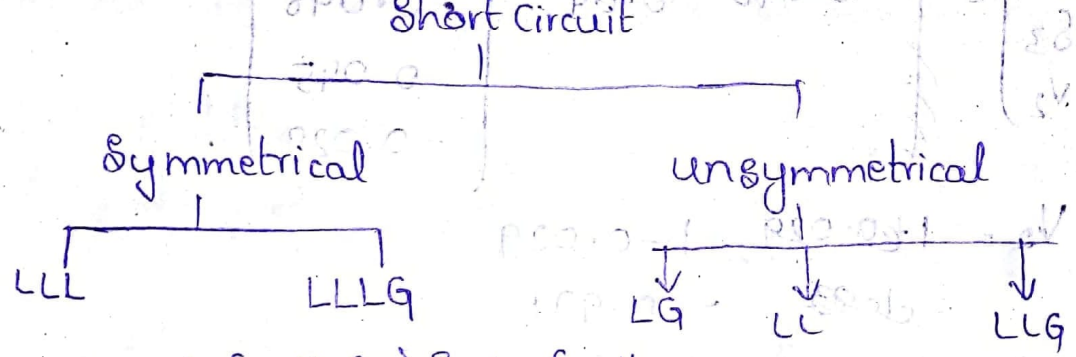
Unit-IV

Symmetrical fault analysis

A fault is defined as failure of insulation on conducting material and these are classified as two types

1) Open Circuit (Series)
2) Short Circuit (Shunt)

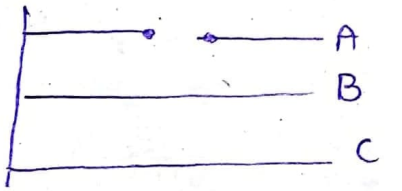


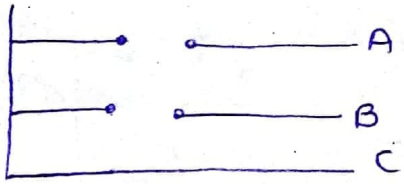


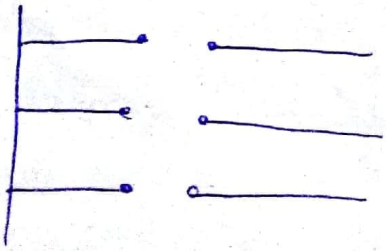
Open Circuit fault (or) Series fault:

* These are due to meeting of Conductor because of excessive Current flowing through the Same Conductor
* Due to excessive load Current we observe Some red hot in the line So that Conductor will open.

Ex:







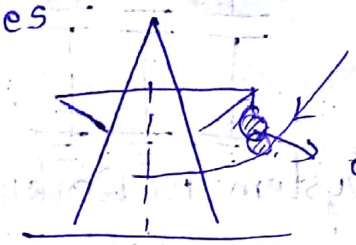
It is

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From fig (3) melting of Conductor all 3 phases will result the existing System will work at no load Conduction and the no load Voltage is same as rated Voltage Hence it is not treated as fault

Short Circuit or Shunt fault:-

The Short Circuit are due to failure of insulation between two Surfaces.



In Overhead transmission line the Short Circuit fault also takes place due to falling of the tree branches

An Short Circuit faults in 3-ϕ resultant as S.C current in phases which is more than a rated Current Hence it would be treated as a fault.

The faults like LLL and LLG are treated as Symmetrical faults

for the Symmetrical fault the fault current, all the phase Currents are equal with a phase displacement of 120°

The Occurance of Symmetrical faults are rear but it is most Severe imposes heavy duty on the Circuit breaker

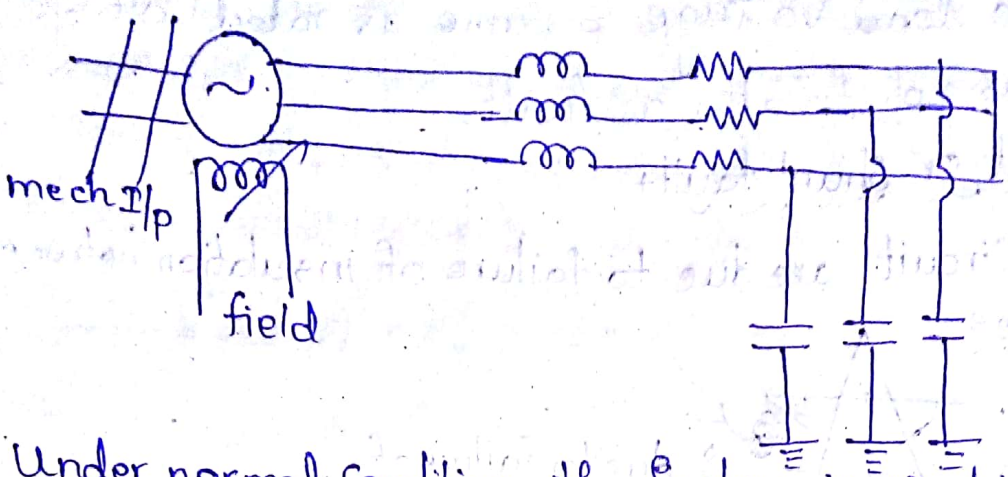
Transient due to S.C in the transmission line :-

Consider an equivalent Circuit of an 3-ϕ transmission line Under normal Condition at no load:

We know that each and every phase has its

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Own resistance and reactance and line to ground Capacitance.



Under normal condition the System is working at normal Values ie the net power

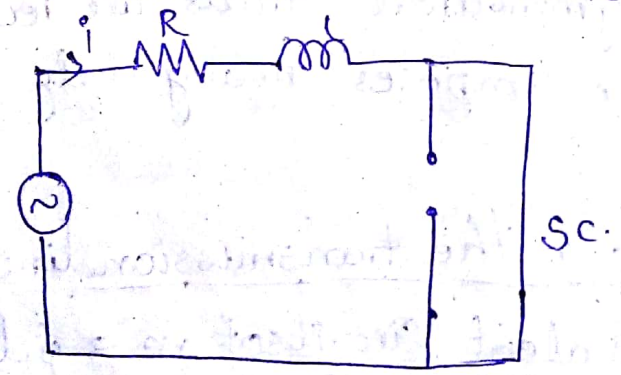
$P = P_S - P_e = 0$

P_S = short power

P_e = electrical power.

The normal condition Speed $N_r = N_S$

Assume there will be a 3-ϕ Symmetrical fault Occured on the System then immediatly the fault Current is flowing through all the 3 phases Under Short Circuited fault the impact of the Capacitance is neglected So the per phase equivalent Circuit under S.C Condition is represented as



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

where.

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where α is delay angle b/w '0' Cross Over point to the point at which fault occurs

$$V_m \sin(\omega t+\alpha) = iR + L\cdot\frac{di}{dt}$$

$$i = ic + ip$$

where ic is Complementary Solution (Source free Solution)

ip is particular Solution

ic: $iR + L\cdot\frac{di}{dt} = 0$

Let $D = \frac{d}{dt}$

$iR + LDi = 0$

$i(R+LD) = 0$

$i(D+R/L) = 0$

$D + \frac{R}{L} = 0$

$D = -\frac{R}{L}$

$\alpha = -\frac{R}{L}$

$ic = k\cdot e^{-\frac{R}{L}xt}$

$ic = k\cdot e^{-t/L/R}$

$ic = k\cdot e^{-t/\tau}$

ip: (force full response)

$iR + L\cdot\frac{di}{dt} = V_m \sin(\omega t+\alpha)$

Let $D = \frac{d}{dt}$

$iR + L\cdot D\cdot i = V_m \sin(\omega t+\alpha)$

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$$i\left(\frac{R}{L}+D\right) = \frac{V_m}{L}\left(\sin(\omega t+\alpha)\right)$$

$$= \frac{V_m}{L\left[\frac{R}{L}+D\right]}\sin(\omega t+\alpha) \qquad D^2 \longrightarrow -a^2$$

$$= \frac{V_m\left(D-\frac{R}{L}\right)}{L\left[D^2-\left(\frac{R}{L}\right)^2\right]}\sin(\omega t+\alpha)$$

$$i_p = \frac{V_m \cdot \frac{d}{dt}\left[\sin(\omega t+\alpha)\right] - \frac{R}{L}\left(\sin(\omega t+\alpha)\right)}{L\left[-\omega^2-\left(\frac{R}{L}\right)^2\right]}$$

$$i_p = \frac{V_m\left[\cos(\omega t+\alpha)\cdot\omega\right] - \frac{R}{L}\left[\sin(\omega t+\alpha)\right]}{-L\left[\omega^2+\left(\frac{R}{L}\right)^2\right]}$$

$$i_p = \frac{V_m}{L}\left[\frac{\frac{R}{L}\left(\sin(\omega t+\alpha) - \frac{L}{R}\cos(\omega t+\alpha)\omega\right]}{\omega^2+\left(\frac{R}{L}\right)^2}\right]$$

$$= \frac{V_m}{L^2}\left[\frac{R\left(\sin(\omega t+\alpha) - \frac{L}{R}\omega\cos(\omega t+\alpha)\right)}{\frac{\omega^2L^2+R^2}{L^2}}\right] \qquad X_L = \omega L$$

$$i_p = \frac{V_m}{X_L^2+R^2}\left[R\sin(\omega t+\alpha) - X_L\cos(\omega t+\alpha)\right]$$

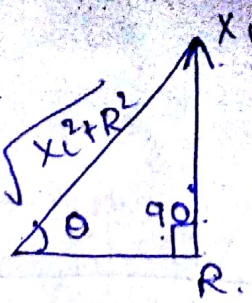
$$i_p = \frac{V_m\cdot\sqrt{X_L^2+R^2}}{\sqrt{X_L^2+R^2}\cdot\sqrt{X_L^2+R^2}}\left[\frac{R}{\sqrt{R^2+X_L^2}}\sin(\omega t+\alpha) - \frac{X_L}{\sqrt{R^2+X_L^2}}\cos(\omega t+\alpha)\right]$$

$$i_p = \frac{V_m}{\sqrt{X_L^2+R^2}}\left[\cos\theta\sin(\omega t+\alpha) - \sin\theta\cos(\omega t+\alpha)\right]$$

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Let $A=\omega t+\alpha$ $B=0$

$$i_p = \frac{V_m}{|Z|}\left[\sin(\omega t+\alpha-\phi)\right]$$



$$i = i_c + i_p$$

$$i = ke^{-t/\tau} + \frac{V_m}{|Z|}\sin(\omega t+\alpha-\phi)$$

$$i = ke^{-t/\tau} + \frac{V_m}{|Z|}\sin\left(\omega t+\alpha-\tan^{-1}\left[\frac{X_L}{R}\right]\right)$$

$$\tan\theta = \frac{X_L}{R} \qquad \cos\theta = \frac{R}{Z} \qquad \sin\theta = \frac{X_L}{Z}$$

To calculate the Constant Value consider the initial conditions $t=0$ the Current flowing through the Circuit is Zero

$t=0$, $i=0$

$$0 = ke^{-0/\tau} + \frac{V_m}{|Z|}\sin(\omega(0)+\alpha-\theta)$$

$$k = -\frac{V_m}{|Z|}\sin(0+\alpha-\theta)$$

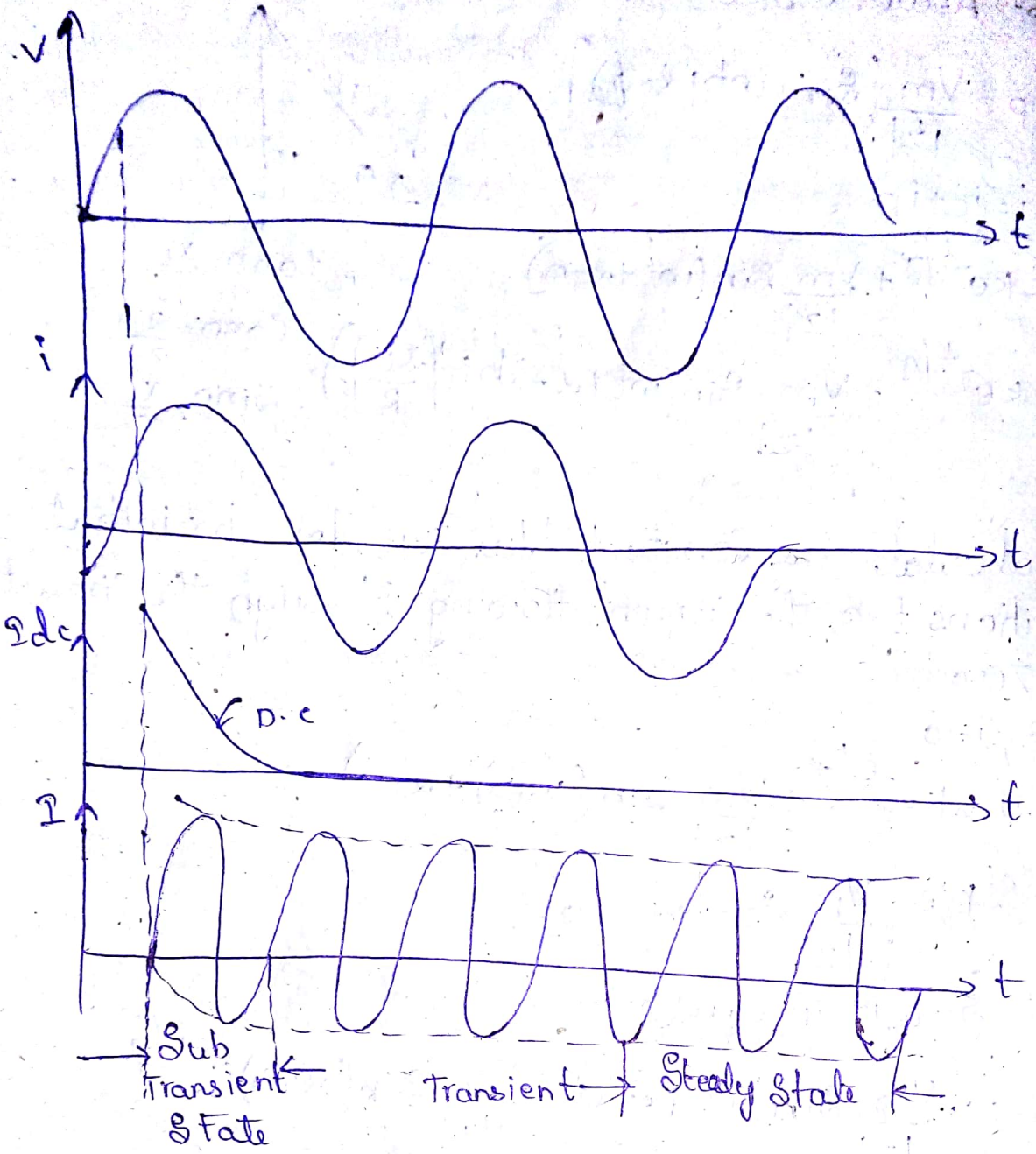
Sub k in eqn ①

$$i = \frac{V_m}{|Z|}\sin(\omega t+\alpha-\theta) - \frac{V_m}{|Z|}\sin(\alpha-\theta)e^{-t/\tau}$$

$$V_{rms} = \frac{V_m}{\sqrt{2}}$$

$$i = \frac{\sqrt{2}V}{|Z|}\left[\sin(\omega t+\alpha-\theta) - \sin(\alpha-\theta)e^{-t/\tau}\right]$$

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From eqn ① the 1st term Varies Sinusoidally with time and the Second term is non-periodic and decays exponential with a time constant of $\tau = L/R$

This non periodic term is Called as DC Component of the Current

From eqn ②

The maximum momentary current is given by

$$I(mm) = \frac{\sqrt{2}V}{|Z|} + \frac{\sqrt{2}V}{|Z|}$$

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This is called double effect

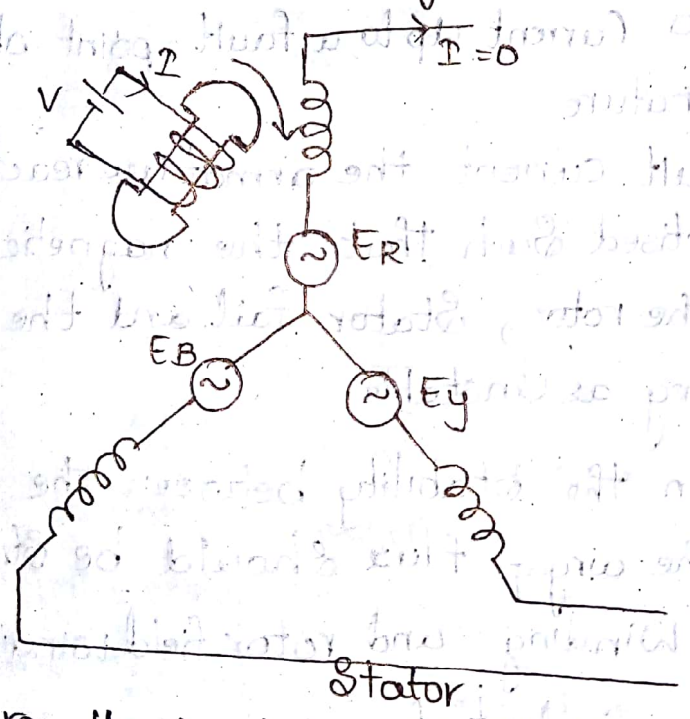
In a sinusoidal waveform the momentary carrying current is a double effect provided by fault should be taking place at zero cross Overpoint. The fault is more severe in magnitude if the fault taking place at zero cross over point

Short Circuit On Synchronous generator

Under normal condition at no load the synchronous generator can be represented as

A synchronous generator has armature winding on stator and the field winding on the rotor

Since the field winding is connected to the DC supply



The resultant rotating flux is able to produce the induced emf in stator winding and induce emf will be able to deliver current to load which will be lagging in nature

This current may influence the rotor flux which is called as armature reaction

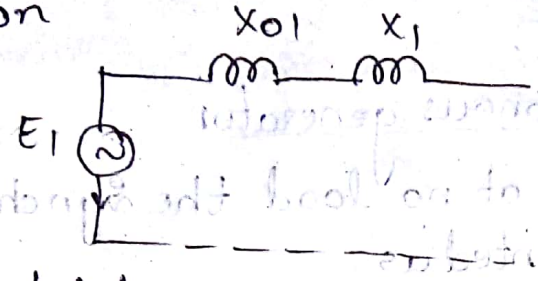
Due to armature reaction the demagnitat takes

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place due to inductive nature

So the Synchronous generator is represented electrically by leakage reactance (X_l) and armature reactance (X_a)

Equivalent Circuit of alternator at no load normal condition



So the total reactance is X_d or $X_s = X_a + X_l$.

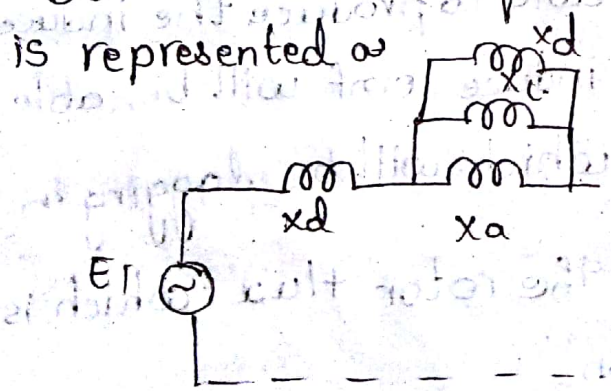
If a short circuit fault occured on alternator will result as the current delivered to load will be zero

But there will be a current up to a fault point which is purely inductive nature

Due to inductive fault current the armature reaction completely demagnetised such that the magnetic coupling between the rotor & Stator fail and the machine has becoming as unstable

In order to maintain the Stability between the Stator and rotor the airgap flux should be strengthen by using damper winding and rotor field winding

So the electrical equivalent of generator under s.c is represented as



X_d = damper winding

X_f = field winding

X_l - Leakage reactance

X_a = armature reactance

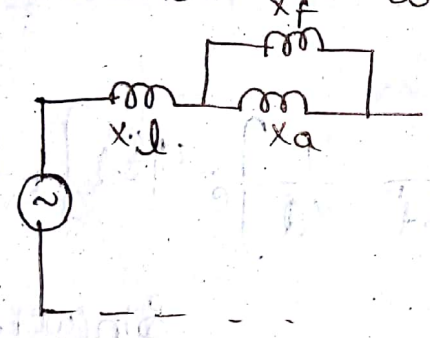
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From the Circuit $X_d'' = X_l + \frac{1}{\frac{1}{X_d} + \frac{1}{X_f} + \frac{1}{X_a}}$

where X_d'' - Sub-transient reactance.

The Counter induced emf is disappeared from the damper winding is mainly depends upon time Constant of alternator Such that the effect of damper winding is disappeared but the effect of field winding is Continued for a particular period

Now the reactance Under this Condition is known as transient reactance and electrical equivalent Circuit of alternator Under this Condition is



$$X_d' = X_l + \frac{1}{\frac{1}{X_f} + \frac{1}{X_a}}$$

X_d' = transient reactance

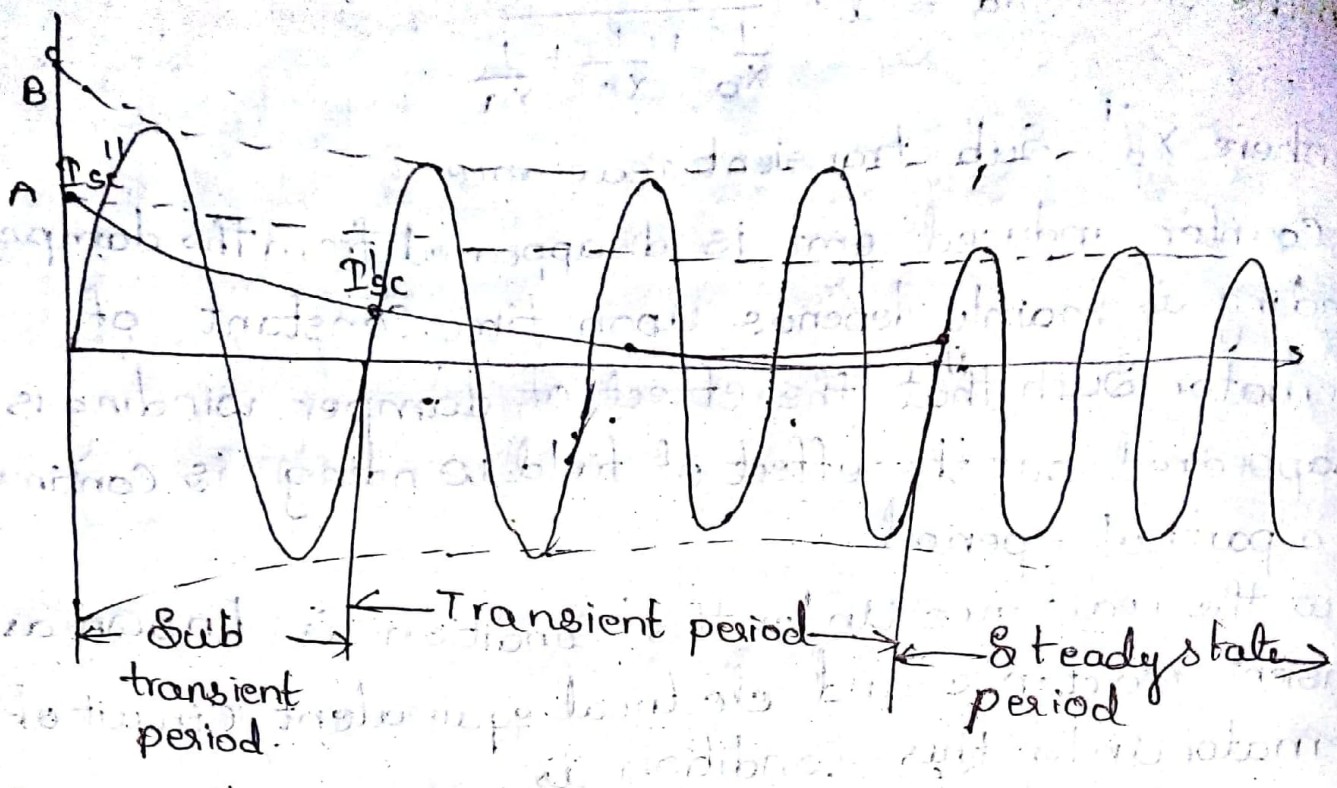
→ The Counter emf due to field winding may not existing for a longer period

→ Hence the alternator Should get into the Steadystate condition by isolating the fault with the help of relays and Circuit breaker

finally $X_d'' < X_d' < X_d$

$$I_{sc}'' > I_{sc}' > I_{sc}$$

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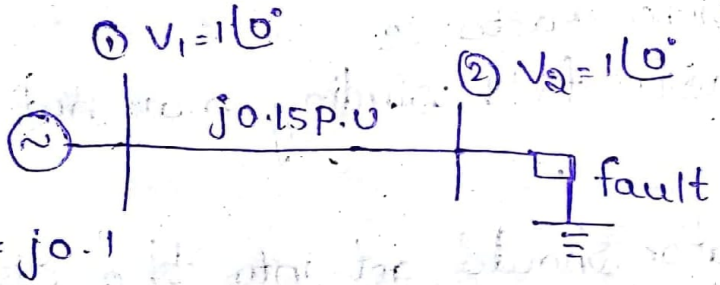


$$I_{sc} = I_{sc}'' + I_{sc}' + I_{sc}$$

$$= \sqrt{2}V\left[\frac{1}{x_d''} - \frac{1}{x_d'}\right]e^{-t/t_d''} + \left[\frac{1}{x_d'} - \frac{1}{x_d}\right]e^{-t/\left[t_d'\right]} + \frac{1}{x_d}\Bigg] \times$$

$$\sin(\omega t + \alpha - \theta)$$

Find the fault current in the following System.



$X_d'' = j0.1$
50 MVA
11 KV

Assumption:

1) System is on No load
2) All bus Voltages are 1.0 P.U.

Calculate the fault current at
1) Bolted fault
2) The fault reactance X = 0.05 P.U

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Initially 1) $Z_f = j0$ P.U (Bolted)

2) $Z_f = j0.05$ P.U

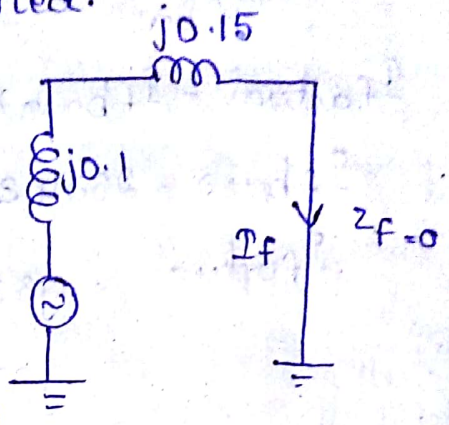
Sol: when $Z_f = j0$ P.U at Bolted condition at the fault Condition $V_2 = 0$ Since it is Shorted.

fault Current $I_f = \frac{V}{Z}$

$$I_f = \frac{V}{X}$$

$$= \frac{1.0}{j0.1 + j0.15}$$

$$I_f = \frac{1.0}{j0.25} = -j4 \text{ P.U}$$



The fault Current

$$I_{f\,p.u} = \frac{I_{f\,actual}}{I_{f\,base}}$$

$$I_{f\,actual} = I_{f\,p.u} \times I_{f\,base}$$

$$I_{f\,base} = \frac{S_{base}}{V_{base}}$$

$$= \frac{50 \times 10^6}{\sqrt{3} \times 11 \times 10^3}$$

$$I_{f\,base} = 2624.3 \text{ A}$$

$$I_{f\,actual} = -j4 \times 2624.3$$

$$= -j10497.2 \text{ A}$$

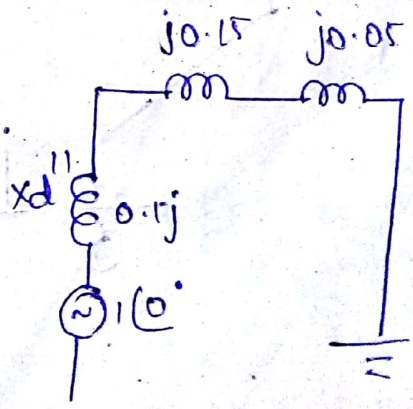
$$= -j10.51 \text{ kA}$$

when $Z_f = j0.05$ P.U

fault Current $I_f = \frac{V}{Z}$

$$= \frac{V}{X}$$

$$= \frac{1.0}{j0.1 + j0.15 + j0.05}$$



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$$I_f = \frac{1}{j0.25 \| j0.05} = \frac{1}{j0.3} = -j3.33 \text{ P.U}$$

$$I_{f\,p.u} = \frac{I_{factual}}{I_{fbase}}$$

$$I_{factual} = I_{fbase} \times I_{f\,p.u}$$

$$I_{f.base} = 2624.3 \text{ A}$$

$$I_{factual} = -j3.33 \times 2624.3$$

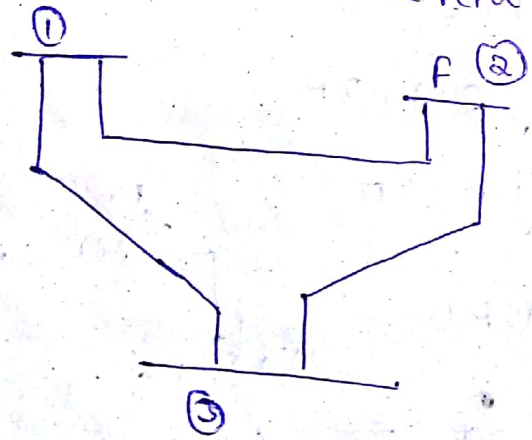
$$= -j8738.9 \text{ A}$$

$$= j\,8738.91 \angle -90^\circ$$

The z-Bus of the 3-bus System is given as

$$Z_{BUS} = \begin{bmatrix} j0.16 & j0.08 & j0.12 \\ j0.08 & j0.24 & j0.16 \\ j0.12 & j0.16 & j0.34 \end{bmatrix}$$

The pre fault Voltages is 1.0 P.U the System Was Unload before the fault A 3-ϕ fault Occures at bus-2. the post fault Voltage at buses ③ and ① in P.U Calculate the P.U fault Current Values at bus ① & ②



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	V_1	V_2	V_3
Prefault	$V_1^1 = 1.0$	$V_2^1 = 1.0$	$V_3^1 = 1.0$
During fault	V_1^2	$V_2^2 = 0$	V_3^2
post fault	V_1^3	V_2^3	V_3^3

Post $V_1^3 = V_1^1 - V_1^2$

$V_2^3 = V_2^1 - V_2^2$

$V_3^3 = V_3^1 - V_3^2$

$V_1^2 = I_f \times Z_{12}$

$V_3^2 = I_f \times Z_{32}$

$$I_f = \frac{V}{X_{22}} = \frac{V}{Z_{22}} = \frac{1}{j0.24} = -j4.16 \text{ P.U}$$

$V_1^2 = -j4.16 \times j0.08$

$= 0.33$

$V_3^2 = I_f \times Z_{32} \Rightarrow -j4.16 \times j0.16 = 0.66$ P.U

$V_1^3 = V_1^1 - V_1^2 \Rightarrow 1 - 0.33 = 0.67$ P.U

$V_3^3 = V_3^1 - V_3^2 = 1 - 0.66 = 0.34$ P.U

Bus ① fault current

$$I_f = \frac{V_2^1}{Z_{11}} = \frac{0.33}{j0.16} = -j2.06 \text{ P.U}$$

Bus ③

$$I_f = \frac{V}{Z_{33}} = \frac{0.66}{j0.34} = -j1.94 \text{ P.U}$$

$\Rightarrow$ ③

The bus impedance matrix of a 4 bus is given by

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$$Z_{Bus} = \begin{bmatrix} j0.15 & j0.08 & j0.04 & j0.07 \\ j0.08 & j0.15 & j0.06 & j0.09 \\ j0.04 & j0.06 & j0.13 & j0.05 \\ j0.07 & j0.09 & j0.05 & j0.12 \end{bmatrix}$$

The prefault Voltages are at bus ① 1.0 P.U A 3-ϕ se fault occured at ④ Calculate post fault Voltages

The fault current $I_f = \frac{V}{X_{44}} = \frac{1}{j0.12} = -j8.3$

During the fault

Bus ① $V_1^2 = I_f \times Z_{14}$

$= -j8.3 \times 0.07j = 0.58$ P.U

Bus ③ $V_3^2 = I_f \times Z_{34}$

$= -j8.3 \times j0.05 = 0.415$ P.U

Bus ② $V_2^2 = I_f \times Z_{24}$

$= -j8.3 \times j0.09 = 0.74$ P.U

Bus ④ $V_4^2 = 0$ at fault

Post fault Voltages

Bus ① $V_1^3 = V_1' - V_1^2 = 1 - 0.58 = 0.42$ P.U

Bus ② $V_2^3 = V_2' - V_2^2 = 1 - 0.74 = 0.26$ P.U

Bus ③ $V_3^3 = V_3' - V_3^2 = 1 - 0.41 = 0.59$ P.U

Bus ④ $V_4^3 = V_4' - V_4^2 = 1 - 0 = 1$ P.U

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Calculate the Sub transient currents at the bus ④

$$I_{f1} = \frac{V_1^2}{Z_{11}} = \frac{0.58}{j0.15} = -j3.86$$

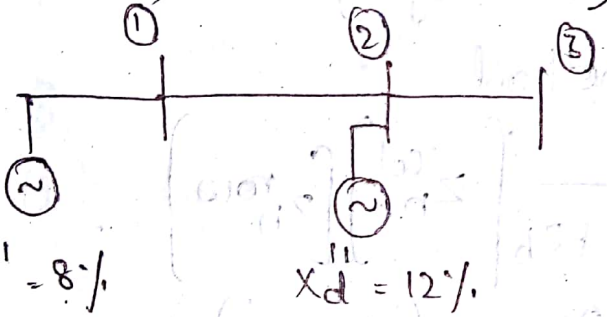
$$I_{f2} = \frac{V_2^2}{Z_{22}} = \frac{0.74}{j0.15} = -j4.93$$

$$I_{f3} = \frac{V_3^2}{Z_{33}} = \frac{0.41}{j0.13} = -j3.15$$

$$I_{f4} = \frac{V_4^2}{Z_{44}} = \frac{1.0}{j0.12} = -j8.33$$

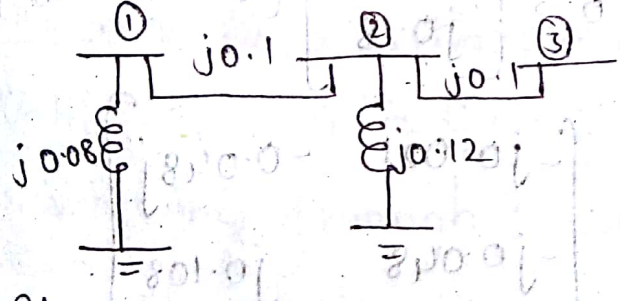
④ Determine the fault currents if 3-ϕ bolted fault occures at a) Bus ③
b) Bus ②
c) Bus ③

Assumptions
1) No load.
2) $V_i = 1.0\angle 0^\circ$

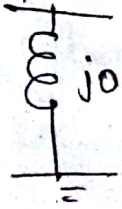


$x_d'' = 8\%$ $x_d'' = 12\%$

Calculation of Z-bus



Step ①

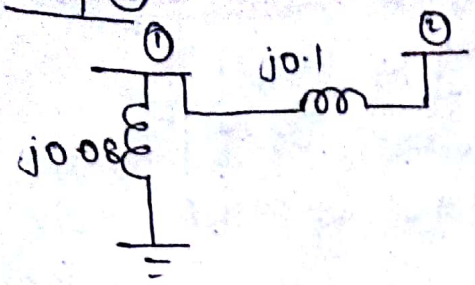


type ①

$Z_{BUS} = [0.08j]$

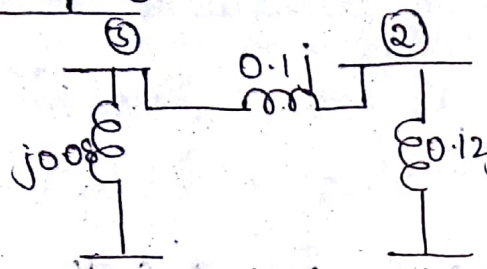
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Step ②



$$Z_{BUS} = \begin{bmatrix} j0.08 & j0.08 \\ j0.08 & j0.18 \end{bmatrix} \begin{matrix} Z_{1j} = Z_{12} \\ Z_{jj} + Z_b \\ Z_{11} + Z_b \end{matrix}$$

Step+③



$$Z_{BUS} = \left[\begin{array}{cc|c} j0.08 & j0.08 & Z_{12} \\ j0.08 & j0.18 & Z_{22} \\ \hline Z_{11} & Z_{22} & Z_{jj} + Z_b \\ & & Z_{22} + Z_b \end{array}\right]$$

$$= \left[\begin{array}{cc|c} j0.08 & j0.08 & j0.08 \\ j0.08 & j0.18 & j0.18 \\ \hline j0.08 & j0.18 & 0.3j \end{array}\right]$$

By kron's reduction method

$$Z_{BUS}^{New} = Z_{Bus}^{old} - \frac{1}{Z_{jj} + Z_b} \begin{bmatrix} Z_n^{col} \end{bmatrix} \begin{bmatrix} Z_n^{row} \end{bmatrix}$$

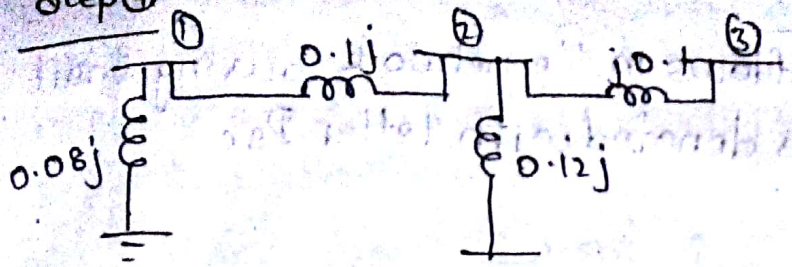
$$= \begin{bmatrix} j0.08 & j0.08 \\ 0.08j & 0.18j \end{bmatrix} - \frac{1}{0.3} \begin{bmatrix} -j0.08 \\ j0.18 \end{bmatrix} \begin{bmatrix} j0.08 & 0.18j \end{bmatrix}$$

$$= \begin{bmatrix} j0.08 & j0.08 \\ j0.08 & j0.18 \end{bmatrix} + \begin{bmatrix} -j0.021 & -0.048j \\ -j0.048 & -j0.108 \end{bmatrix}$$

$$Z_{BUS}^{New} = \begin{bmatrix} j0.0587 & j0.032 \\ j0.032 & j0.072 \end{bmatrix}$$

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Step④



$$Z_{BUS} = \left[\begin{array}{cc|c} j0.0587 & j0.032 & j0.032 \\ j0.032 & j0.072 & j0.072 \\ \hline j0.032 & j0.072 & j0.172 \end{array}\right]$$

Bus ③ at fault

$$I_{f3} = \frac{V}{Z_{33}} = \frac{1.0}{j0.172} = -j5.81 \text{ P.U}$$

Bus ②

$$I_{f2} = \frac{V}{Z_{22}} = \frac{1}{j0.072} = -j13.88 \text{ P.U}$$

Bus ①

$$I_{f1} = \frac{V}{Z_{11}} = \frac{1.0}{j0.0587} = -j17.03$$

percentage reactance

It is defined as the percentage of total phase. Voltage drop in the circuit when full load current is flowing through it it is denoted with (%x)

$$\%X = \frac{IX}{V} \times 100 \quad -①$$

where

I = full load current

V = phase Voltage

X = reactance in Ω per phase.

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Short Circuit Current (I_{sc})

It is a current which flows in the network during short circuit condition. It is denoted with letter I_{sc}.

$$I_{sc} = \frac{V}{X} \quad -(2)$$

From eqn (1)

$$X = \frac{\%.XV}{I \times 100}$$

$$I_{sc} = \frac{V}{\frac{\%.XV}{I \times 100}} = \frac{V.I \times 100}{\%.XV}$$

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

Percentage reactance interms of MVA

$$\%.X = X_{old} \times \frac{MVA_{New}}{MVA_{old}} \times \left[\frac{KV_{old}}{KV_{new}}\right]^2$$

If x is in ohms

$$\%.X = X_{actual} \times \frac{MVA}{(KV)^2}$$

Short Circuit MVA

It is defined as the product of normal System and Short Circuit current at the point of fault

Short Circuit MVA $= 3VI_{sc}$

$$= 3 \times V \times \frac{I}{\%.X} \times 100.$$

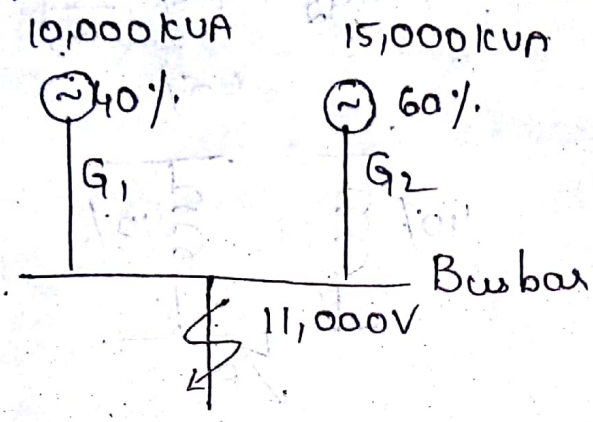
$$S.C\ MVA = Base\ MVA \times \frac{100}{\%.X}$$

$$S.C\ KVA = Base\ KVA \times \frac{100}{\%.X}$$

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Consider the System shown in the fig the % reactance of each alternator is expressed on its own capacitor. Determine the s.c current that will flow into a dead 3-ϕ s.c at F

Solr Short circuit Current $I_{sc} = \frac{I}{\%X} \times 100$.



Base KVA = 25000KVA

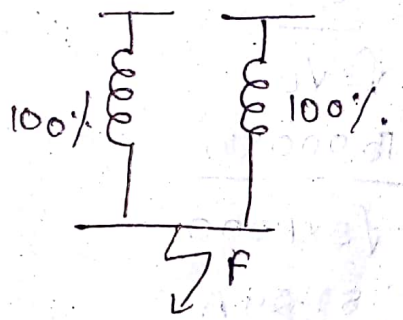
10,000 + 15,000 = 25,000 KVA

$\%X_{G_1} = 40 \times \frac{25}{10} \times \left(\frac{11}{1}\right)^2$

$= 100\%$

$\%X_{G_2} = 60 \times \left(\frac{25}{15}\right) \times \left(\frac{11}{11}\right)^2$

$= 100\%$



$\%X = \frac{100 \times 100}{100+100} = 50\%$

$I_{sc} = \frac{I}{\%X}$

$I = \frac{S}{\sqrt{3}V_L}$

$S = \sqrt{3}V_L I_L$

$= \frac{25000 \times 10^3}{\sqrt{3} \times 11000}$

$I_{sc} = \frac{1312.1}{50} \times 100$

$I_{sc} = 2624.2A$

(or)

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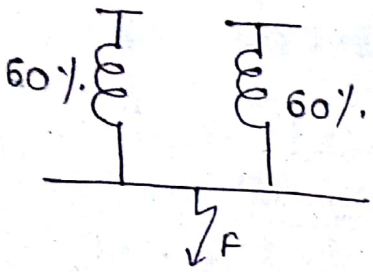
Base KVA = 15,000 KVA

$\%XG_1 = 40 \times \frac{15}{10} \times \left(\frac{11}{11}\right)^2$

$= 60\%$

$\%XG_2 = 60 \times \left(\frac{15}{15}\right) \times \left(\frac{11}{11}\right)^2$

$= 60\%$



$\%X = \frac{60 \times 60}{60+60} = 30\%$

$I_{SC} = \frac{I}{\%X}$

$I = \frac{S}{\sqrt{3}V_L}$

$= \frac{15,000 \times 10^3}{\sqrt{3} \times 11000}$

$= 787.29\ A$

$I_{SC} = \frac{787.29}{60} \times 100$

$I_{SC} = 2624.3\ A$

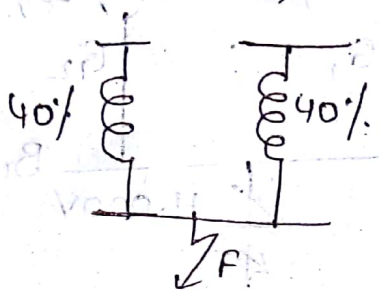
Base KVA = 10,000 KVA

$\%XG_1 = 40 \times \left(\frac{10}{10}\right) \times \left(\frac{11}{11}\right)^2$

$\%XG_1 = 40\%$

$\%XG_2 = 60 \times \left(\frac{10}{15}\right) \times \left(\frac{11}{11}\right)^2$

$= 40\%$



$\%X = \frac{40 \times 40}{40+40} = 20\%$

$I_{SC} = \frac{I}{\%X}$

$I = \frac{S}{\sqrt{3}V_L}$

$= \frac{10,000 \times 10^3}{\sqrt{3} \times 11000}$

$I_{SC} = \frac{524.86}{20} \times 100$

$I_{SC} = 2624.3\ A$

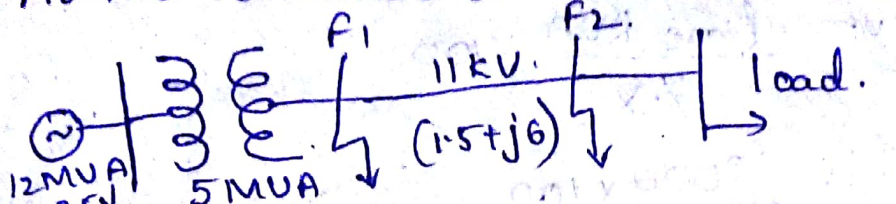
A 3-ϕ line Operating at 11 KV & resistance of 1.5 Ω and reactance of 6 Ω. is connected to a generating Station. through a 5 MVA Step up transforma. having a reactance of 5%. The bus bars are Supplied by a 12 MVA generator having 25% reactance. Calculate the S.C MVA KVA fed

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into a Symmetrical fault.

1) At load end of transformer.

2) At H.V terminals of the transformer.



consider the base MVA KVA = 12MVA

$= 12 \times 10^3$ KVA

= 12000 KVA

$$\%X_G = 25\% \left[\frac{MVA(new)}{MVA(old)}\right]\left[\frac{KVA(old)}{KVA(new)}\right]$$

$$\%X_G = 25 \times \left[\frac{2000}{12000}\right] \times (1)^2 = 25\%$$

$$\%X_T = X_{actual} \times \left(\frac{MVA_N}{MVA_0}\right) \times \left(\frac{KV_0}{KV_N}\right)^2$$

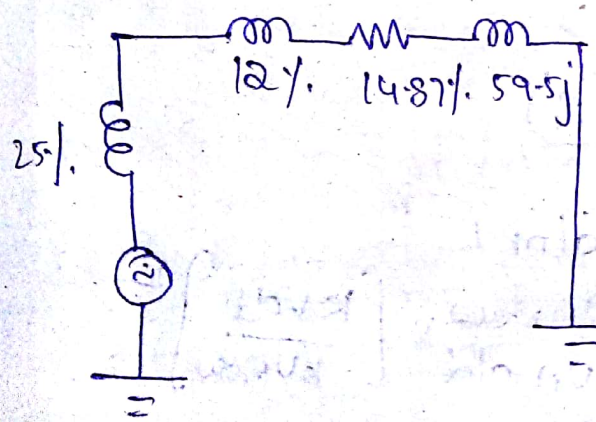
$$= 5 \times \frac{12}{5} \times (1)^2$$

$$\%X_T = 12\%$$

$$\%X_l = X_{actual} \times \frac{(MVA)}{(KV)^2}$$

$$= 6 \times \frac{12}{(11)^2} = 59.5\%$$

$$\%R_l = 1.5 \times \frac{12}{(11)^2} = 14.876\%$$



$\%X = 12 + 25 + 59.5$ ... (1)

$\%X = 96.5\%$

$\%R = 14.87\%$

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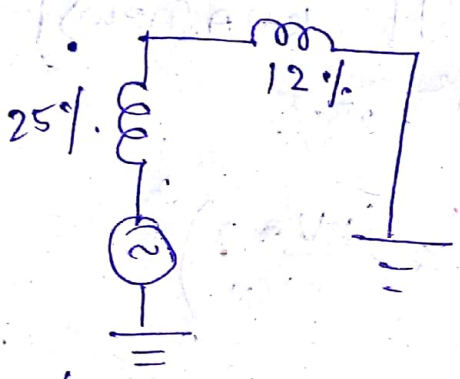
$$\%Z = \sqrt{R^2 + (X_L)^2} = \sqrt{(14.87)^2 + (96.5)^2} = 97.6\%$$

$$S.C\ MVA = \frac{\text{Base KVA}}{\%X} \times 100$$

$$= \frac{12000}{97.6} \times 100$$

$$= 12295.0$$

ii) fault at H.V Side



$$\%X = 25 + 12 = 37$$

$$S.C\ MVA = \frac{12000}{37} \times 100$$

$$S.C\ MVA = 32432.43\ MVA$$

Sol: Base KVA = 15000

$$S.C\ MVA = \frac{\text{Base MVA}}{\%X} \times 100$$

(i) fault at L.V Side (i.e at F_1)

% reactance at Generator)

$$\%X_{G_1} = X_{PU\ old} \times \frac{MVA_{New}}{MVA_{old}} \times \left[\frac{KV_{old}}{KV_{New}}\right]^2$$

$$= 15 \times \left(\frac{15}{15}\right) = 15\%$$

$$\%X_{G_2} = 15\%$$

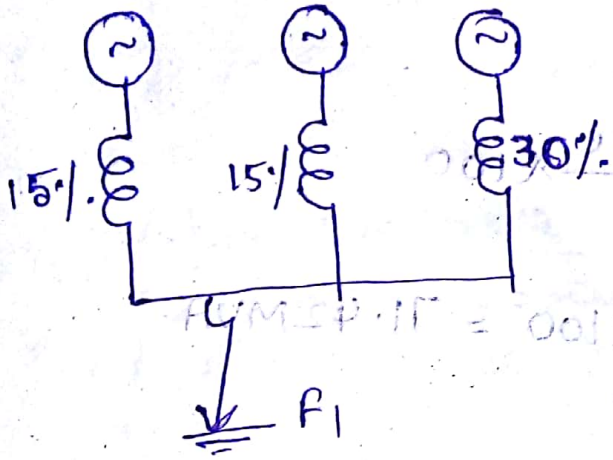
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$\%.X_{G3} = 20 \times \frac{15}{10} \times 1$

$\%.X_{G3} = 30\%.$

$\%.X_T = 6 \times \frac{15}{6} \times 1$

$\%.X_T = 15\%.$



$\%.X_{Total} = \frac{1}{\frac{1}{15} + \frac{1}{15} + \frac{1}{30}}$

$= \frac{1}{\frac{2+2+1}{30}} = \frac{1}{\frac{5}{30}}$

$\%.X\ Total = 6$

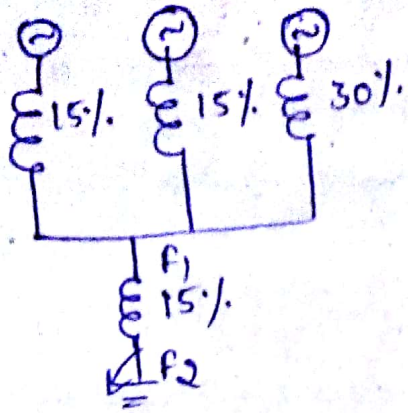
$S.C\ MVA = \frac{Base\ MVA \times 100}{\%.X}$

$= \frac{15}{6} \times 100$

$= 250\ MVA$

fault at HV Side (i.e at f2)

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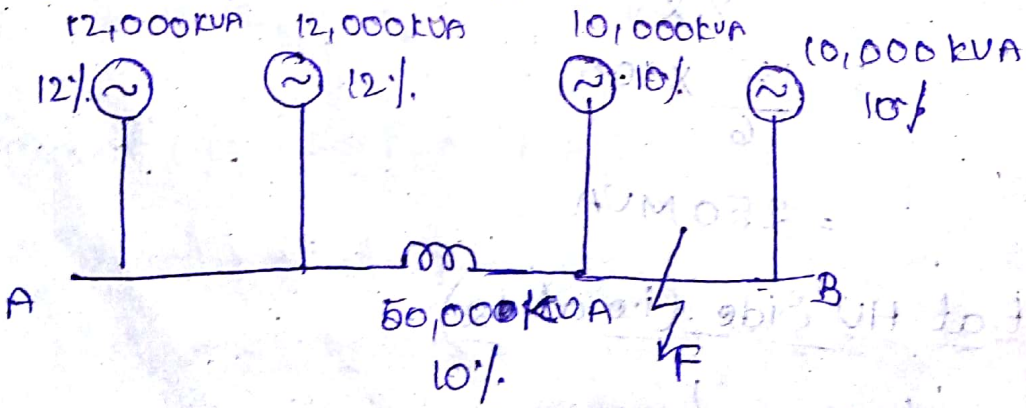
$\%X_{Total} = 6\% + 15\%$

$= 21\%$

$S.C\ MVA = \frac{MVA\ base}{\%X} \times 100$

$= \frac{15}{21} \times 100 = 71.42\ MVA$

There are two generators at bus bar A each rated at 12,000 KVA, 12% reactance or another bus B, two more generators rated at 10,000 KVA with 10% reactance are connected. The two bus bars are connected through a reactor rated at 5000 KVA with 10% reactance. If a dead short circuit occurs between all the phases on bus bar B, what is the S.C MVA fed in to the fault.



Sol: Let base MVA = 12 MVA

% Reactance $X_{G1} = 12 \times \frac{12}{12} = 12\%$

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$\%X_{G2} = 12 \times \frac{12}{12} = 12\%$

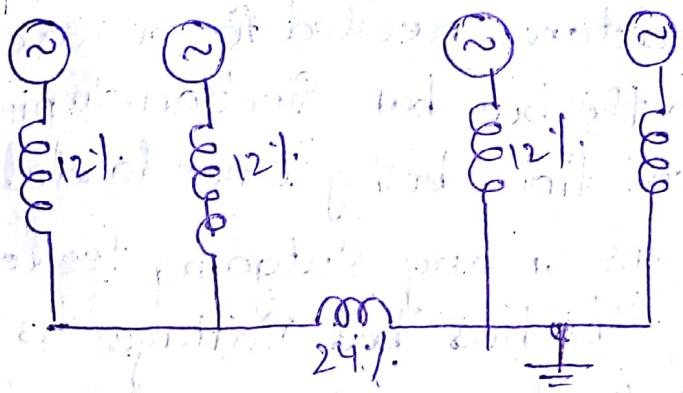
$\%X_{G3} = 10 \times \frac{12}{10} = 12\%$

$\%X_{G4} = 10 \times \frac{12}{10} = 12\%$



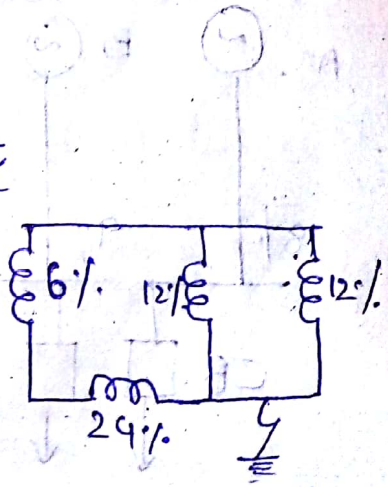
$\%$ Reactance $= \frac{10 \times 12}{5} = 24\%$

The equivalent reactance diagram:



$\%X$ Total $= \frac{1}{\frac{1}{12} + \frac{1}{12} + \frac{1}{12}}$

$= \frac{1}{\frac{3}{12}} = 6$



$\%X$ Total $= 6 + 24 = 30\%$

$30 \| 12 = \frac{30 \times 12}{30 + 12} = 8.5$

$8.5 \| 12 = \frac{8.5 \times 12}{12 + 8.5} = 4.9\% = 5\%$

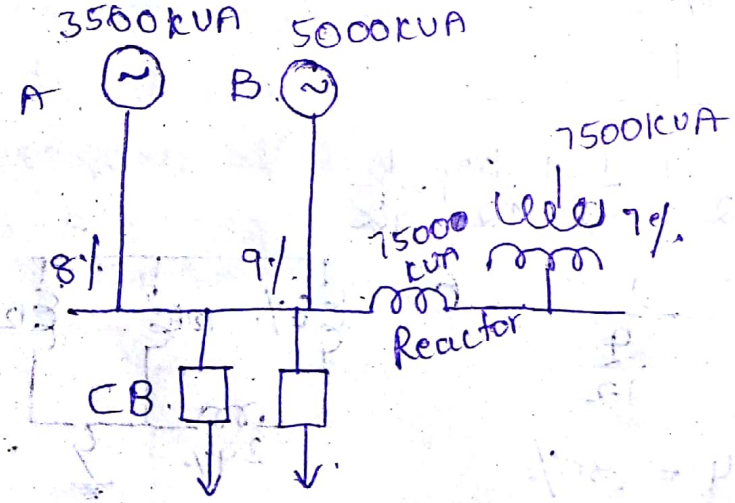
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Fault MVA = $\frac{MVA_{base}}{\%X} \times 100$

$= \frac{12}{5} \times 100$

$= 240$ MVA.

A powerplant has two generating Units rated 3500KVA and 5000KVA with percentage reactances 8% and 9% respectively. The Circuit breakers have breaking Capacity of 175MVA. It is planned to extend the System by Connecting it to the grid through a transformer rated at 7500KVA and 7% reactance. Calculate the reactance needed for a reactor to be connected in the bus-bar Section to prevent the Circuit breaker from being Over loaded if a Short Circuit Occurs on any Outgoing feeder Connected to it. The bus bar Voltage is 3.3 KV



Sol: The base Value is 7,500 KVA

$\%X_{G1} = X_{actual\ P.U.} \times \frac{MVA_{new}}{MVA_{old}}$

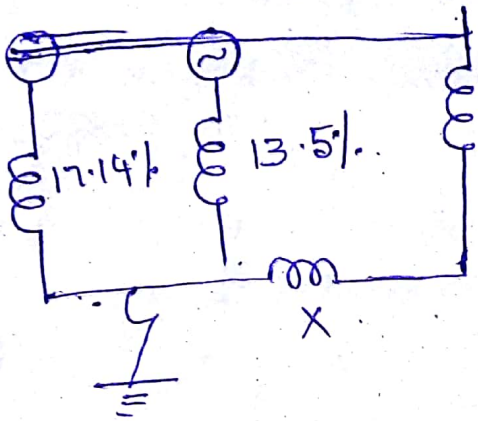
$= 8 \times \frac{7.5}{3.5} = 17.14\%$.

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$\% X_{G_2} = 9 \times \frac{7.5}{5}$

$= 13.5\%$

$\% X_T = 7 \times \frac{7.5}{7.5} = 7\%$



17.14 and 13.5% are in parallel

$= \frac{17.14 \times 13.5}{17.14 + 13.5} = 7.55$

X and 7% are in Series

$= X + 7\%$

7.55 and X+7% are in parallel

$\% X_{Total} = \frac{(7.55)(X+7)}{X + 14.55}$

$= \frac{7.55X + 52.85}{X + 14.55}$

$B.C\,MVA = \frac{Base\ MVA}{\% X} \times 100$

$175 = \frac{7.5 \times 100}{(7.55)(X+7)} \times (X + 14.55)$

$175 = \frac{750(X+14.55)}{7.55X + 52.85}$

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$$175(7.55X + 52.85) = 750X + 10912.5$$

$$1321.25X + 9248.75 = 750X + 10912.5$$

$$571.25X = 1663.75$$

$$X = 2.91\%$$

$$\%X = X_\Omega \frac{MVA}{(KV)^2}$$

$$2.9 = X_\Omega \times \frac{7.5}{(3.3)^2}$$

$$X_\Omega = \frac{2.9 \times (3.3)^2}{7.5}$$

$$X_\Omega = 4.2\ \Omega$$

The short circuit MVA at the bus bar for a power plant A is 1200MVA and for another plant B is 1000MVA at 33KV. If these two are to be interconnected by a tie line with reactance 1.2ohms. Determine the possible short circuit MVA at both the plants

Sol: Let $S.C\ MVA = \frac{Base\ MVA}{\%X} \times 100$.

Let base MVA = 100

For plant 1 $\%X_{G1} = \frac{Base\ MVA}{S.C\ MVA} \times 100$

$$= \frac{100}{1200} \times 100 = 8.33\%$$

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For plant 2.

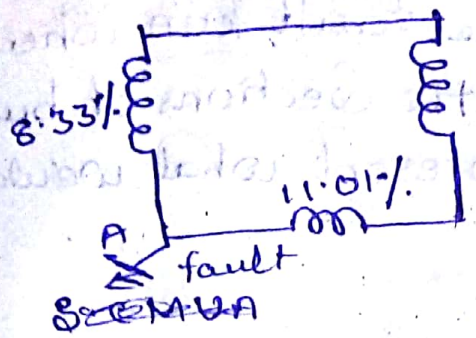
For Generator 2.

$$\%X_{g_2} = \frac{100}{1000} \times 100 = 10\%$$

$$\%X = X_{actual} \times \frac{MUA}{(KU)^2}$$

$$\%X = 1.2 \times \frac{100}{(33)^2} \times 100.$$

$$\%X = 11.01\%$$



S.C MVA

$$\%X = 8.33 // (21.01)$$

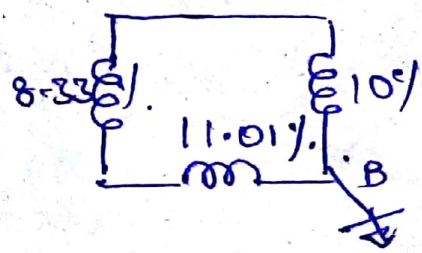
$$= \frac{8.33 \times 21.01}{8.33 + 21.01} = 5.96$$

$$S.C\ MVA = \frac{Base\ MVA}{\%X} \times 100$$

$$S.C\ MVA = \frac{100}{5.96} \times 100$$

$$S.C\ MVA = 1677.8$$

Fault Occurs at plant B:



$$= 19.34 // 10\%$$

$$= \frac{19.34 \times 10}{19.34 + 10} = 6.59.$$

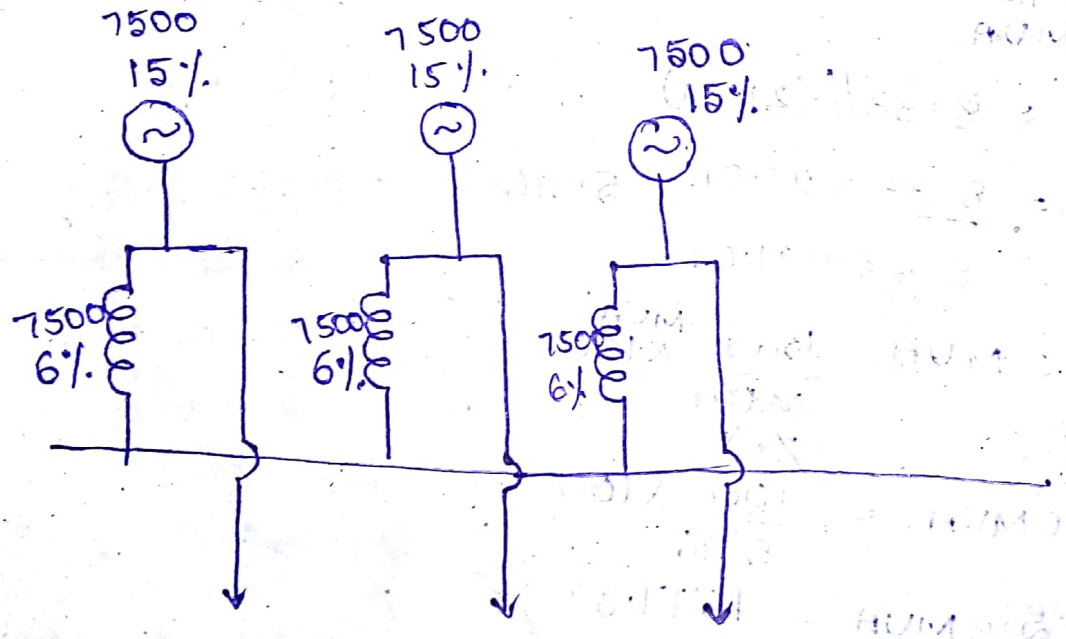
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$$S.C\ MVA = \frac{\text{Base MVA}}{\%x} \times 100$$

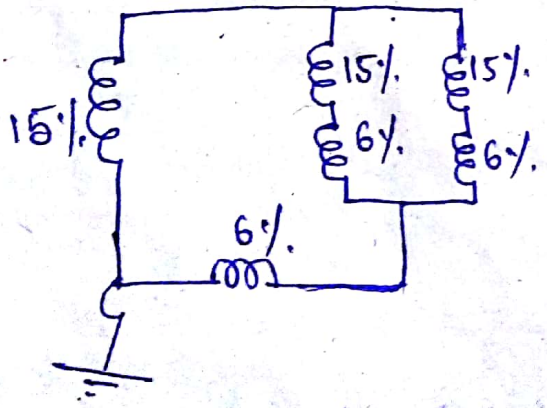
$$= \frac{100}{6.59} \times 100$$

$$S.C\ MVA = 1517.45\ MVA$$

A power plant has 3 generating units each rated at 7500 KVA with 15% reactance. The plant is protected by tie bar System with a reactances rated at 7500 MVA and 6%. Determine the fault KVA when Short Circuit Occurs On One of the Sections of bus bar. If the reactors were not present what would be the fault KVA.



Equivalent Circuit Reactance diagram.



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15.

15+6 = 21%

21% || 21%

$= \frac{21 \times 21}{21+21} = 10.5$

= 10.5 in Series with 6%.

16.5%

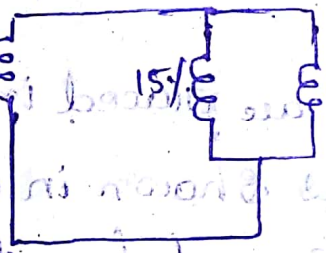
16.5% || 15%

$= \frac{16.5 \times 15}{16.5+15} = 7.85$

$S.C\ kVA = \frac{7500}{7.85} \times 100$

= 95.46 MVA

Case-2



$\%X_T = \frac{15 \times 15}{15+15} = 7.5$

7.5 || 15%

$\%X_T = \frac{7.5 \times 15}{7.5+15} = 5\%$

$S.C\ MVA = \frac{Base\ MVA}{\%X_T} \times 100$

$= \frac{7500}{5} \times 100 = 150000\ kVA$

$= 150\ MVA$

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Construction of reactors

Whenever a fault occurs in power system, large currents will flows in the network. especially if the fault is dead short circuit at the terminals the fault currents will damage the power system equipment

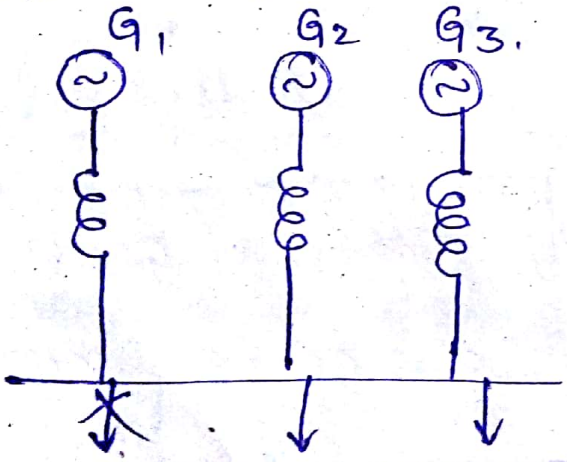
2) To limit the large currents under these circumstances the current limiting reactors are used

3) Based on the location of reactors, these are classified as

1) Generator reactors
2) feeder reactors
3) Busbar reactors
   1. Ring system
   2. Tie line system.

Generator reactors

In this reactors the reactors are placed in series with each of the generators as shown in below. Due to these reactors. the fault current from the generator is limited.



Disadvantages

1) whenever the fault occur at the feeder it may

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causes changes in the Voltages at remaining healthy feeders and also may loose Synchronism.

2) There is a Constant Voltage drop in the reactors and also power looses occur even during normal operation of the network.

feeder reactor

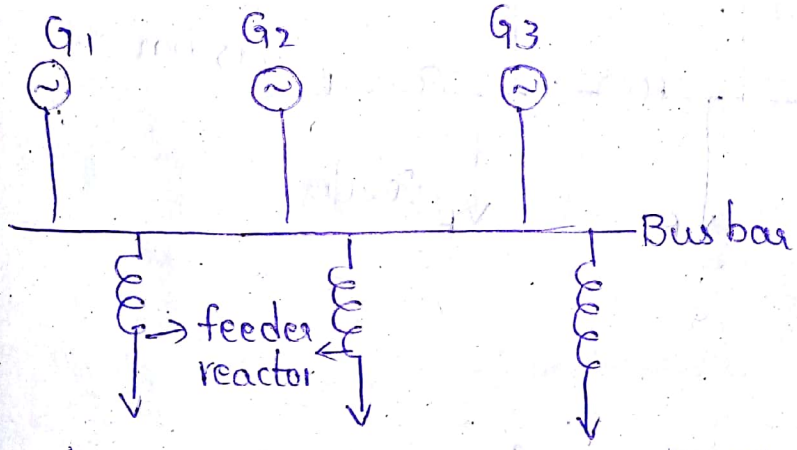
In this method the protection of each feeder is equipped with a Series reactor.

The event of fault on any feeder the fault current drawn is restricted by the reactor.

Disadvantages

1) The Voltage drop and power loss still occurs in the reactor by a feeder fault.

2) The feeder reactor donot offer any protection for bus bar faults



3) bus bar reactors

In the both above methods the reactor carries full load current under normal operation which offers the constant Voltage drops and the power losses occured in the reactor.

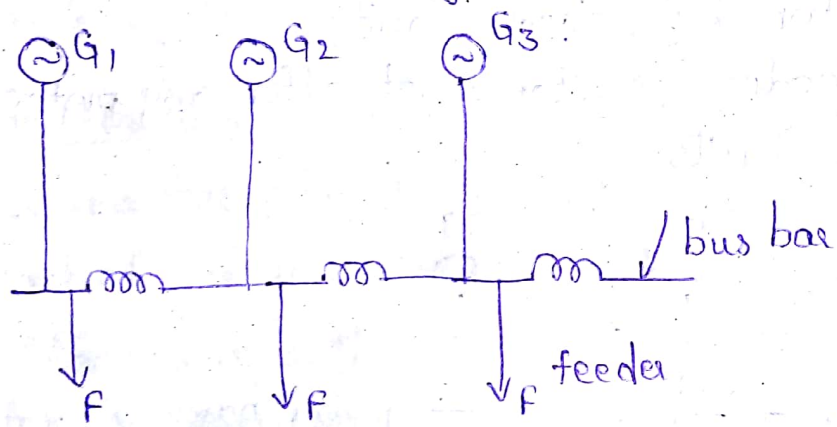
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To avoid these paper losses and voltage drops by dividing the busbars into sections and interconnect the sections through protective reactors.

There are 2 ways of doing this.

1. Ring System :- In this method each feeder is fed by one generator so very little power flows across the reactors during normal operation. Hence the voltage drop and power losses are negligible.

If a fault occurs on any feeder only the generator to which feeder is connected will feed the fault current and rest of the generators are required to feed the fault through reactors.

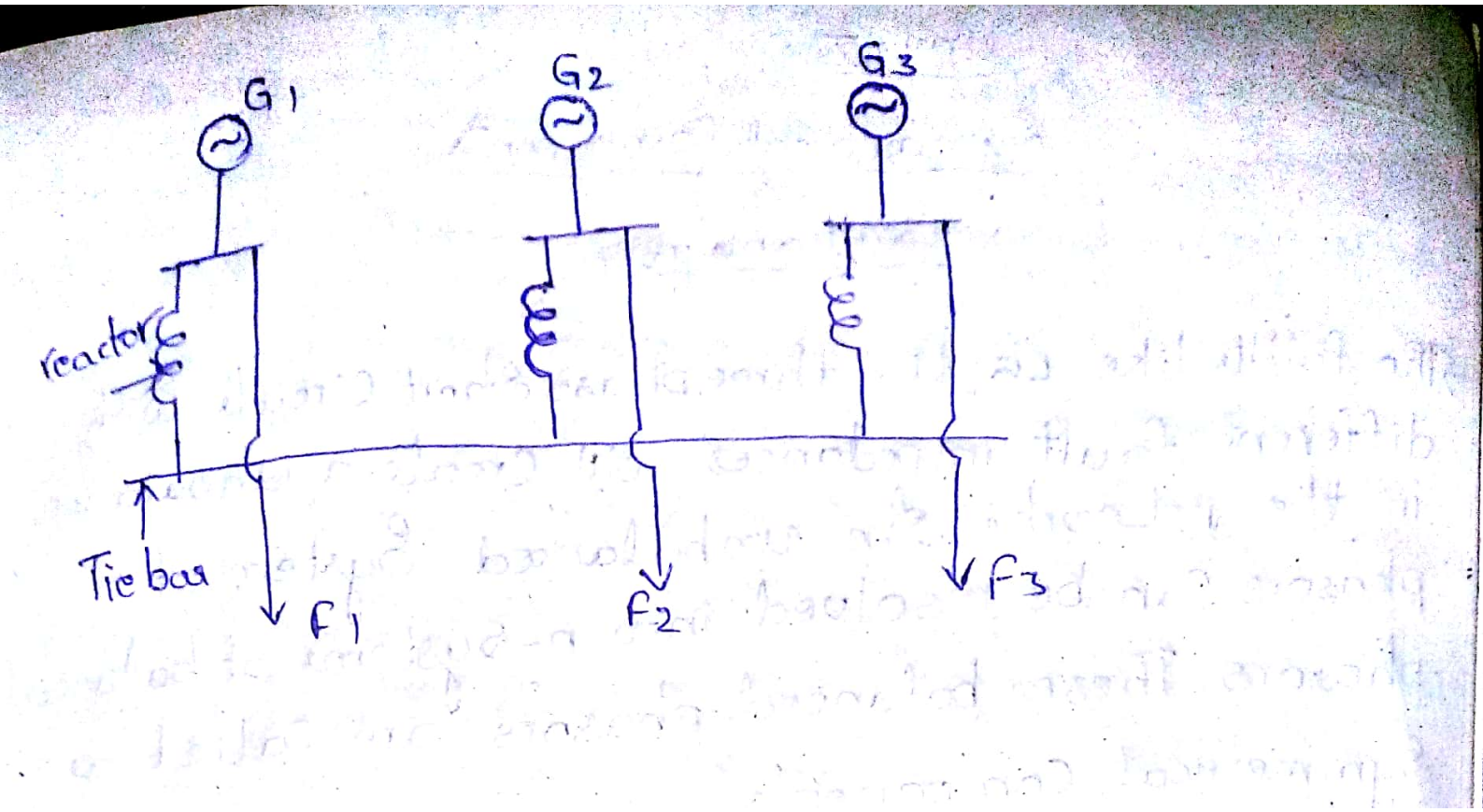


Tie-bar System

This is an improvement of over the ring system. In this system the current fed into a fault has to pass through two reactors which are connected in series between the sections.

For this system it requires an additional bus bar system, the tie-bar.

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