PROTECTION

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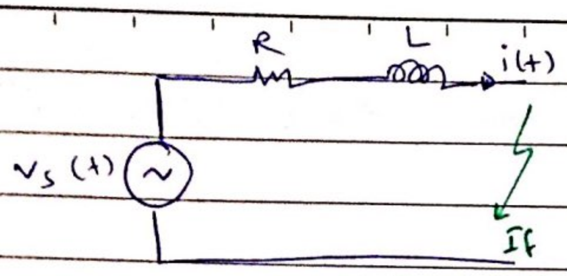
POWERUNIT-JU.COM

PU
2018

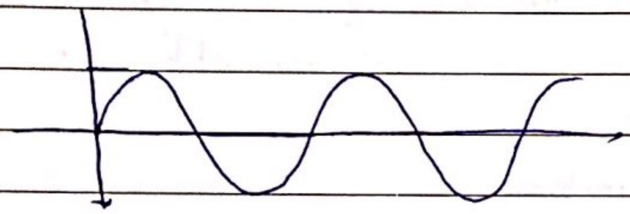
Protection

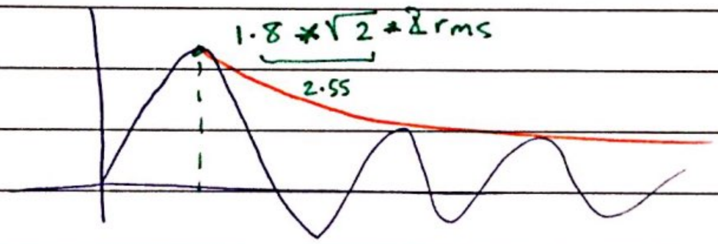
6/2 TUE



$$V_s(t) = Ri + L\frac{di}{dt}$$

$$i(t) = i_{ss} + i_{tr}$$



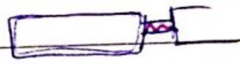


Fuses : over current device

contactor ← 

* ↑ current → بنصهر بسرعة

* TCC :-

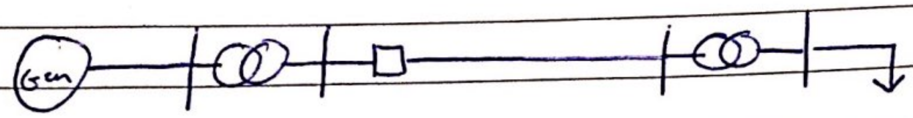
* current = Zero → arc 

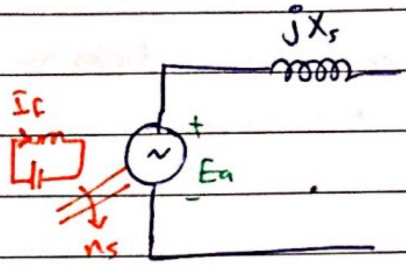
* current بنزل للصفر فبصير عندي arc لما ينقص ال arc بكون ال (current = Zero)

← Switch OFF

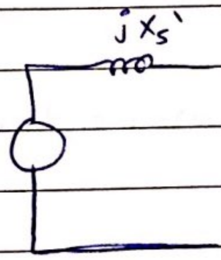
* Recloser → circuit breaker.

2012 TUE

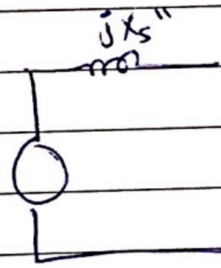




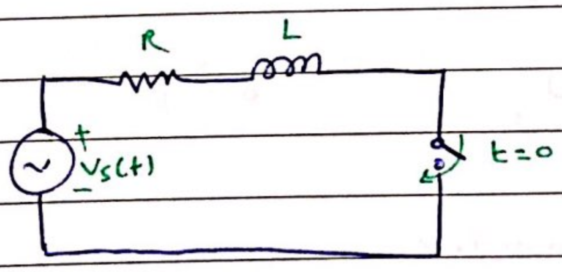
→ steady state model.
→ > 10 cycles.
→ f = 50 HZ → 0.25 sec



transient - state model
8 - 10 cycle
0.16 → 0.25



subtranisient - state - model
2-cycle
0 - 0.048. sec.



$V_s(t) = V_m \sin(\omega t + \alpha)$

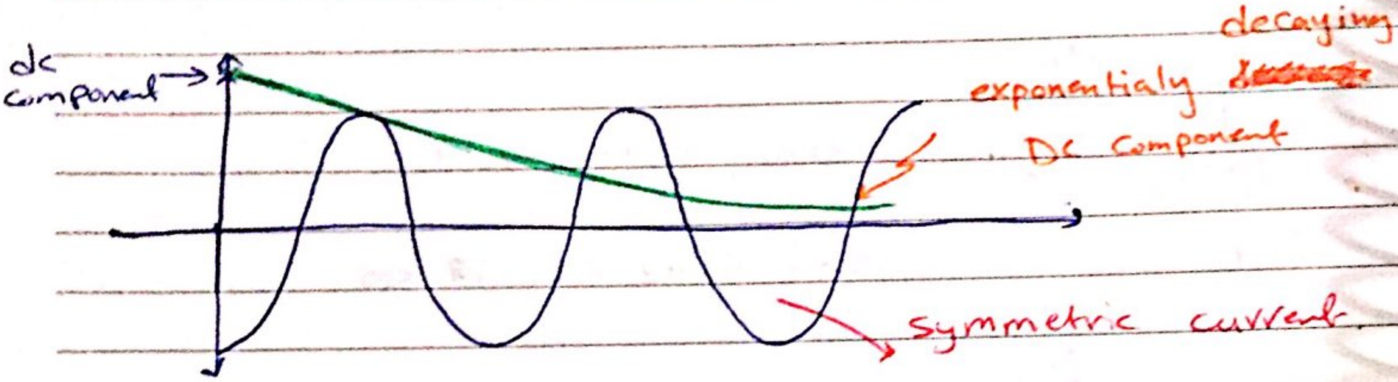
$i(t) = i_{ss} + i_{tr}$

$$= \underbrace{\frac{\sqrt{2}\, V_m}{|Z|} \sin(\omega t + \alpha + \theta)}_{\text{steady state}} + \underbrace{\frac{\sqrt{2}\, V_m \sin(\alpha - \theta)}{|Z|} e^{-t/\tau}}_{\text{transient}}$$

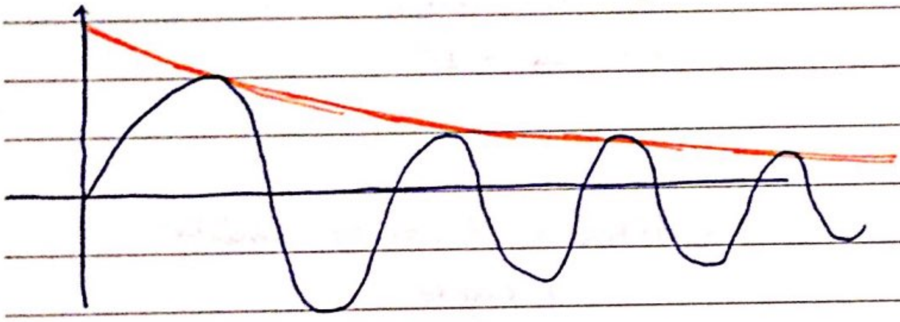
$|Z| = \sqrt{R^2 + (\omega L)^2}$

$\theta = \tan^{-1}\left(\frac{\omega L}{R}\right)$

$\Rightarrow \tau = \frac{L}{R}$



I_m = making current (peak current), momentary current



$I_m = 2.55 \times I_{breaking}$ — where $I_{breaking}$ in peak value
↳ $1.8 \times \sqrt{2}$

$I = 1.6 \times I_{breaking}$ $\Rightarrow I_{breaking} = \frac{X}{\sqrt{2}}$ (RMS current)

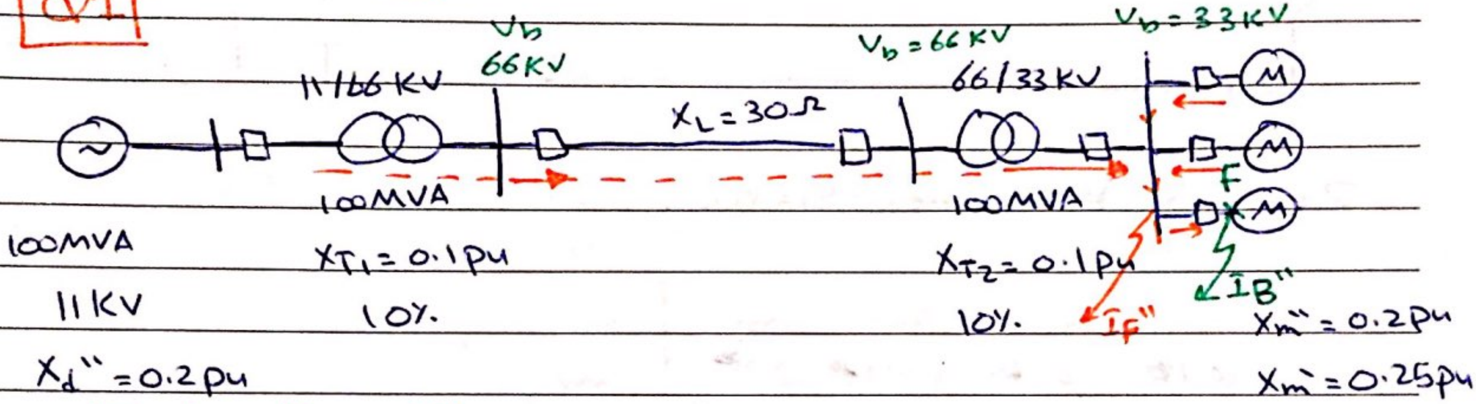
$I_{breaking} = K \times I_{symmetric}$.

1. K = 1.4 → 2 cycle C.B
2. K = 1.2 → 3 cycle C.B
3. K = 1.1 → 5 cycle C.B
4. K = 1.0 → 8 cycle C.B

Refer to Steventon p. 402 (C.B selection).

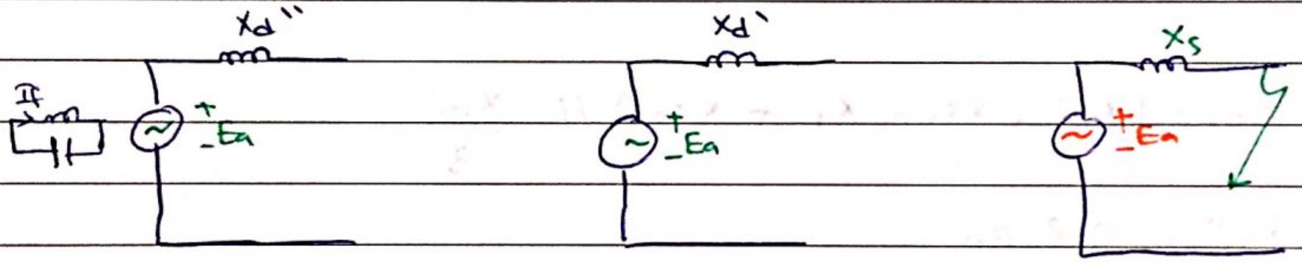
Tutorial #1 8

Q1

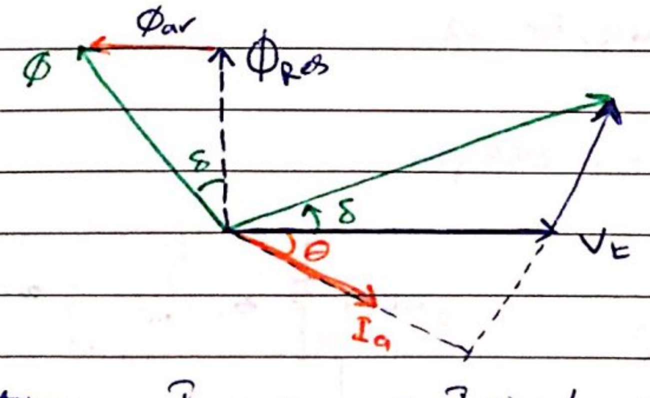


Find I_f'' ?!

Base 20MVA
33KV

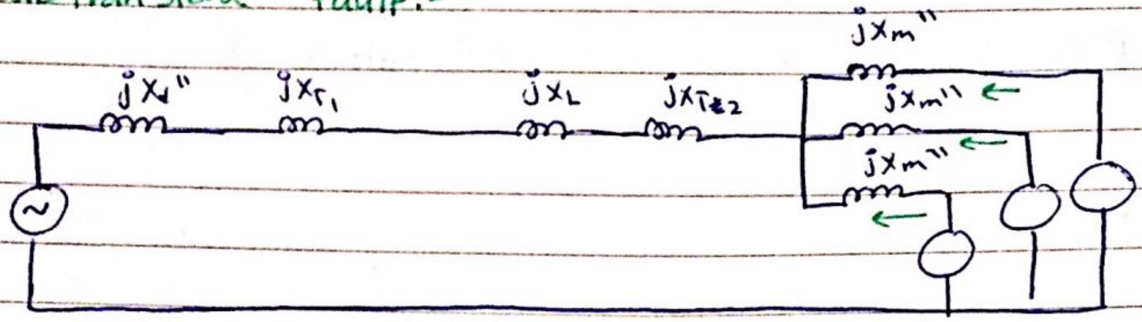


$I_{sc}'' = \frac{E}{X_d''}$ $I_{sc}' = \frac{E}{X_d'}$ $I_{sc} = \frac{E}{X_s}$

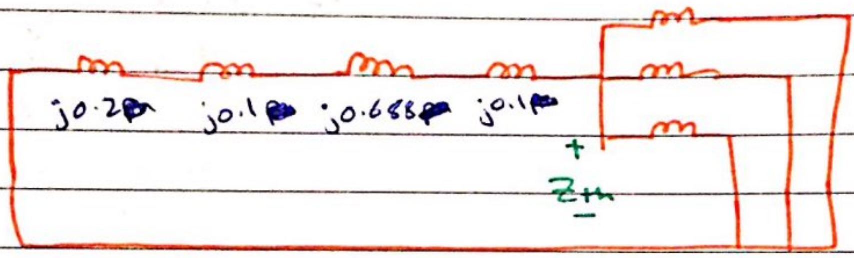


~~[illegible]~~ $I_{breaker} \equiv I_{steady\ state}.$

Subtransient fault:-



$Z_{th} \rightarrow$ Kill the Source.



$$Z_{th} = (X_d'' + X_{T_1} + X_L + X_{T_2}) \,//\, \frac{X_m''}{3}$$

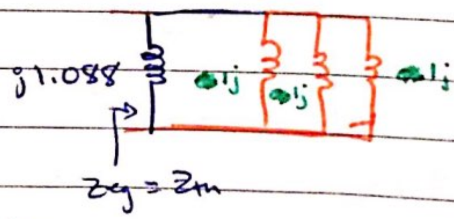
$X_d'' = 0.2$ pu

$X_{T_1} = 0.1 = X_{T_2}$

$X_L = 30\ \Omega$

$\hookrightarrow X_b = \frac{(66)^2}{100} = 43.56\ \Omega$

$$X_{L\,pu} = \frac{30}{43.56} = 0.688 \text{ pu.}$$



$$X_m'' = \frac{S_{new}}{S_{old}} * X_m''\text{ old}$$

$$= \frac{100}{20} * 0.2 = 1\text{ pu}$$

$$\frac{1}{Z_{eq}} = \frac{1}{1.088} + \frac{1}{1.0} + \frac{1}{1.0} + \frac{1}{1.0}$$

$$\frac{1}{Z_{eq}} = 3.92 = I_f''$$

$$Z_{eq} = j0.255 \text{ pu}$$

$V_{th} = 1.0$ pu.

$$I_f'' = \frac{1V}{Z_{eq}} = \frac{1}{j0.255} = -j3.92 \text{ pu}$$

$$I_b = \frac{S_b}{\sqrt{3}V_b} = \frac{100\times10^6}{\sqrt{3} * 33\times10^3} = 1.75 \text{ KA}$$

$$|I_f''| = 3.92 \text{ pu.}$$

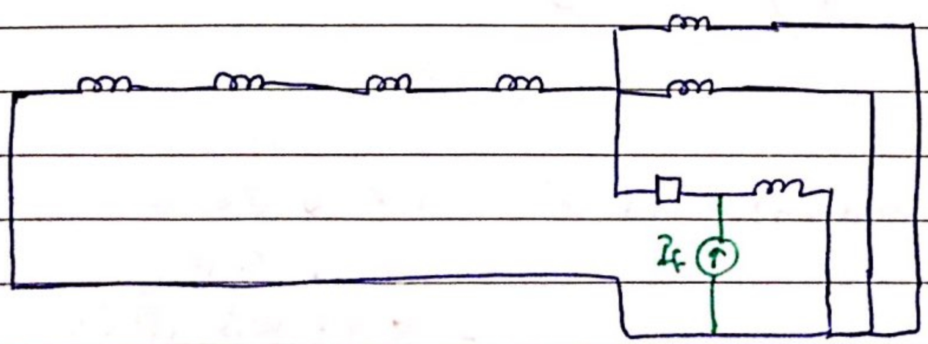
$$I_f'' = 3.92 * 1.75\text{K} = 6.85\text{KA}$$

symmetry current (RMS)

$$I_B'' = I_f'' \times \frac{[1.088 // 0.5]}{0.34 + 1.0}$$

$[1.088 // 0.5] \rightarrow 0.34$

$I_B'' =$



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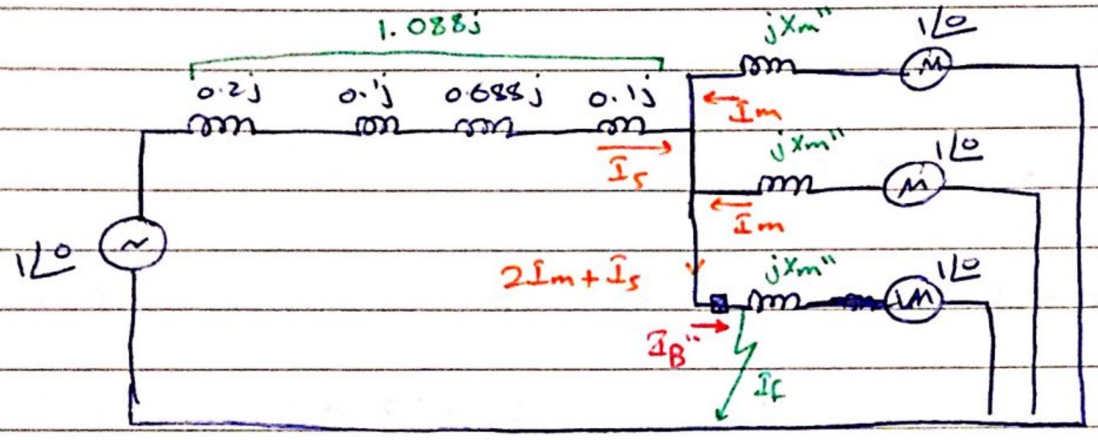
22/2 THU



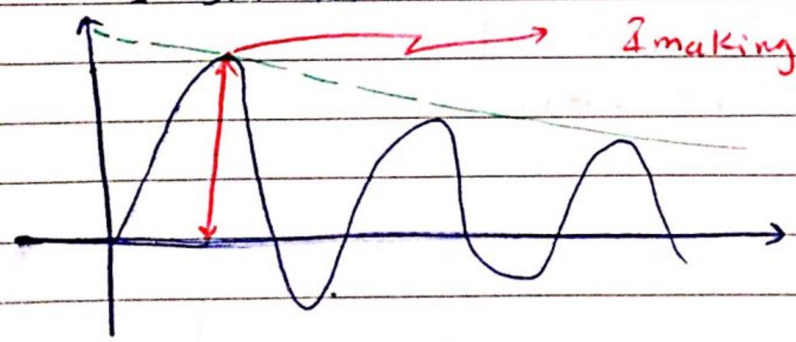
$$I_B'' = \frac{1}{j0.1088} + \frac{1}{j1} + \frac{1}{1j}$$

$= -j0.92 + j2$

$= -j2.92$ pu

$|I_B''| = 2.92 * 1.75$ K

$= 5.11$ KA.



I_{mm_B} (momentary) = I_{rms}'' = $1.6 * I_{sym}$

$= 1.6 * 5.11$

$= 8.17$ KA (RMS value)

Scanned by CamScanner

$I_{interrupting\ CB} = K \cdot I'_{symm.}$

↳ I breaking

for
2-cycle CB → K = 1.4
3-cycle CB → K = 1.3
5 cycle CB → K = 1.1
8 cycle CB → K = 1.0

Use transient reactance :-

$X_m' = 0.25$ at (20MVA, 33KV base)

$X_{m\ new}' = 0.25 * \frac{100}{5} = 1.25$ pu (100 KVA, 33KV base)

$I_{f\ bus}' = \frac{1}{j1.088} + \frac{3}{j1.25} = 0.42 + 2.4j$

$I_{f\ bus}' = 3.32$ pu

$I_{f\ bus}' = 3.32 * 1.75K$

$I_{f\ bus}' = 5.81$ KA

$I_{f\ Breake}' = \frac{1}{j1.088} + \frac{1}{j1.25} + \frac{1}{j1.25}$

I_f' break $= 0.92 + 2 * 0.8$

$= 2.52$ pu

I_f' breaker $= K * 2.52 * 1.75K$

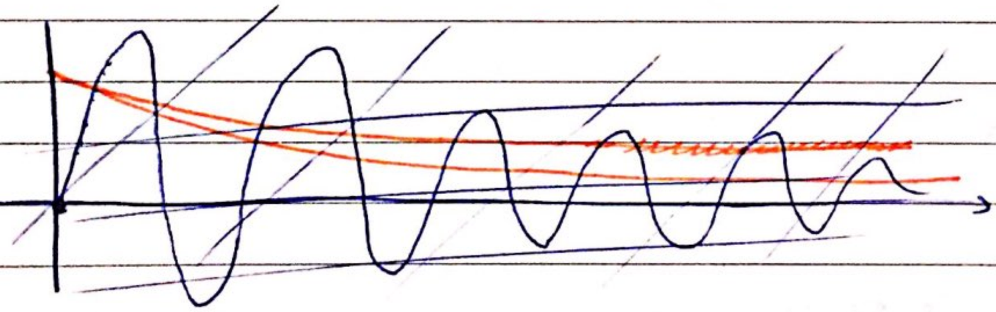
$= K * 4.41$ KA

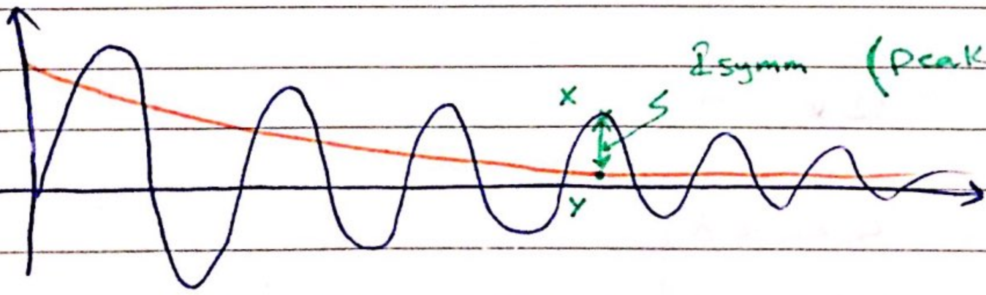
① 2 cycle ⇒ I_f' breaker $= 1.4 * 4.41$ KA $= 6.17$ KA

② 3-cycle ⇒ I_f' breaker $= 1.3 * 4.41$ KA $= 5.6$ KA

③ 5-cycle ⇒ I_f' breaker $= 1.1 * 4.41$ KA $= 4.85$ KA

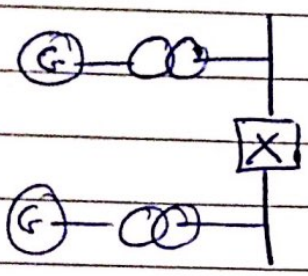
④ 8-cycle ⇒ I_f' breaker $= 1.0 * 4.41$ KA $= 4.41$ KA





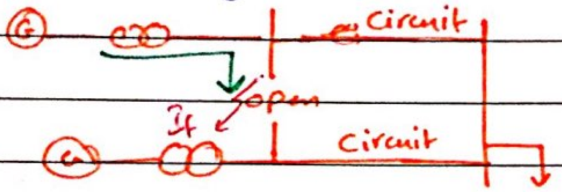
* I interupting $= \sqrt{\left(\frac{x}{\sqrt{2}}\right)^2 + y^2}$ in Americ. (USA)

* $I_{int} = \frac{x}{\sqrt{2}}$ in Europe.



Bus section ← normaly open.
normaly closed.

if normaly open. → اذا صار عندي مشكلة عم الخط .



وصار fault ← [illegible]

no contrebution.

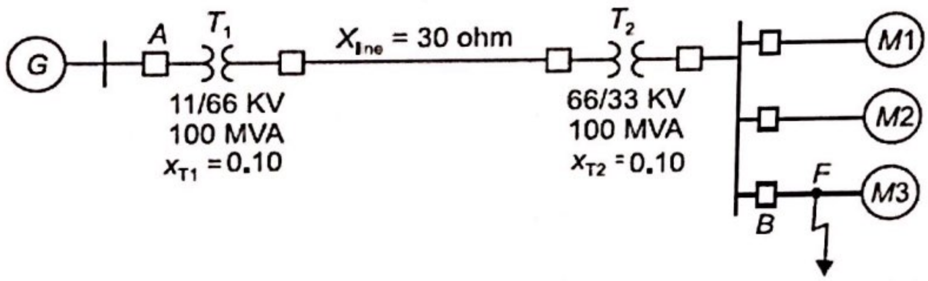
عشان يخفف open → volt level.

* اذا عملتو close لازم اختار CB معين وعشان يتحمل .

Question # 1

A 100 MVA, 11 kV generator with $X''_d = 0.2$ pu is connected through a transformer, and line to a busbar that supplies three identical motor as shown below and each motor has $X''_m = 0.2$ pu and $X'_m = 0.25$ pu on a base of 20 MVA, 33 kV. The bus voltage at the motors is 33 kV when a three-phase fault occurs at the point ***F***. Choose 100 MVA base and 11 kV base at the generator and calculate:

a. the subtransient current in the fault, I''_f.
b. the subtransient current in the circuit breaker B, I''_B.
c. the momentary current in the circuit breaker B, I_{Bmom}.
d. the current to be interrupted by circuit breaker B, I_{Bint} in
   (i) 2 cycles (K=1.4), (i) 3 cycles (K=1.2), (iii) 5 cycles (K=1.1), (iv) 8 cycles (K=1.0),



Solution:

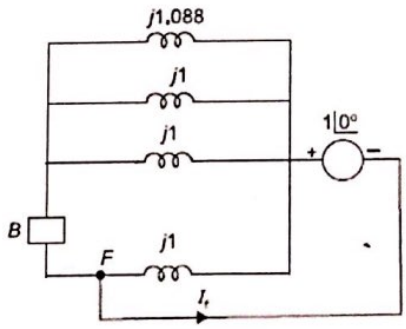
$x''_g = j0.20$ pu.

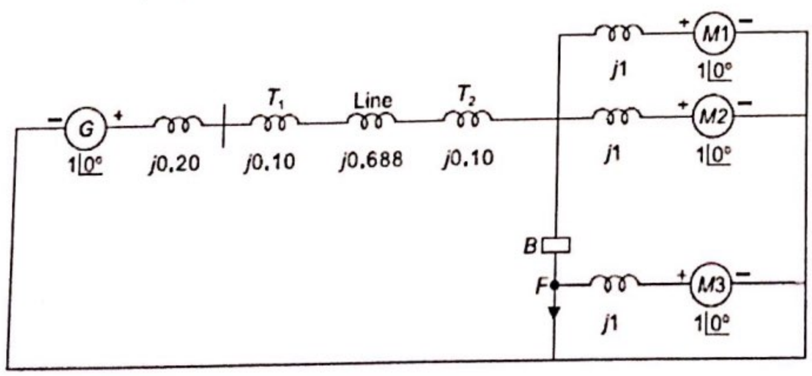
$$x''_m = x''_{m1} = x''_{m2} = x''_{m3} = j0.2 \times \frac{100}{20} = j1.0 \text{ pu.}$$

$$x'_m = x'_{m1} = x'_{m2} = x'_{m3} = j0.25 \times \frac{100}{20} = j1.25 \text{ pu.}$$

$x_{T1} = x_{T2} = j0.10$ pu

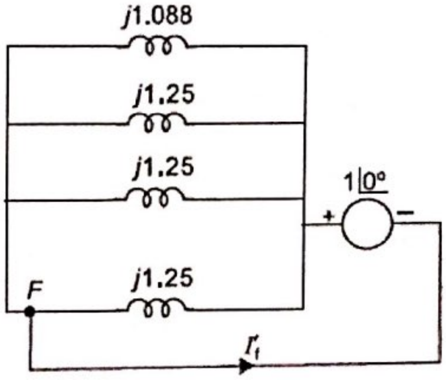
$$x_{line} = 30 \times \frac{100}{(66)^2} = j0.688 \text{ pu.}$$





$$\therefore \qquad x_{eq} = \frac{j}{3.919} = j0.255$$

$$\therefore \qquad I_f = \frac{1\angle 0^\circ}{j0.255} = -j3.919 \text{ pu.}$$



Base current for 33 KV circuit

$$I_B = \frac{100 \times 1000}{\sqrt{3} \times 33} = 1.75 \text{ KA.}$$

$$\therefore \qquad |I_f| = 3.919 \times 1.75 = 6.85 \text{ KA.}$$

(*b*) Current through circuit breaker *B* is,

$$I_{fB} = \frac{2}{j1} + \frac{1}{j1.088} = -j2.919 \text{ pu}$$

$$\therefore \qquad |I_{fB}| = 2.919 \times 1.75 = 5.108 \text{ KA.}$$

(*c*) Momentary current can be calculated by multiplying the symmetrical momentary current by a factor of 1.6 to account for the presence of DC off-set current.
∴ Momentary current through breaker *B*

$$= 1.6 \times 5.108 \text{ KA} = 8.17 \text{ KA.}$$

(*d*) For computing the current to be interrupted by the breaker, motor x''_m $\left(x''_m = j1.0\right)$ is now replaced by x'_m $\left(x'_m = j1.25 \text{ pu}\right)$. The equivalent circuit is shown in Fig. 8.13(*c*).

$$x_{eq} = j0.3012$$

Current to be interrupted by the breaker

$$I'_f = \frac{1}{j0.3012} = -j3.32 \text{ pu}$$

Allowance is made for the DC off-set value by multiplying with a factor of (*i*) 1.4 for 2 cycles (*ii*) 1.2 for 3 cycles (*iii*) 1.1 for 5 cycles (iv) 1.0 for 8 cycles.

Therefore, current to be interrupted as:

(*i*) $1.4 \times 3.32 \times 1.75 = 8.134$ KA
(*ii*) $1.2 \times 3.32 \times 1.75 = 6.972$ KA
(*iii*) $1.1 \times 3.32 \times 1.75 = 6.391$ KA
(*iv*) $1.0 \times 3.32 \times 1.75 = 5.81$ KA.

Question # 2

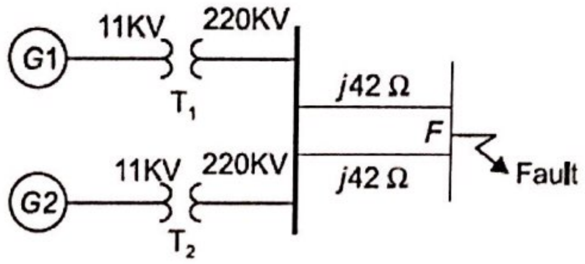
A generating station feeding a 220 KV system is shown below. Determine the total fault current, fault level and fault current supplied by each generator for a three phase fault at the receiving end of the line.

$G1$: 11 KV, 100 MVA, $x'_{g1} = j0.15$

$G2$: 11 KV, 75 MVA, $x'_{g2} = j0.125$

$T1$: 100 MVA, $x_{T1} = j0.10$, 11/220 KV

$T2$: 75 MVA, $x_{T2} = j0.08$, 11/220 KV



Solution:

Let base MVA = 100, Base voltage = 11 KV.

$$x'_{g1} = j0.15, \quad x_{T1} = j0.10$$

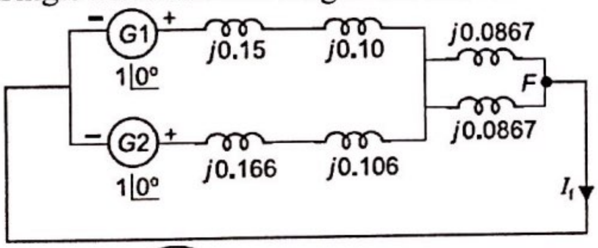
$$x'_{g2} = j0.125 \times \frac{100}{75} = j0.166$$

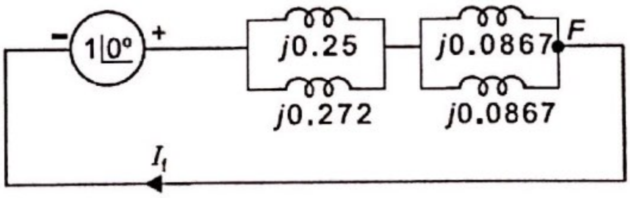
$$x_{T2} = j0.08 \times \frac{100}{75} = j0.106$$

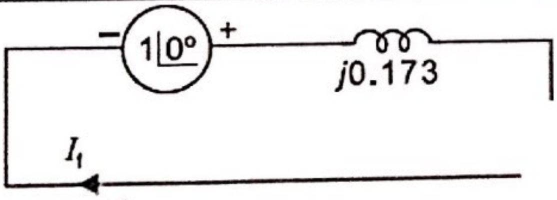
Per unit reactance of each line

$$= j42 \times \frac{100}{(220)^2} = j0.0867 \text{ pu.}$$

Single line reactance diagram is shown below







$$I_f = \frac{1}{j0.173} = -j5.78 \text{ pu}$$

Base current for 220 KV side

$$= I_B \times \left(\frac{220}{11}\right) = 262.43 \times \left(\frac{220}{11}\right)$$

$$= 5248.6 \text{ Amp.}$$

Fault current supplied by the two generators

$$= 5248.6 \times (-j5.78) = 30.34\angle -90^\circ \text{ KA}$$

$$\therefore \quad I_{fg1} = \frac{0.272}{0.522} \times 30.34\angle -90^\circ \text{ KA}$$

$$\therefore \quad I_{fg1} = 15.8\angle -90^\circ \text{ KA}$$

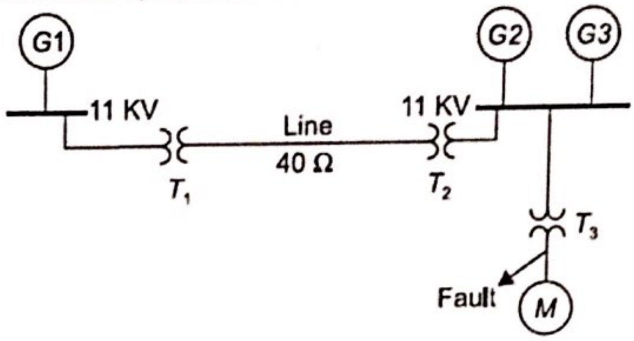
$$I_{fg2} = \frac{0.25}{0.522} \times 30.34\angle -90^\circ \text{ KA}$$

$$\therefore \quad I_{fg2} = 14.53\angle -90^\circ \text{ KA}$$

Question # 3

Two generating stations are connected together through transformers and a transmission line as shown below. If a three phase fault occurs as shown below, calculate the fault current.

$G1$: 11 KV, 40 MVA, 15%
$G2$: 11 KV, 20 MVA, 10%
$G3$: 11 KV, 20 MVA, 10%
T_1 : 40 MVA, 11/66 KV, 15%
T_2 : 40 MVA, 66/11 KV, 15%
T_3 : 5 MVA, 11/6.6 KV, 8%
Line reactance = 40 ohm.



Solution:

Set Base MVA = 40, Base Voltage = 11 KV

$\therefore \quad x_{g1} = j0.15$ pu,

$$x_{g2} = j\frac{40}{20} \times 0.10 = j0.20 \text{ pu}$$

$$x_{g3} = j0.10 \times \frac{40}{20} = j0.20 \text{ pu}$$

$$x_{T1} = j0.15 \text{ pu}$$

$$x_{T2} = j0.15 \text{ pu}$$

$$x_{T3} = j0.08 \times \frac{40}{5} = j0.64 \text{ pu}$$

$$x_{line} = j40 \times \frac{40}{(66)^2} = j0.367 \text{ pu.}$$

Circuit model for fault calculation is shown below.

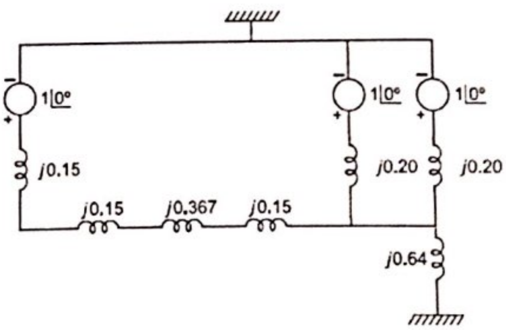
$$I_f = \frac{1\angle 0^\circ}{j0.729} = -j1.37 \text{ pu}$$

$$\text{Base current } I_B = \frac{40 \times 1000}{\sqrt{3} \times 11}$$

$$= 2099.45 \text{ Amp}$$

$$|I_f| = 1.37 \times 2099.45$$

$$= 2.876 \text{ KA}$$



27/2
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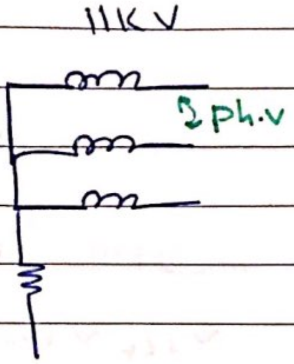


Phase volt = 6350V

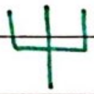
$I = 600A$

$R = \frac{6350}{600} \simeq 10\Omega$

Slide 22:-

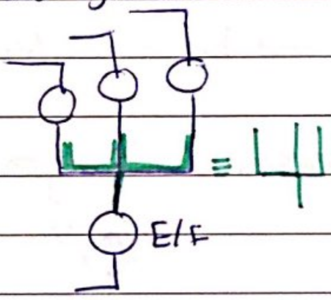
⇒ In H.V side → current I ↓

59G → over voltage relay.



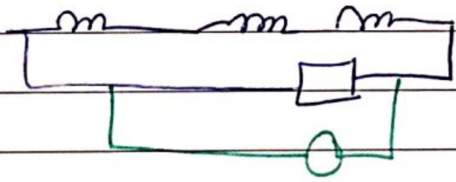
≡ earthing btween neutral and ground.

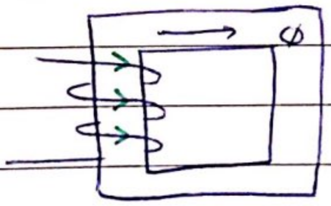
→ residual connection



→ ⊿ delta broken

unbalance, L-G fault





L ≡ flux leakage per unit current

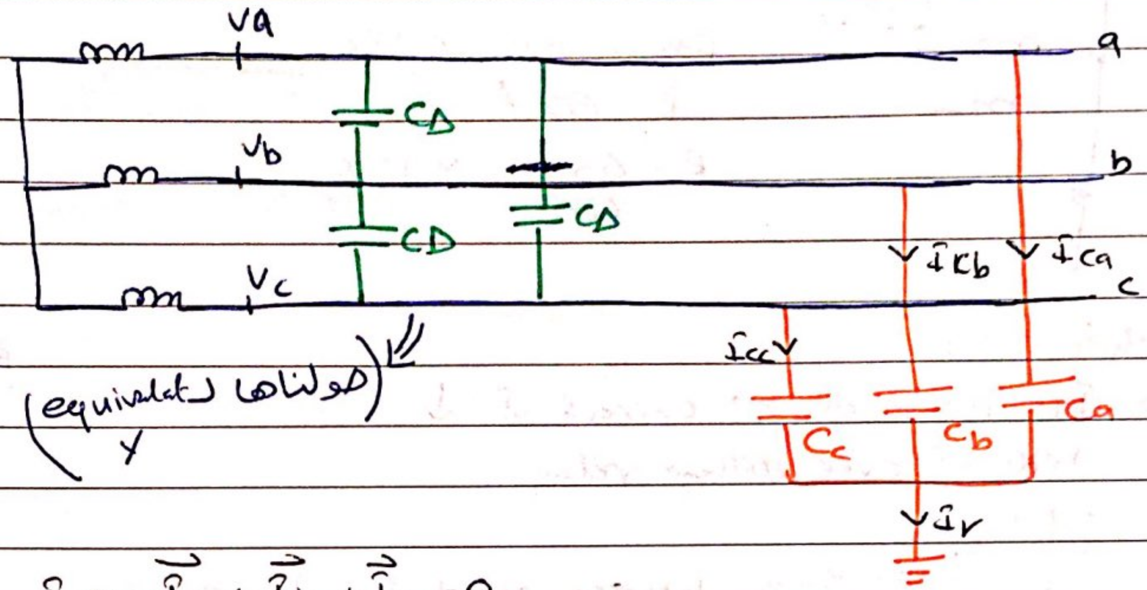
$NI = \phi R$

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

$$L = \frac{N^2}{R}$$

Inductance ↓ → ↑ airgap.

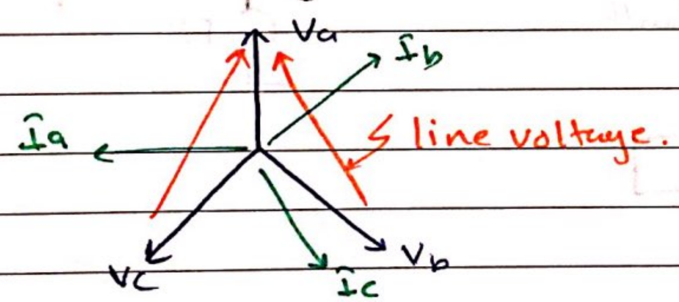
UNgrounded neutral (Isolated) : Δ



$\hat{I}_r = \vec{I}_a + \vec{I}_b + \vec{I}_c = 0$

at balance Nutral ≡ grounded

Phasor diagram:-



current lead volt 90°

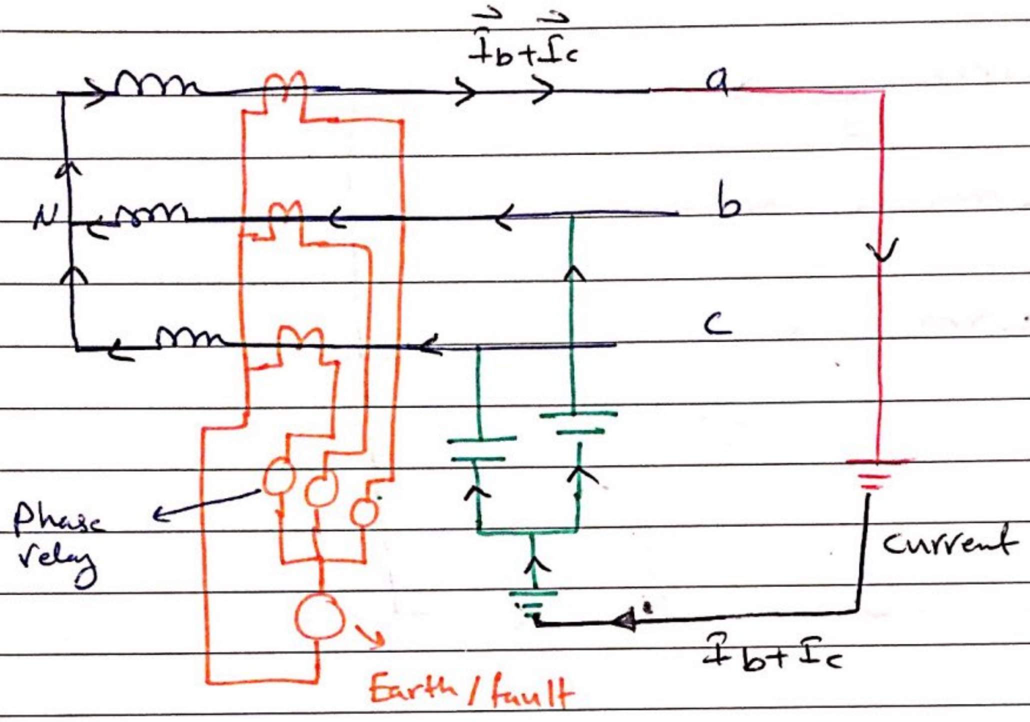
at balance:

$$I_{ca} = \frac{\vec{V_a}}{-jX_{ca}} \Rightarrow \boxed{|I_{ca}| = \frac{V_{ph}}{X_c}}$$

$$|\hat{I}_{ca}| = |I_{cb}| = |I_{cc}| = \frac{V_{ph}}{X_c} = \omega c V_{ph}$$

$$\vec{I_{cb}} = j\frac{V_{ph}}{X_c}$$

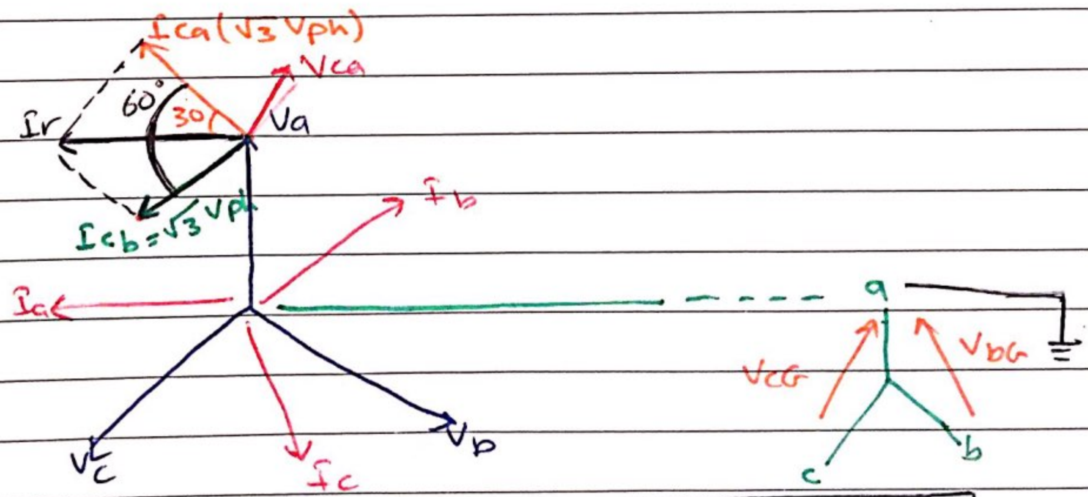
At fault:-



line to ground.
↳ line → Medium voltage.
↳ current قليل

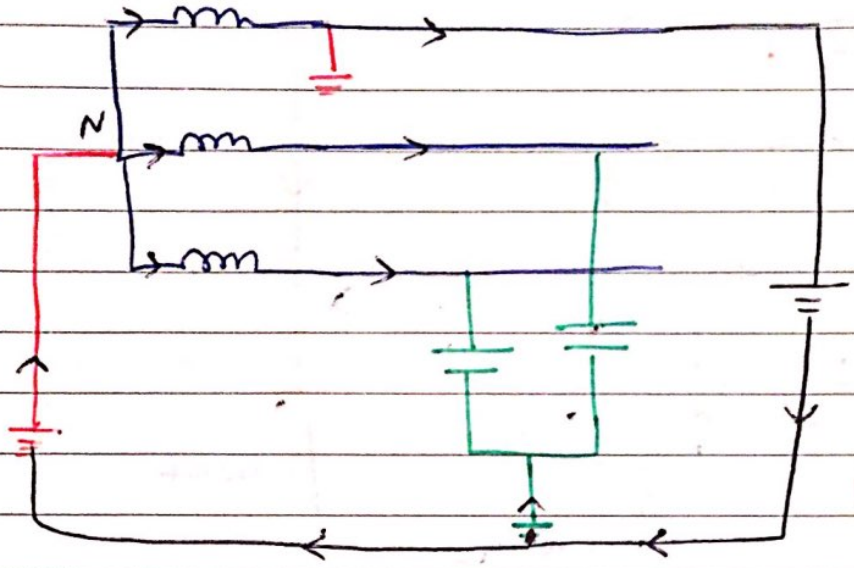
$$|I_b| = \frac{\sqrt{3}\, V_{ph}}{X_c}$$

$$|I_c| = \frac{\sqrt{3}\, V_{ph}}{X_c}$$



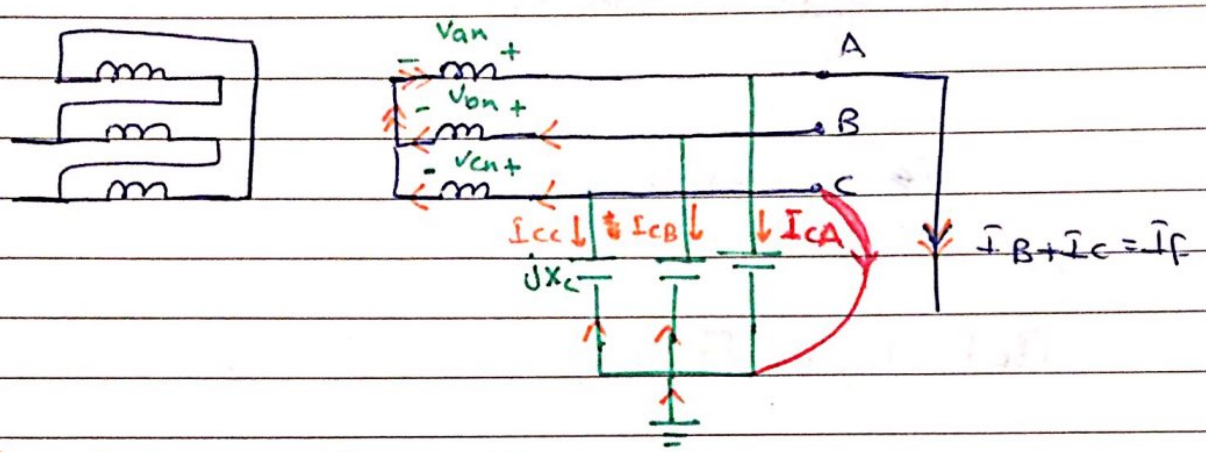
$$V_{cG} = \sqrt{3}\, V_{ph}$$

2 Solidly grounded system:-



Natural Grounding :-

[1] Isolated natural (Ungrounded system).



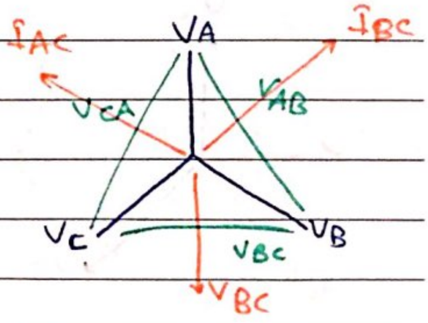
[1] under normal condition :-

$$\vec{I}_{CA} = \frac{V_A}{-jX_c} \qquad \vec{I}_{CB} = \frac{V_B}{-jX_c} \qquad \vec{I}_{cc} = \frac{V_c}{-jX_c}$$

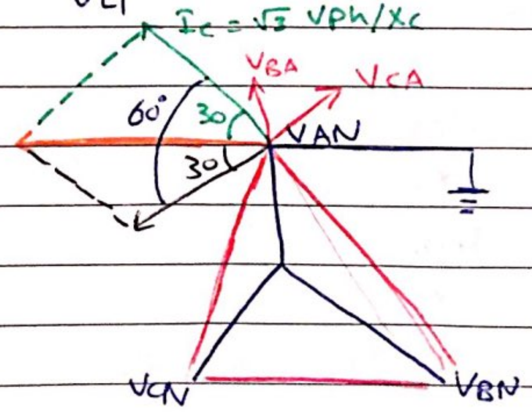
$$|I_{AC}| = |I_{BC}| = |I_{cc}| = \frac{X_{ph}}{1/\omega c} = \omega c V_{ph}$$

$$\frac{N_1}{N_2} = \frac{V_{1ph}}{V_{2ph}} = \frac{V_{L1}}{V_{L2}/\sqrt{3}} = \sqrt{3}\,\frac{V_{L1}}{V_{L2}}$$

$$I_a = \frac{N_2}{N_1} I_A = \frac{V_{L2}}{V_{L1}} \sqrt{3}$$



$I_F = I_B + I_c$



2) LG-fault :-

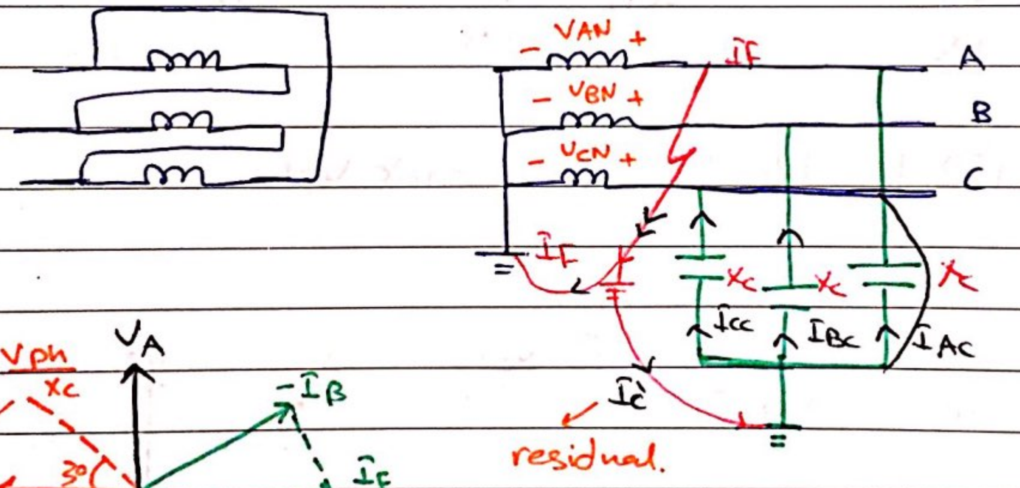
$\hat{I}_F = \hat{I}_B + \hat{I}_C$

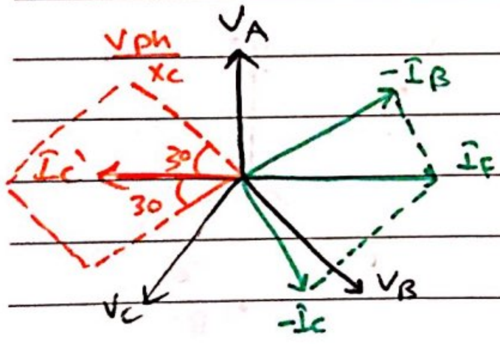
$|\hat{I}_F| = \frac{3 V_{ph}}{X_c} = 3 w_c V_{ph}$

$$V_{NG} = -V_{AN}$$

$|\hat{I}_B| = |\hat{I}_c| = \frac{\sqrt{3}\, V_{ph}}{X_c}$

2 Solidly grounded Systems



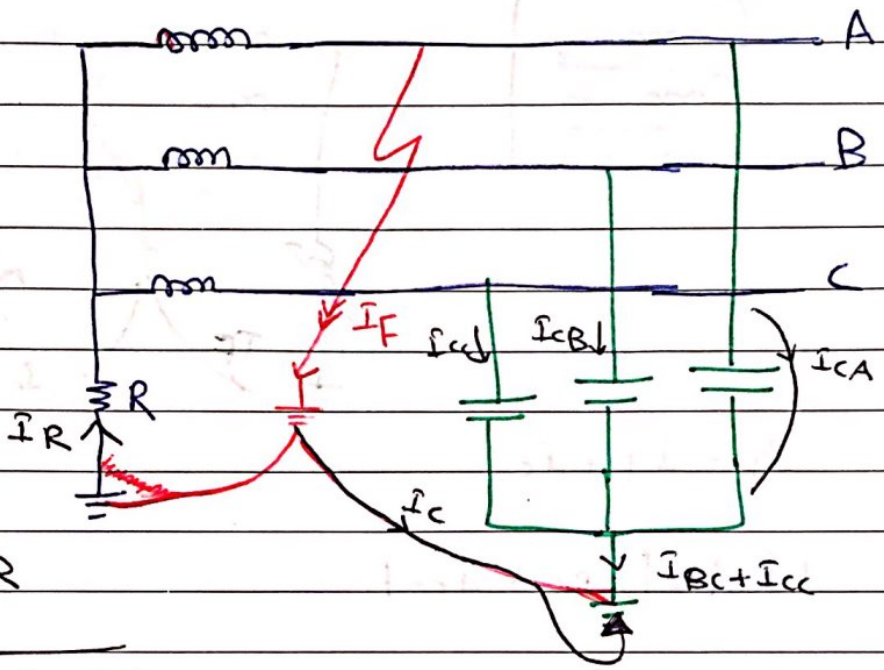


$|\hat{I}_B| = \frac{V_{ph}}{X_c}$

$|\hat{I}_c| = \frac{V_{ph}}{X_c}$

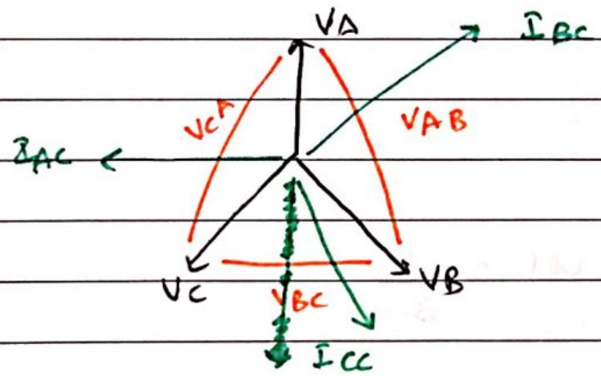
$\hat{I}_c'\ (\text{residual}) = \hat{I}_B + \hat{I}_c$

3 Grounding through R & Δ

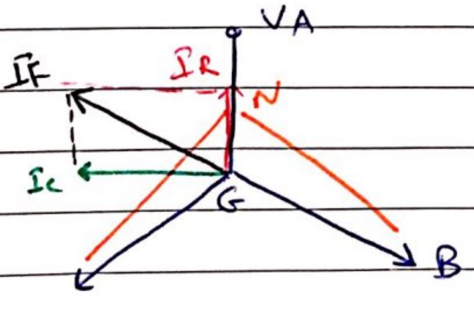


$V_{NG} = I_R \cdot R$

$|I_F| = \sqrt{I_R^2 + I_c^2}$



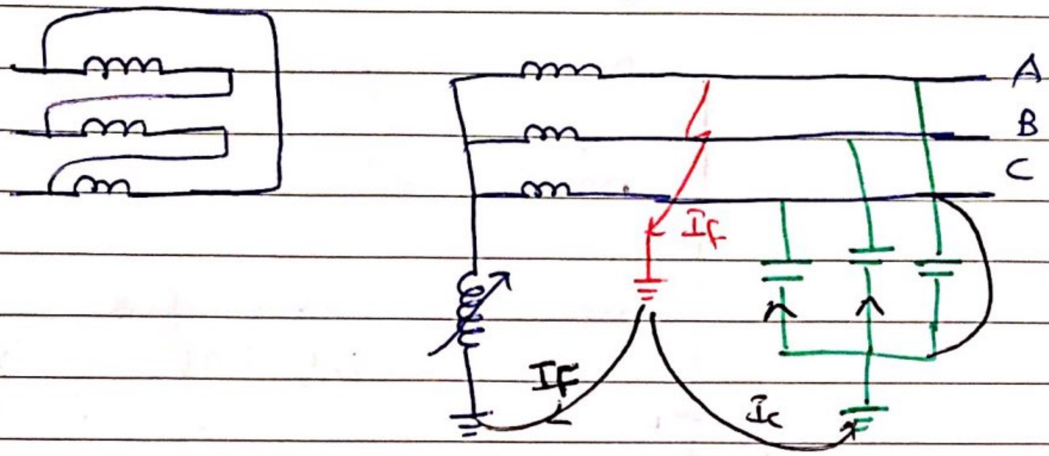
Normal condition.



LG Fault

$|I_F| = \sqrt{I_R^2 + |I_c|^2}$

4 person coil grounding :-



$$I_f = I_F + I_c$$

$$|I_c| = |I_{Bc} + I_{cc}|$$

$$|I_c| = \frac{3V_{ph}}{X_c}$$

$$I_F = \frac{V_{ph}}{X_L}$$

$$\frac{V_{ph}}{X_L} = \frac{3V_{ph}}{X_c}$$

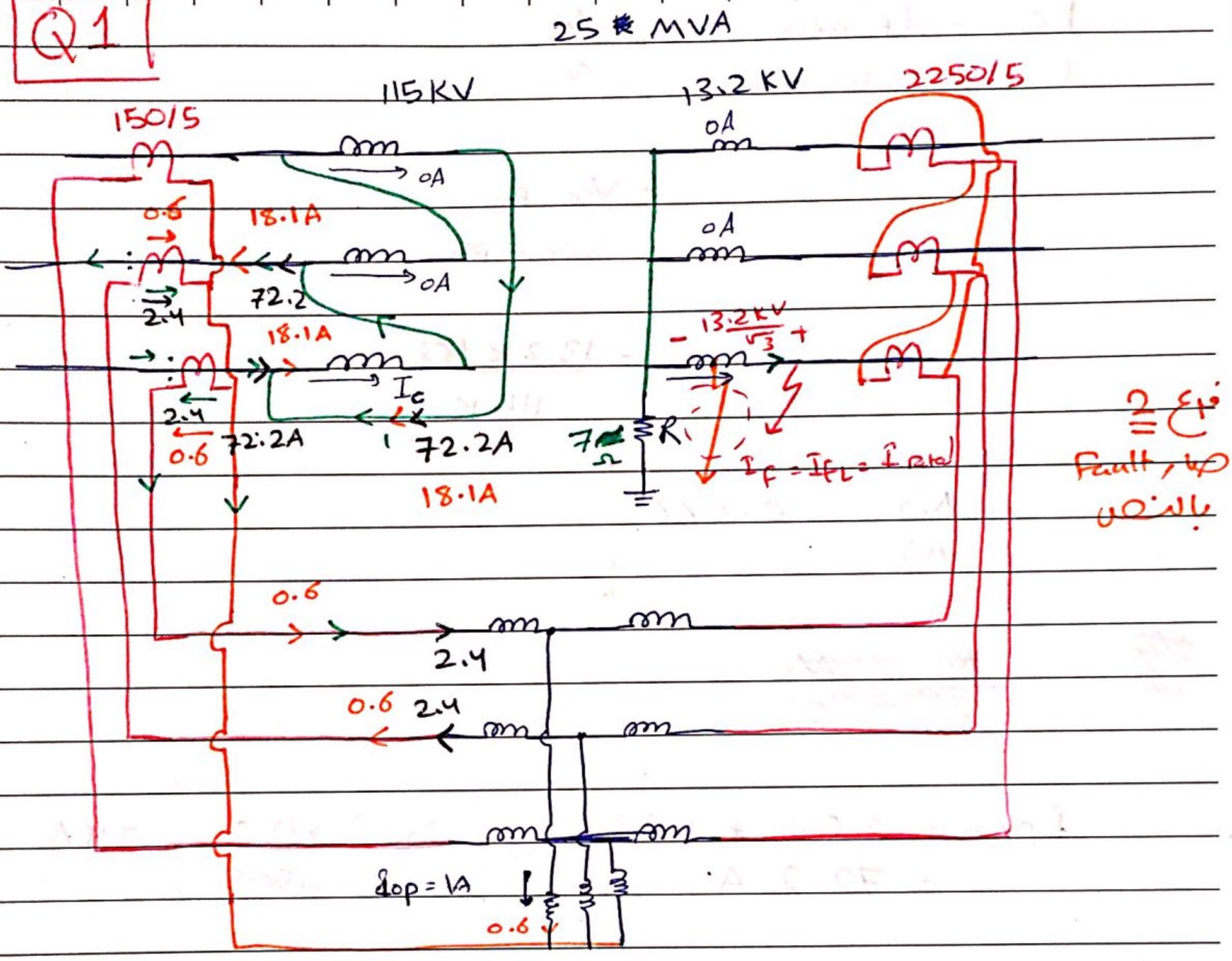
$$X_L = \frac{X_c}{3} \rightarrow \omega L = \frac{1}{3\omega c}$$

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

Tutorial

6/3 Tue

Q1



$$I_{FL1} = I_{rated} = \frac{25 \times 10^6}{\sqrt{3} * 13.2 \times 10^3} = 1093.5\ A$$

$$V_{ph\ sec} = \frac{13.2KV}{\sqrt{3}} = 7.62\ KV$$

$$I_F = I_{rated} = 1093.5 = \frac{V_{phase}}{R}$$

$$R = \frac{7.62KV}{1093.5} = 6.97\ \Omega$$

$$\boxed{R = 7\ \Omega}$$

$$\frac{I_c}{I_c} = \frac{I_{primary}}{I_{secondary}} = \frac{N_2}{N_1}$$

$$= \frac{V_{sec\,ph}}{V_{prim\,ph}}$$

$$= \frac{13.2K/\sqrt{3}}{115K}$$

$$\boxed{\frac{N_2}{N_1} = 0.066}$$

$$I_{prim} = 0.066 * 1093.5 = 72.2\ A$$

$\Rightarrow$ in CT $\rightarrow \frac{72.2}{150/5} = 2.4\ A$

[2] Fault in the midlle.

$$I_c = \left(\frac{N_2/2}{N_1}\right) * 546.7$$

$$= \frac{0.066}{2} * 546.7$$

$$\boxed{I_c = 18.1\ A}$$

$\Rightarrow$ in CT $\rightarrow \frac{18.1}{150/5} = 0.6\ A$

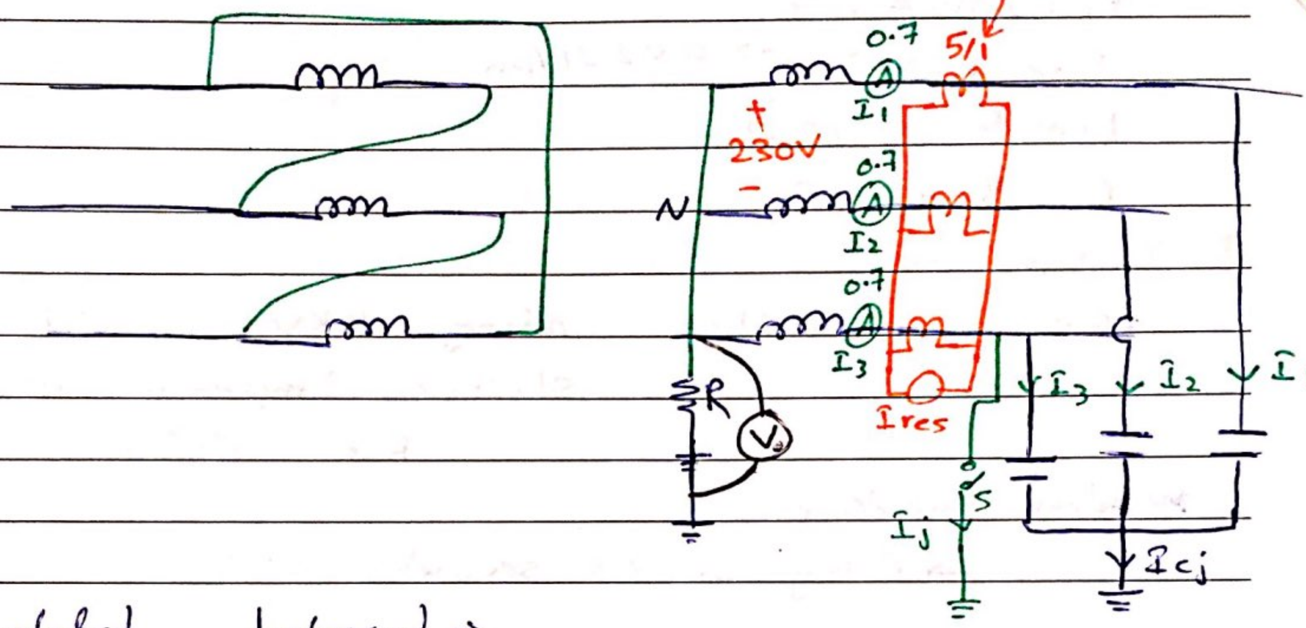
* كم نسبة من ال winding مش محمية في differential

متوقع 2018 ==

* 50% من winding الـ بشغل ال relay.

* مش كل ال winding بنحميه في Line to Line.

Q2



1. Isolated balanced ⇒

$I_{res} = 0$ A

$I_{cj} = 0$ A

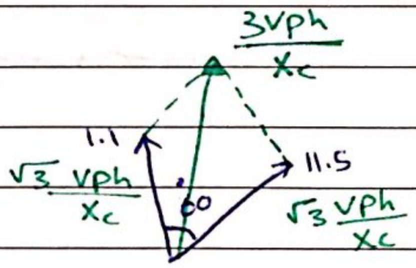
$V_o = 0V \quad (0 * R)$

2. Isolated have fault ⇒ Switch close.

$I_1 = 1.15A$

$I_2 = 1.1A$

Capcitor 3 → shorted.



I_{cj} = لا نجمعهم جمع جبري

$$I_{cj} = 1.95 \text{ A} = \sqrt{3}\left(\frac{1.15 + 1.1}{2}\right) \text{ A}$$

$$V_o = V_{ph} = \frac{230}{\sqrt{3}}$$

$$|I_j| = |I_c| = I_3$$

G = 2MVA , 10% $MVA_b = 20MVA$

T_1 = 2MVA , 7%

line 1, 2, 3 → 0.02 Ω/ph.

Line 5 = 0.02 Ω

Line 8 = 0.2 Ω

⇒ IE Sys. no

Icon - Grid → click   rating 11 KV (nominal)   %X

short cir impedance 10%.

bus وصلتها ب   10

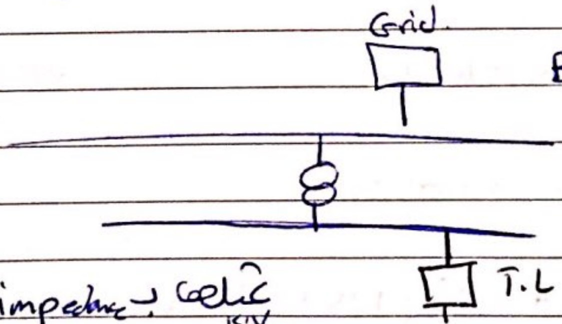
Winding impedance

→ Rating → 3.3 secondary.

~~winding impedance~~ → impedance. 3.7   7% ← base نفس

7

~~Grid → rating → 10~~



BUS اختار

T.L → impedance عادي

click Rating   KV 3.3   Balanced.

~~[illegible]~~

R X Y

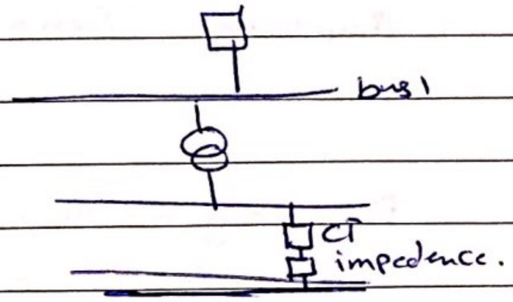
0.02

persen بعطيها قيمة ~~[illegible]~~

مع ال base.

Five Apple

* add bus. and CT :



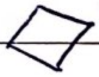
Ratio — Prim — sec

CT → 200A — 1A

class

De ⇒ 10P5 — stander error 5%

2.5VA

add Relay 

Over current relay

OCR

↳ library

↳ Model - REJ 525

☑ Function overcurrent.

curve type normal impedance.

Lumped load. 

Name plate →

KVA	PF%
2000	85

Project stander → 50 HZ.

Power Grid → Rating %V ← Operating

100

2-winding Transformer → Grounding

primary Y Solid

sec Y Solid.

impedence. Rating Base KV

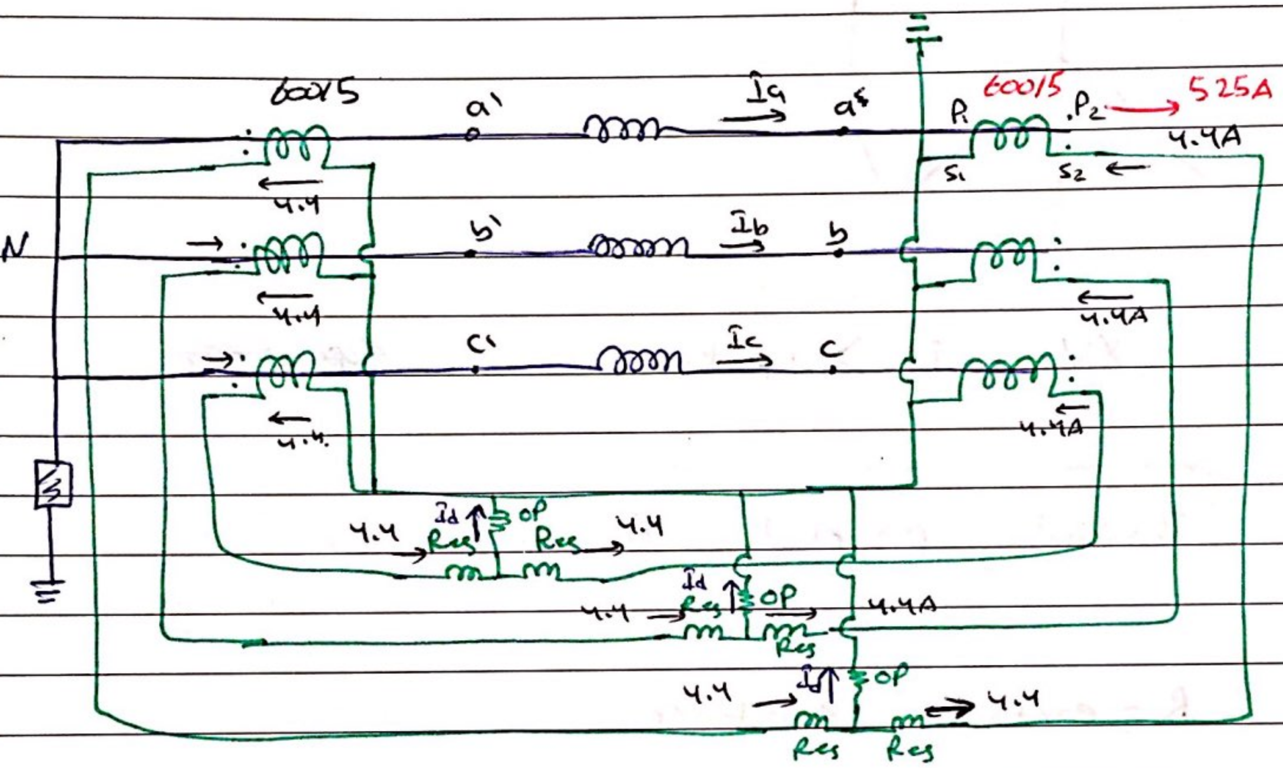
Display option

→ AC display on diagram

R → Unint [KV] power

- Amp تهمني

Differential Protection schemes of synchronous Generator
- consider Y-connected Generator.

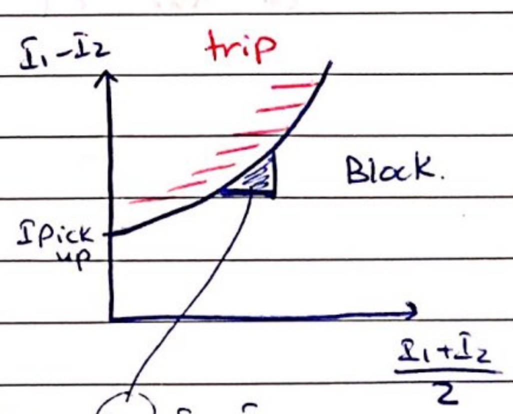


10MVA, 11KV Gen. pF=0.8

$$I_{FL} = \frac{10\times10^6}{\sqrt{3}\times 11\times10^3} = 525\,A.$$

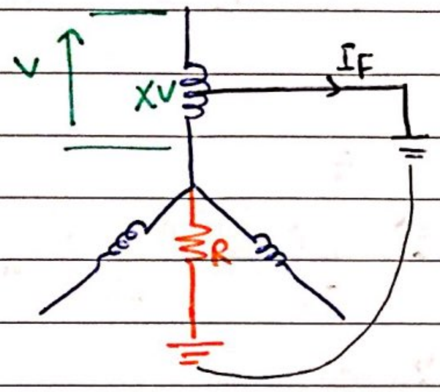
$$I_d = I_1 - I_2$$

$$I_{res} = \frac{I_1 + I_2}{2}$$



$$I_d = K \frac{I_1 + I_2}{2}$$

trip $I_d > K * I_{res}$



$$\frac{XV}{R} = I_F \geq I_{pickup}.$$

$$\% \text{ winding protected} = \frac{R \cdot I_0}{V} \times 100\%$$

R = earthing resistance.

V = Full-line-neutral voltage.

I = Full-load current of the Gen.

I_0 = minimum operating current in the primary of the CT

Q 1

10MVA , 13.2KV

% winding protected against LG = 85%

% winding protected = 15%

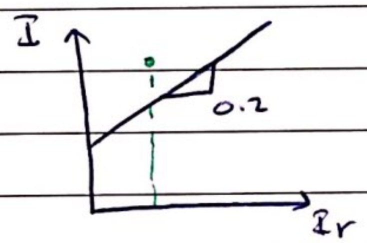
$I_{pick\,up} \geq 20\%\ I_{rated}$.

Sol:-

$$I_{rated} = \frac{10 \times 10^6}{\sqrt{3} * 13.2K} = 437\ A$$

$$I_{pick\,up} = 0.2 * 437 = 87.5\ A$$

$$V_{ph} = \frac{13.2\ K}{\sqrt{3}}$$



الخط وما فوق
21 يحل trip

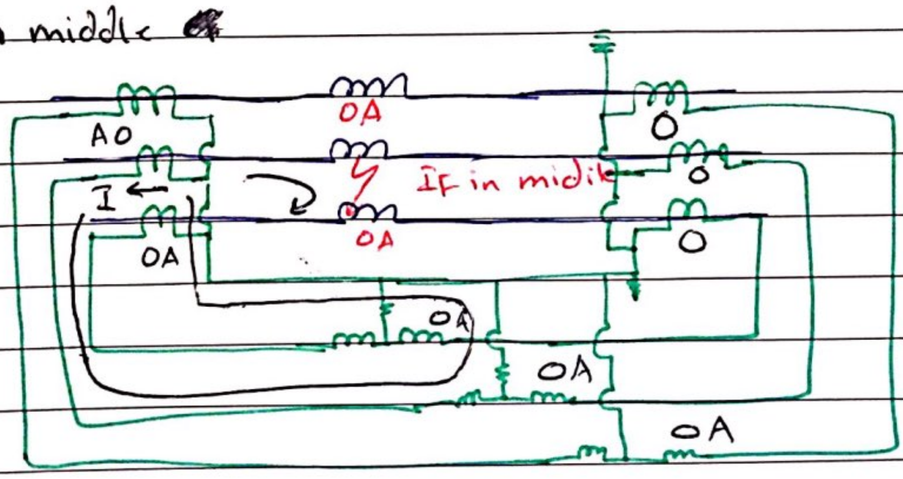
$$V_{ph} = 7.6\ KV$$

$$V_{ph} = 7621\ V$$

$$15 = \frac{R * 87.5}{7621} * 100.$$

$$R = 13.07\ \Omega$$

I_F in middle



A 115/13.2 kV Dy1 transformer rated at 25MVA has differential protection as indicated below. The transformer is connected to a radial system, with the source on the 115 kV side. The minimum operating current of the relays is 1 A. The transformer 13.2 kV winding is earthed via a resistor which is set so that the current for a single-phase fault on its secondary terminals is equal to the nominal load current. Draw the complete three-phase diagram and indicate on it the current values in all the elements for:

(i) Find the value of the grounding resistance R.

(ii) When a fault occurs at the middle of the winding on phase C, on the 13.2 kV side, assuming that the transformer is not loaded. For both cases indicate if there is any relay operation.

<u>Solution:</u>

Full load conditions

The full load conditions for the maximum load of the transformer are as follows:

$$I_{FL(13.2kV)} = \frac{25\times10^{6}}{\sqrt{3}\times13.\times10^{3}} = 1093.5\,A, \qquad R = \frac{13.2\times10^{3}/\sqrt{3}}{1093.46} = 6.97\,\Omega$$

Fault at the middle of 13.2 kV winding C

Since the transformer is earthed through a resistor that limits the current for faults at the transformer 13.2 kV bushings to the rating of the winding, and since the fault is at the middle of the winding, the fault current is then equal to half the rated value as follows:

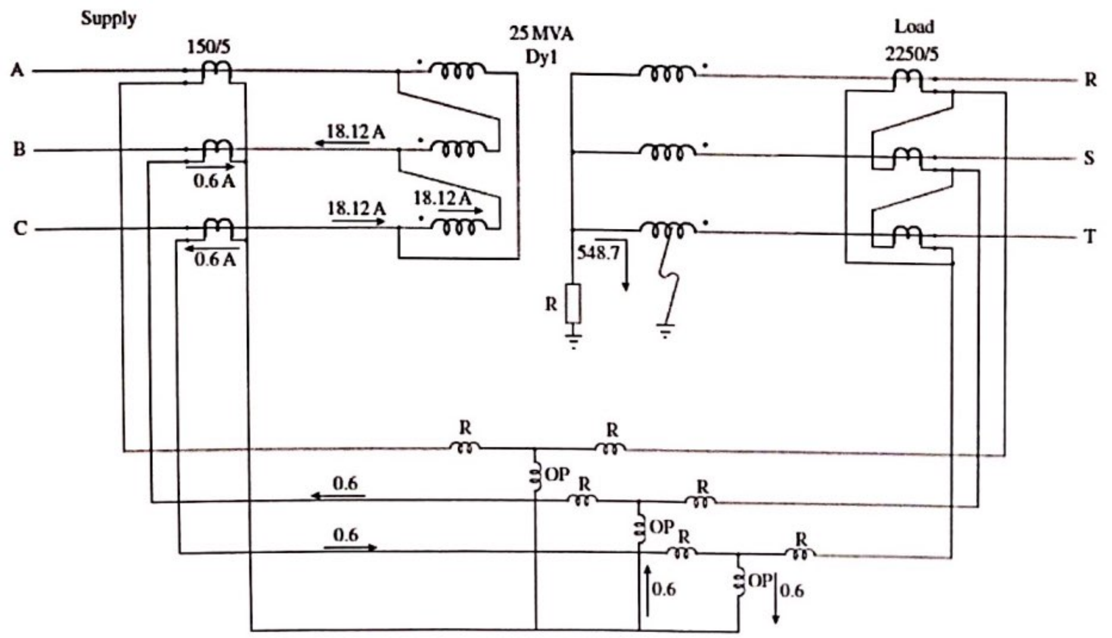
$$I_{fault} = (I_{nom(13.2kV)})/2 = 1093.47/2 = 546.7\text{ A}$$

The primary current within the delta winding is

$$I_{prim} = I_{fault} \times \frac{(N_2/2)}{N_1}, \quad \frac{N_2}{N_1} = \frac{V_2/\sqrt{3}}{V_1}$$

$$I_{prim} = \frac{1}{\sqrt{3}\times VR} = 546.5\times\frac{\left(13.2/\sqrt{3}\right)/2}{115} = 18.1\,A$$

The differential relays **<u>do not operate</u>** since the current through their operating coils is only 0.6 A, which is less than the 1A required for relay operation.



Conditions for a fault at the middle of the winding on phase C on the 13.2 kV side

Question #2

I. For the circuit shown in below, with an input voltage **U_2 = 230** V together with **R_o** = ∞ (infinite), and the switch **S is open**. The currents I_1, I_2 , I_3 and I_{res} are measured. For I_1, I_2 , and I_3 are as given in Table 1-a, what will be the readings of I_{res}, I_{cj} and U_o?

Table 1-a

I_1 (A)	I_2 (A)	I_3 (A)	I_{res} (A)	I_{cj} (A)	U_o (V)
0.7	0.7	0.7	0.0	0.0	0.0

II. For the circuit shown below, with an input voltage **U_2 = 230** V together with **R_o** = ∞ (infinite), and the switch **S is closed.** The currents I_1, I_2, I_3, I_{res}, and I_j are measured. For I_1 and I_2 are as given in Table 1-b, what will be the readings of I_3, I_{res}, I_j and I_{cj} and U_o?

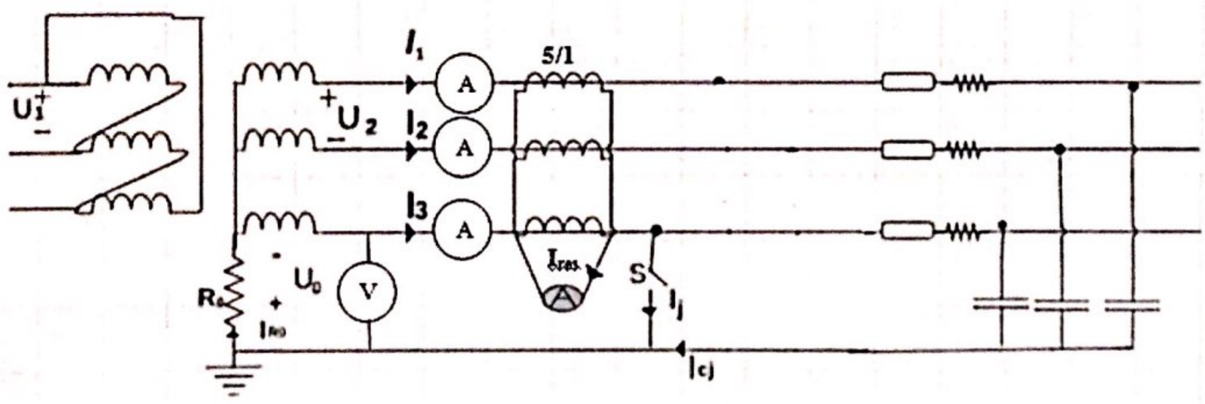
Table 1-b

I_1 (A)	I_2 (A)	I_3 (A)	I_{res} (A)	I_j (A)	I_{cj} (A)	U_o (V)
1.15	1.1	2.25	0.0	2.25	2.25	133

III. For the circuit shown below, with an input voltage **U_2 = 230** V together with **R_o = 50 Ω** (infinite), and the switch **S is closed.** The currents I_1, I_2, I_3, I_{res}, and I_j are measured. For I_1, I_2, I_3, I_{res} and I_{cj} are as given in Table 1-c, what will be the readings of I_j, I_{Ro} and U_o?

Table 1-c

I_1 (A)	I_2 (A)	I_3 (A)	I_{res} (A)	I_{cj} (A)	I_j (A)	I_{Ro} (A)	U_o (V)
1.25	0.45	3.3	0.52	2.1	3.3	2.6	130



Term Project-I

EE483-Project-OC Coordination-ETAP

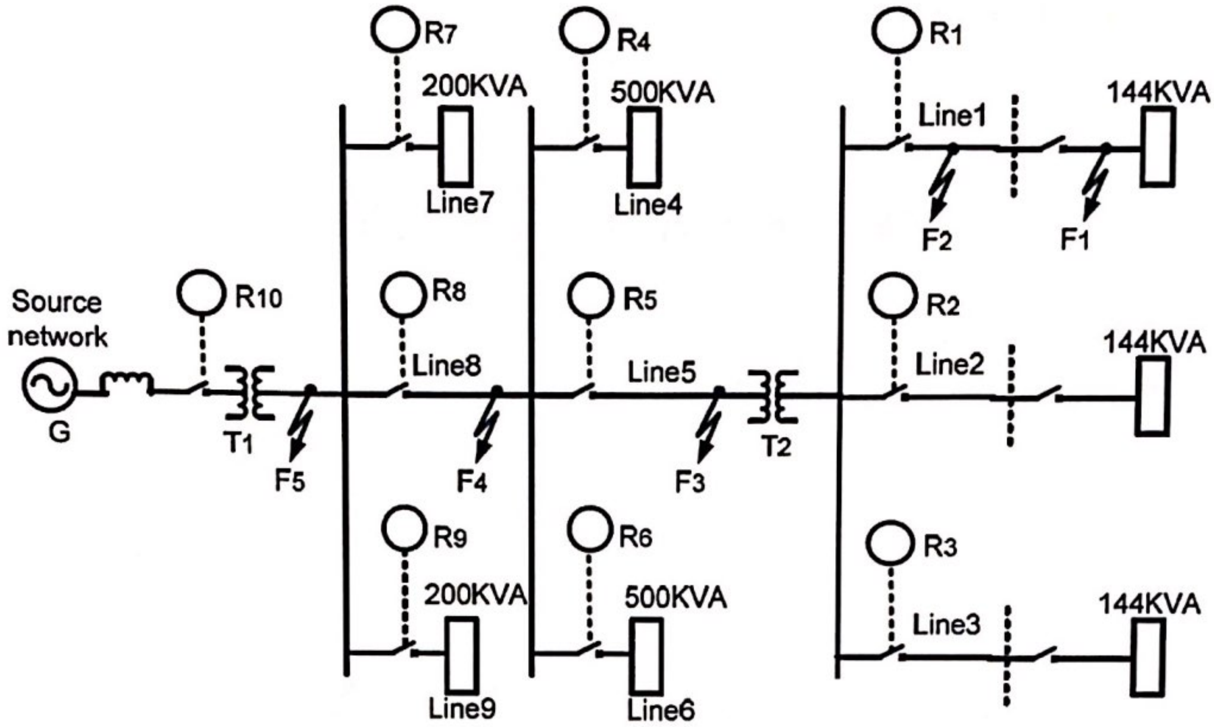
LOYALTY OATH:

I signify by my signature below that all of the attached work on the Term Project for the course EE483 for the 2nd Semester is that entirely of our own, and We did NOT seek assistance from any other classmate or other personnel, or provide any assistance to any other classmate in the completion of this term project.

Name______________________________ S.N. _____ Signature______________

Name______________________________ S.N. _____ Signature______________

Objective:	Design the protective scheme of the power system shown below. It is required to size all the CTs, define type of protection and relay setting.
Procedure:	You can use ETAP software programs.
Steps:	1. Draw the network with all the data as provided. 2. Run a load flow to determine your steady state conditions. 3. Perform short circuit analysis at different buses. 4. Select and size all CT. 5. Connect relays where appropriate. 6. Carry out coordinating studies to adjust relay settings. 7. Check for relay operation for selected fault locations.
Report:	Prepare a detailed report of your work.
Team Work:	You may work in a group of two but no more.
Report Submission:	March 22, 2018



Protection of radially-connected network

Apply inverse definite minimum-time (IDMT) relay with normal inverse characteristic given as

$$t = \frac{0.14}{\left(\frac{I}{I_S}\right)^{0.02} - 1} T_P$$

Where t = tripping time of relay, T_p = time

Network parameters: G: 2MVA, 10%; T_1: 2MVA, 11/3.3KV, 7%; T_2: 500KVA, 3.3/0.415KV, 6%; Lines 1, 2, 3: 0.02 Ω/ph; Line 5: 0.2Ω/ph; Line 8: 0.2Ω/ph; System MVA base = 20MVA; Positive and negative sequence impedances are assumed equal.

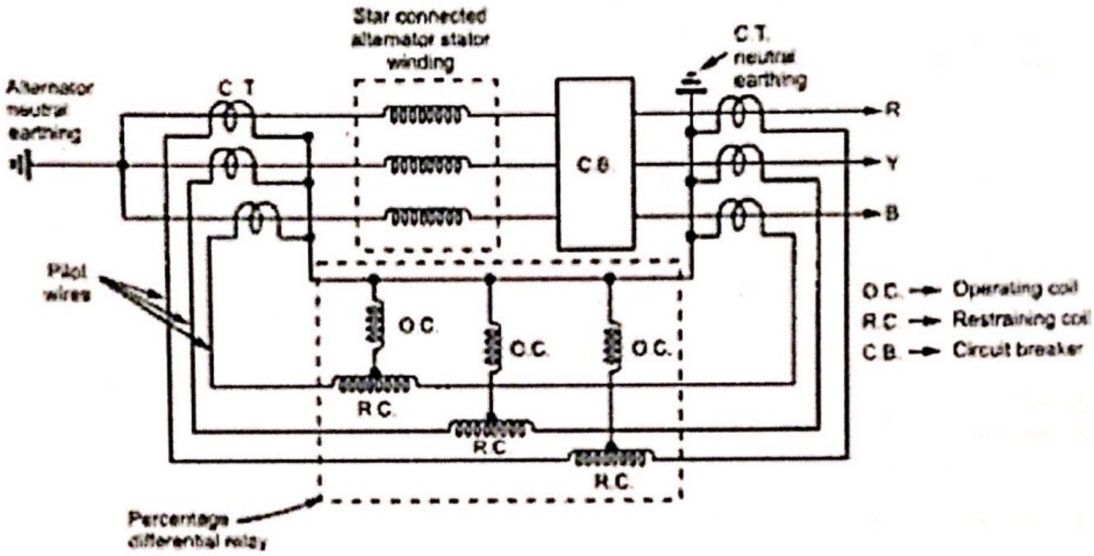
In this network, for a fault at the point F_1, relays R_1, R_2 and R_3 must not operate in less than 0.5s.

Reactance of $G = 1p.u$; Reactance of $T_1 = 0.7p.u$; Reactance of Line 8 = $0.367p.u$; Reactance of Line 5 = $0.367p.u$; Reactance of $T_2 = 2.4p.u$; Reactance of Line 1 = $2.323p.u$;

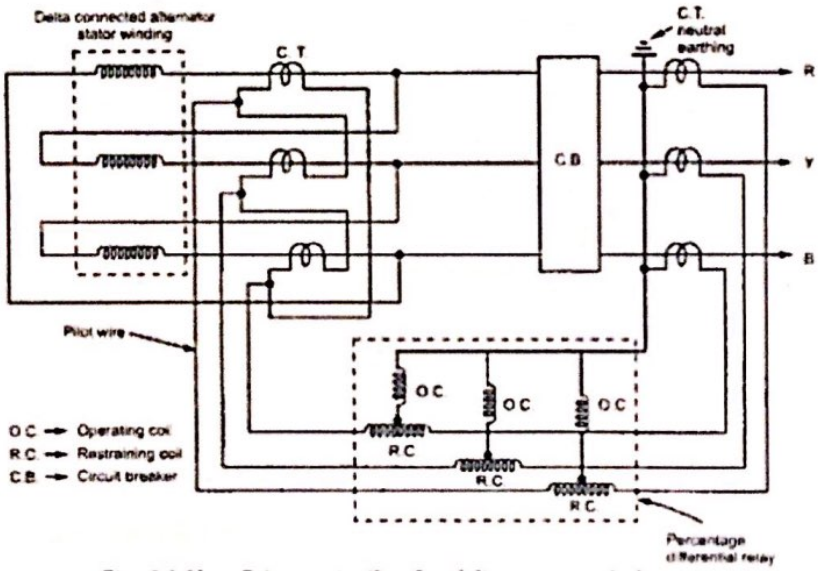
For example, the feeder relay and breaker, which are downstream, should clear a feeder fault before the supply-side relay and breaker (upstream) could trip. Generally, CTI of about 0.4 seconds

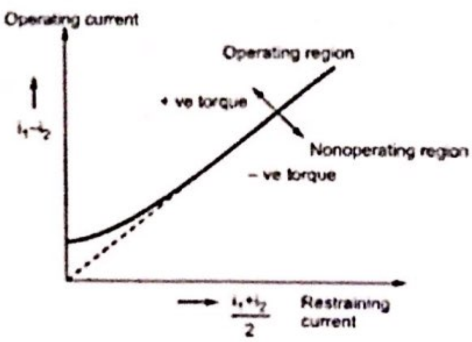
Generator Differential Protection

Differential Protection for Y-Connected Generator

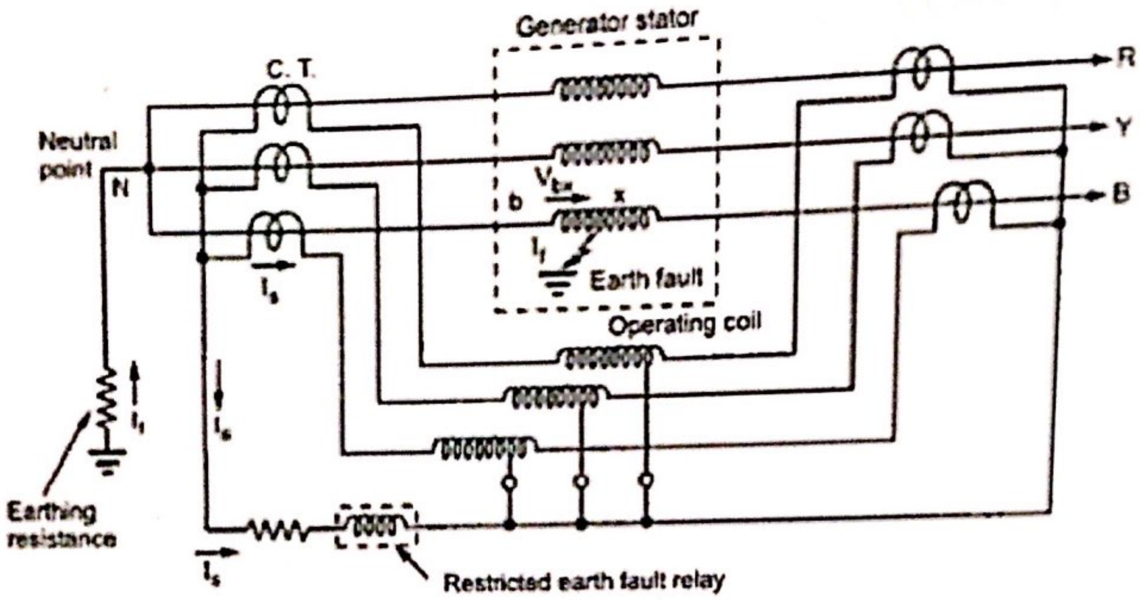


Differential Protection for Delta Connected Generator

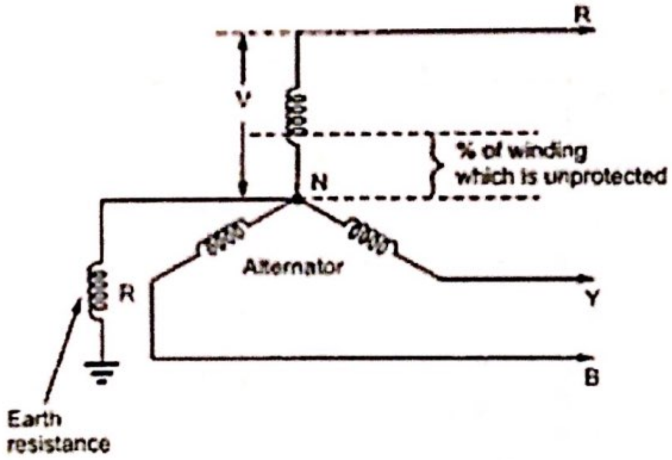




Restricted Earth Fault Protection of a Generator



Let us see the effect of earth resistance on the % of the winding which remains unprotected.



Consider the earth resistance R used to limit earth fault current as shown

The value of the resistance R limits the earth fault current.

If the resistance R is very small i.e. the neutral is almost solidly grounded, then the fault current is very high. But high fault currents are not desirable hence small R is not preferred for the large machines.

For low resistance R, the value of R is selected such that full load current passes through the neutral, for a full line to neutral voltage V.

In medium resistance R, the earth fault current is limited to about 200A for full line to neutral voltage V, for a 60 MW machine.

In high resistance R, the earth fault current is limited to about 10 A. This is used for distribution transformers and generator-transformer units.

Now higher the value of earth resistance R, less is the earth fault current and less percentage of winding gets protected. Large percentage of winding remains unprotected.

Let V = Full line to neutral voltage

I = Full load current of largest capacity generator

R = Earth resistance

Then the value of the resistance R is,

$$R = \frac{V}{I}$$

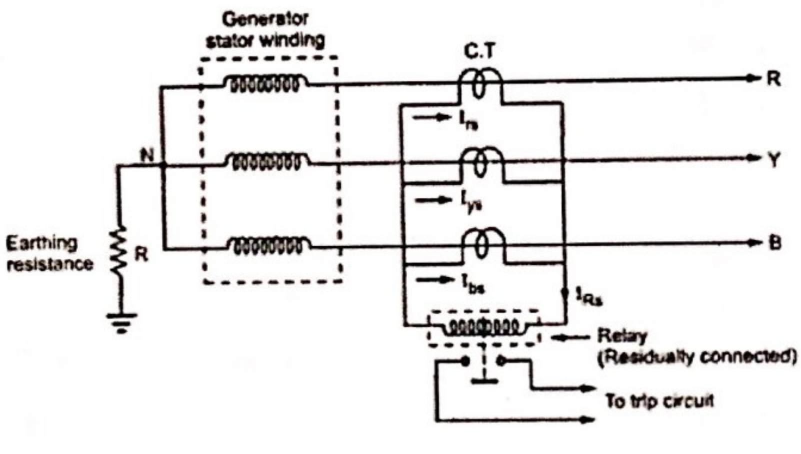
And the percentage of winding unprotected is given by,

$$\boxed{\% \text{ of winding unprotected} = \frac{RI_o}{V} \times 100}$$

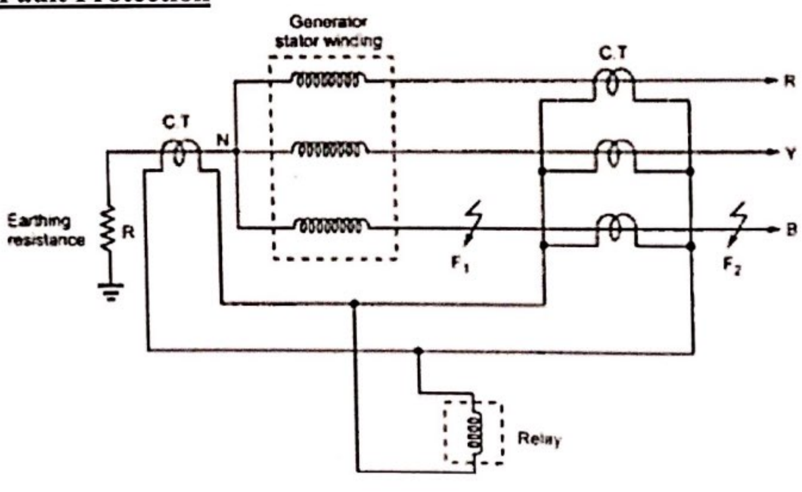
where I_o = Minimum operating current in the primary of C.T.

If relay setting used is 15% then I_o is 15% of the full load current of the **largest machine** and so on.

Unrestricted Earth Fault Protection Scheme



Balanced Earth Fault Protection



Question # 1

A generator is protected by restricted earth fault protection. The generator ratings are 13.2 kV, 10 MVA. The percentage of winding protected against phase to ground fault is 85%. The relay setting is such that it trips for 20% out of balance. Calculate the resistance to be added in the neutral to ground connection.

Solution:

$$I = \frac{\text{Rating in VA}}{\sqrt{3}\, V_L} = \frac{10\times10^6}{\sqrt{3}\times13.2\times10^3} = 437.386\ \text{A}$$

$$V = \text{Line to neutral voltage} = \frac{V_L}{\sqrt{3}} = \frac{13.2\times10^3}{\sqrt{3}} = 7621.02\ \text{V}$$

Relay setting is 20% out of balance i.e. 20% of the rated current activates the relay.

$$I_o = 4387.386\times\frac{20}{100} = 87.477\ \text{A} = \text{Minimum operating current}$$

% of winding unprotected = 15% as 85% is protected

$$15 = \frac{RI_o}{V}\times100 = \frac{R\times87.477}{7621.02}\times100 \Rightarrow R = 13.068\ \Omega$$

Question # 2

A star connected 3-phase, 12 MVA, 11 kV alternator has a phase reactance of 10%. It is protected by differential circulating scheme which is set to operate for fault current not less than 200 A. Calculate the value of earthing resistance to be provided in order to ensure that only 15% of the alternator winding remains unprotected.

Solution:

$$12\times10^6 = \sqrt{3}\times11\times10^3\times I_L \Rightarrow I_L = \frac{12\times10^6}{\sqrt{3}\times11\times10^3} = 629.8366 \text{ A}$$

$$V = \frac{V_L}{\sqrt{3}} = \frac{11\times10^3}{\sqrt{3}} = 6350.8529 \text{ V}$$

$$\%\text{ Reactance} = \frac{IX}{V}\times100$$

$$10 = \frac{629.8366X}{6350.8529}\times100 \Rightarrow X = 1.0083\ \Omega$$

$\therefore$ Reactance of unprotected winding = (% of unprotected winding) × (X)

$$= \frac{15}{100}\times1.0083 = 0.1512\ \Omega$$

v = voltage induced in unprotected winding

$$= \frac{15}{100}\times V = 0.15\times6350.8529 = 952.6279 \text{ V}$$

i = Fault current = 200 A

$$Z = \text{Impedance offered to the fault} = \frac{v}{i} = \frac{952.6279}{200} = 4.7631\ \Omega$$

Z = r + j (reactance of unprotected winding)

$$Z = r + j\,(0.1512)\ \Omega \Rightarrow |Z| = \sqrt{r^2+(0.1512)^2} = 4.7631\ \Omega$$

$\Rightarrow r = 4.7607\ \Omega$ This is the earthing resistance required.

Question # 3

The neutral point of a 11 kV alternator is earthed through a resistance of 12 Ω, the relay is set to operate when there is out of balance current of 0.8 A. The CTs have a ratio of 2000/5. What percentage of the winding is protected against earth faults? What must be the minimum value of earthing resistance required to give 90% of protection to each phase?

Solution:

$V_L = 11$ kV $R = 12\ \Omega$ CTR = 2000/5 $i_o = 0.8$ A = relay current

I_o = minimum operating line current (C.T. primary) $= i_o \times \frac{2000}{5} = \frac{0.8 \times 2000}{5} = 320$ A

V = line to neutral voltage $= \frac{V_L}{\sqrt{3}} = \frac{11 \times 10^3}{\sqrt{3}} = 6350.8529$ V

% Winding unprotected $= \frac{RI_o}{V} \times 100 = \frac{12 \times 320}{6350.8529} \times 100 = 60.46$ %

$\therefore$ % Winding protected = 100 − 60.46 = 39.53 %

$\Rightarrow$ Thus with R = 12 Ω only 39.53 % winding is protected.

It is necessary to give 90% protection.

$\therefore$ % Winding unprotected = 100 − 90 = 10% $\Rightarrow$ $10\% = \frac{R \times I_o}{V} \times 100$

$$10 = \frac{R \times 320}{6350.8529} \times 100 \Rightarrow R = 1.9846\ \Omega$$

This is the minimum value of resistance to give 90% protection to the largest machine.

Question # 4

A 50 MVA, 33 kV, 3-phase synchronous generator is protected by differential protection scheme using 1000/5 CTR. It is provided with restricted earth fault protection with the earthing resistance of 7.5 Ω. Calculate the percentage of winding unprotected in each phase against earth faults if the minimum operating current of the relay is 0.5 A.

Solution:

$V_L = 33$ kV $R = 7.5$ CTR = 1000/5 $i_o = 0.5$ A = relay current $V = \frac{V_L}{\sqrt{3}} = \frac{33 \times 10^3}{\sqrt{3}} = 19052.55$ V

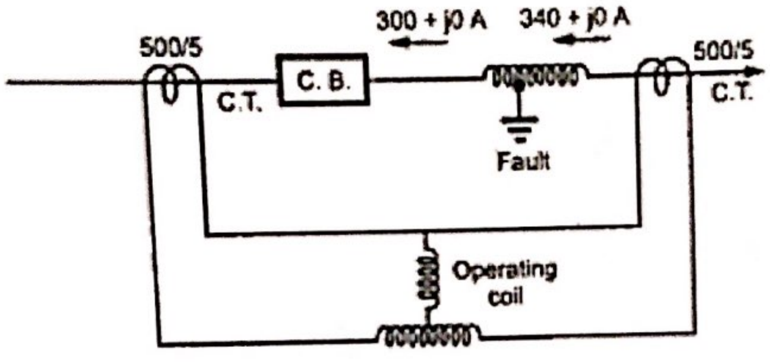
I_o = minimum operating line current (C.T. primary) $= i_o \times \frac{1000}{5} = \frac{0.5 \times 1000}{5} = 100$ A

% Winding unprotected $= \frac{RI_o}{V} \times 100 = \frac{7.5 \times 100}{19052.55} \times 100 = 3.936\%$

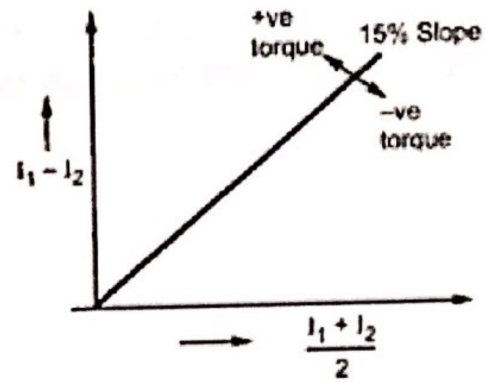
Question # 5

An alternator stator winding protected by a percentage differential relay is shown below. The relay has 15% slope of characteristics (I_1-I_2) against (I_1-I_2)/2. The high resistance ground fault has occurred near the grounded neutral end of the generator winding while the generator is carrying load. The currents flowing at each end of the generator winding are also shown. Assuming CTR = 500/5, will the relay operate to trip the circuit breaker?

Solution:



(a)

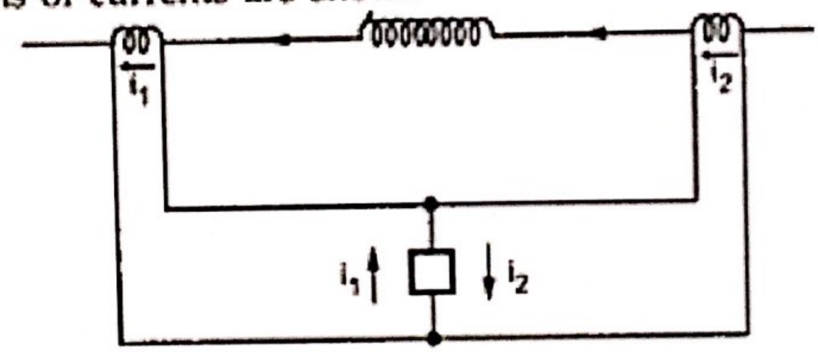


(b)

From the given current at two ends, let us calculate C.T. secondary currents at two ends,

$$i_1 = (300 + j\,0) \times \frac{5}{500} = 3 \text{ A} \qquad i_2 = (340 + j\,0) \times \frac{5}{500} = 3.4 \text{ A}$$

The directions of currents are shown

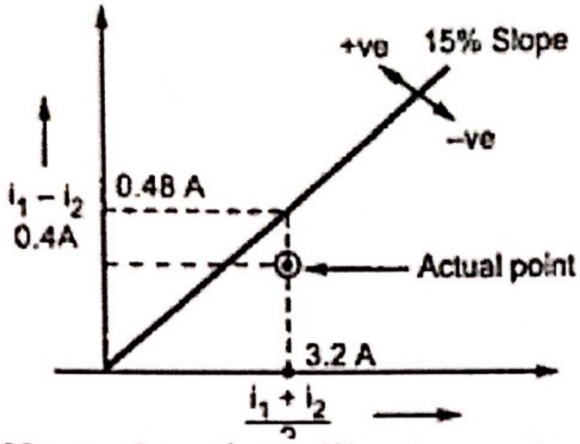


The current flowing through the relay coil is $i_1 - i_2$.

$$i_1 - i_2 = 3 - 3.4 = -0.4 \text{ A} \qquad \frac{i_1 + i_2}{2} = \frac{3+3.4}{2} = 3.2 \text{ A}$$

From the characteristics of 15 % slope, corresponding to $\frac{i_1 + i_2}{2}$ the out of balance current required is,

$$i_1 - i_2 = \text{Slope} \times \left(\frac{i_1 + i_2}{2}\right) = 0.15 \times 3.2 = 0.48 \text{ A}$$



Thus $i_1 - i_2$ must be more than 0.48 A i.e. above the line to operate the relay but actual point is located below the line in negative torque region.

Hence the relay will not operate.