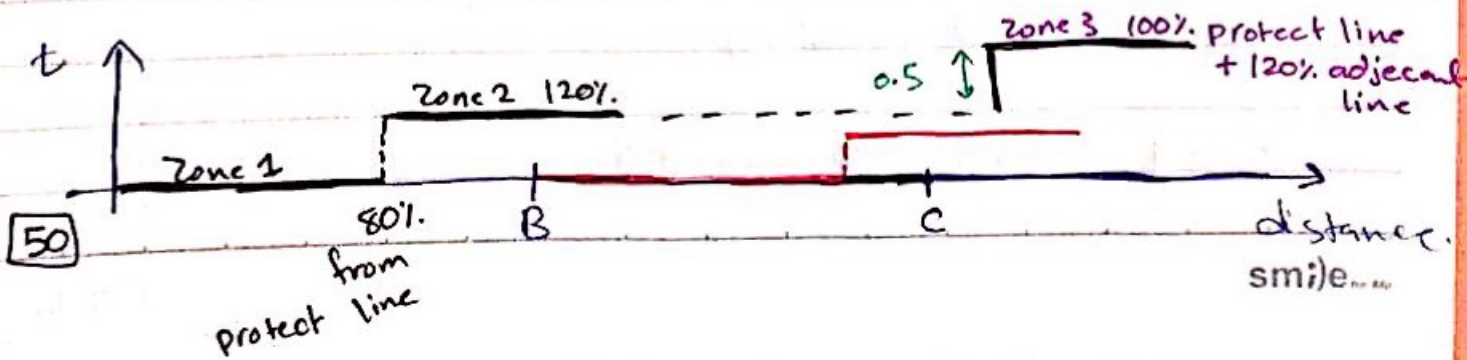
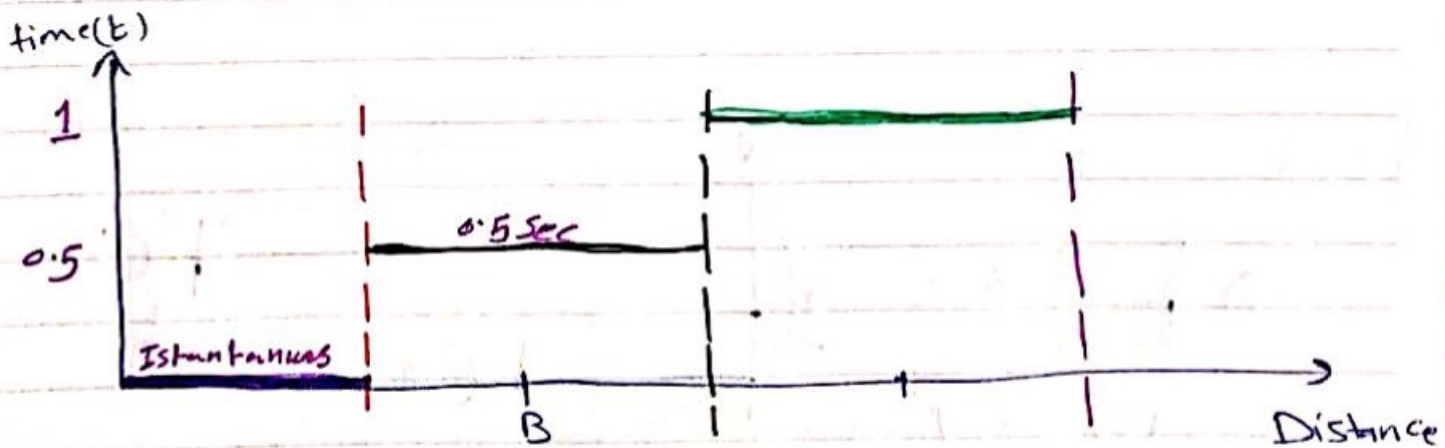
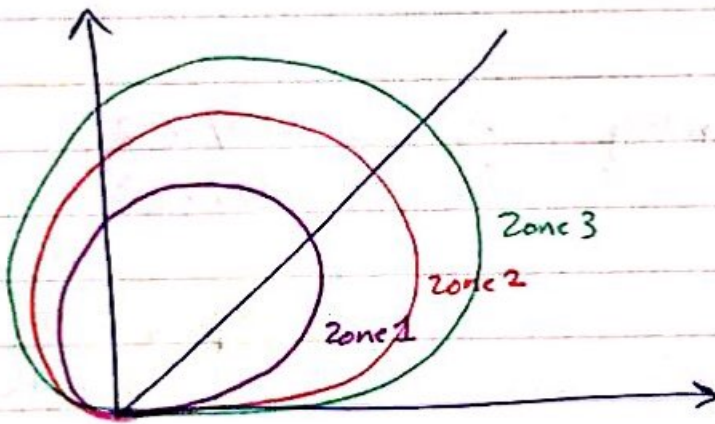
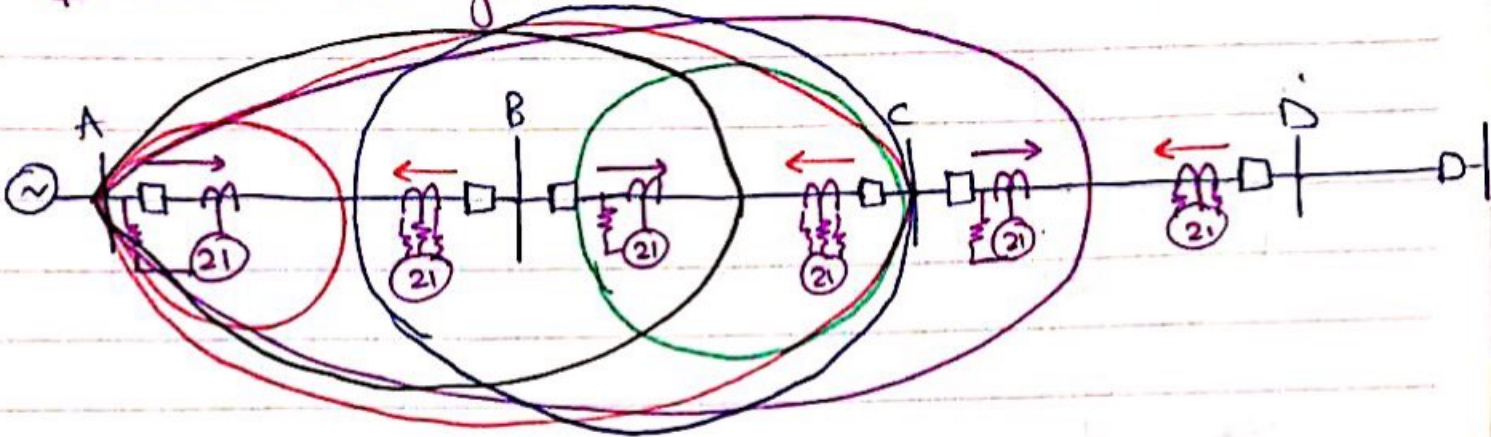
$$\vec{I}_{FLHV} = \frac{5 \times 10^6}{\sqrt{3} \times 11 \times 10^3} = 262 A$$

$$\vec{I}_{np} = \frac{5}{100} \times 262 = 13 A \text{ (Primary)} \rightarrow \text{Sec} = \frac{13}{2} = 6.5 A = \vec{I}_{ns}$$

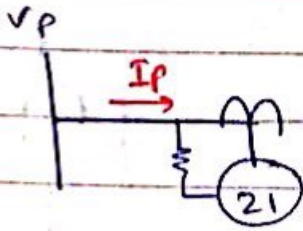
49



# Distance Relay :-



\* Relay <sup>seen</sup> → impedance step down.



$$\frac{V_p}{I_p} = Z$$

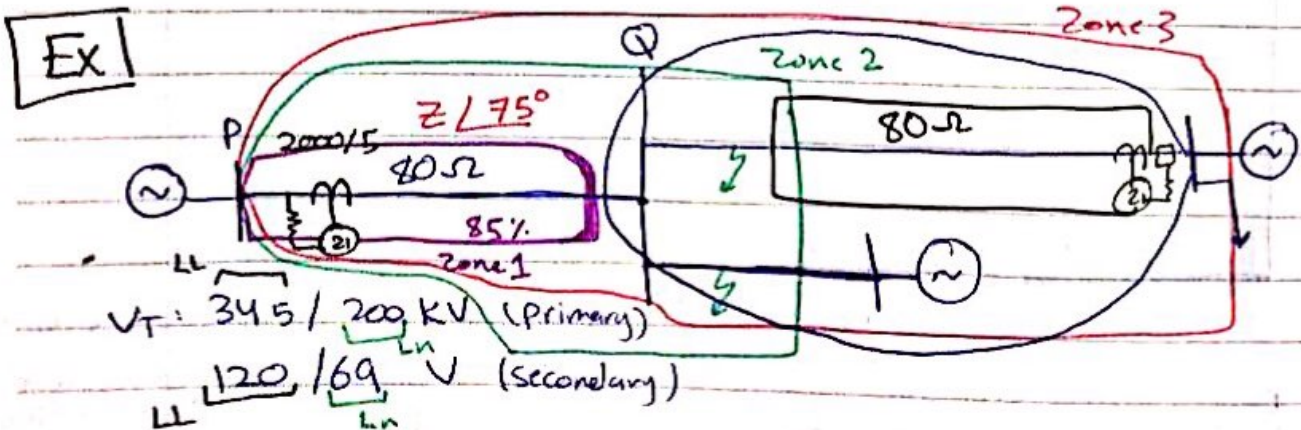
$$V_s = V_p / VTR$$

$$I_s = I_p / CTR$$

$$Z_{\text{seen by the relay}} = \frac{V_s}{I_s} = \frac{V_p / VTR}{I_p / CTR}$$

$$= Z_p \times \frac{CTR}{VTR}$$

$$Z_r = Z_p \times \frac{CTR}{VTR}$$



Zone 1 is 85% of line PQ.

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smile...



$$Z_{\text{one 1}} = 0.85 \times 80 = 68 \Omega.$$

Zone 2:

for zone 2:  $\rightarrow$  115% protected line ( )  
 $\rightarrow$  100% from protected line + 50%  
 Shorted line. (~~protected~~)  
 Prefaulted

$$115\% \Rightarrow \frac{115}{100} \times 80 = 92 \Omega$$

$$100\% + 50\% \Rightarrow 80 + 0.5 \times 40 = 100 \Omega \text{ (Prefaulted)}$$

$$Z_{r1} = 68 \times \frac{2000/5}{\frac{200000}{69}}$$

$$= 68 \times 0.138$$

$$= 9.384 \Omega$$

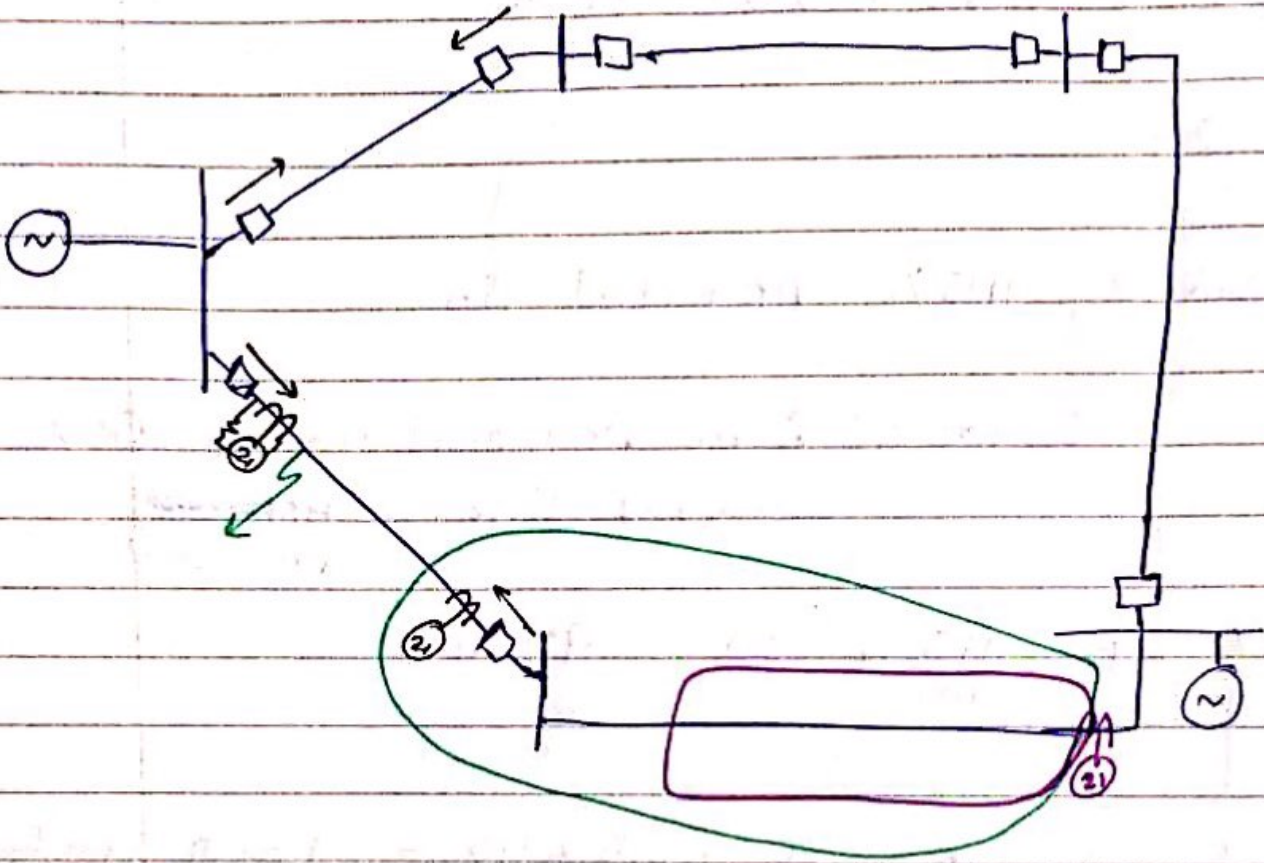
$$Z_{r2} = 100 \times 0.138 = 13.8 \Omega$$

if  $Z_r < Z_{r1} \rightarrow$  Instantaneous

$$40 < 0.138 \times 9.38$$

$$40 + 0.138 < 9.38$$

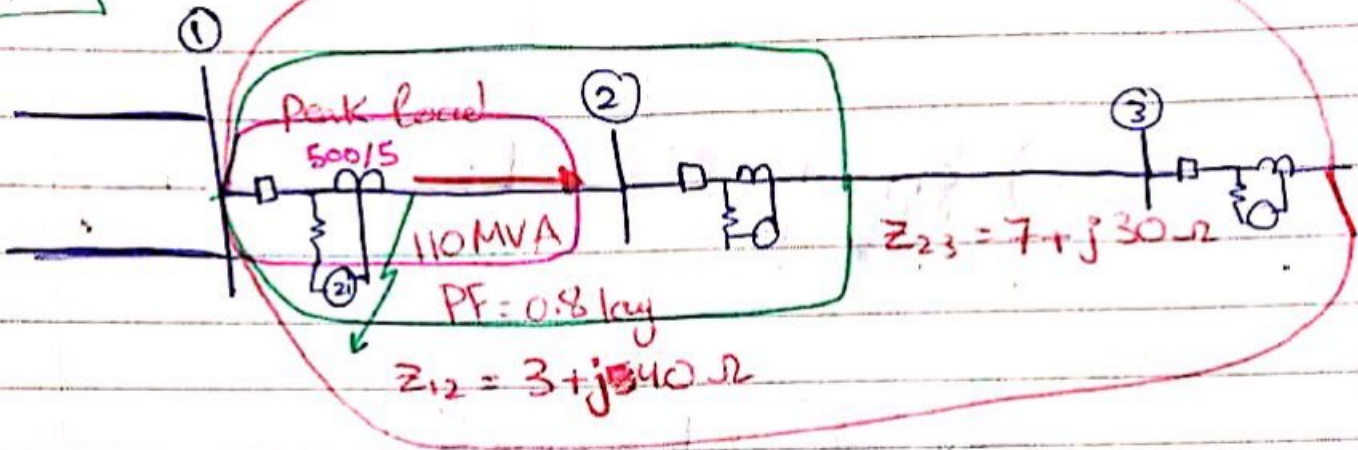
52







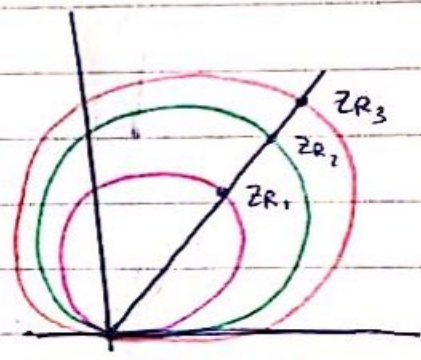
Q2



a  
b  
c

$I_f = 500 \text{ A}$

$$R_{arc} = \frac{2.9 \times 10^4}{I^{1.4}}$$



impedance locus for  
pure reactance.

$$1 \text{ MVA} \xrightarrow{132 \text{ KV}} 4.37 \text{ A}$$

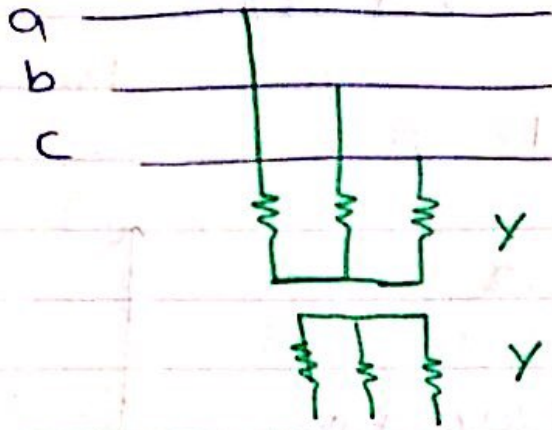
$$110 \text{ MVA} \xrightarrow{\quad}$$

$$I_L = \frac{110 \times 10^6}{\sqrt{3} \times 132 \text{ K}} = 481.1 \text{ A}$$

$$CTR = \frac{500}{5} = 100$$



$$V_{TR} = \frac{132000 / \sqrt{3}}{67} = 1137.46$$



$$Z_{sec} = Z_p * \frac{CTR}{V_{TR}} = Z_p * \frac{100}{1137.46} = Z_p * 0.0879$$

$$Z_{12}' = Z_{12} * \frac{CTR}{V_{TR}}$$

Relay

$$= (3 + j40) * 0.0879$$

$$= 0.26 + j3.52 \Omega = 3.53 \angle 85.7^\circ$$

$$Z_{23}' = Z_2 * \frac{CTR}{V_{TR}} = (7 + j30) * 0.0879$$

$$= 0.615 + j2.64 \Omega = 2.71 \angle 76.4^\circ \Omega$$

$$|Z_L| = \frac{|V_{LL}|^2_{KV}}{|S_L|_{MVA}} = \frac{(132)^2}{110} = 158.4 \Omega$$

$$Z_L = 158.4 \angle 36.9 \ \Omega$$

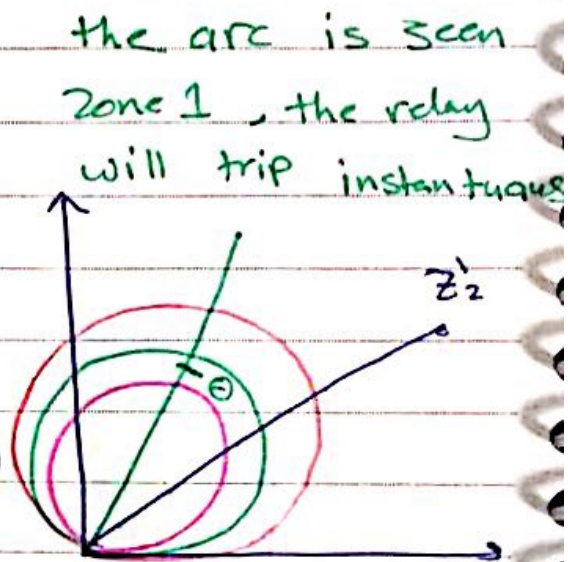
$$Z_L' = 158.4 \angle 36.9 \times 0.0879$$

$$= 13.9 \angle 36.9 \ \Omega$$

$$= 11.1 + j8.4 \ \Omega$$

$$Z_{r1} = 0.8 Z_{12}' \quad (80\% \text{ of the protected line})$$

$$Z_{r2} = 1.2 Z_{12}' \quad (120\% \text{ of the protected line})$$



$$Z_{r3} = Z_{12}' + 1.2 Z_{23}'$$

$$Z_{r1} = 2.83 \angle 85.7^\circ \ \Omega$$

$$Z_{r2} = 4.2 \angle 85.7^\circ \ \Omega$$

$$Z_{r3} = (0.26 + j3.52) + 1.2(0.615 + j2.64)$$

$$= 6.76 \angle 81.5^\circ \ \Omega$$

$$Z_f' = 0.5 Z_{12}' + R_{arc}'$$

$$R_{arc}' = \frac{2.9 \times 10^4 \times 3.5}{5000^{1.4}} = 16.9 \ \Omega$$

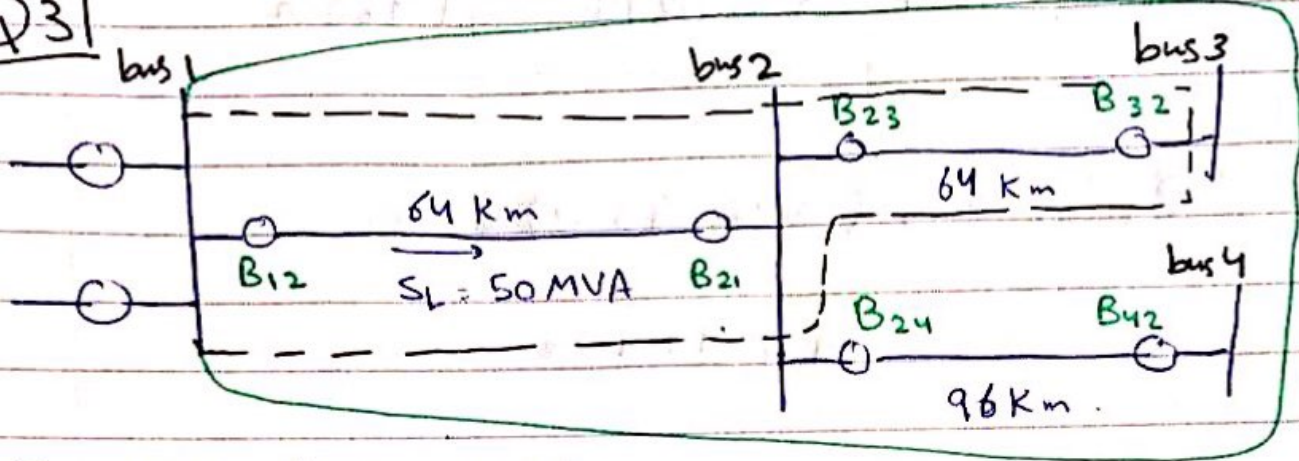


$$R_{arc}' = 16.9 \times 0.0879 = 1.486 \Omega$$

$$Z_{f'} = 0.5 (0.26 + j3.52) + 1.49$$

$$= 2.39 \angle 47.4^\circ \Omega$$

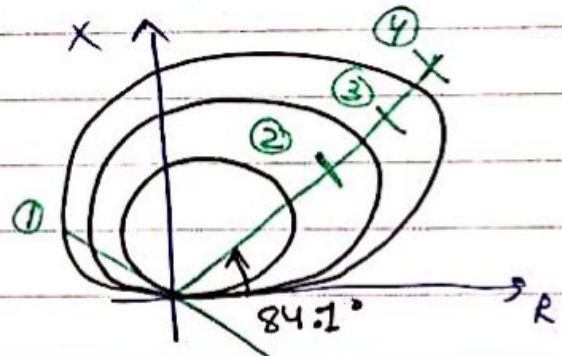
Q3



$$Z = 0.05 + j0.5 \text{ } \Omega/\text{km}$$

$$Z = 0.05 + j0.5 = 0.502 \angle 84.1^\circ \text{ } \Omega$$

$$X/R = 10$$



$$Z_{12} = 64(0.05 + j0.5) = 3.2 + j32$$

$$Z_{12} = 32.16 \angle 84.3^\circ \text{ } \Omega$$

$$Z_{23} = Z_{12}$$

$$Z_{24} = 96(0.05 + j0.5) = 4.8 + j48$$

$$Z_{24} = 48.2 \angle 84.3^\circ \text{ } \Omega$$

$$Z_{sec} = Z_p \times \frac{CTR}{VTR}$$



$$|\bar{I}_{Lmax}| = \frac{50 \times 10^6}{\sqrt{3} \times 138 \times 10^3} = 209.2 \text{ A}$$

$$\Rightarrow \text{CTR} = \frac{200}{5} = 40$$

$$\Rightarrow \text{VTR} = \frac{138000}{\sqrt{3}} = 1189.1$$

$$\Rightarrow Z_{sec} = Z_p \times \frac{200/5}{1189.1} = Z_p \times 0.0336$$

$$\Rightarrow Z_{12}' = 0.0336 (3.2 + j32) = 0.11 + j1.1 = Z_{23}'$$

$$\Rightarrow Z_{2u}' = 0.0336 (4.8 + j48) = 0.16 + j1.6 \Omega$$

$$\begin{aligned} \Rightarrow Z_{r1} &= 0.8 (0.11 + j1.1) \\ &= 0.88 + j8.8 = 0.884 / 84.3^\circ \Omega \end{aligned}$$

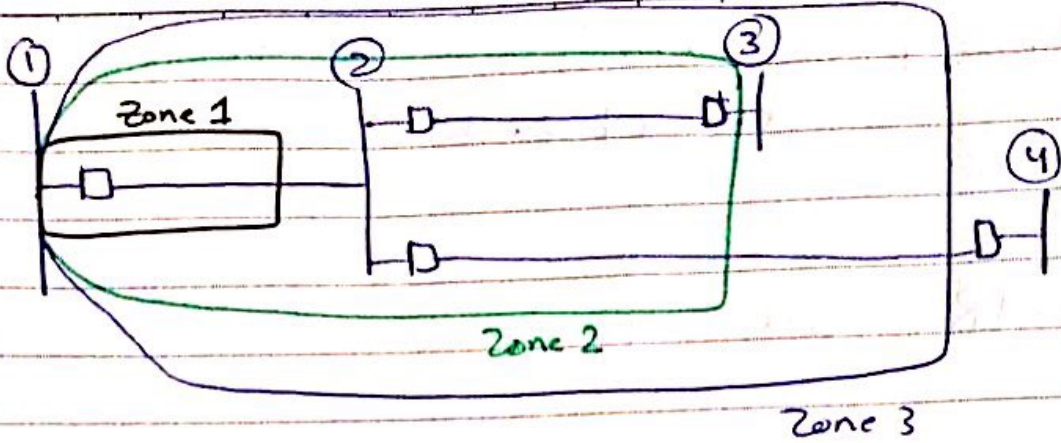
$$\Rightarrow Z_{r2} = Z_{12}' + 0.5 \times Z_{22}'$$

↳ 50% of the shortest line  
(Recommended) if bigger

OR

$$\begin{aligned} Z_{r2} &= 1.2 Z_{12}' \\ &= (0.11 + j1.1) + 0.5(0.11 + j1.1) \\ &= 0.165 + j1.65 = 1.658 / 84.3^\circ \end{aligned}$$

60



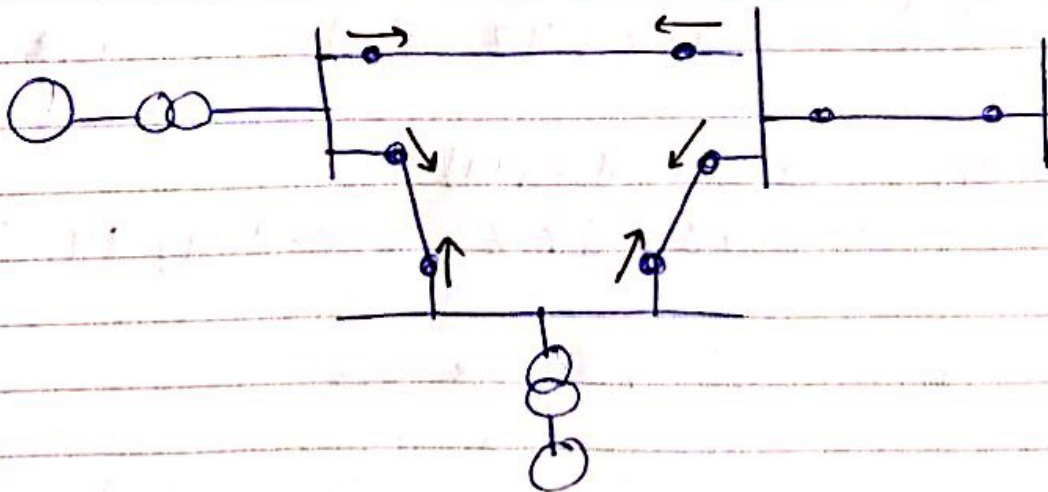
$$Z_{r3} = Z_{r2} + 1.2 Z_{24}$$

$$= (0.11 + j1.1) + 1.2 (0.16 + j1.6)$$

$$= 0.302 + j3.02 \Omega$$

$$Z_{r3} = \boxed{3.035 \angle 84.3^\circ \Omega}$$

Q4

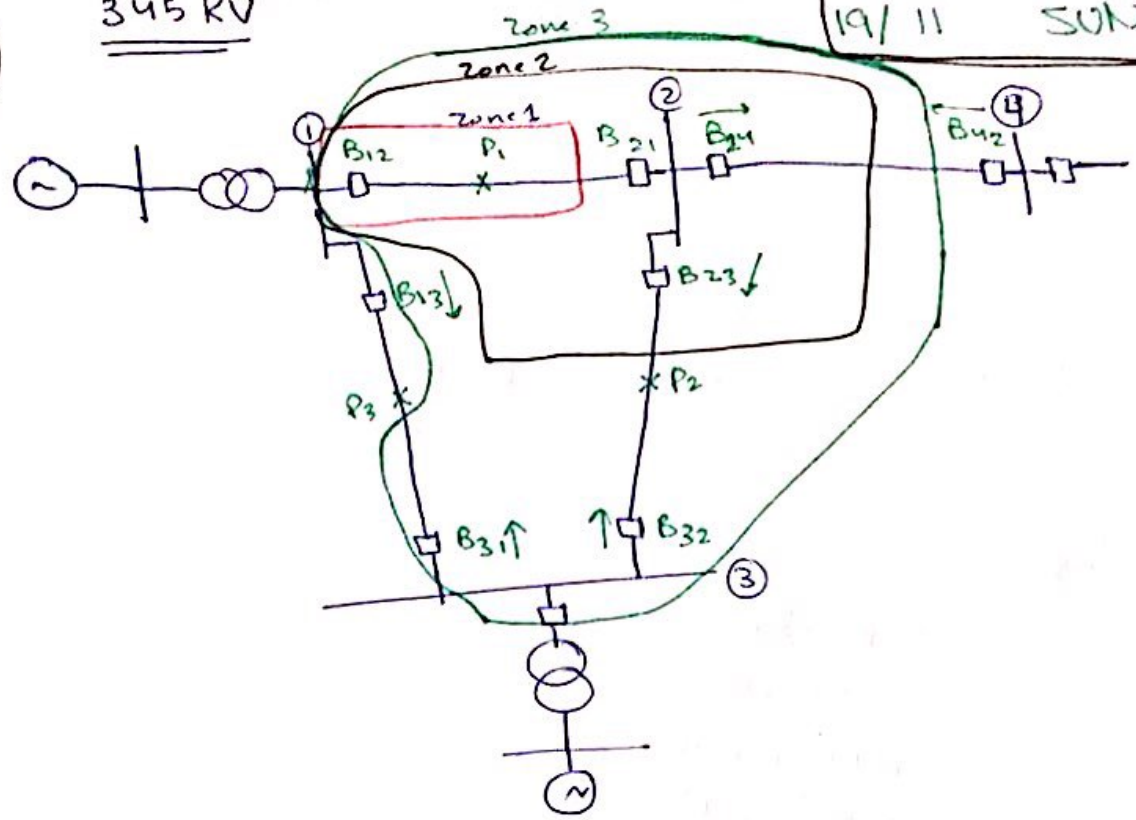




Q4

345 KV

19/11 SUN



$$CTR = \frac{1500}{5}$$

$$VTR = \frac{3000}{1}$$

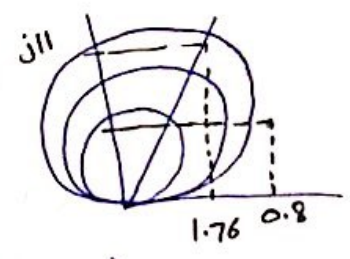
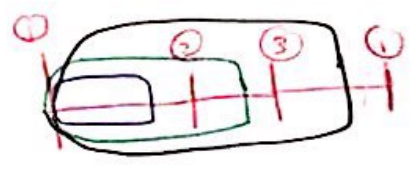
$I_{Lmax} = 1500 \text{ A}$ ,  $PF = 0.95 \text{ lag}$

$$Z_{12} = 8 + j50 \Omega$$

$$Z_{24} = 5.3 + j33 \Omega$$

$$Z_{23} = 8 + j50 \Omega$$

$$Z_{31} = 3 + j27 \Omega$$



$$Z_{sec} = Z_p \times \frac{CTR}{VTR} = Z_p \times \frac{1500/5}{3000} = Z_p \times 0.1$$

$$Z'_{12} = 0.1 \times Z_{12} = 0.1(8 + j50) = 0.8 + j5 \Omega$$

$$Z'_{23} = 0.1(Z_{23}) = 0.1(8 + j50) = 0.8 + j5 \Omega$$

$$Z'_{24} = 0.1(Z_{24}) = 0.1(5.3 + j33) = 0.53 + j3.3 \Omega$$

$$Z'_{31} = 0.1(Z_{31}) = 0.1(3 + j27) = 0.3 + j2.7 \Omega$$

$$Z_{r1} = 0.8 \quad Z'_{12} = 0.8(8 + j5) = 0.64 + j4 = 4.05 \angle 80.9^\circ$$

$$Z_{r2} = 1.2 Z'_{12} = 1.2(0.8 + j5) = 0.96 + j6 \Omega = 6.08 \angle 80.9^\circ$$

$$\text{OR } Z_{r2} = Z_{r1}' + 0.5 Z_{\text{short ckt.}}$$

$$= (0.8 + j5) + 0.5(0.53 + j3.3)$$

$$= 1.065 + j6.65$$

$$= 6.75 \angle 80.9^\circ$$

$$\text{Choose } Z_{r2} = 6.73 \angle 80.9^\circ \Omega$$

$$Z_{r3} = Z_{r1}' + 1.2 Z$$

$$= (0.8 + j5) + 1.2(0.8 + j5)$$

$$= 2.2(0.8 + j5)$$

$$= 1.76 + j11 \Omega$$

$$= 11.1 \angle 80.9^\circ$$

$$Z_L = \frac{V_{LL} / \sqrt{3}}{I_{L \max}} = \frac{\cancel{21500} 345 \times 10^3 / \sqrt{3}}{1500}$$

$$= 132.8 \Omega$$

$$Z_L = 132.8 \angle 18.2^\circ$$

$$Z_L' = 0.1 \times 132.8 \angle 18.2^\circ$$

$$Z_i = 13.28 \angle 18.2^\circ$$

$$\text{if } Z_{r2} = 1 + j30 \Omega$$

$$Z_{r1}' = 0.1 + j3$$

$$Z_{r1} = 0.8(0.1 + j3) = 0.08 + j2.4$$

$$Z_{r2} = \cancel{0.8} \overset{1.2}{(0.1 + j3)} = 0.12 + j3.6 = 3.6 \angle 88^\circ$$

$$Z_{r2} = 4.7 \angle 85.5^\circ$$

$$\text{OR } \Rightarrow Z_{r2} = (0.1 + j3) + 0.5(5.3 + j33)$$



$$Z_{r3} = (0.1 + j3) + 1.2(0.8 + j5)$$

$$= 9.1 \angle 83.3^\circ$$

