G 6553 (Pages : 2) Reg. No...............................

Name..................................

M.TECH. DEGREE EXAMINATION, MARCH 2011

Second Semester

Branch—Electrical and Electronic Engineering

Specialization—Power Electronics and Power Systems

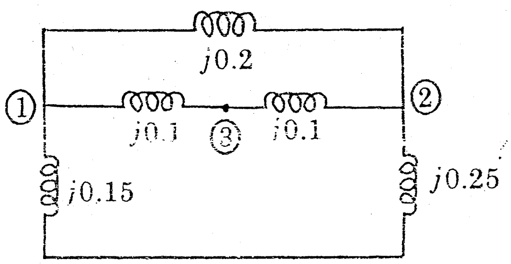
PEPS 205-3—COMPUTER APPLICATION IN POWER SYSTEMS (Elective II)

Time : Three Hours Maximum : 100 Marks

Answer any **five** *questions.*
All questions carry equal marks.

1. (a) Explain the representation of wye delta and phase shift transformers in power system network. (5 marks)

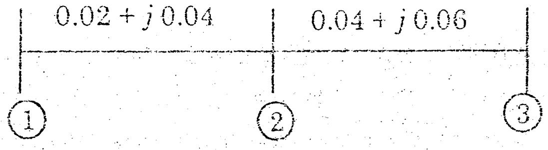
(b) For the three bus network shown, determine Z_{BUS} using Building algorithm.



(15 marks)

2. (a) With flow chart explain the algorithm of fast decoupled load flow method. (10 marks)

(b) For the network shown in figure, find the busbar voltage at bus 2 at the end of first iteration using GS method. Line impedances are in PU.



BUS	P	Q	V	Type
1 ...	—	—	$1.0\underline{|0}$	Slack
2 ...	– 5.9	1.5	—	PQ
3 ...	6.0	—	1.02	PV

(10 marks)

Turn over

3. (a) Explain how voltage control can be effected by injection of reactive power. (8 marks)

(b) Write short notes on the following :—

(i) Tap changing transformers.

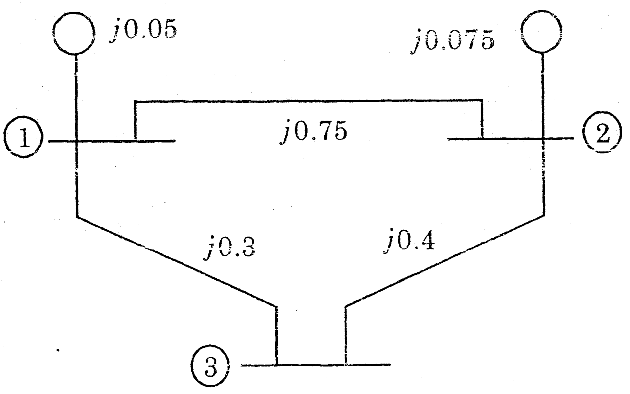
(ii) SVC.

(iii) Unified power flow controller.

(12 marks)

4. (a) Explain the behaviour of synchronous generator during the subtransient period of short circuit. (5 marks)

(b) The one line diagram of a simple three bus system is shown in figure. The generator and line reactances are in PU on a common MVA base. A three-phase fault occurs at bus 3 through impedance $Z_f = 0.15$ p.u. Use Thevinin's theorem to find the fault current in p.u., assuming prefault bus voltages as 1.0 p.u. Also determine the bus voltages and line currents during fault.



(15 marks)

5. (a) Explain the types of series faults in power systems. (5 marks)

(b) A 20 MVA, 13.8 kV salient pole generator has direct axis synchronous reactance of 0.2 p.u. The negative and zero sequence reactances are 0.3 and 0.15 p.u. respectively. The neutral of the generator is solidly grounded. Determine the subtransient current and line to line voltages at the fault when a line to line fault occurs at the terminals of the generator. Assume that the generator is unloaded and operating at rated voltage when the fault occurs.

(15 marks)

6. (a) Explain contingency analysis using Z_{bus} in a superposition method. (10 marks)

(b) Explain mathematical modelling of transformers in a six phase system. (10 marks)

7. (a) Explain optimal load flow solution considering inequality constraints on control variables. (10 marks)

(b) Draw the flow chart and explain Newton-Raphson method for load flow analysis. (10 marks)

[5 × 20 = 100 marks]

G.6553

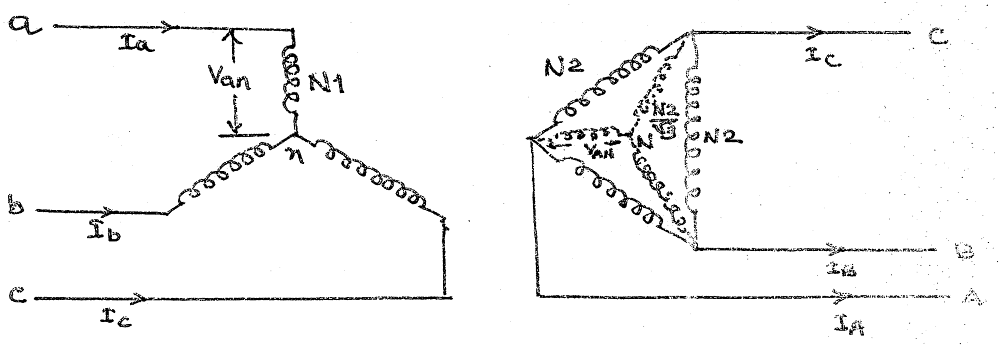
M.Tech. Degree Examination, March 2011

Second Semester, Electrical and Electronics Engineering

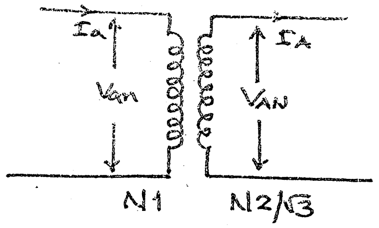
Power Electronics and Power Systems PEPs 205-3

COMPUTER APPLICATION IN POWER SYSTEMS (Elective II)

1a For representing a wye-delta transformer, the delta side has to be replaced by an equivalent star connection as shown dotted.



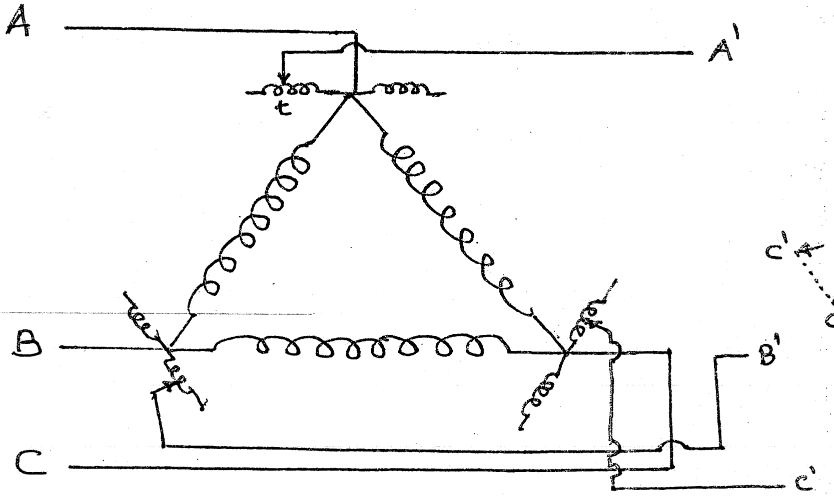
So a single phase equivalent can be obtained as given below



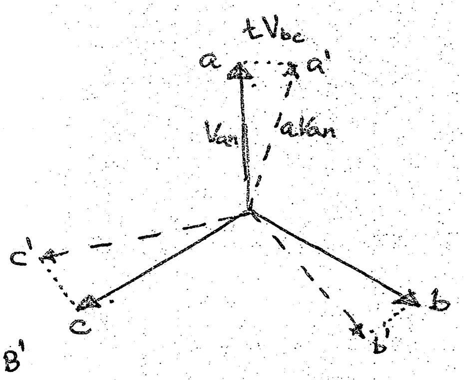
Single phase equivant of wye delta transformer

On the delta side, the voltage to the neutral V_{AN} and the line current I_A have a phase shift from the star side values Van and Ia. Since both voltage and current shift through the same phase angle (90° in this case) from star to delta, the transformer per phase impedance and power flow are preserved in the single phase equivalents. The wye delta transformers are represented like this as this gives the magnitude of the voltages and currents correctly for balanced circuits.

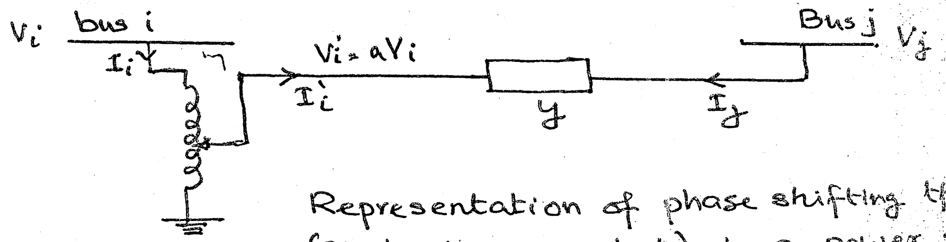
The phase shifting transformers changes the voltage Van to aVan where $a = 1\angle\delta$ where δ is a small angle of phase shift. The magnitude of a can also vary from unity.



Phase shifting transformer



Phasor diagram of input & output Voltages of Phase shifting tfr.



Representation of phase shifting tfr (single phase equivalent) in a power system at bus i in the line from i to j bus.

The mathematical representation of phase shifting tfr can be obtained neglecting losses

Power injected in bus i through line ij $S_i = V_i I_i^* = V_i' I_i'^*$

ie, $V_i I_i^* = aV_i I_i'^*$ $\therefore$ $I_i^* = a I_i'^*$ ~~= a~~

$I_i = a^* I_i'$

$I_i' = (aV_i - V_j)\, y$

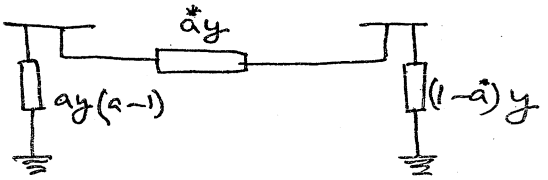
$I_i = a^* I_i^* = a^*(aV_i - V_j)y = a^2 y V_i - a^* y V_j$

$I_j = y(V_j - aV_i) = -ayV_i + yV_j$

ie,

$$\begin{bmatrix} I_i \\ I_j \end{bmatrix} = \begin{bmatrix} a^2 y & -a^* y \\ ay & y \end{bmatrix} \begin{bmatrix} V_i \\ V_j \end{bmatrix}$$

So in a power system a phase shifting transformer of ratio 'a' is represented as shown below



1b

$$\begin{array}{c|ccc|c} & \textcircled{1} & \textcircled{2} & \textcircled{3} & \textcircled{3}-\textcircled{1} \\ \textcircled{1} & j0.15 & j0.15 & j0.15 & 0 \\ \textcircled{2} & j0.15 & j0.35 & j0.35 & j0.2 \\ \textcircled{3} & j0.15 & j0.35 & j0.45 & j0.3 \\ \hline \textcircled{3}-\textcircled{1} & 0 & j0.2 & j0.3 & j0.4 \end{array}$$

$j0.4 \leftarrow j0.15 + j0.45 + j0.10 - 2 \times j0.15$

$(Z_{11} + Z_{33} + Z_b - 2 \times Z_{13})$

Reducing to 3x3 matrix using the formula

$$Z_{jk\,new} = \frac{(Z_{j,n+1})(Z_{n+1,k})}{Z_{n+1,n+1}}$$

$$\begin{array}{cccc} & \textcircled{1} & \textcircled{2} & \textcircled{3} \\ \textcircled{1} & j0.15 & j0.15 & j0.15 \\ \textcircled{2} & j0.15 & j0.25 & j0.20 \\ \textcircled{3} & j0.15 & j0.20 & j0.225 \end{array}$$

Now connecting the earth impedance to bus ②

$$\begin{array}{c|ccc|c} & \textcircled{1} & \textcircled{2} & \textcircled{3} & \textcircled{2}E \\ \textcircled{1} & j0.15 & j0.15 & j0.15 & j0.15 \\ \textcircled{2} & j0.15 & j0.25 & j0.20 & j0.25 \\ \textcircled{3} & j0.15 & j0.20 & j0.20 & j0.20 \\ \hline \textcircled{2}\text{-}E & j0.15 & j0.25 & j0.225 & j0.50 \end{array}$$

$j0.50 \leftarrow Z_{22} + Z_{2E}$

$(j0.25 + j0.25)$

Then reducing to 3x3 matrix

$$Z_{BUS} = \begin{vmatrix} j0.105 & j0.075 & j0.09 \\ j0.075 & j0.125 & j0.10 \\ j0.09 & j0.10 & j0.145 \end{vmatrix}$$

[ANS]

2a The decoupled load flow method makes use of an approximate version of the Newton Raphson procedure. The principle underlying the decoupled approach is based on two observations.

(i) The change in the voltage angle δ primarily affects the flow of real power P and leaves the flow of Q relatively unchanged. i.e., $\frac{\partial Q}{\partial \delta}$ tends to zero.

(ii) The change in the voltage magnitude primarily affects Q and leaves P relatively unchanged. i.e., $\frac{\partial P}{\partial |V|}$ tends to zero.

The N.R. equation $\begin{bmatrix} \frac{\partial P}{\partial \delta} & \frac{\partial P}{\partial |V|} \\ \frac{\partial Q}{\partial \delta} & \frac{\partial Q}{\partial |V|} \end{bmatrix} \begin{bmatrix} \Delta \delta \\ \frac{\Delta V}{|V|} \end{bmatrix} = \begin{bmatrix} \Delta P \\ \Delta Q \end{bmatrix}$ becomes decoupled

$$\left[\frac{\partial P}{\partial \delta}\right]\left[\Delta \delta\right] = \left[\Delta P\right] \quad \text{and} \quad \left[\frac{\partial Q}{\partial |V|}\right]\left[\frac{\Delta V}{|V|}\right] = \Delta Q$$

In Fast decoupled load flow analysis, further approximations $\cos(\delta_i - \delta_j) = 1$, $\sin(\delta_i - \delta_j) = \delta_i - \delta_j$ are made since $\delta_i - \delta_j$ is very small.

Also it is assumed the line is predominantly susceptive so that $G_{ij} \sin(\delta_i - \delta_j) << B_{ij} \cos(\delta_i - \delta_j)$

and $Q_i << |V_i|^2 B_{ii}$

The approximations yield the off-diagonal elements of the Jacobian $\frac{\partial P_i}{\partial \delta_j} = -|V_i V_j| B_{ij}$

and diagonal elements $\frac{\partial P_i}{\partial \delta_i} = -|V_i|^2 B_{ii}$

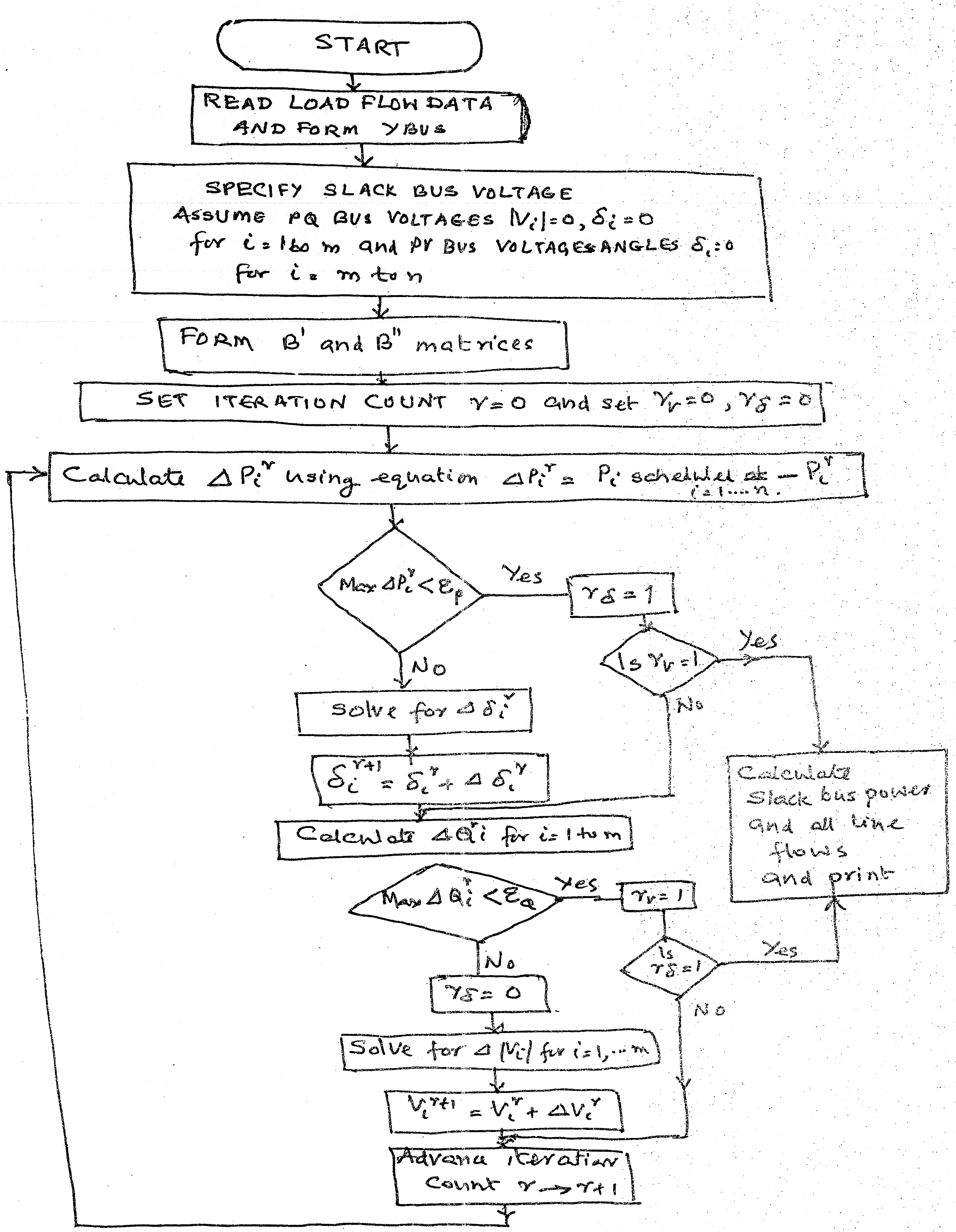
Then voltages are removed from the entries in the coefficient matrix

Finally the equations become

$$\begin{bmatrix} -B_{22} & -B_{23} & -B_{24} \\ -B_{32} & -B_{33} & -B_{34} \\ -B_{42} & -B_{43} & -B_{44} \end{bmatrix} \begin{bmatrix} \Delta \delta_2 \\ \Delta \delta_3 \\ \Delta \delta_4 \end{bmatrix} = \begin{bmatrix} \frac{\Delta P_2}{|V_2|} \\ \frac{\Delta P_3}{|V_3|} \\ \frac{\Delta P_4}{V_4} \end{bmatrix} \quad \cdots ①$$

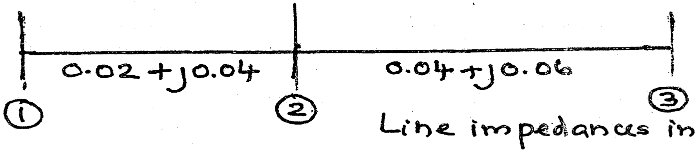
and

$$\begin{bmatrix} -B_{22} & -B_{23} & -B_{24} \\ -B_{32} & -B_{33} & -B_{34} \\ -B_{42} & -B_{43} & -B_{44} \end{bmatrix} \begin{bmatrix} \Delta |V_2| \\ \Delta |V_3| \\ \Delta |V_4| \end{bmatrix} = \begin{bmatrix} \frac{\Delta Q_2}{|V_2|} \\ \frac{\Delta Q_3}{|V_3|} \\ \frac{\Delta Q_4}{V_4} \end{bmatrix} \quad \cdots\cdots ②$$

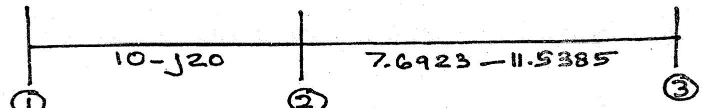


FLOW CHART FOR FDLF algorithm.

2b



Line impedances in Pu



Line Admittances in p.u.

$$Y_{BUS} \text{ of the system } = \begin{vmatrix} 10-j20 & -10+j20 & 0 \\ -10+j20 & 17.6923-j31.5385 & -7.6923+j11.5385 \\ 0 & -7.6923+11.5385 & 7.6923-11.5385 \end{vmatrix}$$

Given, $V_1' = 1\angle 0$ $\quad |V_3| = 1.02 \quad$ Let $|V_2|^0 = 1$, $\delta_2^0 = 0$, $\delta_3^0 = 0$

Using G.S. method,

$$V_2' = \frac{1}{Y_{22}}\left[\frac{P_2 - jQ_2}{(V_2^0)^*} - Y_{21}V_1' - Y_{23}V_2^0\right]$$

Given $P_2 = -5.9$ p.u., $Q_2 = 1.5$ p.u.

$$V_2' = \frac{1}{17.6923-j31.5385}\left[\frac{-5.9-j1.5}{1\angle 0} - (-10+j20)1\angle 0 - (-7.6923+j11.5385)1.02\angle 0\right]$$

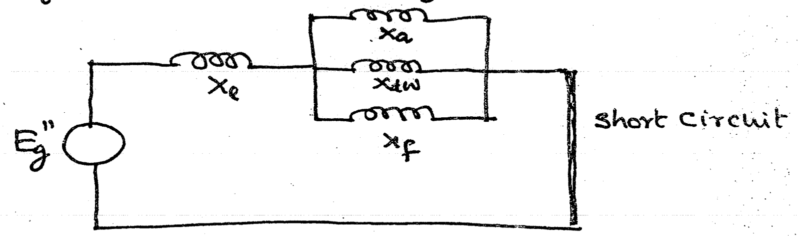
$$= 0.02765\angle 60.7^\circ\left[-5.9-j\overset{1.5}{\cancel{1.5}}+10-j20+7.846-j11.769\right]$$

$$= 0.02765\angle 60.7^\circ\left[11.946-j33.269\right]$$

$$= 0.964-j0.162 = 0.977\angle -9.55^\circ \text{ p.u.}$$

Busbar Voltage at bus 2 at the end of first iteration using G.S. method is $\underline{\underline{0.977\angle -9.55^\circ \text{ p.u.}}}$

4 a Consider a three phase alternator delivering a current I_L. During short circuit, the circuit model of subtransient state of an alternator is given below.

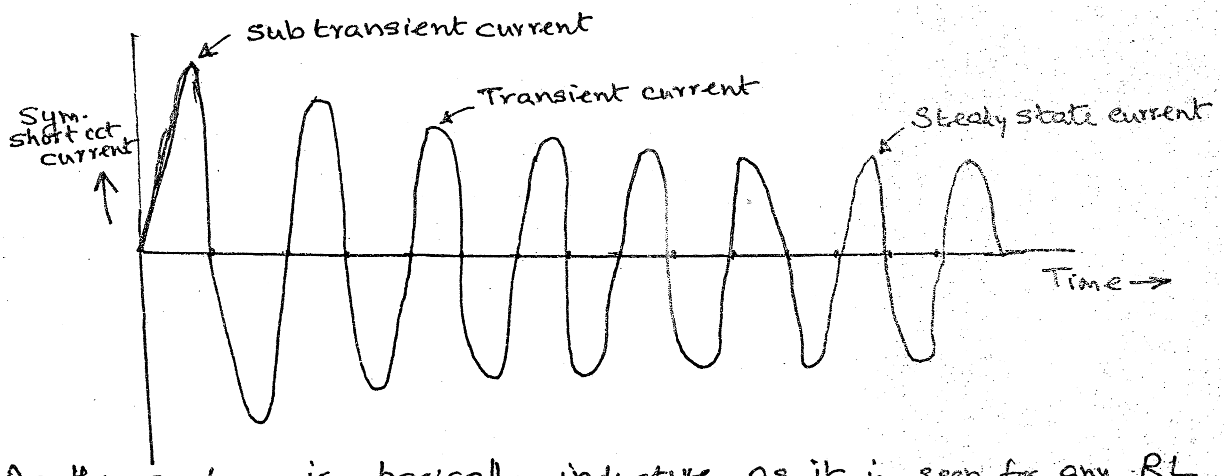


Under steady state, the armature reaction of the synchronous generator produces a demagnetising effect. So the leakage reactance X_l and armature reaction reactance will be presented in series. So E_g will be equal to terminal voltage $V + I_L(X_l + X_a)$ But at the instant of short circuit, during subtransient period, the increase in field current and damper winding current will set up flux in a direction to augment the main flux. This effect can be represented by two reactances X_f and X_{dw} in parallel with the armature reaction reactance.

So the total reactance upto short circuit reduces to

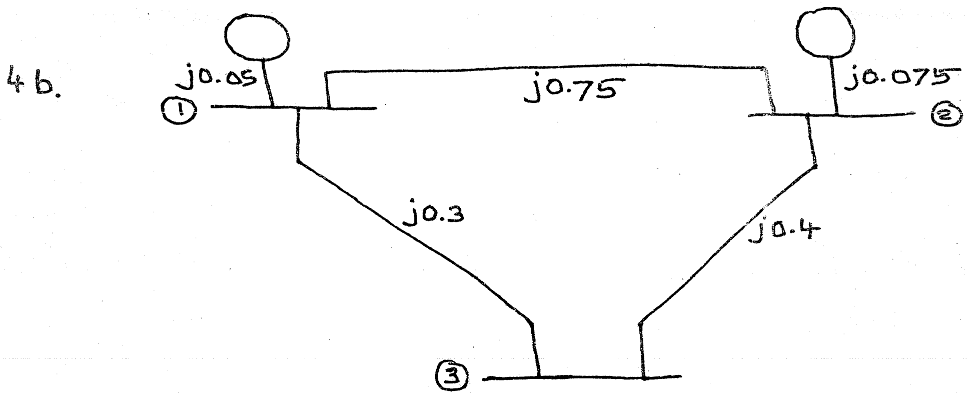
$$X_l + \left(\frac{1}{X_a} + \frac{1}{X_{dW}} + \frac{1}{X_f}\right)^{-1}$$

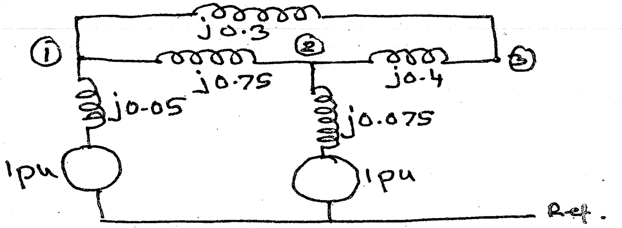
during subtransient period. This reduction of reactance causes a heavy rush of a.c. current and the oscillogram of the short circuit current after removing the D.C. off set current is as given below



As the system is basically inductive, as it is seen for any RL circuit, there is also a d.c. offset current whose maximum is equal to $\frac{V_m}{|Z|} + \frac{V_m}{|Z|}\cos\alpha$ if short circuit occurs ~~at~~ when $v(t)$ is $V_m \sin(\omega t + \alpha)$.

4 b.





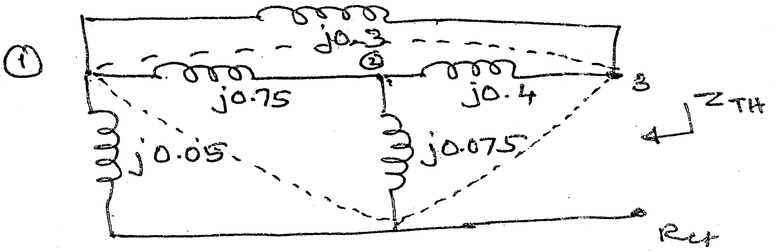
Per Unit Impedance diagram

Fault occurs between ③ and ref through an impedance $Z_f = j0.15$

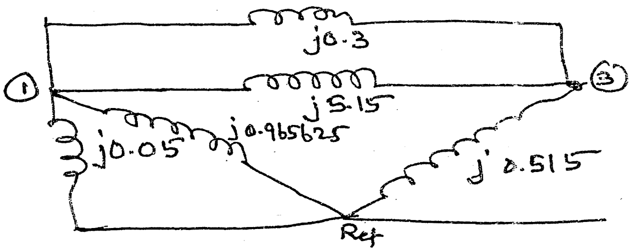
Fault current equals $\dfrac{V_{\text{Thevenin at bus 3}}}{Z_{\text{Thevenin}} + Z_f}$.

$V_{Th} = 1$ p.u. (Given prefault bus voltages = 1 p.u.)

To find Z_{TH}, ~~voltages~~ generators are ~~assumed~~ ~~shorted and~~ replaced by their internal impedance



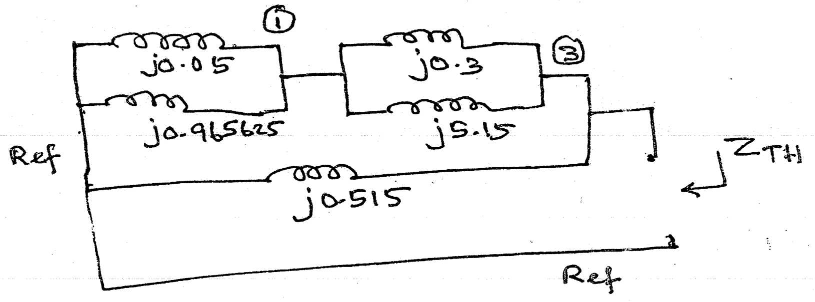
Node ② is eliminated, using star to delta transformation

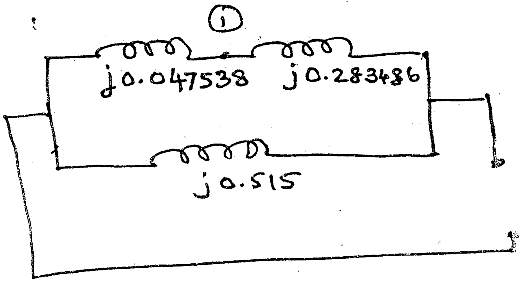


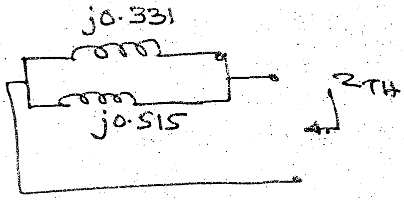
$$Z_{13} = j0.75 + j0.4 + \frac{j0.75 \times j0.4}{j0.075} = j5.15$$

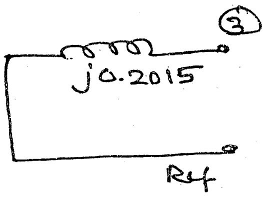
$$Z_{1ref} = j0.75 + j0.075 + \frac{j0.75 \times j0.075}{j0.4} = j0.965625$$

$$Z_{3ref} = j0.075 + j0.4 + \frac{j0.075 \times j0.4}{j0.75} = j0.515$$









$Z_{TH} = j0.201495$ pu.

$$\therefore \quad I_a = \frac{E_{TH}}{Z_{TH}+Z_F} = \frac{1\angle 0}{j0.201495+j0.15} = 2.845 \text{ p.u.} \angle -90^\circ$$

$$I_b = 2.845\angle -210^\circ \text{ pu}$$

$$I_c = 2.845\angle +30^\circ \text{ pu.}$$

At Bus 3, $V_a = I_a Z_f = 2.845\angle -90 \times j0.15 = \underline{0.42675 \text{ p.u.}}$ $[V_{Bus 3}]$

$$\text{Voltage at Bus 1} = 1 - \left\{\begin{array}{l}\text{Fault current through} \\ \text{one parallel path} \\ \text{with } \text{~~abc~~ } Z \text{ j0.331}\end{array}\right\} \times j0.047538$$

$$= 1 - \left\{2.845\angle -90 \times \frac{j0.515}{j0.846}\right\} \times j0.047538$$

$$= \underline{\underline{0.91767 \text{ p.u.}}} \quad [V_{Bus 1}]$$

Voltage at Bus 2 =

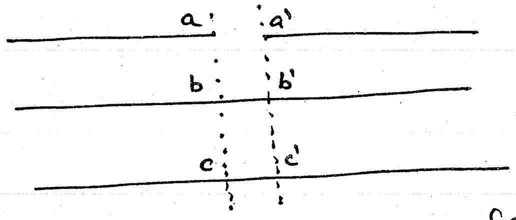
$$\text{Current from generator 1} = \frac{E_1 - V_1}{X_1} = \frac{1 - 0.91767}{j0.05}$$

$$= 1.6466\angle -90^\circ \text{ pu}$$

$$\therefore \text{Current from generator 2} = \underset{\angle -90}{2.845} - \underset{\angle -98}{1.6466} = 1.1984 \text{ pu.}$$

$$\text{Voltage at Bus 2} = 1 - \underset{\angle 90^\circ}{0.075} \times \underset{\angle -90^\circ}{1.1984} = \underline{\underline{0.910 \text{ p.u.}}}$$

5a There are two types of series faults in the power system.
(i) One conductor open and (ii) two conductors open.
The open conductor fault is in series with the line.



One conductor open fault.

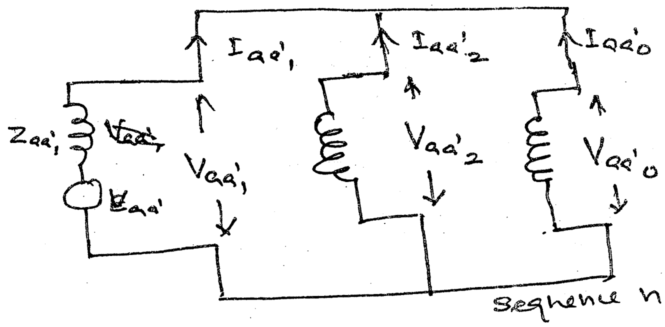
For one conductor open fault, $V_{bb'} = V_{cc'} = 0$ $I_a = 0$

$$\begin{bmatrix} V_{aa'0} \\ V_{aa'1} \\ V_{aa'2} \end{bmatrix} = \frac{1}{3}\begin{bmatrix} 1 & 1 & 1 \\ 1 & a & a^2 \\ 1 & a^2 & a \end{bmatrix}\begin{bmatrix} V_{aa'} \\ V_{bb'} \\ V_{cc'} \end{bmatrix} = \frac{1}{3}\begin{bmatrix} 1 & 1 & 1 \\ 1 & a & a^2 \\ 1 & a^2 & a \end{bmatrix}\begin{bmatrix} V_{aa'} \\ 0 \\ 0 \end{bmatrix}$$

$\therefore V_{aa'1} = V_{aa'2} = V_{aa'0} = \frac{1}{3} V_{aa'}$

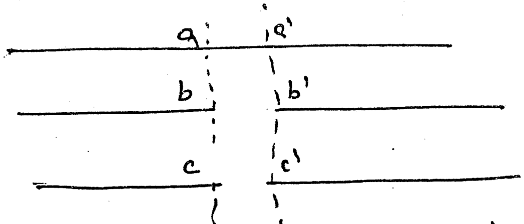
Also as $I_{aa'} = 0$, $I_{a1} + I_{a2} + I_{a0} = 0$

This shows the sequence connection as follows

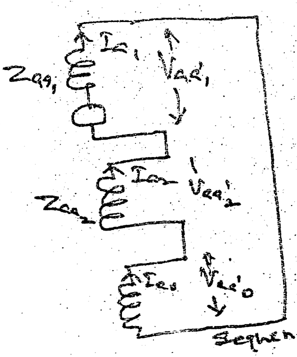


Sequence network for one conductor open.

This suggests a parallel connection of sequence networks.



Two Conductor open fault.



Sequence network.

$V_{aa'} = 0$
$I_b = I_c = 0$

$\therefore V_{aa'1} + V_{aa'2} + V_{aa'0} = 0$, $I_{a1} = I_{a2} = I_{a0} = \frac{1}{3} I_a$

This suggests a series connection of sequence networks

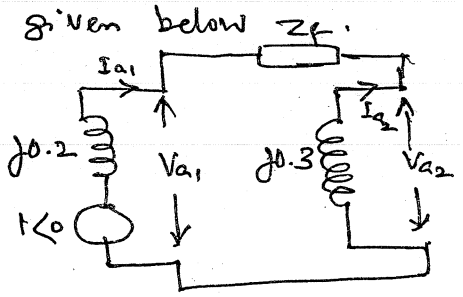
5b MVA 20

kV 13.8 $\therefore$ Base current = $\frac{20\times10^6}{\sqrt{3}\times13.8\times10^3}$ = 836.74 A

$X_d = X_1 = j0.2_{pu}$ $X_2 = j0.3_{pu}$ $X_0 = j0.15_{pu}$

For line to line fault, sequence net work is as given below Z_f.

Here $Z_f = 0$.



$I_{a_1} = \frac{1\angle0}{j0.5} = 2\angle{-90^\circ}$ pu

$I_{a_2} = -I_{a_1} = 2\angle{+90^\circ}$ pu.

Fault current = $I_b = -j\sqrt{3}\,I_{a_1} = -\sqrt{3}\times2\angle0^\circ$

$= -3.464$ p.u.

$= -3.464 \times I_b = \underline{\underline{-2898.47\ A}}$

$V_{a_1} = 1\angle0 - I_{a_1}\times j0.2$

$= 1\angle0 - 2\angle{-90}\times0.2\angle90 = \underline{\underline{0.6\ pu.}}$

$V_{a_2} = -I_{a_2}\cancel{X}_2 = -2\angle{+90}\times j0.3 = \underline{\underline{0.6\ pu.}}$

$V_{a_0} = 0$. (As this is a line to line fault.)

$V_a = V_{a_1} + V_{a_2} + V_{a_0} = 1.2$ pu. =

$V_b = a^2V_{a_1} + aV_{a_2} = (a^2+a)V_{a_2} = -0.6$ pu (Since $a^2+a = -1$)

$V_c = aV_{a_1} + a^2V_{a_2} = -0.6$ pu.

Line Voltage $V_{ab} = V_a - V_b = 1.2 - (-0.6) = 1.8$ pu.

$V_{ac} = V_a - V_c = 1.2 - (-0.6) = 1.8$ pu

$V_{bc} = V_b - V_c = 0$ kV. (as lines b & c are shorted)

$V_{ab} = \frac{1.8\times13.8}{\sqrt{3}} = \underline{\underline{14.34\ kV}}$

$V_{ac} = \underline{\underline{14.34\ kV}}$ and V_{bc} = zero kV.

6(a) Generally contingency analysis in a power system can be done either by using Z_{bus} in a super position method or by Brown's Z_{bus} contingency method. In the Superposition method, the bus impedance matrix is used with linearised loads replaced by current injections. If a generator load changes by a small amount ΔI_k at bus k, the voltage after the change is expressed using superposition theorem.

$$E_{BUS}(F) = E_{BUS}(0) + Z_{BUS} \times \Delta I$$

$$= E_{BUS}(0) + \begin{bmatrix} Z_{1k} \\ Z_{2k} \\ \vdots \\ Z_{mk} \end{bmatrix} \Delta I_k$$

If ΔI_k change is determined by an external impedance, this method is very similar to fault calculation at the bus. If a line from bus 'p' to 'q' was to open circuit, a method to estimate the system voltage is as follows in this method.

(i) Initial voltage magnitudes and phase angles are specified at all buses of the system.

(ii) Replace all loads and generators by constant current Sources. The line from 'p' to 'q' is replaced by current sources i_{pq} and i_{qp} which are input to the line π-equivalent. All elements to the ground are removed.

(iii) Calculate Z_{BUS} with line removed by adding $-Z_{pq}$ as a link

(iv) Calculate the effect of reversing the current in line 'pq' by injections at bus 'p' and 'q'.

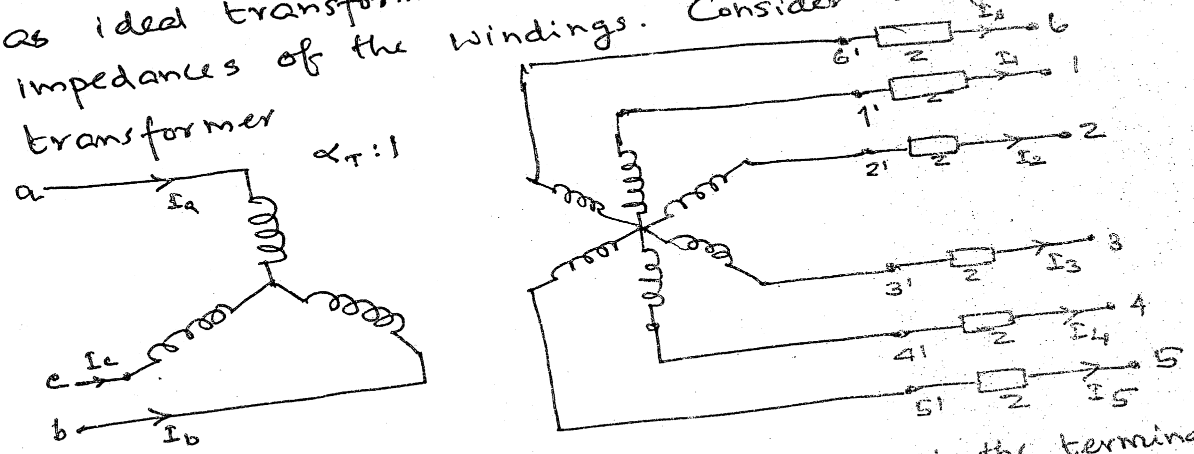
$$\Delta E_{BUS} = \begin{bmatrix} \Delta E_1 \\ \Delta E_2 \\ \vdots \\ \Delta E_m \end{bmatrix} = Z'_{BUS} \Delta I = Z'_{BUS} \begin{bmatrix} 0 \\ 0 \\ \vdots \\ -i_{pq} \\ \vdots \\ -i_{qp} \\ 0 \end{bmatrix}$$

Note that only two columns of Z'_{bus} are necessary

(v) Calculate $E_{BUS}(F) = E'_{BUS}(0) + \Delta E_{BUS}$.

This method is very easy for contingency Analysis.

b) Mathematical model of various elements of six phase systems are developed. In transformers associated with six phase systems, six phase conversion is obtained from the commonly available three phase units employing a variety of connection schemes, viz wye|star, delta|star, & wye|hexagon etc. In developing the mathematical model, transformers are represented as ideal transformers with equivalent per unit leakage impedances of the windings. Consider a wye star transformer



The voltage and current relations at the terminals of the ideal transformer in series with the equivalent per unit leakage impedance of the windings can be calculated. At the terminals of the ideal transformer

$$V'^{6}_{p} = N V^3_p \quad \text{or} \quad V^3_p = \frac{1}{2} N^T V'^{6}_{p}$$

$$I^6_p = N I^3_p \qquad I^3_p = \frac{1}{2} N^T I^6_p$$

$$V^6_p = V'^{6}_{p} - [Z]\, I^6_p$$

$$V^3_p = [V_a\ V_b\ V_c]^T$$

$$V^6_p = [V_1\ V_2\ V_3\ V_4\ V_5\ V_6]^T$$

$$I^3_p = [I_a\ I_b\ I_c]^T$$

$$I^6_p = [I_1\ I_2\ I_3\ I_4\ I_5\ I_6]^T$$

$$N^T = \begin{bmatrix} 1 & 0 & 0 & -1 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & -1 \\ 0 & -1 & 0 & 0 & 1 & 0 \end{bmatrix}$$

$$I^6_p = [Y][N]\, V^3_p - [Y]\, V^6_p$$

$$I^3_p = \frac{1}{2}[N]^T[y][N]\, V^3_p - \frac{1}{2} N^T [Y]\, V^6_p$$

This gives the mathematical model which can be represented in matrix form. For other types of transformers also models are developed.

7(a) The optimal power flow solution requires the real and reactive power flow to be adjusted so as to minimise instantaneous operating costs, with the power quality with the power quality maintained and with sufficient security. The power quality and security constraints gives rise to many inequality constraints on controlled and dependent variables.

$P_{Gi\,min} \leq P_{Gi} \leq P_{Gi\,max}$ is an inequality constraint on control variable. After a control variable reaches any of the limits, its component in the gradient should continue to be computed in later iterations as the variable may come within limits at some later stage.

Often the upper and lower limits of dependent variables are specified are specified as

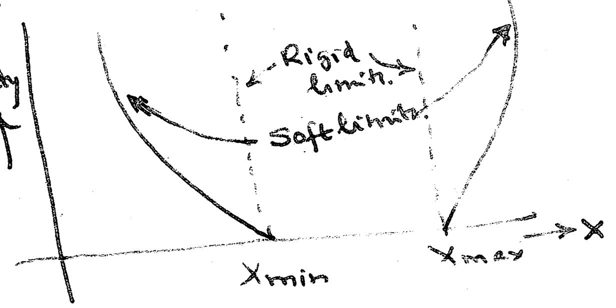
$|V|_{min} \leq V \leq |V|_{max}$ on a PQ bus

such inequality functions can be conveniently handled by the penalty function method. The objective function is augmented ~~for~~ by penalties for ~~close to constraint limits~~ inequality constraints violations. This forces the solution to lie sufficiently close to the constraint limits, when these limits are violated. The penalty function method is valid in this case because these constraints are seldom rigid limits in the strict sense, but are in fact soft limits

A suitable penalty function is defined as

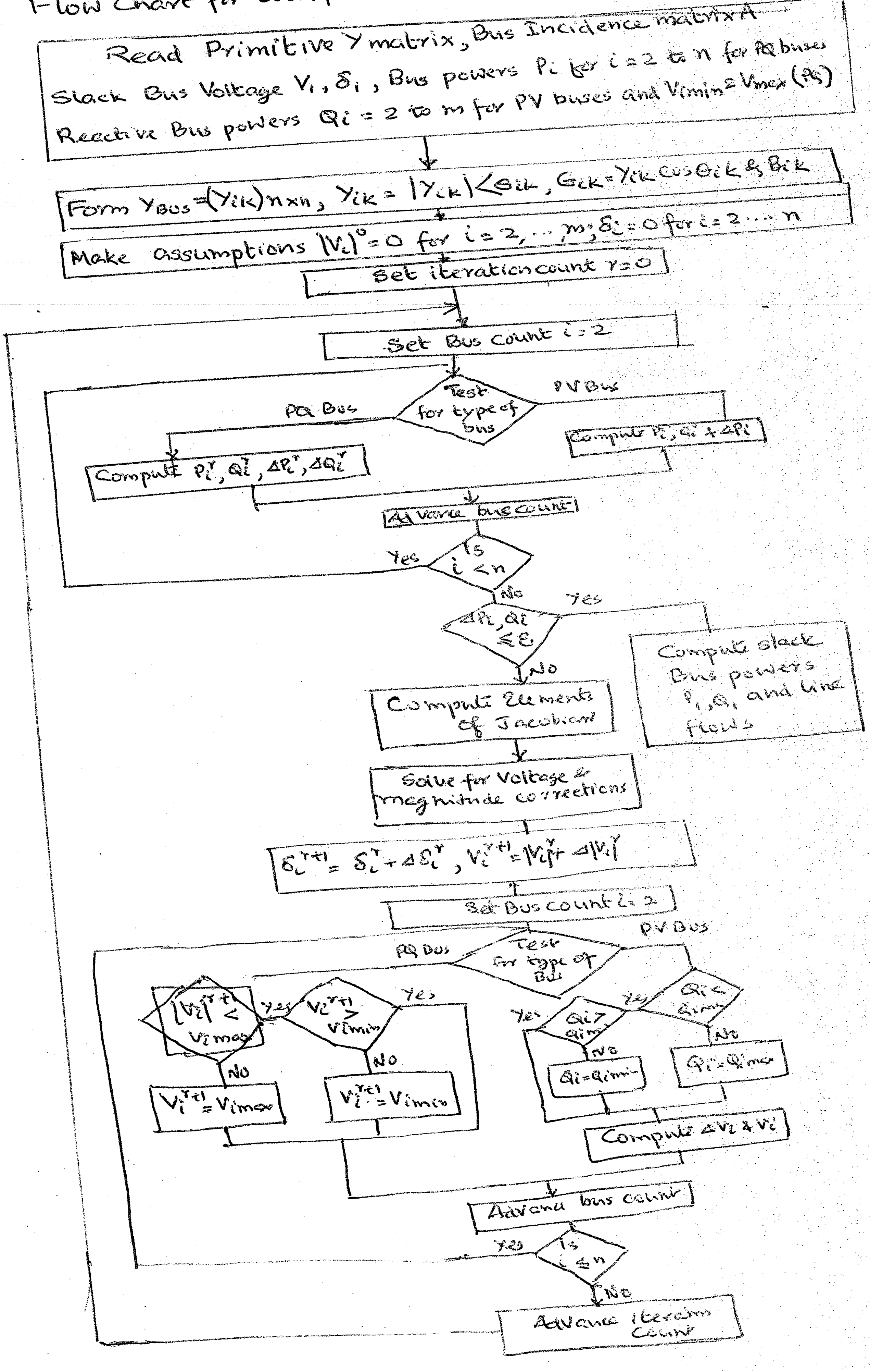
$W_j = \gamma_j (x_j - x_{j\,max})^2$ whenever $x_j > x_{j\,max}$

γ_j is a real positive number which controls the degree of penalty and is called penalty factor.



By choosing a higher value of γ_j the penalty function can be made steeper.

7 b. Flow Chart for Load flow solution by N.R Method



G 6550

(Pages : 2)

Reg. No.....................................

Name.....................................

M.TECH. DEGREE EXAMINATION, MARCH 2011

Second Semester

Branch : Electrical and Electronics Engineering

Specialization : Power Electronics and Power Systems

PEPS-202—ELECTRIC DRIVES

Time : Three Hours

Maximum : [illegible] Marks

Answer any five questions.
All questions carry equal marks.

1. (a) What are the components of Load torque ? Explain with necessary graphs. ([illegible] marks)

(b) A motor having a suitable control circuit develops a torque given by the relationship $T_M = aw + b$, where a and b are positive constants. This motor is used to drive a load whose torque is expressed as $T_L = cw^2 + d$, where c and d are some other positive constants. The total inertia of rotating mass is J.

(i) Determine the relations among the constants a, b, c and d in order that the motor can start together with the load and have an equilibrium operating speed ?

(ii) Calculate the equilibrium operating speed.

(iii) Will the drive be stable at this speed ?

(iv) Determine the initial acceleration of the drive.

(v) Determine the maximum acceleration of the drive.

([illegible] marks)

2. (a) Draw the power circuit diagram and explain the operation of a three-phase fully controlled bridge rectifier with d.c. motor load. Draw the waveforms of voltage and current for continuous load current. III

([illegible] marks)

(b) A 3-phase full converter is used to control the speed of a [illegible] d.c. motor. The a.c. supply is 240 V, 50 Hz, The motor e.m.f. constant is [illegible] and the armature resistance is 1.5 Ω. For α = 60°, the motor speed us 800 r.p.m. Determine :

(i) average value of motor current, assuming it to be ripple free.

(ii) r.m.s. value of supply line current and supply power factor.

([illegible] marks)

3. (a) Discuss briefly on Linear Transfer function model of Power Converters. ([illegible] marks)

(b) Describe with neat block diagram a closed loop chopper fed d.c. drive system. ([illegible] marks)

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Turn over

dc → series / shunt.
it is not economic

1 (a). What are the components of load torque? Explain with necessary graphs.

Components of load torque :-

The load torque is represented by T_L

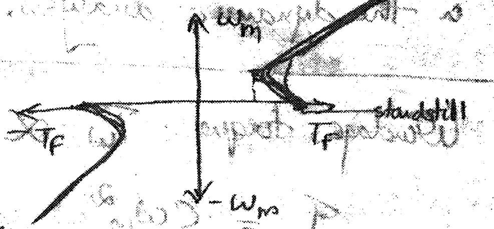
T_L — Friction torque T
— Windage torque
— for doing usef mech. work - T_L

T_F ⇒ friction is mainly present at the motor shaft.
This is the equivalent value of various friction torques referred to the motor shaft.

T_W ⇒ When a motor runs, wind (air) generates a torque opposing the motion known as windage torque.

T_L ⇒ The nature of this torque depends on particular applin. It may be const & independent of speed, funcn of speed, depends on position & path followed by load. It can be time variant or time invariant. It changes with load's mode of operation.

→ Friction torque with speed ⇒

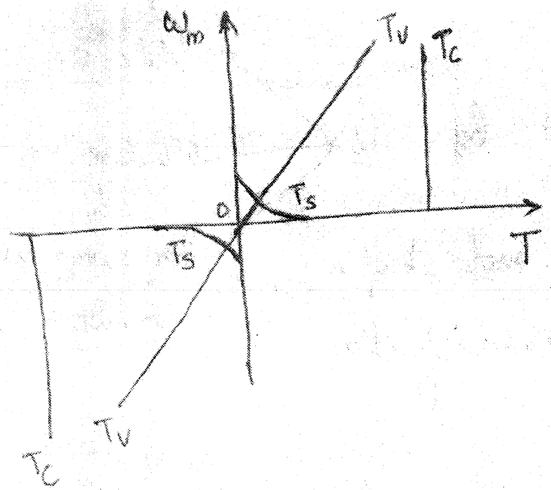


The value of T_F at standstill is much higher than its value slightly above zero speed.

Friction @ zero speed ⇒ stiction / static friction.

For the motor to start, the motor torque should exceed stiction.

T_F — T_V (viscous friction)
— T_C (Coulomb friction)
— T_S (additional torque at standstill)



T_V ⇒ linearly varying with speed

$T_V = B\omega_m$ B ⇒ viscous friction Coefficient.

T_C ⇒ independent of Speed.

T_S ⇒ it is Present only @ Standstill & not taken into account in the dynamic analysis.

Windage torque $T_W \propto$ Speed Squared.

$$T_W = C\omega_m^2$$

C = Const.

From the above discussions

$$T_e = T_L + \overbrace{\underbrace{B\omega_m}_{\downarrow \, T_V} + T_c}^{T_F} + \underbrace{C\omega_m^2}_{\downarrow \, T_W},$$

$\underline{T_c + C\omega_m^2}$ is negligible when compared with T_L + very small when compared with $B\omega_m$ (T_V)

$$T = J\frac{d\omega_m}{dt} + T_L + B\omega_m \cdot$$

If there is a torsional elasticity in the shaft (that couples load to the motor), an additional component of load τ will be present $\Rightarrow$ Coupling τ.

$$T_e = K_e \theta_e \cdot$$

$\theta_e \Rightarrow$ torsional angle of coupling (radians)

$K_e \Rightarrow$ rotational stiffness of the shaft (Nm/rad).

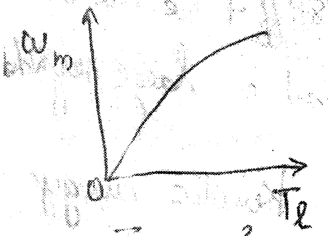
In most of applns, shaft is perfectly stiff + K_e can be neglected. This has adverse effect, if present in large magni There is potential energy associated with K_e + kinetic energy with the dynamic τ. Exchange of energy b/w these two energ storage tends to produce oscillations, which are damped by T_V When B is small, oscillation occurs produces noise + als shaft may break, when the drive is started.

At low speeds, windage τ is neglegible. $\therefore$ net τ is mainly due to gravity, which is Const & independent of speed. ie T_c. ~~eg:- hoist (low speed)~~.

ie T_c is dominating. eg:- Paper mill drive.

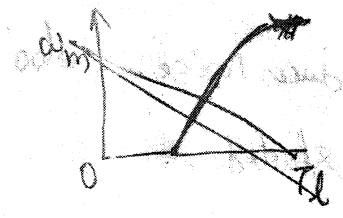
In fans, Compressors, aeroplanes, centrifugal pumps, Ship Propellers, traction etc, T_l is a func of speed.

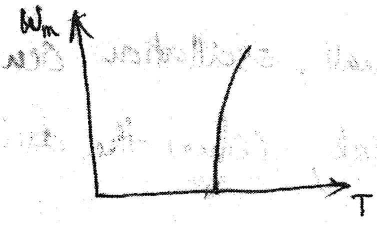
In fans, compressors & aeroplanes, the windage dominates, as the windage is the opposition offered by air to the motion. Hence $T_l \propto \omega_m^2$ (ie $T_W = c\omega_m^2$)



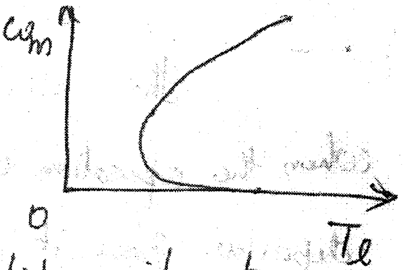
$T_l \propto \omega_m^2$

In high speed hoist $\Rightarrow$ T_V & T_W has large magnitude, in addition to gravity.





for traction load, when moving on a levelled ground. Stiction is very large, bcoz of its heavy mass. Near zero speed, net τ is mainly due to stiction. Bcoz of large ~~speed &~~ stiction & need for accelerating a heavy mass, the motor τ required for starting a train is much larger than what is reqd to run it at full speed. The stiction disappears at a finite speed & windage & viscous friction dominates.



Load torques can be broadly classified into two categories
- active
- passive.

Active load torques ⇒ Load torques which have the potential to drive the motor under equilibrium condition are called active load torques. Such load torques usually retain their sign, when the direction of the drive rotation is changed.

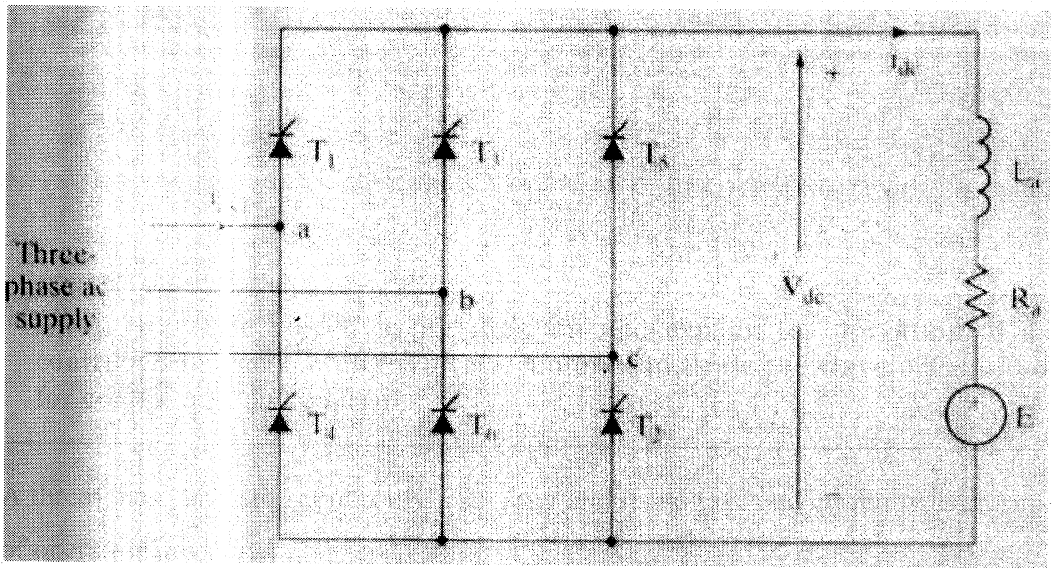
eg: τ due to gravitational force, tension, compression & torsion undergone by an elastic body.

Passive load torques:- Load τ which always oppose the motion & change their sign on the reversal of motion are called passive load τ.

eg: 'τ' due to friction, windage, cutting etc.

2 (a). Draw the power circuit diagram and explain the operation of a three phase fully controlled bridge rectifier with dc. motor. load.Draw the waveforms of voltage and current for continuous load current.

A three-phase thyristor-cont rolled converter and its voltage and current waveforms in the rectifier mode of operation are shown.

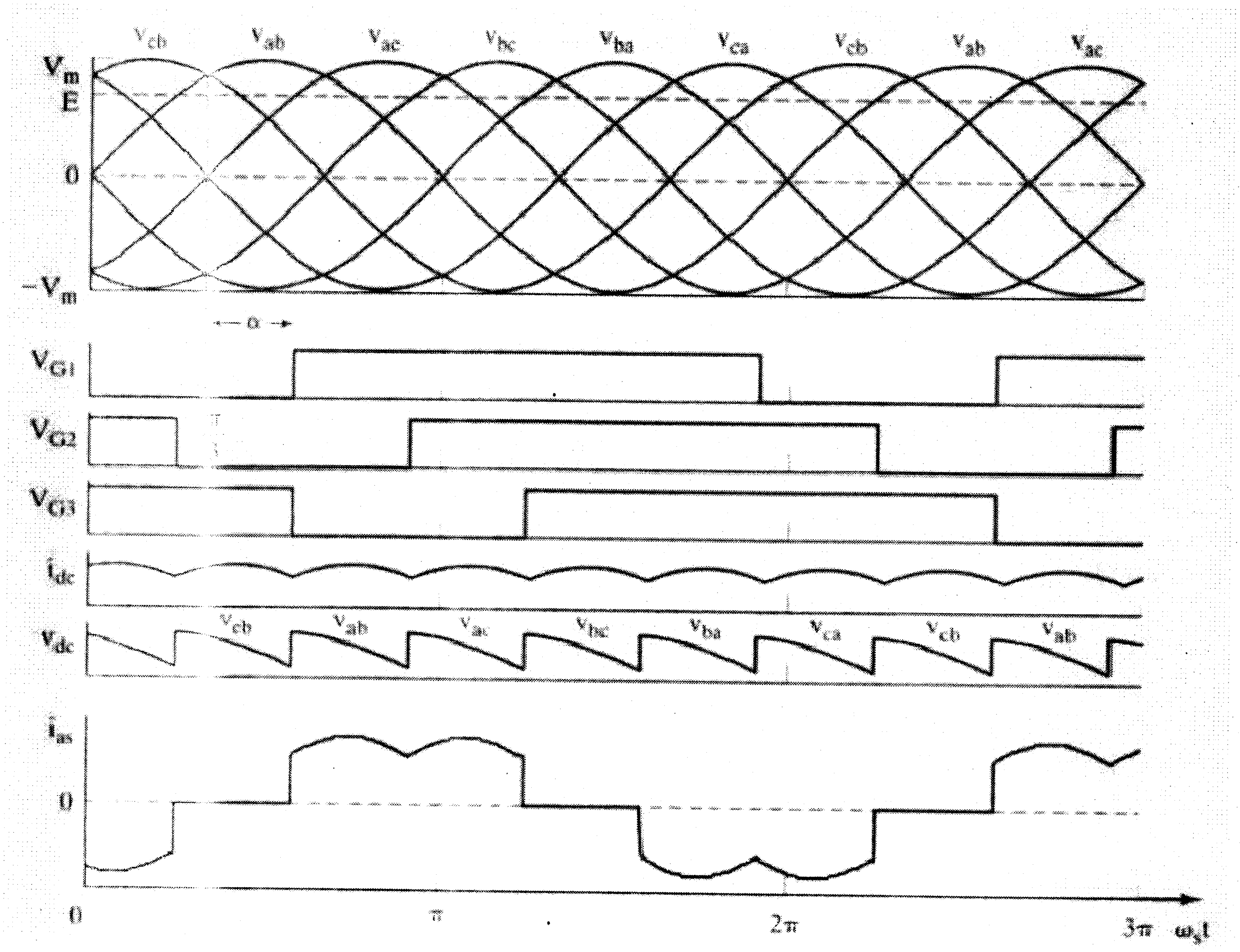


A three-phase thyristor-controlled converter is shown in Figure and its voltage and current waveforms in the rectifier mode of operation are shown in Figure 3.11. The current is assumed to be continuous for the present. At a given instant, two thyristors are conducting. Assuming that the voltage between phases *a* and *b* is maximum, then the thyristors T_1 and T_6 are conducting. The next line voltage to get more positive than *ab* is *ac*. At that time, the triggering signal for T_6 will be disabled and that of T will be enabled. Note that the anode of T_2 is more negative than the cathode of T because line voltage *ac* is greater than the line voltage *ab*. That will turn off T_6 and transfer the current from T_6 to T_2. The delay in current transfer from T_6 to T_2 is dependent on the source inductance. During this current transfer, T_1, T_6, and T_2 are all conducting, and the load voltage is the average of the line voltages *ab* and *ac*. This phenomenon is the commutation overlap, which results in a reduction in the load voltage. The load current will remain the same during commutation of T_6. The current in T_6 declines by the same proportion as current in T_2 rises. It is to be

observed that the current transfer is effected by the source voltages: voltage *ac* becoming greater than the voltage *ab*, resulting in the reverse biasing of T_6 and forward biasing of T_2. Similarly, it could be seen that the firing/gating sequence is $T_1T_2T_3T_4T_5T_6$ and so on. Also, each of these gating signals is spaced by sixty electrical degrees. The thyristors require small reactors in series to limit the rate of rise of currents and snubbers, which are resistors in series with capacitors across the devices, to limit the rate of rise of voltages when the devices are commutated.

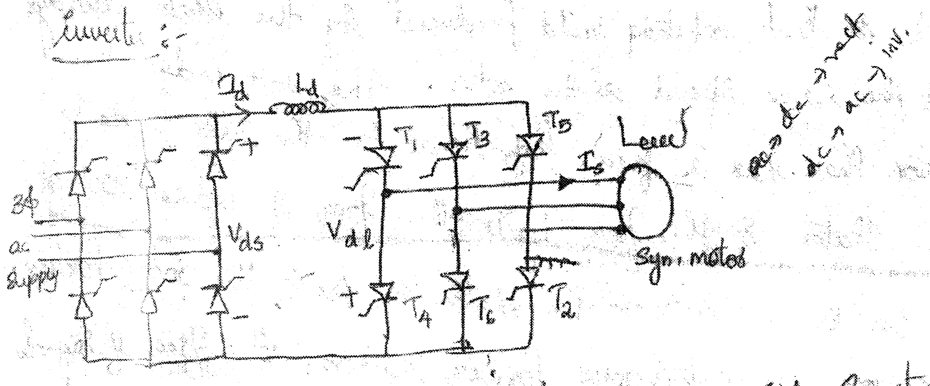
The transfer characteristic of the three-phase controlled rectifier is derived as

$$V_{dc} = \frac{1}{\pi/3}\int_{\frac{\pi}{3}+\alpha}^{\frac{2\pi}{3}+\alpha} V_{ab}\,d(\omega_s t) = \frac{3}{\pi}\int_{\frac{\pi}{3}+\alpha}^{\frac{2\pi}{3}+\alpha} V_m \sin(\omega_s t)\,d(\omega_s t) = \frac{3}{\pi}V_m \cos\alpha$$



7 (a). Draw and explain the block diagram of a self-controlled synchronous fed from 3-phase inverter.

Self Controlled Syn. motor drive employing load Commutated thyristor inverter :-



The drive employs two Converters, source side Converter & load side Converter. The source side Converter is a 6 pulse line Commutated thyristor converter.

For a firing angle range $0 \le \alpha_s \le 90°$, it works as a line Commutated fully Controlled rectifier, delivering +ve V_{ds} & $\overset{+ve}{I_d}$.

For the range of firing angle $90° \le \alpha_s \le 180°$, it works as a line Commutated inverter delivering -ve V_{ds} & +ve I_d.

When a Syn. motor operates at a leading Pf, thyristors of the load side Converter Can be Commutated by the motor induced voltages, in the same way, as thyristors of a line Commutated Converter are Commutated by line voltages.

Commutation of thyristors by induced voltages of load, (load → here is a motor), is known as load Commutation