• Improve presentation

• Try to avoid calculation mistake

MADE EASY

Leading Institute for ESE, GATE & PSUs

ESE 2025 : Mains Test Series

UPSC ENGINEERING SERVICES EXAMINATION

Electrical Engineering

Test-6 : Power Systems + Power Electronics & Drives + Communication Systems

Name : ....

Roll No :

Test Centres			Student's Signature
Delhi ☑	Bhopal ☐	Jaipur ☐	
Pune ☐	Kolkata ☐	Hyderabad ☐	

Instructions for Candidates

1. Do furnish the appropriate details in the answer sheet (viz. Name & Roll No).
2. There are Eight questions divided in TWO sections.
3. Candidate has to attempt FIVE questions in all in English only.
4. Question no. 1 and 5 are compulsory and out of the remaining THREE are to be attempted choosing at least ONE question from each section.
5. Use only black/blue pen.
6. The space limit for every part of the question is specified in this Question Cum Answer Booklet. Candidate should write the answer in the space provided.
7. Any page or portion of the page left blank in the Question Cum Answer Booklet must be clearly struck off.
8. There are few rough work sheets at the end of this booklet. Strike off these pages after completion of the examination.

FOR OFFICE USE

Question No.	Marks Obtained
Section-A	
Q.1	40
Q.2	
Q.3	
Q.4	32
Section-B	
Q.5	28
Q.6	42
Q.7	
Q.8	49
Total Marks Obtained	191

Signature of Evaluator: Sourabh kumar

Cross Checked by: ....

IMPORTANT INSTRUCTIONS

CANDIDATES SHOULD READ THE UNDERMENTIONED INSTRUCTIONS CAREFULLY. VIOLATION OF ANY OF THE INSTRUCTIONS MAY LEAD TO PENALTY.

DONT'S

1. Do not write your name or registration number anywhere inside this Question-cum-Answer Booklet (QCAB).
2. Do not write anything other than the actual answers to the questions anywhere inside your QCAB.
3. Do not tear off any leaves from your QCAB, if you find any page missing do not fail to notify the supervisor/invigilator.
4. Do not leave behind your QCAB on your table unattended, it should be handed over to the invigilator after conclusion of the exam.

DO'S

1. Read the Instructions on the cover page and strictly follow them.
2. Write your registration number and other particulars, in the space provided on the cover of QCAB.
3. Write legibly and neatly.
4. For rough notes or calculation, the last two blank pages of this booklet should be used. The rough notes should be crossed through afterwards.
5. If you wish to cancel any work, draw your pen through it or write "Cancelled" across it, otherwise it may be evaluated.
6. Handover your QCAB personally to the invigilator before leaving the examination hall.

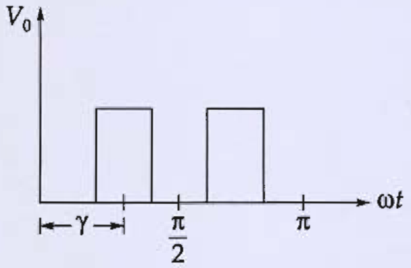
Do not write in this margin

Section-A : Power Systems + Power Electronics & Drives + Communication Systems

1 (a) Explain multiple pulse modulation with neat diagram.

(i) Derive the Fourier series expansion of output voltage V_0 in MPM.PWM inverters.

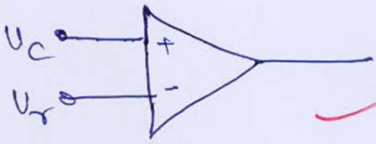
(ii)

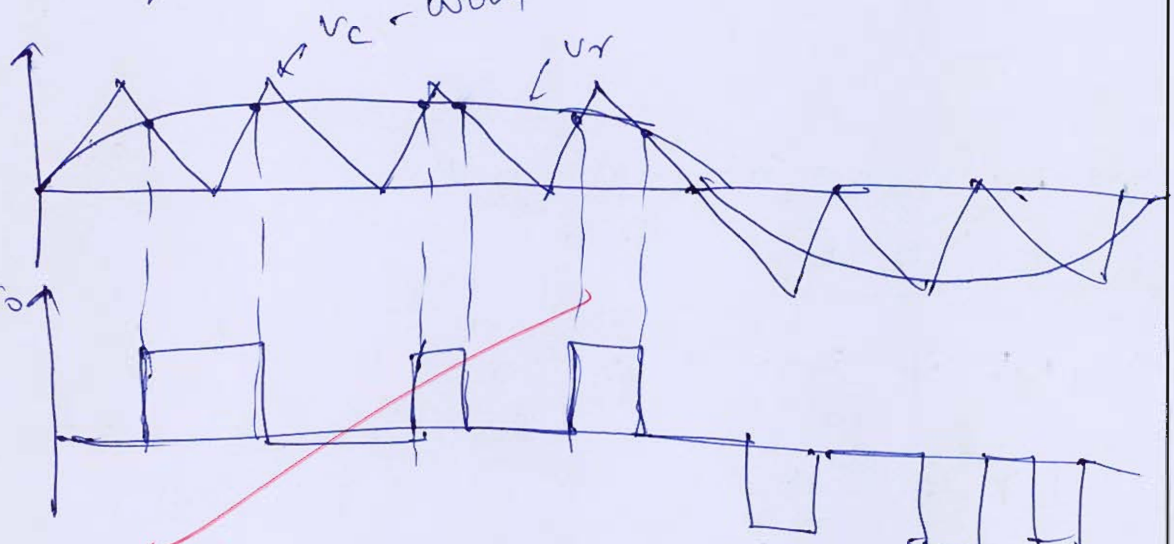


From the above PWM waveform derive, the expression for γ in terms of N(Number of pulses per half cycle) and pulse width.

[12 marks]

multiple pulse modulation





In multiple PWM triangular carrier wave is compared with sinusoidal reference wave.

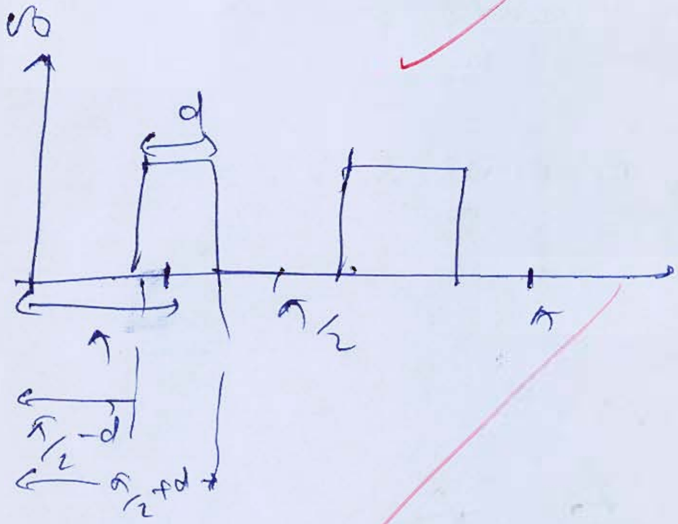
(i) The output voltage & fourier series expression of multiple PWM inverters is —

$$v_0 = \sum_{n=1,3,5}^{\infty} \frac{4V_s}{n\pi} \sin n\gamma \sin nd \sin n\omega t$$

where γ = space width

$2d$ = pulse width

(ii)



If N number of pulse in each half cycle.

$$(N+1)\gamma + 2d = \pi$$

$$\boxed{\gamma = \frac{\pi - 2d}{N+1}}$$

7

Do not write in this margin

1 (b) A 3-ϕ short transmission line is delivering power to a 3-ϕ load of 800 kW per phase at 0.8 p.f. leading. The transmission line is having series resistance of 0.015 Ω/km and series reactance of 0.02 Ω/km. The sending end voltage is maintained at 3300 V and the length of the line is 20 km. Calculate the receiving end voltage and line current.

[12 marks]

Given :- 3 ϕ load 800 kW at 0.8 pf leading

let V_R per phase receiving end voltage

I_R per phase receiving end current

$pf = 0.8$ leading

$\Rightarrow V_R I_R \cos\phi = 800 \times 10^3$

$$I_R = \frac{800 \times 10^3}{V_R \times 0.8}$$

$$I_R = \frac{10^6}{V_R} \quad \text{— (1)}$$

Given :- $Z = (0.015 + j\,0.02)\ \Omega/\text{km}$

$l = 20$ km

So Total impedance

$$Z_T = Z l = (0.015 + j\,0.02) \times 20$$

$$Z_T = (0.3 + j\,0.4)\ \Omega$$

$R = 0.3\Omega \quad X = 0.4\ \Omega$

$$V_s = \frac{3300}{\sqrt{3}} = 1905.25\text{ V}$$

$$V_s = \left[(V_R \cos\phi + I_R R)^2 + (V_R \sin\phi - I_R X)^2\right]^{1/2}$$

$$\Rightarrow 1905.25 = \left(\left[V_R \times 0.8 + \frac{10^6}{V_R} \times 0.3\right]^2 + \left(V_R \times 0.6 - \frac{10^6}{V_R} \times 0.4\right)^2\right)^{1/2}$$

$$\Rightarrow (1905.25)^2 = (0.8)^2 V_R^2 + \frac{9 \times 10^{10}}{V_R^2} + 48000$$

Do not write in this margin

$$4(0.r)^2 V_R^2 + \frac{16 \times 10^{10}}{V_R^2} - 45000$$

$$\Rightarrow \cancel{3628997} \; 3630000 = V_R^2 + \frac{25 \times 10^{10}}{V_R^2}$$

$$\Rightarrow V_R^4 - 3630000\, V_R^2 + 25 \times 10^{10} = 0$$

$$V_R^2 = 3559770,\ 70229$$

$$V_R = 1886.7\,V,\ 265\,V$$

this value is ~~rejected~~ avoid as V_R is too small

∴ receiving end voltage per phase voltage

$$V_R = 1886.7\,V$$

and receiving end current

$$I_R = \frac{10^6}{V_R} = \frac{10^6}{1886.7}$$

$$\boxed{I_R = 530.02\,A}$$

10

$$(V_R)_{ph} = 1886.7\,V$$

or $(V_R)_{l-l} = 32678.6\,V$

Do not write in this margin

1 (c) What are the different types of error in Delta modulation? How can these errors be removed?

[12 marks]

Different error in delta modulation are -

(1) slope Overload Distortion

(2) Granular Noise (or Quantization Noise)

(3)

This error is removed by -

(1) slope overload distortion - The input signal is changing ~~too~~ rapidly for the modulator to keep up

- Step size is Δ is too small

- To ~~aoo~~ avoid such slope of the inputs signal must be greater the modulator step size.

$$\frac{\Delta}{T_s} \geq \frac{d\,m(t)}{dt}$$

7

(2) Granular noise

The input signal is changing slowly or is constant

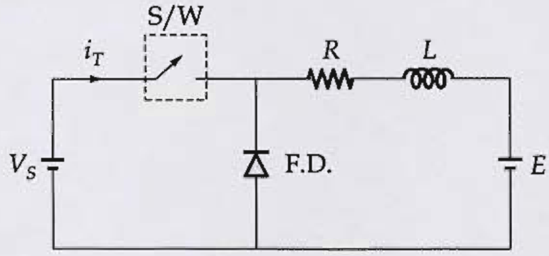
- Step size is too large

- step size is to be reduced to avoid granular noise

1 (d) With the help of suitable waveforms, for an ideal type-A chopper feeding RLE load as depicted in the figure below, show that the average input (or thyristor) current is given by

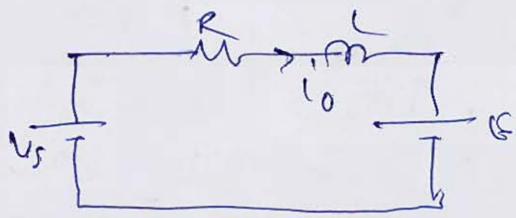
$$I_{Tavg} = \frac{\alpha(V_S - E)}{R} - \frac{L}{RT}(I_{max} - I_{min})$$

(Where symbols have their usual meaning).



[12 marks]

when CH - ON



$v_s = Ri + L\frac{di}{dt} + E$

$\frac{di}{dt} + \frac{R}{L}i = \frac{V_s - E}{L}$

solution of the above eq^n -

$i(t) = i(\infty) + (i(0) - i(\infty))e^{-t/\tau}$

$i(\infty) = \frac{V_s - E}{R}$ $\quad i(0) = I_{min}$

$i(t) = \frac{V_s - E}{R} + \left[I_{min} - \left(\frac{V_s - E}{R}\right)\right]e^{-t/\tau}$

$t = T_{on}$ $\quad i(t) = I_{max}$ $\qquad \tau = L/R$

$I_{max} = \left(\frac{V_s - E}{R}\right) + \left(I_{min} - \left[\frac{V_s - E}{R}\right]\right)e^{-T_{on}/\tau}$

Do not write in this margin

during Ton -

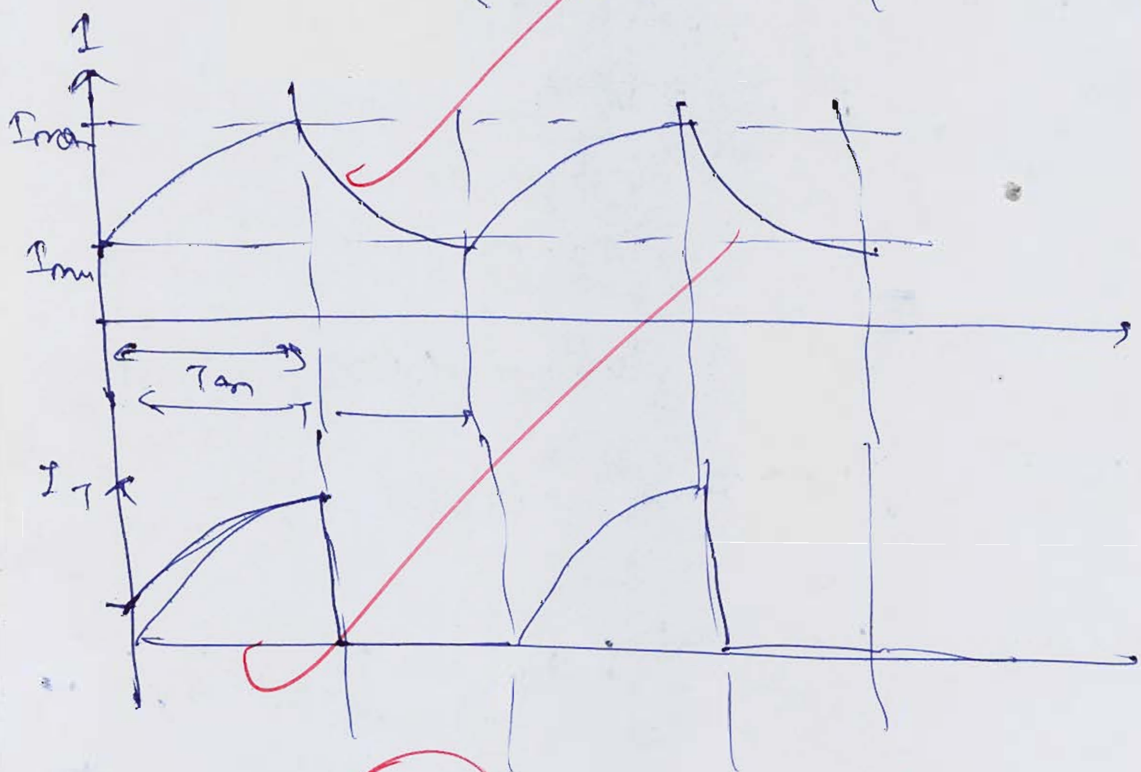
$L\frac{di}{dt} = \left(\frac{V_s - E}{R}\right) \Rightarrow \Delta I = L\left(\frac{I_{max} - I_{min}}{RT}\right)$

$I_{T\,avg} = \alpha I_{avg} - \frac{\Delta I}{2}$

$I_{avg} = \frac{V_s - E}{R}$

$\Delta I = L\left(\frac{I_{max} - I_{min}}{RT}\right)$

$I_{T\,avg} = \alpha\left(\frac{V_s - E}{R}\right) - L\left(\frac{I_{max} - I_{min}}{R}\right)$



9

Improve presentation

.1 (e) The equation of FM wave is given by:

$V = 15 \sin [3 \times 10^8 t + 50 \sin(2500)t]$ volts

(i) What are the values of carrier and modulating frequencies?

(ii) Modulation index.

(iii) Maximum frequency deviation.

(iv) Power delivered to 75 Ω resistor by this wave.

[12 marks]

Equation of FM wave

$V = 15 \sin [3 \times 10^8 t + 50 \sin(2500t)] V$

Comparing the above eqn with standard FM wave

$V = A_c \sin [2\pi f_c t + K_f A_m \sin(2\pi f_m t)]$

we get -

$2\pi f_c = 3 \times 10^8$ and $2\pi f_m = 2500$

$f_c = 47.74 \text{ MHz}$ $f_m = 397.8 \text{ Hz}$

(i) carrier frequency, $f_c = 47.74 \text{ MHz}$

Modulating frequency, $f_m = 397.8 \text{ Hz}$

(ii) $K_f A_m = 50$

$\beta = \frac{K_f A_m}{f_m} = \frac{50}{397.8} = 0.1256$

7

(iii) maximum frequency deviation

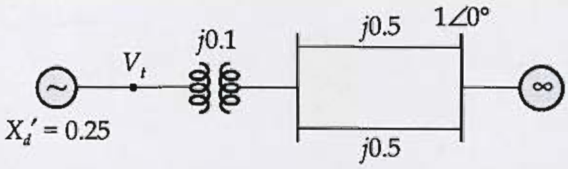
$\Delta f_{max} = K_f A_m = 50 \text{ Hz}$

Do not write in this mar

~~(iv) Power delivered to 75 Ω resistor~~

$$\cancel{P = \frac{A_c^2}{2R} = \frac{15^2}{2\times 15} = 7.5\text{ W}}$$

.2 (a) The generator of figure given below is delivering 1.0 p.u. power to the infinite bus ($|V_t| = 1.0$ p.u.).



A fault occurs and line is shorted in the middle. The generator has an inertia constant of 4 MJ/MVA. What is the initial angular acceleration? If this acceleration can be assumed to remain constant for $\Delta t = 0.05$s, find the rotor angle at the end of this time interval and the new acceleration. (Take $f = 50$ Hz)

[20 marks]

$P = 1$ pu $V = 1\angle 0°$

$|V_t| = 1.0$ $H = 4$ MJ/MVA

$V = 1\angle 0°$

Q.2 (b) A three phase 50 Hz, 400 km long transmission line is delivering power to a 3-ϕ load of 48 MVA at 0.75 p.f. leading and at 220 kV. The line parameters are:

$r = 0.125\ \Omega/\text{km}$, $L_1 = 1.273\ \text{mH/km}$ and $y = 2.8 \times 10^{-6}\ \mho/\text{km}$.

Determine:

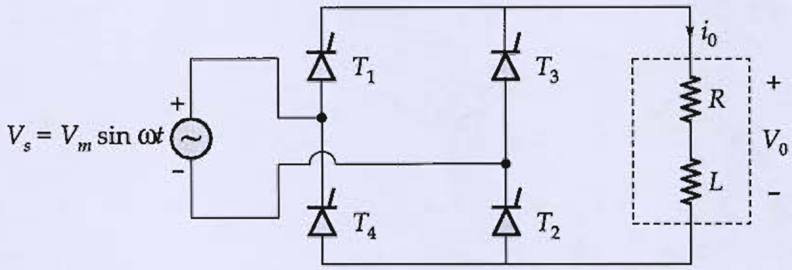
(i) The ABCD parameters of the line.

(ii) The sending end line voltage of the line.

(iii) Sending end power factor and power.

[20 marks]

.2 (c) A single phase fully controlled converter is fed through a single phase, 120 V, 60 Hz ac mains to supply a load consisting of $R = 10\ \Omega$ and $L = 20$ mH, as shown in the figure below.



For the firing angle of 60°,

Determine:

(i) The expression for the load current as a function of time.

(ii) The extinction angle (in degree) of the load current by using Newton-Raphson method and comment upon the continuity of the load current.

(iii) The average load current.

[6 + 10 + 4 marks]

Do not write in this marg

Do not write in this marg

Q.3 (a) A single phase 50 Hz alternator supplies an inductive load of $5000\sqrt{2}$ kVA at a power factor of $\frac{1}{\sqrt{2}}$ lagging by means of an overhead transmission line 20 km long. The line resistance and inductance of overhead line are 0.0195 Ω and 0.63 mH per km respectively. The voltage at the receiving end is required to be kept constant at 10 kV.

Find:

(i) The sending-end voltage and voltage regulation of the line.

(ii) The value of the capacitors to be placed in parallel with the load such that the regulation is reduced to 50% of that obtained in part (i).

(iii) Compare the transmission efficiency in part (i) and (ii).

[20 marks]

Do not write in this marg

Do not write in this margin

.3 (b) The speed of 25 HP, 320 V , 960 rpm separately excited d.c. motor is controlled by a 3-ϕ full convertor. The field current is controlled by a three phase full converter and is set to a maximum possible value. The 3-ϕ a.c. input is star-connected 210 V, 50 Hz supply. The armature and field circuit resistances are 0.2 Ω and 130 Ω respectively. The motor torque constant is 1.2 V-sec/rad-A. Assuming the armature and field currents to be continuous and ripple free.

Determine:

(i) The firing angle of the armature converter if the field converter is operating at the maximum field current and the developed torque is 110 N-m at 960 rpm.

(ii) The speed of the motor if the field circuit converter is set for the maximum field current, the developed torque is 110 N-m and the firing angle of the armature converter is 0°.

(iii) The firing angle of the field converter if the speed has to increase to 1750 rpm, for the same load requirement in part (ii). Neglect the system losses.

[20 marks]

Do not write in this marg

Do not write In this margin

.3 (c) (i) Briefly explain the methods to improve string efficiency for an insulator.

(ii) A transmission line has a span of 270 m between level supports. The diameter of the conductor is 2.76 cm and height is 0.865 kg/m. Its ultimate strength is 9060 kg. If the conductor has ice coating of radial thickness 1.82 cm and subjected to a wind pressure of 3.8 gm/cm^2 of project area. Then determine the sag for a safely factor of 2. (Weight of 1 c.c. of ice is 0.91 gm)

[6 + 14 marks]

Do not write in this marg

Do not write in this margin

.4 (a) A single phase full bridge inverter fed from 230 V dc, is connected to an R-L load. The inverter is operating with output frequency of 50 Hz. The load parameters to be $R = 10\ \Omega$ and $L = 0.03$ H. Determine the power delivered to the load when the inverter is operating with

(i) square wave output,

(ii) two symmetrically spaced pulses per half cycle with an ON-period of 0.5 of a cycle. (Consider significant harmonics upto 3rd harmonics).

[20 marks]

Given $V_{dc} = 230V$

$R = 10\Omega \quad L = 0.03H \quad f = 50Hz$

$X_L = 2\pi f L = 2\pi \times 50 \times 0.03$

$= 9.424\ \Omega$

① square wave output

the output voltage fourier series expression is -

$$V_0 = \sum_{n=1,3,5}^{\infty} \frac{4V_{dc}}{n\pi} \sin n\omega_0 t$$

$$V_{01} = \frac{4V_{dc}}{\pi \times \sqrt{2}} = \frac{2\sqrt{2}}{\pi} \times 230 = 207.07V$$

$$Z_1 = \sqrt{R^2 + (\omega L)^2} = \sqrt{10^2 + (9.424)^2}$$

$$= 13.74\ \Omega$$

$$I_{01} = \frac{V_{01}}{Z_1} = \frac{207.07}{13.74} = 15.07 A$$

3rd harmonic

$$V_{03} = \frac{4V_{dc}}{3\pi \times \sqrt{2}} = \frac{2\sqrt{2} \times 230}{3\pi} = 69V$$

$$Z_3 = \sqrt{R^2 + (3\omega L)^2} = \sqrt{10^2 + (3 \times 9.424)^2}$$

$$Z_3 = 29.98\ \Omega$$

$I_{o3} = \frac{V_{o3}}{Z_3} = \frac{69}{29.97} = 2.3\ A$

Rms ~~stead~~ value of output current

$I_{or} = \sqrt{I_{o1}^2 + I_{o3}^2} = \sqrt{15.07^2 + 2.3^2}$

$I_{or} = 15.24\ A$

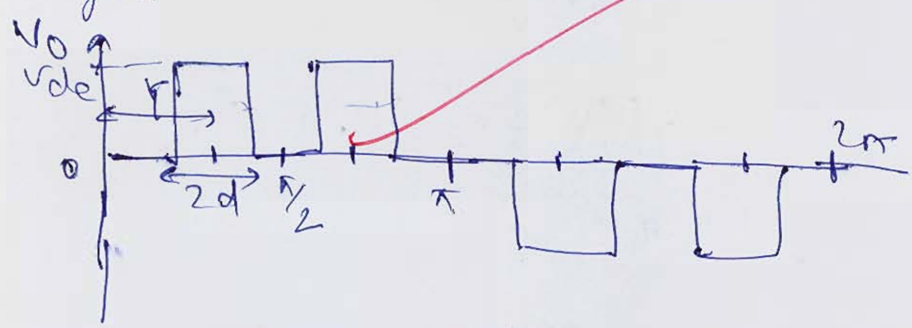
Power delivered to load

$P = I_{or}^2 \times R$

$= 15.24^2 \times 10$

$\boxed{P = 2324\ W}$

(11) two symmetrical space pulses per half cycle



pulse width $2d = \pi/4$

$\boxed{d = \pi/8}$

Now, fourier series expression of output valtage

$v_0 = \sum_{n=1,3,5}^{\infty} \frac{4V_{dc}}{n\pi} \sin n\gamma \sin nd \sin n\omega t$

where $\gamma = \pi/4$

$V_{01} = \frac{4 V_{dc}}{\pi \sqrt{2}} \sin \gamma \sin d$

$= \frac{2\sqrt{2}}{\pi} \times 230 \sin\frac{\pi}{4} \sin\frac{\pi}{8}$

$V_{01} = 56.03\ V$

$Z_1 = 13.74\,\Omega$

$I_{01} = \frac{V_{01}}{Z_1} = \frac{56.03}{13.74} = 4.078\ A$

$V_{03} = \frac{4 V_{dc}}{3\pi \sqrt{2}} \sin 3\gamma \sin 3d$

$= \frac{2\sqrt{2} \times 230}{3\pi} \sin\left(\frac{3\pi}{4}\right) \sin\left(\frac{3\pi}{8}\right)$

$V_{03} = 45.09\ V$

$Z_3 = 29.98\,\Omega$

$I_{03} = \frac{V_{03}}{Z_3} = \frac{45.09}{29.98} = 1.5\ A$

Total rms current

$I_{or} = \sqrt{I_{01}^2 + I_{03}^2} = \sqrt{4.078^2 + 1.5^2}$

$I_{or} = 4.345\ A$

Power delivered to load

$P = I_{or}^2 R = 4.345^2 \times 10 = 188.8\ W$

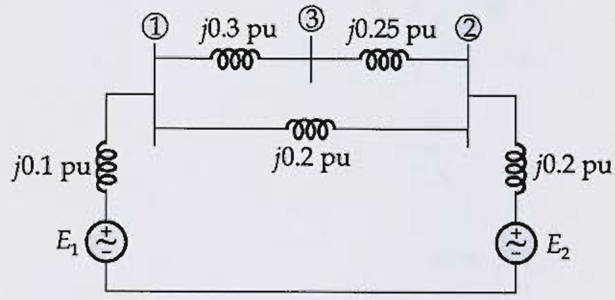
$\boxed{P = 188.8\ W}$

12

Q.4 (b) For the power system whose equivalent circuit is shown in figure below, compute the bus voltages and branch currents for a 3-ϕ fault on bus-1. Assuming the fault impedance $Z_f = j0.2$ pu.

$$[Z_{bus}] = j\begin{bmatrix} 0.0776 & 0.0448 & 0.0597 \\ 0.0448 & 0.1104 & 0.0806 \\ 0.0597 & 0.0806 & 0.2075 \end{bmatrix}$$

(Assume a pre-fault constant voltage of $1.0\angle 0°$ pu.)



[20 marks]

for 3 ϕ fault at bus - 1

fault current -

$$I_f = \frac{V_p}{Z_{11} + Z_f} = \frac{1\angle 0°}{j0.0776 + j0.2}$$

$$\boxed{I_f = -j3.602 \text{ p.u}}$$

Now bus voltages -

$$V_1 = V_p - I_f Z_{11}$$

$$= 1\angle 0° - (-j3.602) \times (j0.0776)$$

$$\boxed{V_1 = 0.72 \text{ pu}}$$

$$V_2 = V_p - I_f Z_{12}$$

$$= 1\angle 0° - (-j3.602) \times (j0.0448)$$

$$\boxed{V_2 = 0.8386 \text{ pu}}$$

Do not write in this margin

$v_3 = V_p - I_f Z_{13}$

$= 1\angle 0° - (-j\,3.602) \times (j\,0.0597)$

$\boxed{V_3 = 0.7849 \text{ p.u}}$

Now branch current

$I_{12} = \dfrac{V_1 - V_2}{Z_{12}} = \dfrac{0.72 - 0.8386}{j\,0.0448}$

$\boxed{I_{12} = 2.6473\, i}$

$I_{13} = \dfrac{V_1 - V_3}{Z_{13}} = \dfrac{0.72 - 0.7849}{j\,0.0597}$

$\boxed{I_{13} = 1.087\, i}$

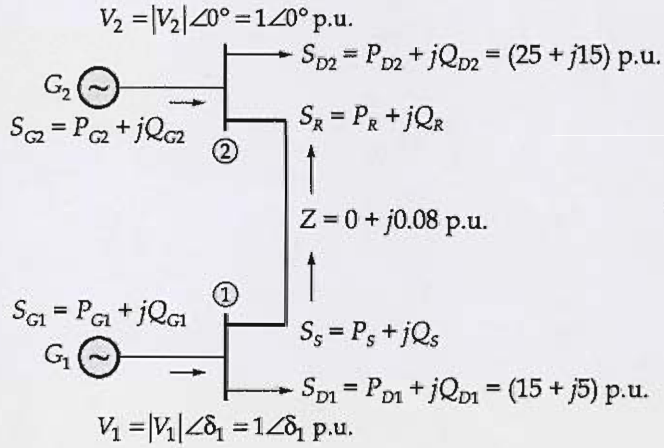
$I_{23} = \dfrac{V_2 - V_3}{Z_{23}} = \dfrac{0.8386 - 0.7849}{j\,0.0801}$

$\boxed{I_{23} = -0.666\, j}$

14

Do not write in this margin

Q.4 (c) An inter-connector cable links two generating stations as shown in the figure below. It is desired that the voltage profile is flat at the buses i.e., $|V_1| = |V_2| = 1.0$ p.u. The station loads are equalized by the flow of power in the cable. Estimate the torque angle and power factor of station-1 for the given cable of impedance $Z = 0 + j0.08$ p.u. It is known that the generator G_1 can generate a maximum of 30.0 p.u. real power.



[20 marks]

Total real power and ~~and~~ reactive power must be balance in the system.

∴ Total $P_g = P_{g1} + P_{g2}$.

Total $P_D = P_{D1} + P_{D2}$

$= 15 + 25$

$P_D = 40$ pu

∴ Total $Q_g = Q_{G1} + Q_{G2}$

Total $Q_D = 15 + 5 = 20$ pu

∴ $P_g = P_D$

$P_{g1} + P_{g2} = 40$

∴ $(P_{g1})_{max} = 30$ pu

$P_{g2} = 10$ pu

Do not write in this margin

it means ~~keep~~

$P_{D_1} = 15\,pu \quad P_{g_1} = 30\,pu$

means $P_{g_1} - P_{D_1} = 30 - 15 = 15\,pu$

real is transfer from bus ① to bus ②

$\therefore \quad P = \dfrac{V_1 V_2 \sin \delta_1}{X} = 15$

$\Rightarrow \quad \dfrac{1 \times 1 \sin \delta_1}{0.08} = 15$

$\sin \delta_1 = 15 \times 0.08$

$\delta =$

6

In complete solution

Do not write in this margin

Section-B : Power Systems + Power Electronics & Drives + Communication Systems

Q.5 (a) A 600 V, 1500 rpm, 70 A separately excited dc motor is fed through a three-phase semiconverter from three-phase 400 V supply. If the motor armature resistance is 1 Ω and the armature current is assumed to be constant and ripple free then for the firing angle of 45° at 1200 rpm,

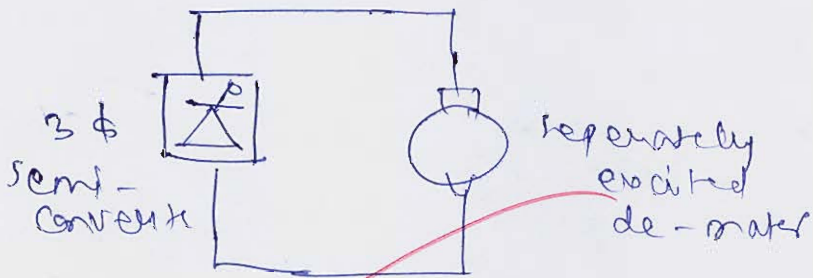
Determine:

(i) RMS value of source and thyristor currents.

(ii) Average value of thyristor current.

(iii) Input supply power factor.

[12 marks]



$V_s = 400\,V$ $\qquad R_a = 1\,\Omega$

$V_{ml} = 400\sqrt{2}\,V$

At $600\,V$, $1500\,rpm$, $70\,A$ -

$E_{b1} = V - I_a R_a$

$= 600 - 70 \times 1$

$E_{b1} = 530\,V$ $\qquad N_1 = 1500\,rpm$

For $N_2 = 1200\,rpm$

$E_{b2} = \frac{E_{b1} \times N_2}{N_1} = \frac{530 \times 1200}{1500}$

$E_{b2} = 424\,V$

At $\alpha = 45°$

$V_0 = \frac{3 V_{ml}}{2\pi}\left[1 + \cos\left(\alpha + \frac{\pi}{3}\right)\right]$

$= \frac{3 \times 400\sqrt{2}}{2\pi}\left[1 + \cos\left(\frac{\pi}{4} + \frac{\pi}{3}\right)\right]$

Try to avoid

$V_0 = \cancel{\frac{3\sqrt{3}V_m}{}} \frac{3V_{ml}}{2\pi}(1+\cos\alpha)$

$= \frac{3 \times 400\sqrt{2}}{2\pi}(1+\cos 45^\circ)$

$V_0 = 461.05\,V$

output current —

$I_0 = \frac{V_0 - E_{b_2}}{R_a} = \frac{461.05 - 424}{1}$

$\boxed{I_0 = 37\,A}$

(i) $(I_s)_{rms} = I_0 = 37\,A$

$(I_T)_{rms} = I_0\sqrt{\frac{1}{3}} = \frac{37}{\sqrt{3}} = 21.36\,A$

(ii) $(I_T)_{avg} = \frac{I_0}{3} = \frac{37}{3} = 12.33\,A$

(iii) Input supply power factor

$IPF = \cancel{V_{or}I_0}\ \frac{3}{\pi}\cos\alpha$

$= \frac{3}{\pi}\cos 45^\circ$

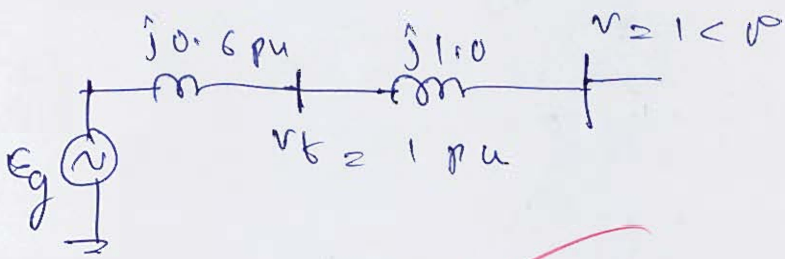
$= 0.675$

9

 Do not write in this margin

Q.5 (b) Find the steady state power limit of a power system consisting of a generator of equivalent reactance of 0.6 p.u. connected to an infinite bus through a series reactance of 1.0 p.u. The terminal voltage of the generator is held at 1.50 p.u. and the voltage of the infinite bus is 1.0 p.u.

[12 marks]



$V_t = 1 \angle \phi$

$I = \frac{1\angle\phi - 1\angle 0^\circ}{j1}$

$I = 1\angle\phi - 90 - 1\angle -90^\circ$

$E_g = 1\angle\phi + j0.6\,(1\angle\phi - 90 - 1\angle -90^\circ)$

$= 1\angle\phi + 0.6\angle\phi - 1$

$= \cos\phi + j\sin\phi + 0.6\cos\phi + j\sin\phi \times - 1$

$E_g = (1.6\cos\phi - 1) + j\,1.6\sin\phi$

At steady state $\delta = 90^\circ$

$\therefore$ no real part

$1.6\cos\phi - 1 = 0$

$\phi = 51.31^\circ$

$\therefore |E_g| = 1.6\sin\phi = 1.6\sin 51.31$

$= 1.249$ pu

Steady state power limit

$$P_{max} = \frac{E_g \cdot V}{X_{eq}}$$

$$= \frac{1.249 \times 1}{1.6}$$

$$\boxed{P_{max} = 0.78\,pu}$$

5

Do not write in this margin

Q.5 (c) In a superheterodyne receiver having no RF amplifier the loaded Q of the antenna coupling circuit (at the input of mixer) is 90. If the intermediate frequency is 455 kHz calculate the following:

(i) The image frequency and image frequency rejection ratio at 950 kHz.

(ii) The image frequency and its rejection ratio at 10 MHz.

[12 marks]

Do not write in this margin

Q.5 (d) Design a PCM multiplexing system using a 256 level quantizer for the transmission of 3 signals $m_1(t)$, $m_2(t)$ and $m_3(t)$ band limited to 5 kHz, 10 kHz and 5 kHz respectively. Assume that each signal is sampled at Nyquist rate. Compute :

(i) Maximum bit duration.

(ii) Channel bandwidth required to pass the PCM signal.

(iii) Commutator speed in RPM.

(iv) Increment in the channel bandwidth if 512 quantization levels are used.

[12 marks]

$L = 256 = 2^n = 2^7$

$\boxed{n = 7}$

$f_{m_1} = 5\,kHz \quad f_{m_2} = 10\,kHz \quad f_{m_3} = 5\,kHz$

$f_{max} = 10\,kHz, \quad f_{min} = 5\,kHz$

(i) maximum bit duration

$(T_b)_{max} = \dfrac{1}{(R_b)_{min}}$

$(R_b)_{min} = \cancel{2 f_{max} = 0\ 20 \times}\ n f_s$

$= 7 \times 2 \times 5 = 70$

$(T_b)_{min} = \dfrac{1}{70} = 0.0142\ msec$

(ii) $BW = \dfrac{(R_b)_{max}}{2}$

$(R_b)_{max} = 7 \times 2 \times 10 = 140$

$BW = \dfrac{140}{2} = 70\ kbps$

(iii) ~~commutator speed~~

N 2

(iv) $L = 512 = 2^9$

$n = 9$

$R_b = 9 \times 2 \times 10 = 180$

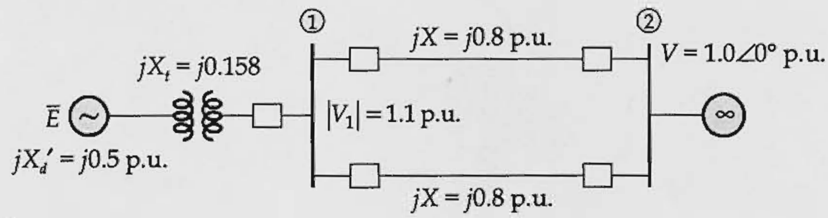
$(BW)_{new} = \frac{180}{2} = 90$ KbPs

movement in bandwidth = 10Kbps

6

Do not write in this margin

Q.5 (e) A 60 Hz alternator has a transient reactance of 0.5 p.u. and an inertia constant of 5.66 MJ/MVA. The generator is connected to an infinite bus through a transformer and a double circuit line, as shown in the figure below. Resistances are neglected and reactances are expressed on a common MVA base. The generator is delivering a real power of 0.95 per unit to the bus bar-1. The voltage magnitude at bus-1 is 1.1 and the infinite bus voltage $V = 1.0\angle 0°$ p.u.



Determine:

(i) The generator excitation voltage and the power angle.

(ii) Obtain the swing equation for the given system.

[12 marks]

Given :- $V_2 = 1 \angle 0^\circ$

Real power — $V_1 = 1 \angle \delta_1$

$$P = \frac{V_1 V_2}{X_{eq}} \sin(\delta_1 - \delta_2)$$

$$\Rightarrow 0.95 = \frac{1.1 \times 1}{0.4} \sin(\delta_1 - 0)$$

$$\delta_1 = 20.2^\circ$$

$$\therefore V_1 = 1 \angle 20.2^\circ \text{ pu}$$

Current $I = \dfrac{1 \angle 20.2 - 1 \angle 0^\circ}{j0.4}$

$$= 0.876 \angle 10.1^\circ \text{ pu}$$

$$E_g = V_t + IX$$

$$= 1 \angle 20.2 + 0.876 \angle 10.1 \, (j0.5 + j0.158)$$

$E_g = 1.238 \angle 47.39^\circ$ pu

$\therefore$ $E_g = 1.238$ pu

Power angle $\delta = 47.39^\circ$

(ii) Swing eq^n –

$$M \frac{d^2\delta}{dt^2} = P_a = P_s - P_e$$

$P_e = P_{max} \sin\delta$ $\qquad P_s = 0.95$

$$= \frac{1.238 \times 1}{1.058} \sin\delta$$

$$= 1.17 \sin\delta$$

8

$$M = \frac{HS}{\pi f} = \frac{5.66 \times 1}{\pi \times 50} = 0.036$$

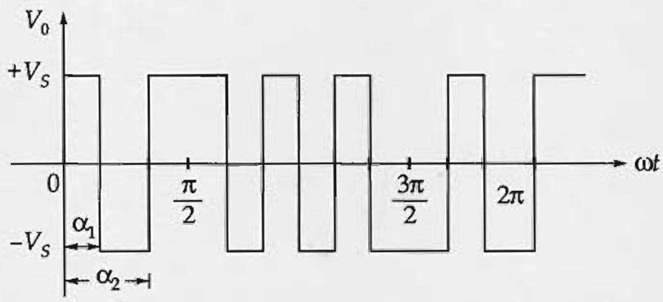
$\therefore$ swing eq^n –

$$\boxed{0.036 \frac{d^2\delta}{dt^2} = 0.95 - \cancel{0.036}\ 1.17 \sin\delta}$$

Do not write in this margi

Q.6 (a) (i) A two notch PWM inverter output voltage waveform as shown in the figure below. Show that the Fourier series representation of the output voltage is given by:

$$V_0(t) = \sum_{n=1,3,5}^{\infty} C_n \sin n\omega t \; ; \qquad \text{where, } C_n = \frac{4V_s}{n\pi}[1 - 2\cos n\alpha_1 + 2\cos n\alpha_2]$$



(ii) Determine the values of α_1 and α_2 to eliminate 3rd and 5th harmonic from the output.

[20 marks]

Fourier series representation —

$$V_0 = a_0 + \sum a_n \cos n\omega_0 t + b_n \sin n\omega_0 t$$

The output is quarter wave symmetry it's symmetrical about $\pi/2$

$a_0 = 0 \qquad a_n = 0$

$$b_n = \frac{2}{\pi/2}\left[\int_0^{\alpha_1} V_s \sin n\omega t + \int_{\alpha_1}^{\alpha_2} (-V_s) \sin n\omega t + \int_{\alpha_2}^{\pi/2} V_s \sin n\omega t \, d\omega t\right]$$

$$= \frac{4V_s}{\pi}\left[\int_0^{\alpha_1} \sin n\omega t \, d\omega t \int_{\alpha_1}^{\alpha_2} \sin n\omega t \, d\omega + \int_{\alpha_2}^{\pi/2} \sin n\omega t \, d\omega t\right]$$

$$= \frac{4V_s}{\pi}\left[\left(\frac{-\cos n\omega t}{n}\right)_0^{\alpha_1} - \left(\frac{-\cos n\omega t}{n}\right)_{\alpha_1}^{\alpha_2} + \left(\frac{-\cos n\omega t}{n}\right)_{\alpha_2}^{\pi/2}\right]$$

Do not write in this margin

$$= \frac{4V_s}{n\pi}\left[1 - \cos n\alpha_1 - (\cos n\alpha_1 - \cos n\alpha_2) + \cos n\alpha_2 - \cos n\frac{\pi}{2}\right]$$

$$= \frac{4V_s}{n\pi}\left(1 - 2\cos n\alpha_1 + 2\cos n\alpha_2 - \cos n\frac{\pi}{2}\right)$$

$$b_n = \frac{4V_s}{n\pi}\left(1 - 2\cos n\alpha_1 + 2\cos n\alpha_2\right) \quad \text{for } n = 1, 3, 5$$

$$= 0 \quad n = 2, 4, 6$$

$$v_0 = \sum_{n=1,3,5}^{\infty} b_n \sin n\omega t$$

$$\text{where } C_n = \frac{4V_s}{n\pi}\left[1 - 2\cos n\alpha_1 + 2\cos n\alpha_2\right]$$

(ii) $b_3 = 0$

$$1 - 2\cos 3\alpha_1 + 2\cos 3\alpha_2 = 0 \quad \text{— (i)}$$

$$b_5 = 0$$

$$1 - 2\cos 5\alpha_1 + 2\cos 5\alpha_2 = 0 \quad \text{— (ii)}$$

$$2\cos 3\alpha_1 - 2\cos 3\alpha_2 = 1$$

$$2\cos 5\alpha_1 - 2\cos 5\alpha_2 = 1$$

$\cos 3\alpha_1 - \cos 3\alpha_2 = \cos 5\alpha_1 - \cos 5\alpha_2$

$\cos 3\alpha_1 - \cos 5\alpha_1 = \cos 3\alpha_2 - \cos 5\alpha_2$

$2 \sin(4\alpha_1) \sin(\alpha_1) = 2 \sin(4\alpha_2) \sin(\alpha_2)$

$\alpha_2 + \alpha_1 = \pi/2$

$\alpha_2 = \frac{\pi}{2} - \alpha_1$

$2 \cos 3\alpha_1 - 2 \cos 3\left(\frac{\pi}{2} - \alpha_1\right) = 1$

$2 \cos 3\alpha_1 + 2 \cos 3\alpha_1 = 1$

$\cos 3\alpha_1 = 0.25$

$3\alpha_1 = 75.52$

$\boxed{\alpha_1 = 25.17^\circ}$

10

$\alpha_2 = 90 - 25.17$

$\boxed{\alpha_2 = 64.82^\circ}$

12

Q.6 (b) **(i)** Using the Gauss-Seidel method, determine the values of the voltage at bus 2 and 3 [Two iterations]. For the power system shown in figure below.

(ii) Find the slack bus real and reactive power after second iteration.

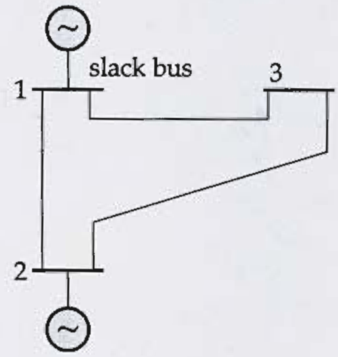


Table-1 : Scheduled generation are as loads and assumed bus voltage for sample power system [Base MVA = 100].

		Generation		Load	
Bus code (1)	**Assumed bus voltage**	**MW**	**MVAR**	**MW**	**MVAR**
1 (SB)	1.05 + j0.0	-	-	0	0
2	1 + j0.0	50	30	305.6	140.2
3	1.0 + j0.0	0.0	0.0	138.6	45.2

Table-2 : Line impedances

Bus code ($i-k$)	**Impedance Z_{ik}(pu)**
1 - 2	0.02 + j0.04
1 - 3	0.01 + j0.03
2 - 3	0.0125 + j0.025

[20 marks]

$$Y_{12} = \frac{-1}{0.02+j0.04} = -10+j20 = Y_{21}$$

$$Y_{13} = \frac{-1}{0.01+j0.03} = -10+j30 = Y_{31}$$

$$Y_{23} = \frac{-1}{0.0125+j0.025} = -16+j32 = Y_{32}$$

$$Y_{11} = \frac{1}{0.02+j0.04} + \frac{1}{0.01+j0.03}$$

$$Y_{11} = 10-j20 + 10-j30 = 20-j50$$

$$Y_{22} = \frac{1}{0.02+j0.04} + \frac{1}{0.0125+j0.025}$$

$$= 10-j20 + 16-j32$$

$$Y_{22} = 26 - j52$$

$$Y_{33} = \frac{1}{0.01+j0.03} + \frac{1}{0.0125+j0.025}$$

$$= 10-j30 + 16-j32$$

$$= 26-j62$$

$$Y_{Bus} = \begin{bmatrix} 20-j50 & -10+j20 & -10+j30 \\ -10+j20 & 26-j52 & -16+j32 \\ -10+j30 & -16+j32 & 26-j62 \end{bmatrix}$$

let $V_1^0 = 1\angle 0^\circ$ $V_2^0 = 1\angle 0^\circ$ $V_3^0 = 1\angle 0^\circ$

First iteration

$$V_2^1 = \frac{1}{Y_{22}}\left[\frac{P_2 - jQ_2}{V_2^*} - V_1^0 Y_{12} - V_3^0 Y_{32}\right]$$

$$= \frac{1}{26-j52}\left[\frac{-3.05+j1.402}{1} - 1(-10+j20) - 1(-16+j32)\right]$$

$$\boxed{V_2^1 = 0.955 \angle -2.167^\circ \text{ pu}}$$

$$V_3^1 = \frac{1}{Y_{33}}\left[\frac{P_3 - jQ_3}{V_3^*} - V_1^0 Y_{13} - V_2^1 Y_{32}\right]$$

$$= \frac{1}{26 - j62}\left[\frac{-1.386 + j0.452}{1} - 1(-10 + j30) - 0.955\angle -2.167^\circ (-16 + j32)\right]$$

$$\boxed{V_3^1 = 0.9635 \angle -2.21^\circ \text{ pu}}$$

<u>Second iteration</u>

$$V_2^2 = \frac{1}{Y_{22}}\left[\frac{P_2 - jQ_2}{V_2^{1*}} - V_1^0 Y_{12} - V_3^1 Y_{23}\right]$$

$$= \frac{1}{26 - j52}\left[\frac{-3.05 + j1.402}{0.955\angle 2.167} - 1(-10 + j20) - 0.9635\angle -2.21(-16 + j3\ldots\right.$$

$$\boxed{V_2^2 = 0.9304 \angle -3.629^\circ \text{ pu}}$$

$$V_3^2 = \frac{1}{Y_{33}}\left[\frac{P_3 - jQ_3}{V_3^{1*}} - V_1^0 Y_{13} - V_2^2 Y_{32}\right]$$

$$= \frac{1}{26 - j62}\left[\frac{-1.386 + j0.452}{0.9635\angle 2.21} - 1(-10 + \ldots\right.$$

Do not write in this margin

$- 0.9304 \angle -3.629 (-10+j30)]$

$\boxed{\cancel{V_3^2 = 0.9501 \angle -3.0318^0 \text{ pu}}}$

(ii) Slack bus power

$S_1 = \cancel{S_{12}+S_{13}} \; V_1 I_1^*$

$= V_1 [Y_{11} V_1 + Y_{12} V_2^2 + Y_{13} V_3^2]^*$

$= 1 \angle 0^0 [1 \angle 0^\circ \times (20 - j50)$

$+ (-10+j20) \times 0.9304 \angle -2.629$

$+ (-10+j30) \times 0.9501 \angle -3.0318]^*$

$= 4.33 \angle 25.604$

$= 3.9048 + j1.871$ pu

$\therefore$ Real power $P = 3.9048$ pu

$= 390.48$ MW

Reactive power $Q = 1.871$

$= 187.1$ MVAR

12

Do not write this margin

Q.6 (c) A 50 Hz, 4 pole, turbogenerator rated 200 MVA, 11 kV has moment of inertia of 81000 kg-m^2. The generator was initially delivering 40 MW to an electrical load. When the input to the generator is suddenly raised to 60 MW.

(i) Find the inertia constant (in MJ/MVA) and the stored Kinetic energy.

(ii) For the said sudden change in input to the generator find the rotor acceleration in rpm/sec.

(iii) If the rotor acceleration is maintained for 15 cycles, determine the change in rotor angle and rotor speed in rpm at the end of this period.

[20 marks]

Given :- moment of inertia $I = 81000$ kg-m^2

$\omega_s = \frac{2\pi N_s}{60}$

$= \frac{2\pi \times 1500}{60} = 157.07$ r/s

(1) Stored Kinetic energy

$K.E = \frac{1}{2} I \omega^2$

$= \frac{1}{2} \times 81000 \times (157.07)^2$

$\boxed{KE = 999.3 \text{ MJ}}$

Inertia constant

$H = \frac{\text{Stored K.E}}{\text{MVA capacity}}$

$= \frac{999.3}{200}$

$\boxed{H = 4.996 \text{ MJ/MVA}}$

(ii) accelarating power

$$P_a = 60 - 40$$

$$= 20 MW$$

$$M = \frac{GS}{\pi f} = \frac{GS}{180 f}$$

$$= \frac{200 \times 4.996}{180 \times 50}$$

$M = 0.111$ ~~elec. deg / s2~~

$$M \alpha = P_a$$

$$\alpha = \frac{P_a}{M} = \frac{20 \cancel{\times 10^6}}{0.111}$$

$$\boxed{\alpha = 180.12 \text{ elec deg}/s^2}$$

(iii)

$$t = 15 \times \frac{1}{50} = 0.3 s$$

$$\alpha = 180.12 \text{ ele. deg}/s^2$$

$$\delta_f = \frac{1}{2} \alpha t^2$$

$$= \frac{1}{2} \times 180.12 \times (0.3)^2$$

$$\boxed{\delta = 8.1^\circ}$$

Change in rotor angle

$$\delta = 8.1^\circ$$

$$\theta_e = \frac{P}{2} \cdot \theta_m$$

$$= \frac{4}{2} \cdot \theta_m$$

$$\theta_m = \frac{\theta_e}{2}$$

$$\alpha = 180.12 \times \frac{1}{2} \cdot \text{mech. deg}/s^2$$

$$= 90.06 \times \frac{60}{360} \text{ rpm}/s$$

$$\alpha = 15.01 \text{ rpm}/s$$

$t = 0.3$

$\therefore$ change in rotor speed

$$\Delta N = 15.01 \times 0.3$$

$$= 4.503 \text{ rpm}$$

Rotor speed

$$= N + \Delta N$$

$$= 1500 + 4.503$$

$$= 1504.503 \text{ rpm}$$

18

Good Approach

(a) (i) A boost converter supplies an output voltage of 10 V from 5 V supply. It has a non ideal inductor with r_L as the series resistance. Determine the expression for efficiency in terms of duty ratio D, load resistance R and r_L. Assume inductor current to be continuous.

(ii) For $R = 10\ \Omega$ and $r_L = 48\ \text{m}\Omega$, calculate the efficiency.

[20 marks]

Do not write in this

Q.7 (b) What is the universal relay torque equation? Using this equation, derive the impedance relay, reactance relay and mho relay characteristics. Also, draw the operating characteristic and indicate clearly the zones of operation and no operation.

[20 marks]

Do not write in this margin

7 (c) A 220 kV circuit breaker is used to protect a line. During short circuit, the power factor of the fault was 0.5 lag, the armature reaction demagnetizing effect brought down the voltage to 90% of rated voltage and the natural frequency of oscillation was found to be 20 kHz.

Determine:

(i) The maximum value of RRRV for grounded fault and ungrounded fault.

(ii) The average RRRV for grounded fault and ungrounded fault.

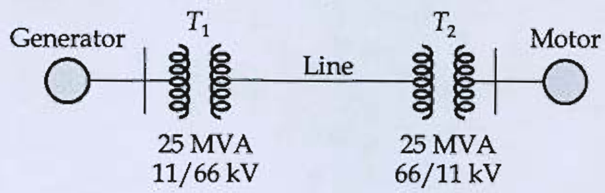
(iii) The time at which maximum transient recovery voltage occurs.

[20 marks]

Do n
write
this m

Do not write in this ma

Q.8 (a) A synchronous generator and a synchronous motor each rated 25 MVA, 11 kV having 15% subtransient reactance are connected through transformers and a line as shown in the figure below. The transformers are rated 25 MVA, 11/66 kV and 25 MVA, 66/11 kV with leakage reactance of 10% each. The line has a leakage reactance of 10% on a base of 25 MVA, 66 kV. The motor is drawing 15 MW at 0.8 power factor leading and a terminal voltage of 10.6 kV when a symmetrical 3-phase fault occurs at the motor terminals. Find the subtransient current in the generator, motor and fault.



[20 marks]

Given :- $x_g = 15\% = 0.15$ pu $\quad x_m = 0.15$ pu

$x_{T_1} = x_{T_2} = 0.1$ pu

$x_l = 0.1$ pu

$S_{base} = 25$ MVA $\quad$ kV$_{base}$ on generator side $= 11$ kV

kV$_{base}$ on line $= 66$ kV

kV$_{base}$ on motor side $= 11$ kV

$P = 15$ MW at 0.8 pf

$V_t = 10.6\,kV = \frac{10.6}{11} = 0.9636$ pu

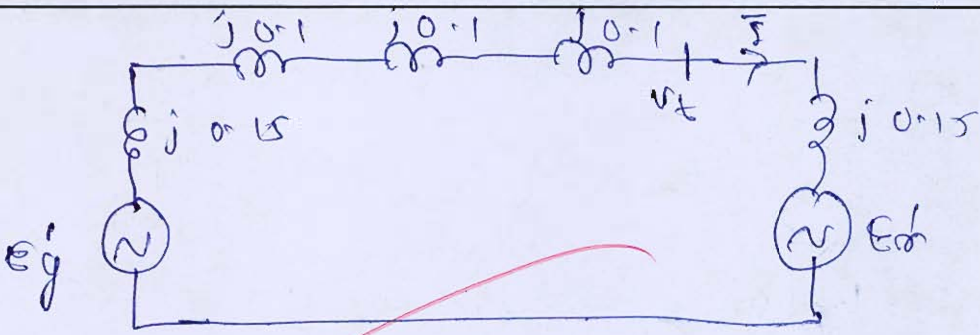
$P = \frac{15}{25} = 0.6$ pu

$\Rightarrow V_t I \cos\phi = 0.6$

$0.9636 \times I \times 0.8 = 0.6$

$I = 0.778$ pu at 0.8 leading

$\bar{I} = 0.778\angle 36.87^\circ$ pu



$V_t = 0.9636 \angle 0^\circ$ pu

$I = 0.778 \angle 36.87^\circ$ pu

$E_m' = V_t - I(jX_m)$

$= 0.9636 \angle 0^\circ - 0.778 \angle 36.87^\circ \times j0.15$

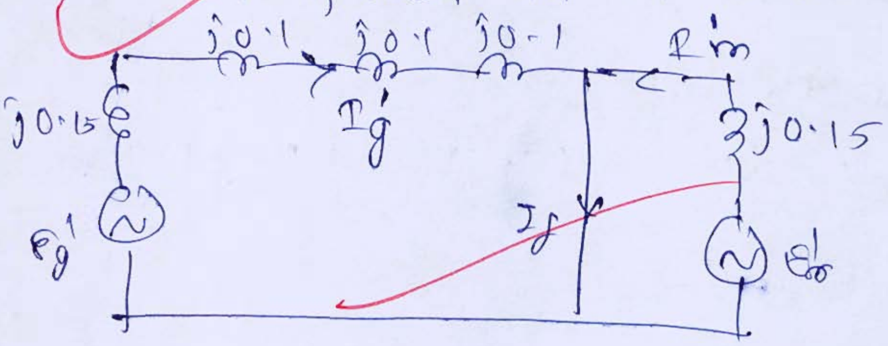
$E_m' = 1.037 \angle -5.16^\circ$ pu

$E_g' = V_t + I(jX_g + X_{T_1} + X_{T_2} + X_\ell)$

$= 0.9636 \angle 0^\circ + 0.778 \angle 36.87^\circ (j0.15 + j0.1 + j0.1 + j0.1)$

$E_g' = 0.8039 \angle 20.39^\circ$ pu

Now 3φ fault at the motor terminals



$\therefore \quad I_m'' = \dfrac{E_g'}{jX_m''} = \dfrac{1.037 \angle -5.16^\circ}{j0.15}$

$I_m'' = 6.913 \angle -95.16^\circ$ pu

Do not write in this margin

$$I_g' = \frac{E_g'}{X_{eq}} = \frac{0.8039 \angle 20.39}{j0.15 + j0.1 + j0.1 + j0.1}$$

$$I_g' = 1.786 \angle -69.61^\circ \text{ pu}$$

fault current

$$I_f = I_g' + I_m'$$

$$= 1.786 \angle -69.61^\circ + 6.913 \angle -95.16$$

$$I_f = 8.56 \angle -90^\circ \text{ pu}$$

$$I_{base} = \frac{S_{base}}{\sqrt{3} \times kV_{base}} = \frac{25 \times 10^6}{\sqrt{3} \times 11 \times 10^3}$$

$$I_{base} = 1.312 \text{ kA}$$

18

∴ sub transient motor current

$$|I_m'| = 6.913 \times 1.312 = 9.07 \text{ kA}$$

Good Approach

generator current

$$|I_g'| = 1.786 \times 1.312 = 2.343 \text{ kA}$$

fault current

$$|I_f| = \cancel{8.850}\ 8.57 \times 1.312$$

$$|I_f| = 11.23 \text{ kA}$$

b) (i) Determine efficiency and percentage of total power carried by the sidebands of the AM wave for the modulation index = 0.3. Also find the percentage power saving, when transmitted as DSB-SC and SSB signal.

(ii) For a modulating signal:

$$m(t) = 2\cos 100t + 18\cos 2000\pi t$$

1. Write expression for $\phi_{PM}(t)$ and $\phi_{FM}(t)$ when amplitude of carrier wave $A = 10$ Volt. $\omega_c = 10^6$, $k_f = 1000\pi$ and $k_p = 1$.
2. Estimate the bandwidth of $\phi_{FM}(t)$ and $\phi_{PM}(t)$.

[10 + 10 marks]

(i) AM wave eq^n -

$$s(t) = A_c \cos 2\pi f_c t + \frac{A_c \mu}{2}\cos 2\pi(f_c - f_m)t + \frac{A_c \mu}{2}\cos 2\pi(f_c + f_m)t$$

carrier power $P_c = \frac{A_c^2}{2R}$

side band power

$$P_{LSB} = P_{USB} = \frac{A_c^2 \mu^2}{8R}$$

∴ Total side band power

$$P_{SB} = P_{LSB} + P_{USB} = \frac{A_c^2\mu^2}{8R} + \frac{A_c^2\mu^2}{8R}$$

$$= \frac{A_c^2 \mu^2}{4R} = \frac{P_c \mu^2}{2}$$

Total power

$$P_T = P_c + P_{SB}$$

$$P_T = P_c + \frac{P_c \mu^2}{2} = P_c\left(1 + \frac{\mu^2}{2}\right)$$

and efficiency

$$\eta = \frac{P_{SB}}{P_T} = \frac{\frac{P_c \mu^2}{2}}{P_c\left(1+\frac{\mu^2}{2}\right)} = \frac{\mu^2}{2+\mu^2}$$

For $\mu = 0.3$

Total power $P_T = P_c\left(1 + \frac{0.3^2}{2}\right)$

$$\boxed{P_T = 1.045 P_c}$$

and efficiency

$$\eta = \frac{\mu^2}{2+\mu^2} = \frac{(0.3)^2}{2+(0.3)^2}$$

$$\eta = 0.043 \text{ or } 4.30\%.$$

Power saving in DSB-SC

$$= \frac{P_c}{P_c\left(1+\frac{\mu^2}{2}\right)} = \frac{2}{2+\mu^2} = \frac{2}{2+(0.3)^2}$$

$$= 0.957 \text{ or } 95.7\%$$

Power saving in SSB

$$= \frac{P_c + \frac{P_c \mu^2}{4}}{P_c\left(1+\frac{\mu^2}{2}\right)} = \frac{4+\mu^2}{2(2+\mu^2)}$$

$$= \frac{4+0.3^2}{2(2+0.3^2)} = 0.9784 \text{ or } 97.84\%$$

(ii) $m(t) = 2\cos 10\pi t + 18\cos 2\omega_0\pi t$

$A_c = 10\text{ V}$ $\quad \omega_c = 10^6$ $\quad k_f = 1000\pi$

$k_p = 1$

(i) $\phi_{pm}(t) = A_c \cos(2\pi f_c t + k_p A_m \cos 2\pi f_m t)$

$\phi_{pm}(t) = 10\cos[10^6 t +$
$2\cos 100t$
$+ 18\cos 2000\pi t]$

$\phi_{fm}(t) = A_c \cos[2\pi f_c t + 2\pi k_f \int m(t)\,dt]$

$= 10\cos[10^6 t + 2\pi \times 1000\pi$
$\int(2\cos 100t$
$+ 18\cos 2000\pi t)\,dt]$

$\phi_{fm}(t) = 10\cos(10^6 t + 394.78 \sin 100t$
$+ 56.54 \sin 2000\pi t)$

Bandwidth for $\phi_{fm}(t)$

$\beta_1 = \frac{k_f A_{m_1}}{f_{m_1}} = 1000\pi\left[\frac{2}{100}\right] = 62.83$

$\beta_2 = \frac{k_f A_{m_2}}{f_{m_2}} = 1000\pi\left(\frac{18}{2000\pi}\right) = 9$

$\beta = \sqrt{\beta_1^2 + \beta_2^2} = \sqrt{62.83^2 + 9^2} = 63.47$

$f_{max} = 1\text{ kHz}$

$BW = 2(\beta+1) f_{max} = 2\times(63.47+1)\times 1$

$\boxed{BW = 129\text{ kHz}}$

18

Good Approach

For $\phi_{pm}(t)$

$\beta_1 = k_p A_{m_1} = 1\times 2 = 2, \quad \beta_2 = 18$

$\beta = 18.11$

$BW = 2\times(18.11+1)\times 1 = 38.22\text{ kHz}$

$\boxed{BW = 38.22\text{ kHz}}$

Do n
write
this r

Q.8 (c) A 3-ϕ, 60 Hz transmission line of length 150 km is delivering 40 MW at 0.9 p.f. lagging at 220 kV. The resistance and reactance of the line per phase per half kilometer are 0.2 and 0.4 Ω respectively, while capacitive admittance is 2.5×10^{-6} S/km/phase.

Determine:

(i) The current and voltage at sending end.

(ii) Efficiency of transmission.

Using nominal *T*-method.

[20 marks]

Given :- 3ϕ, $60\,Hz$ $l = 150\,km$

$$V_R = \frac{220\,kV}{\sqrt{3}} = 127.01\,kV$$

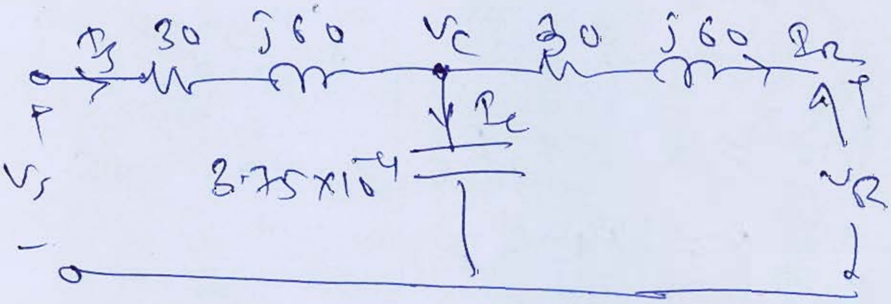
Total series impedance

$$Z = (0.2 + j0.4) \times 150 \times 2$$
$$= (60 + j120)\,\Omega$$

$$Y = 2.5 \times 10^{-6} \times 150 = 3.75 \times 10^{-4}\,\mho$$

(1)

<u>Nominal T</u>



$$V_R = 127.01 \times 10^3 \angle 0^\circ\ V$$

$$I_R = \frac{40 \times 10^6}{\sqrt{3} \times \cancel{127.01} \, 220 \times 10^3} = \cancel{101.0} \; 104.97$$

$$I_R = \cancel{101.0} \; 104.97 \angle -25.84^\circ\ A$$

$V_C = 127.01 \times 10^3 \angle 0^\circ + (30 + j60) \times \cancel{}\ 104.97 \angle -25.84$

$V_C = \cancel{}\ 132.6 \times 10^3 \angle \cancel{}\ 1.85^\circ\ V$

$I_C = V_C \cdot Y$

$= 132.6 \times 10^3 \angle 1.85 \times 3.75 \times 10^{-4} j$

$I_C = \cancel{51.32 \angle 93.11^\circ}\ A$

$= 49.74 \angle 91.85$

$\therefore$ sending end current

$I_s = I_R + I_C$

$= \cancel{}\ 104.97 \angle -25.84 + \cancel{}\ 49.74 \angle 91.85$

$\boxed{I_s = \cancel{}\ A}$

$\boxed{I_s = 92.94 \angle 2.44^\circ}$ Ans

sending end voltage

$V_s = V_C + I_s (Z)$

$= 132.6 \times 10^3 \angle 1.85 + 92.94 \angle 2.47^\circ \times 10 \times (30 + j60)$

$\boxed{V_s = \cancel{}\ 135.5 \angle \cancel{}\ kV}$

$\boxed{V_s = 135.44 \angle 4.20^\circ\ kV}$

$\boxed{\cancel{(V_s)_{l-l} = 245.4\ V}}$

$\boxed{V_s (l-l) = 234.7\ kV}$

(ii) Sending end power –

$P_s = \sqrt{3} V_s I_s \cos\phi_s$

$= \sqrt{3} \times \frac{2}{3}\cancel{4}9.6 \times 10^3 \times \cancel{40.40} - 2.44$
$\cancel{56.3.4}\ 92.94 \times \cos(9.9\cancel{7}\cancel{+09.87})$

$\boxed{P_s = \cancel{67.74\ MW}}$ 46 MW

efficiency $\eta = \frac{P_R}{P_S} \times 100$

$= \frac{40}{67.74} \times 100$

$= 59\%$

$\eta = \frac{40}{46} \times 100$

$= 86.95\ \%.$

13

Space for Rough Work

Space for Rough Work