POWER SYSTEM ANALYSIS.

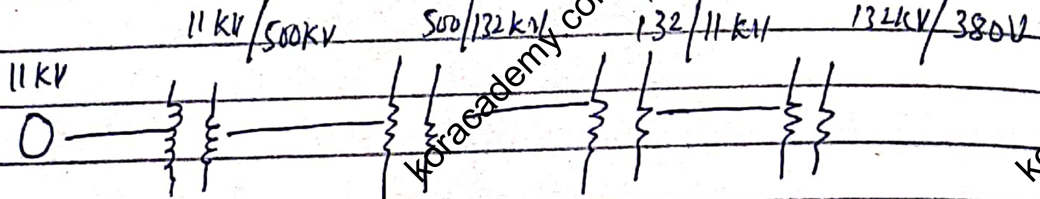
17/11/20

William D Stevenson (3rd edition)

Power System.

A network of electrical components that generates / transmits and supply / distribute electrical power to the load centres.

Generation → Transmission → Sub Transmission / Primary Distribution → Distribution → Feeder



380 V Line to line voltage.
220 V Line to phase voltage.

Transmission system.

Carries power from the generating end to the load centre.

Transmission lines are often known as connecting links b/w generator and load.

Distribution system

It feeds power from the distribution grid station to the ~~feeders~~ load centres through feeders.

Transmission at 33kV, 66, 132, 220, 500, 1000, [illegible]

Breakdown of air = 30kV/cm

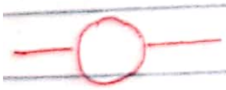
Why not use higher voltage?
- Insulation cost
- All equipment is for 220.
- Higher chances of accidents.

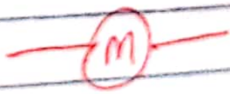
Generating stations are always balanced;
- Equal number of turns.
- Same material of all coils.
- Same resistance

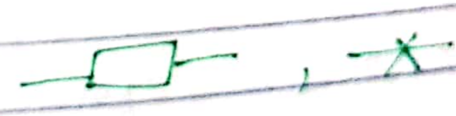
A three phase balanced system can always be replaced by a single phase system for analysis.

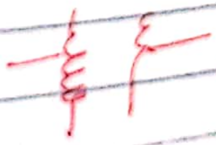
If we replace actual things by symbols → single line diagram.

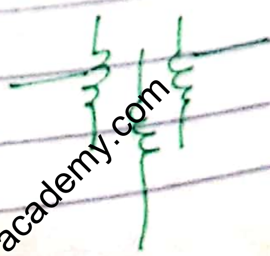
Symbols

 , rotating machine.

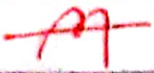
 generator  motor etc

Circuit breaker 

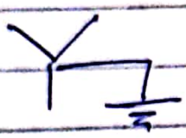
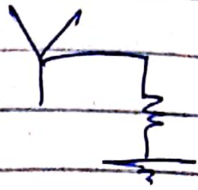
Δ Y

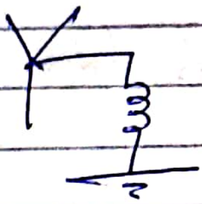
 CT

 PT

 Static load

 Transmission line

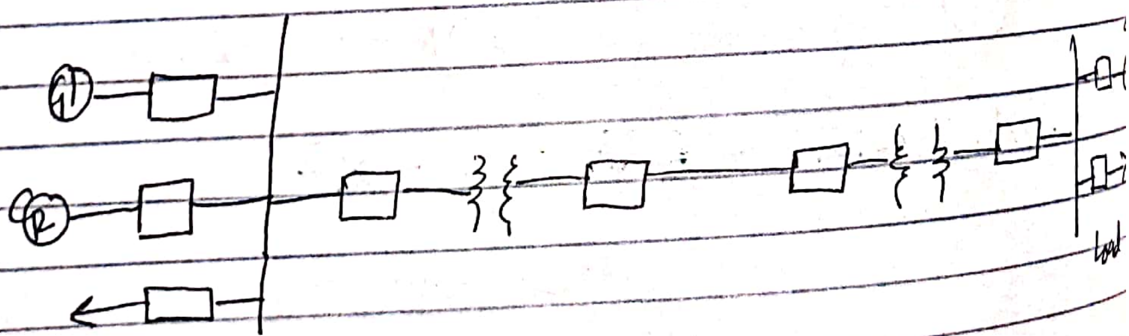
 solidly grounded 



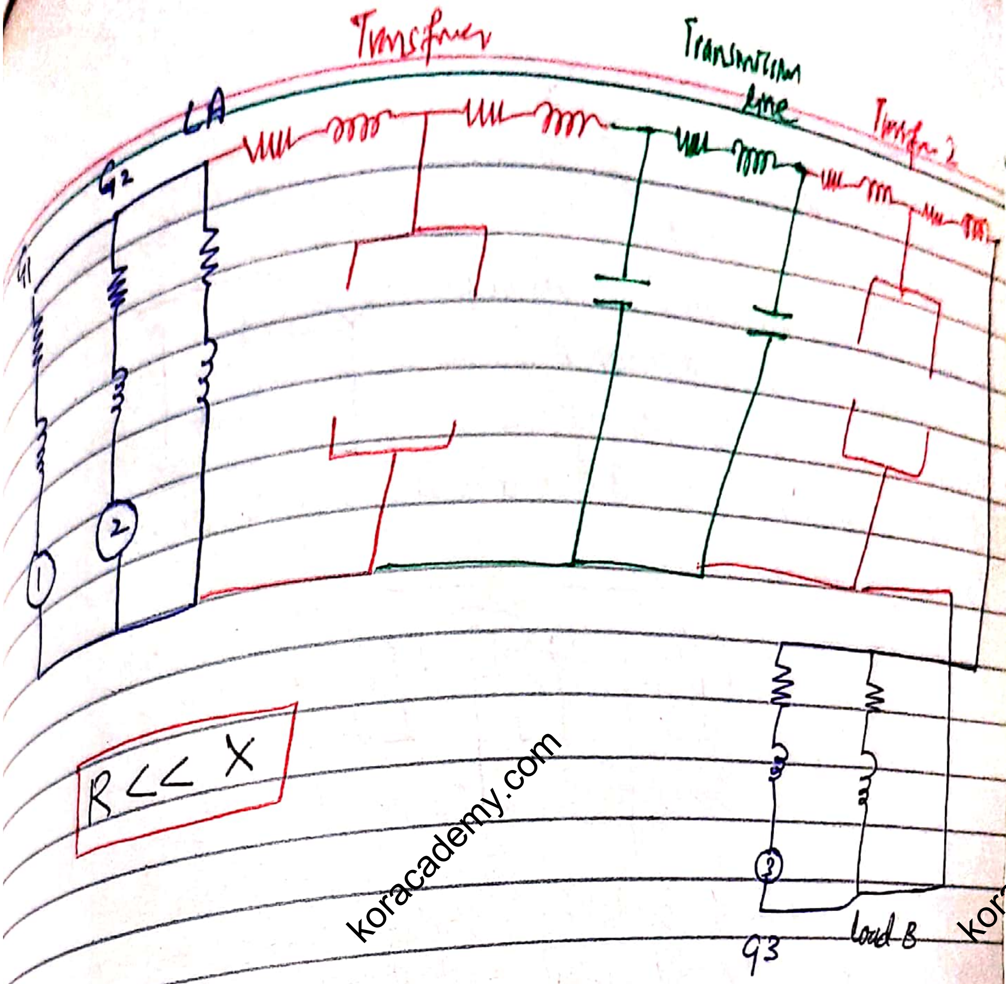
Ground Fault Neutralizer / Peterson coil

3 ϕ system is used b/c;
- It is economical
- Reduces conductor size.
- Reduces power losses.

** <u>Converting single line diagram into reactance diagram</u>

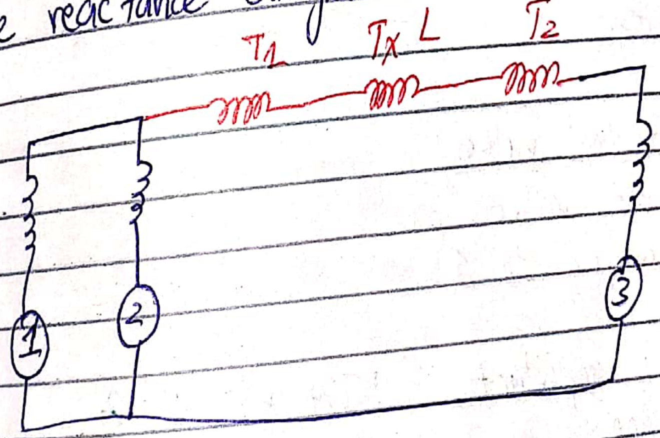


Load A



$$\boxed{R << X}$$

The reactance diagram is as;

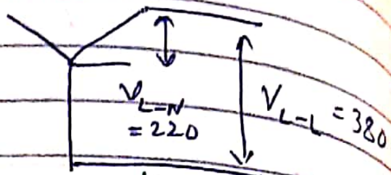


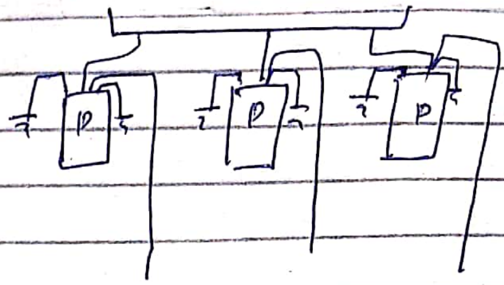
Lecture 2 : 24/11/20

3 types of reactances;

- X → synchronous reactance.
- X' → transient reactance.
- X" → subtransient reactance

- All the data is 3 phase untill mentioned.
- Voltages are always line to line
- Impedance provided is always a single phase impedance.
- Current is always for one line.
- Data provided for 3 ϕ bank is single phase data.





- Fault, Load, and stability study cannot be done with single line diagram.

Per Unit System.

$$Pu = \frac{\text{Actual value}}{\text{Base value}}$$

values are nearer to 1.

4 quantities are very important; KVA, KV, I, Z
Select base quantity for 2 of them and derive for other two.
Normally select base, KVA and KV and derive for I and Z.

let KVA → single phase KVA, Z → per unit imp
KV → L-N voltage, I → line current

$(KVA)_b$, $(KV)_b$

$$\boxed{I = \frac{P}{V} = \frac{(KVA)_b}{(KV)_b}} \quad \text{— (1)}$$

$$Z_{base} = \frac{V_{base}}{I_{base}} = \frac{(kV)_b \times 1000}{(kVA)_b / (kV)_b} \quad — ②$$

$$\boxed{Z_{base} = \frac{(kV)_b^2 \times 1000}{(kVA)_b}}$$

Ex

Base KVA = ~~18000~~ 3000

Actual = 18000 KVA, 108 kV, 120 kV

$$pu = \frac{18000}{3000} = pu\ 0.6$$

Similarly for single phase, $pu = \frac{18000/3}{3000/3} = 0.6\,pu$

Similarly $pu = \frac{108}{120} = 0.9\,pu$

and $pu = \frac{108/3}{120/3} = 0.9\,pu$

Let $(kVA)_b \rightarrow 3\phi$ kVA $\quad (kV)_b$ = L-L voltage

$$I_b = \frac{(kVA)_b/3}{(kV)_b/\sqrt{3}} = \frac{(kVA)_b \times \sqrt{3}}{(kV)_b \times 3}$$

$$\boxed{I_{base} = \frac{(kVA)_b}{\sqrt{3}(kV)_b}} \quad — ③$$

$$\left(I = \frac{P}{\sqrt{3}V \cos\theta}\right)$$

$$Z_{base} = \frac{\left((kV)_b/\sqrt{3}\right)^2 \times 1000}{(kVA)_b/3} = \boxed{\frac{(kV_b)^2 \times 1000}{(kVA)_b}}$$

$$= \frac{(kV_b)^2}{(MVA)_b}$$

Now.

$$Z_{pu} = \frac{Z_{actual}}{Z_{base}} = \frac{Z_{act}}{\frac{(kV_b)^2 \times 1000}{(kVA)_b}}$$

$$= \frac{Z_{act} \times (kVA)_b}{(kV)_b^2 \times 1000} = \frac{Z_{act} \times (MVA)_b}{(kV)_b^2}$$

$$Z_{pu} \propto K \frac{(MVA)_b}{(kV)_b^2}$$

$$Z_{pu\,(new\,base)} = Z_{pu\,(old\,base)} \times \frac{(kVA)_{b\,(new)}}{(kVA)_{b\,(old)}} \times \frac{(kV_b)^2_{old}}{(kV_b)^2_{new}}$$

- Such a base quantity is selected where per unit quantities become equal or closer to 1.

- KVA base, once selected, does not change for the entire circuit.
- KV base changes when you encounter a transformer. It changes in accordance with transformation ratio.
- The specified per unit values are always specified on rating of the system.

The power of motor is in horse power s/c it is mechanical power.

For induction motor; hp = KVA

For synchronous machine at unity pf ; KVA = 0.85 hp

" at 0.8 pf ; KVA = 1.10 hp

Let Z_{HT} - HT side impedance Z_{LT} - LT side impedance.

~~KV_L → rated LV voltage~~ KV_H → rated HV voltage

KVA → KVA of transformer.

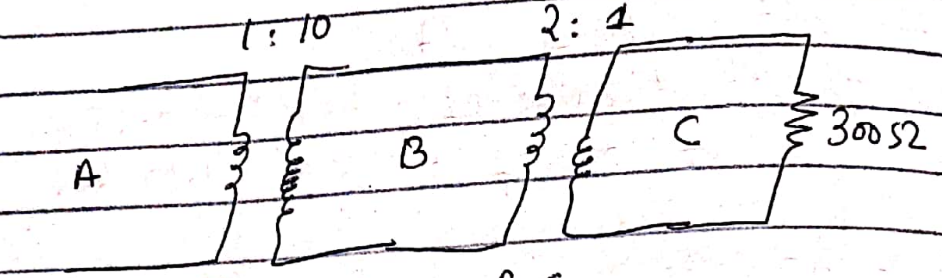
$$Z_{LT} = Z_{HT}\left(\frac{KV_{LT}}{KV_{HT}}\right)^2$$

$$Z_{pu_{LT}} = \frac{Z_{HT}\left(\frac{\cancel{KV_{LT}}}{KV_{HT}}\right)^2 \times KVA_b}{\cancel{KV_{b_{LT}}}^2 \times 1000}$$

$$\boxed{Z_{pu(LT)} = \frac{Z_{HT} \times KVA_b}{(KV_{HT})^2 \times 1000}} \quad -①$$

$$\boxed{Z_{pu(HT)} = \frac{Z_{HT} \times (KVA)_b}{(KV_{b(HT)})^2 \times 1000}} \quad -②$$

Ex 3 parts of a single phase system are A, B, C are connected to each other through transformers as shown;



A–B
$X = 0.1\ pu$
10000 kVA
(13.8 – 138 kV)

B–C
$X = 0.08\ pu$
10000 kVA
(69 – 138) kV.

System base = Circuit B = 10000 kVA, 138 kV.

Draw impedance / reactance diagram neglecting the magnetizing current, resistance of Xfmr and Xmission line.
Determine the voltage regulation if voltage at load is 66 kV, assume voltage i/p to A B constant.

C

$$(KVA)_b = 10000$$

$$(KV)_b = 138\left(\frac{1}{2}\right) = 69\ KV$$

$$Z_{act} = 300\ \Omega$$

$$Z_{base} = \frac{(KV_b)^2}{(KVA)_b} \times 1000 = \frac{(69)^2}{10000} \times 1000 = 476\ \Omega$$

$$Z_{pu} = \frac{Z_{act}}{Z_{base}} = \frac{300}{476} = 0.63\ pu$$

B

$$Z_{b\ \text{actual}} = Z_c\left(\frac{2}{1}\right)^2 = 300\left(\frac{4}{1}\right) = 1200\ \Omega$$

$$Z_{base} = \frac{(138)^2 \times 1000}{10000} = 1900\ \Omega$$

$$Z_{pu} = \frac{1200\ \Omega}{1900\ \Omega} = 0.63\ pu.$$

A

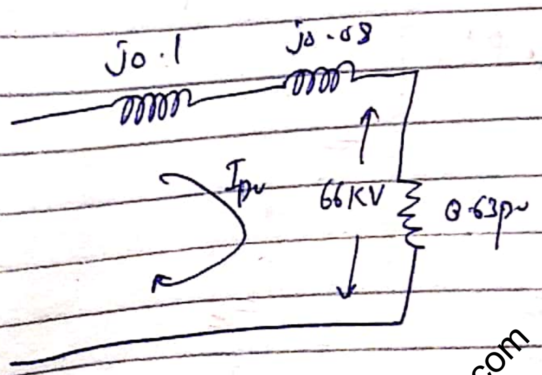
$$138\left(\frac{1}{10}\right) = 13.8\ KV$$

$$Z = 300\left(\frac{2}{1}\right)^2\left(\frac{1}{10}\right)^2 = 12\ \Omega$$

$$= 1200\left(\frac{1}{10}\right)^2 = 12\ \Omega$$

$$Z_{base} = \frac{(13.8)^2 \times 1000}{10000} = 19\ \Omega.$$

$$Z_{pu} = \frac{12}{19} = 0.63\ pu$$



$$V_{L(pu)} = \frac{66}{69} = 0.957\ pu$$

$$I_L = \frac{V_L}{Z_L} = \frac{0.957}{0.63} = 1.52\ pu$$

$V_{NL} = 0.957 + I_L (j0.18)$

$V_{NL} = 0.995$

Lecture

Per Unit Impedences of three winding transformer.

In two winding T/F KVA rating of each winding is the same.

→ In three winding, it is different.

So to solve this problem, we need to convert all the quantities into a single base or single KVA rating.

These impedances are measured by short circuit tests.

Z_{ps} = leakage imp measured in primary winding with secondary short circuited and tertiary is kept open.

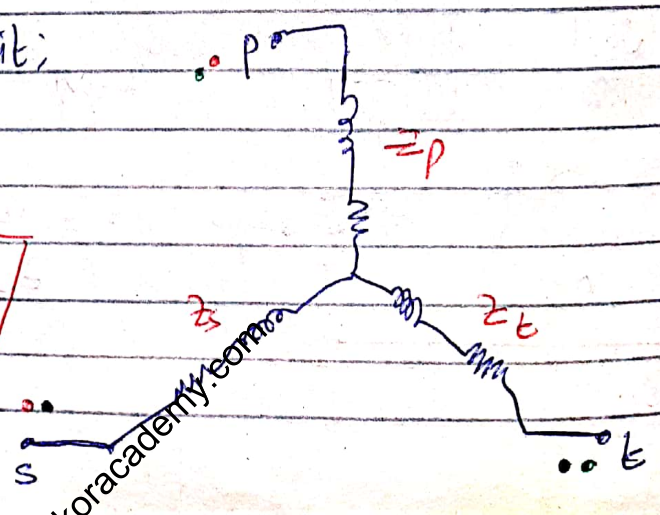
Z_{pt} = meas in pri, ter sh cir and tertiary kept open.

Z_{st} = meas in sec, tert sh cr and primary kept open.

The equivalent circuit;

Z_{ps} Z_{pt} Z_{st}

$$\boxed{\begin{aligned} Z_{ps} &= Z_p + Z_s \\ Z_{pt} &= Z_p + Z_t \\ Z_{st} &= Z_s + Z_t \end{aligned}}$$



Solving simultaneously

$$\boxed{\begin{aligned} Z_p &= \frac{1}{2}\left(Z_{ps} + Z_{pt} - Z_{st}\right) \\ Z_s &= \frac{1}{2}\left(Z_{st} + Z_{ps} - Z_{pt}\right) \\ Z_t &= \frac{1}{2}\left(Z_{pt} + Z_{st} - Z_{ps}\right) \end{aligned}}$$

Three phase rating of a 3 winding transformer are;

P : Y connected 66 KV, 15MVA
S : Y connected 13.2 KV, 10MVA
T: Δ connected 2.3 KV, 5MVA.

$Z_{ps} = 7\%$ based on 15MVA, 66KV
$Z_{pt} = 9\%$ 15MVA, 66 KV
$Z_{st} = 8\%$ 10 MVA, 13.2 KV

Find Z_p, Z_s and Z_t for the base of 15MVA, 66KV.

P : 15MVA, 66KV

S : 15MVA, $66 \times \frac{13.2}{66} = 13.2$ KV

T: 15MVA, $66 \times \frac{2.3}{66} = 2.3$ KV

No need to convert Z_{ps} and Z_{pt} b/c they are measured already in the same base (primary)

$$Z_{st} = (0.08)\left(\frac{15MVA}{10MVA}\right)\left(\frac{13.2}{13.2}\right)^2 = 12.1$$

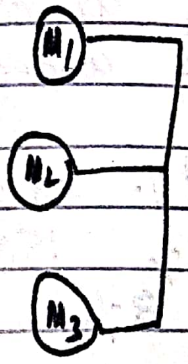
Now,

$$Z_p = \frac{1}{2}\left(j0.07 + j0.09 - j0.12\right) = j0.03pu$$

$$Z_s = \frac{1}{2}\left(j0.07 + j0.12 + j0.09\right) = j0.05pu$$

$$Z_t = \frac{1}{2}\left(j0.09 + j0.12 - j0.07\right) = j0.07pu$$

Convert all the quantities to a base of 10000KVA, 6.6KV.



M_1: SM, 5000hp, pf = 0.8,
rated V = 6.9KV
subtransient reactance, $X'' = 0.17pu$

M_2 = SM, 3000hp, 1, 6.9KV, 0.15pu

M_3 = IM, 3500hp, , 6.9KV, 0.2pu
↳ IM does not have a pf b/c it operates on a lagging pf (so depends on the load).

$KVA_1 = 1.1 \times hp = 1.1 \times 5000 = 5500KVA$
$KVA_2 = 0.85 \times hp = 0.85 \times 3000 = 2550KVA$
$KVA_3 = 3500KVA$

$$pu \text{ of } M_{1(ns)} = 0.17\left(\frac{10000}{5500}\right)\left(\frac{6.9}{6.6}\right)^2 =$$

$\frac{new}{old}$

$$pu \text{ of } M_2 (nb) = 0.45 \left(\frac{10000}{2550}\right)\left(\frac{6.9}{6.6}\right)^2 =$$

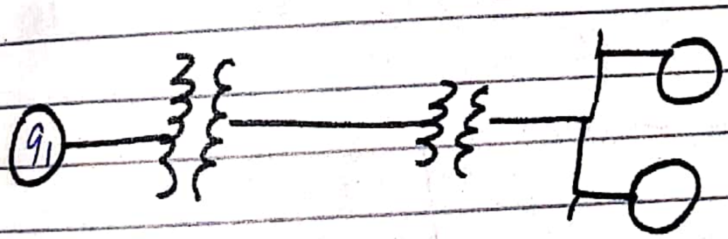
$$pu \text{ of } M_3 (nb) = 0.2 \left(\frac{10000}{3500}\right)\left(\frac{6.9}{6.6}\right)^2 =$$

A 30000 KVA, 13.8 KV 3ϕ generator has $X'' = 15\%$.

The gen supplies two motors over a transmission line having T/Fs at both ends (fig)

Motors has rated i/p of 20000 and 10000 KVA. Both are 12.5 KV and $X'' = 0.2$

3ϕ T/Fs at both ends are rated 35000 KVA, 13.2 Δ – 115 Y with leakage reactane 10%.



TL has reactance of 80 Ω.

Select the generator ie 30000 KVA, 13.8 KV as a base and transform all reactances to this.

$$(KV)_{b, TL} = 13.8 \times \frac{115}{13.2} = 120 \text{ KV} \quad (\text{TL base})$$

$$(KV)_{b (m)} = 13.8 \times \frac{115}{13.2} \times \frac{13.2}{115} = 13.8$$

② $(kV)_{b(M)} = 120\left(\frac{13.2}{115}\right) = 13.8\,kV$

$$X(TF_1)_{(nb)} = (0.1)\left(\frac{30000}{35000}\right)\left(\frac{13.2}{13.8}\right)^2 = 0.078\,pu$$

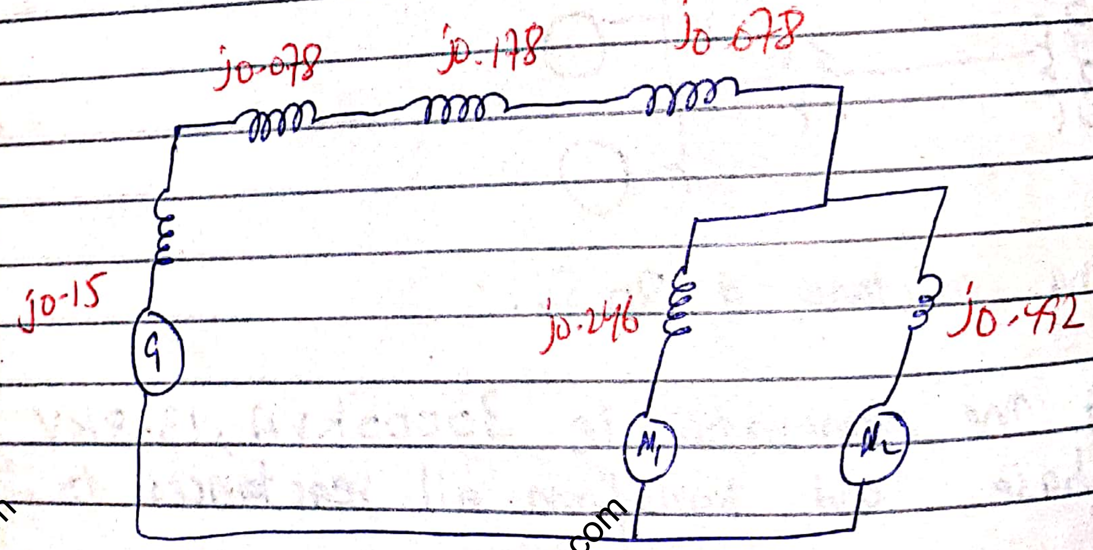
↳ or $\left(\frac{115}{120}\right)^2$

$$X(TF_2)_{nb} = (0.1)\left(\frac{30000}{35000}\right)\left(\frac{12.5}{13.8}\right)^2 =$$

$$pu \text{ of } TL_{(nb)} = \frac{80 \times 30000}{(120)^2 \times 1000} = 0.167\,pu$$

$$pu \text{ of } M_1\,(nb) = 0.2\left(\frac{30000}{20000}\right)\left(\frac{12.5}{13.8}\right)^2 = 0.246\,pu$$

$$pu \text{ of } M_2\,(nb) = 0.2\left(\frac{30000}{10000}\right)\left(\frac{12.5}{13.8}\right)^2 = 0.492\,pu$$



300MVA, 20KV generator with $X'' = 0.2$ pu supplies number of motors over a 64 km long transmission line. All motors = 13.2 kV

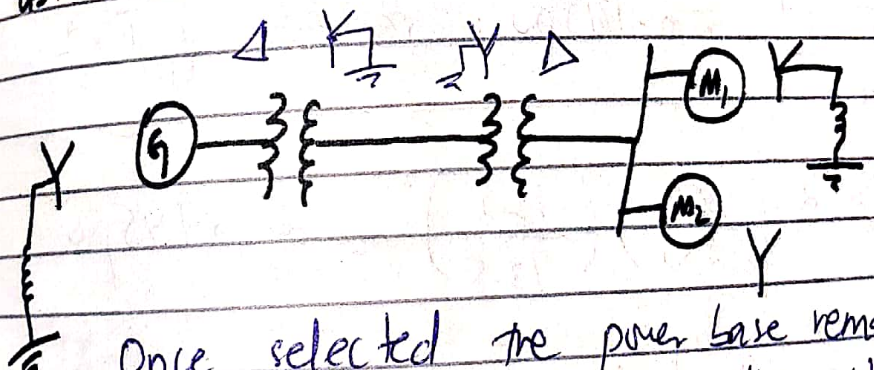
Neutral of M_1 and grounded and M_2 not grounded. Rated i/ps = 200MVA and 100MVA.
$X'' = 0.2$ pu for both.

3ϕ TFs T_1: 350MVA, 230/20 kV with leakage reactance, $X = 10\%$.

T_2: three ϕ bank each rated 127/13.2 kV and 100MVA with $X = 0.1$ pu

The series reactance of TxL, $X = 0.5\ \Omega/\text{km}$.

Draw reactance diagram using generator rating as a base.

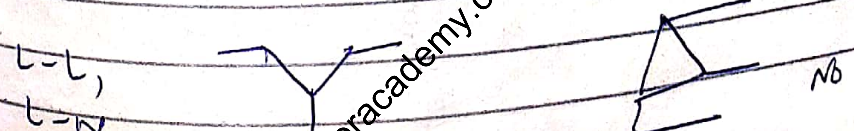


Once selected the power base remains the same, the only thing that changes is the voltage base.

T2: making 3ϕ data from 1ϕ

$3 \times 100 = 300$ MVA

Line to line voltage ratio $= \dfrac{\sqrt{3}\,(127)}{13.2}$



$$TxL = 20\,kV \left(\frac{230\,kV}{20\,kV}\right) = 230\,kV$$

$$M = 230 \left(\frac{13.2}{127 \times \sqrt{3}}\right) = 13.8\,kV$$

$$X_{(TF_1)ns} = 0.1 \times \frac{300}{350} = 0.857\,pu$$

voltage base? if you consider primary side, new base and old base so they are 20. if you consider transmission or secondary side, old and new base both are 230.

$$X'(TF_2)_{ns} = 0.1 \times \frac{300}{350} \times \left(\frac{13.2}{13.8}\right)^2 = 0.0915\,pu$$

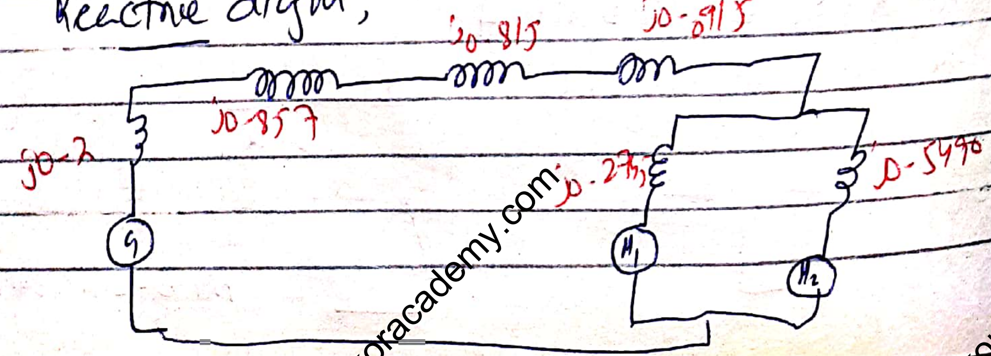
Transmission line, $X_{act} = \frac{V^2}{P} = \frac{230^2}{300} = 176.3\Omega$

$$\frac{0.5 \times 64}{176.3} = 0.1815\,pu = \text{reactance of } Tx\,L.$$

$$X_{M1\,(ns)} = 0.2\left(\frac{300}{200}\right)\left(\frac{13.2}{13.8}\right)^2 = 0.2745\,pu$$

$$X_{M2\,(ns)} = 0.2\left(\frac{300}{100}\right)\left(\frac{13.2}{13.8}\right)^2 = 0.4590\,pu$$

Reactance diagram;



Lecture

Faults

→ Symmetrical faults

→ Asymmetrical faults

↓

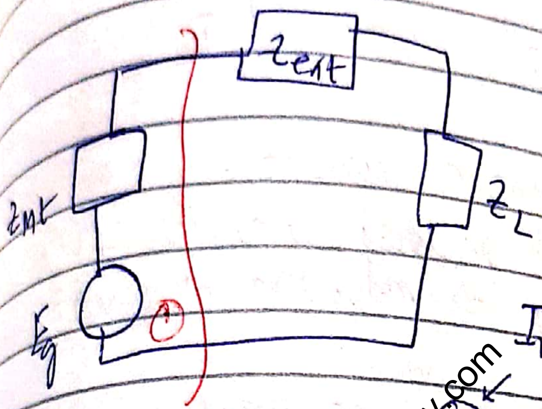
system is unbalanced

→ L-L

→ L-G

→ LLG

→ Symmetrical component method.



As $I = V/Z$

Normal current;

$$I_n = \frac{E_g}{Z_{int} + Z_{ext} + Z_L} \quad \text{(i)}$$

If fault at generator end;

$$I_{f1} = \frac{E_g}{Z_{int}} \rightarrow \text{(ii)}$$

If fault at load end;

$$I_{f2} = \frac{E_g}{Z_{int} + Z_{ext}} \rightarrow \text{(iii)}$$

Duties of Circuit breaker;

i. To carry normal current for an infinite period of time.

ii. To carry very high current for a very short period of time.

iii. To interrupt high current if it sustains.

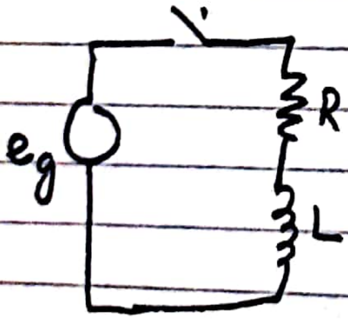
When a fault occurs in a power system, the current is determined by three things:-
- Internal voltage of the source.
- Internal impedance of generator.
- Impedance of the network (G → fault)

Fault occurs I_A, few cycles I_B, sustained I_C.
↳ These 3 differ b/c of armature current.
↳ produces armature flux, which opposes the main flux ⇒ reduction in current.

Initial — steady state ⇒ change in current.
⇒ X, X', X'' changes b/c E_g is the same.

$$\frac{E_g}{I}, \frac{E_g}{I'}, \frac{E_g}{I''}$$

Consider:



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

$t = 0$ at the time of applied voltage.

α determines the magnitude of voltage when the circuit is just closed.

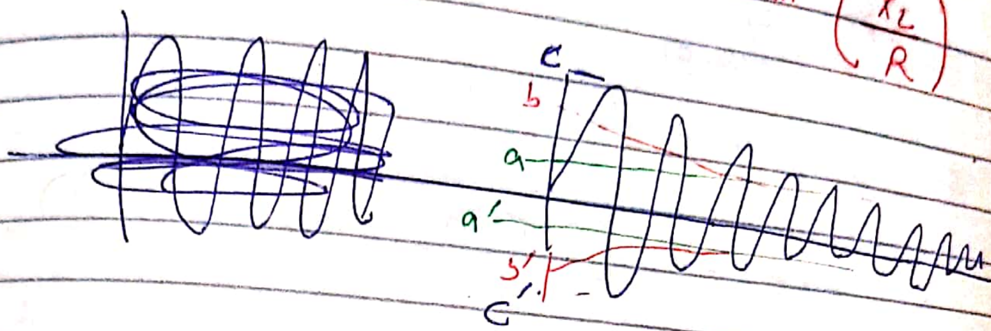
$$V_m \sin(\omega t + \alpha) = iR + L\frac{di}{dt}$$

$$i = i_{ac} + i_{dc}$$

i_{ac} → due to voltage source.
i_{dc} → due to transients and decay after some time.

$$i = \frac{V_m}{Z}\left[\sin(\omega t + \alpha - \theta) - e^{-Rt/L}\sin(\alpha - \theta)\right]$$

$$Z = \sqrt{R^2 + (\omega L)^2}, \quad \theta = \tan^{-1}\left(\frac{X_L}{R}\right)$$



oa → steady state current., $I = oa \times 0.707$ → rms value.

$X = E_g / I$ = Direct axis steady state reactance/synchronous reactance.

current lags voltage b/c internal reactance of the generators are quite large compared to their internal resistance.

ob → maximum transient current, $I' = 0.707(ob)$ → rms.

$X' = E_g / I'$ → direct axis transient reactance.

oc → subtransient reactance, $I'' = 0.707(oc)$ → rms.

just at the occurance of fault.

$X'' = E_g / I''$ → direct axis subtransient current.

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

→ Interrupting capacity of circuit breakers;

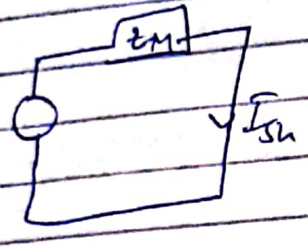
$X'' \rightarrow G$ $\quad X' \rightarrow SM$ $\quad IM$ ✗

Fault MVA = $\sqrt{3}$ × Nominal KV × $I_{sc} \times 10^{-3}$

$$Z_{pu} = \frac{I_{base}}{I_{sh\,ckt}}$$

As $S.C\ MVA = \sqrt{3} \times N\,KV \times I_{sc} \times 10^{-3}$

$$I_{sc} = \frac{SC\ MVA}{\sqrt{3} \times NKV \times 10^{-3}} \quad — (1)$$



$$I_{sh} = \frac{NKV / \sqrt{3} \times 10^{+3}}{Z_m} \quad — (2)$$

$$Z_M = \frac{NKV / \sqrt{3} \times 10^{+3}}{I_{sh}} \quad — (3)$$

(1) ⇒ (2)

$$Z_M = \frac{NKV / \sqrt{3} \times 10^{-3}}{SC\ MVA} \times \sqrt{3} \times NKV \times 10^{-3}$$

$$Z_m = \frac{(NKV)^2}{SC\ MVA}$$

As $Z_{pu} = \dfrac{Z_{act} \times MVA}{(KV_b)^2}$

$$\Rightarrow Z_{pu} = \frac{(NKV)^2}{SC\ MVA} \times \frac{(MVA)_b}{(KV)_b^2}$$

Assume $(KV)_b = NKV$

$$\Rightarrow Z_{pu} = \frac{(MVA)_b}{SC\ MVA}$$

$$Z_{pu} = \frac{\sqrt{3} \times (kV)_b \times I_{base} \times 10^{-3}}{\sqrt{3} \times (N\,kV) \times I_{sc} \times 10^{-3}}$$

$$\Rightarrow \boxed{Z_{pu} = \frac{I_{base}}{I_{sc}}}$$

Lecture

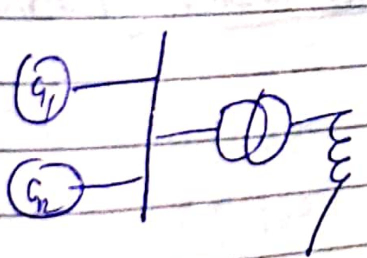
Two generators are connected in parallel. ~~load is on~~ ~~the LT side of a 3ϕ Δ-Y~~.

Gen 1 = 50 000 KVA, 13.8kV
Gen 2 = 25000 KVA, 13.8kV } $X'' = 0.25$
T/F = 75000 KVA, 13.8 Δ − 69Y , X = 10%.

Before fault HT side V = 66kV, b/f fault T/F is unloaded and no circulating current b/w gens.

Circulating current flows b/w the generators when both have different voltage ratings.

I_g'', I_f = ? when a 3ϕ S.C occurs on HT side.

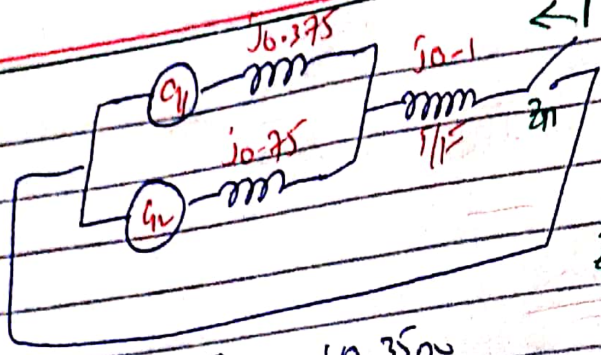


let the selected base is 75000 KVA, 69 kV. (T/F)

$$KV_b\,(LT) = 69\left(\frac{13.8}{69}\right) = 13.8\ kV$$

$$X_{g_1}(ns) = 0.25\left(\frac{75000}{50000}\right)\left(\frac{13.8}{13.8}\right)^2 = j0.375\,pu$$

$$X_{g_2}(ns) = 0.25\left(\frac{75000}{25000}\right)\left(\frac{13.8}{13.8}\right)^2 = j0.75\,pu$$



$$V_f = \frac{66}{69} = 0.975 \text{ pu}$$

$$Z_{th} = \frac{(j0.375)(j0.75)}{j0.35 + j0.75} + j0.1$$

$$Z_{th} = j0.35 \text{ pu}$$

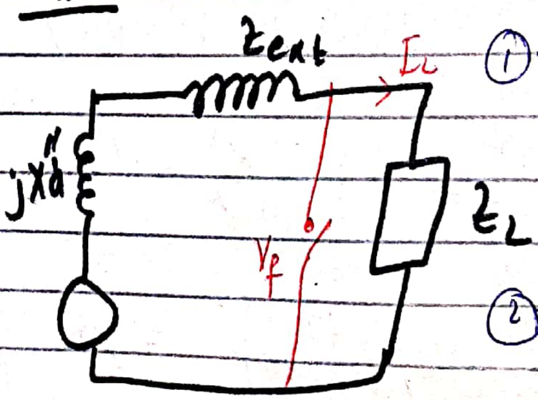
$$I_f'' = \frac{V_f}{Z_f} = \frac{0.95}{j0.35} = -j2.785 \text{ pu}$$

$$I_{g_1}'' = \frac{I_f''(j0.75)}{j0.75 + j0.375} = -j1.823 \text{ pu}$$

$$I_{g_2}'' = \frac{I_f''(0.375)}{j0.75 + j0.375} = -j0.911 \text{ pu}$$

For actual ~~fault~~ current multiply with base i.e $\frac{75000}{\sqrt{3} \times 69}$

Internal voltages of Loaded machines under transient conditions.



$$Z_{th} = \frac{(Z_{ext} + jX_d'') \times Z_L}{Z_{ext} + jX_d'' + Z_L} \quad \text{—} (1)$$

$$I_f'' = \frac{V_f}{Z_{th}} = \frac{V_f(Z_{ext} + jX_d'' + Z_L)}{(Z_{ext} + jX_d'') Z_L} \quad \text{—} (2)$$

$$I_f'' = \frac{E''}{jX_d'' + Z_{ext}} \quad \text{—} (3)$$

Scanned with CamScanner

I_L

② and ③ → $\dfrac{E''}{\cancel{jX_d'' + Z_{ext}}} = \dfrac{V_f \,(Z_{ext} + jX_d'' + Z_L)}{Z_L \,\cancel{(Z_{ext} + jX_d'')}}$

$$E'' = I_L \,(Z_{ext} + jX_d'' + Z_L)$$

$$\rightarrow E'' = I_L\,(Z_{ext} + Z_L) + I_L\,(jX_d'')$$

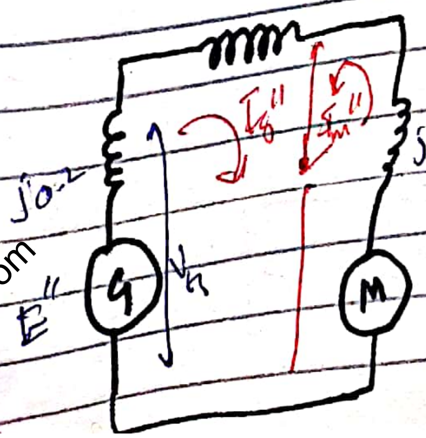
$$\boxed{\begin{aligned} E'' &= V_L + I_L X_d'' \\ E' &= V_t + I_L X_d' \\ E''_{motors} &= V_t - I_L X_d'' \rightarrow E_m' = V_L - I_L X_d' \end{aligned}}$$

For unloaded generators; $E' = E'' = E = E_g$

In loaded conditions, $E' \neq E'' \neq E$

An alternator and SM are rated 30000 kVA, 13.2 kV with $X_g'' = X_m'' = 0.2$ pu.
The line connecting them, $X_{TL} = 0.1$ pu.
Motor o/p = 20000 kVA, 0.8 pf, 12.8 kV

A symmetrical 3φ fault occurs at the motor end.



Consider system base as base;
30000 kVA, 13.2 kV

$$V_{f(pu)} = \frac{12.8}{13.2} = 0.97 \text{ pu}$$

fault voltage

$$I_b = \frac{30000}{\sqrt{3} \times 13.2} = 1312 \text{ A.}$$

$$I_L = \frac{20000}{\sqrt{3} \times 12.8 \times 0.8} = 1128 \angle 36.8^\circ$$

$$I_{pu} = \frac{I_{act}}{I_b} = \frac{1128 \angle 36.8}{1312} = 0.86 \angle 36.8^\circ \text{ pu.}$$

$$E_g'' = V_t + j I_L X_d''$$

As $V_t = V_f + I_L Z_{ext} = (0.918 + j0.069)$ pu

$$E_g'' = 0.814 + j0.207 \text{ pu}$$

$$E_m'' = V_{t_m} - j I_L X_L'' = (0.97 - j0.86 \angle 36.8)(j0.2)$$

$$\Rightarrow E_m'' = (1.074 - j0.138) \text{ pu}$$

$$I_g'' = \frac{E_g''}{j0.3} = (0.69 - j2.71) \text{ pu}$$

$j0.3 \rightarrow$ generator to fault point

$$I_m'' = \frac{E_m''}{j0.2} = (-0.69 - j5.37) \text{ pu}$$

$j0.2 \rightarrow$ motor to fault point.

$$I_f'' = I_g'' + I_m'' = -j8.08 \text{ pu}$$

Fault MVA = ?

$$I''_{f_{actual}} = (-j8.08) \times 1312 = \boxed{-j10600 \text{ A}}$$

Fault MVA $= \sqrt{3} \times V_L \times I_{sc} \times 10^{-3}$

$= 242.4$ MVA.