L-5

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ESE 2019 : Mains Test Series

UPSC ENGINEERING SERVICES EXAMINATION

Electrical Engineering

Test-4 : Electrical Machines

Power Systems - 1

Electrical Circuits -2 + Microprocessors - 2

Name : Kartikeya Singh

Roll No : E E 1 9 M B D L A 7 3 2

Test Centres					Student's Signature
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Instructions for Candidates

1. Do furnish the appropriate details in the answer sheet (viz. Name & Roll No).
2. Answer must be written in English only.
3. Use only black/blue pen.
4. 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.
5. Any page or portion of the page left blank in the Question Cum Answer Booklet must be clearly struck off.
6. Last two pages of this booklet are provided for rough work. Strike off these two pages after completion of the examination.

FOR OFFICE USE

Question No.	Marks Obtained
Section-A	
Q.1	52
Q.2	30
Q.3	
Q.4	
Section-B	
Q.5	53
Q.6	
Q.7	41
Q.8	23
Total Marks Obtained	199

Signature of Evaluator: K. Sudhakar

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Section A : Electrical Machines

(a) A 500 V, 10 hp, shunt motor has a full load efficiency of 85%, with the same field and armature currents it is desired to reduce the speed by 30% by insertion of resistance in the armature circuit. Assuming that all losses except copper losses vary directly as the speed, calculate the value of the inserted resistance and the efficiency of the motor when running at the reduced speed. The resistance of the field and the armature are 400 Ω and 0.25 Ω respectively. (1 hp = 746 W)

[12 marks]

At full load

Output = 10 × 746 = 7460 W

Input = $\frac{O/P}{efficiency}$ = $\frac{7460}{.85}$ = 8776.47 W

Input current I_L = $\frac{8776.47}{500}$ = 17.553 A

$I_{sh} = \frac{500}{400} = 1.25$ A

I_a = 17.553 − 1.25

I_a = 16.3029 A

Now E_b = 500 − 16.3029 × .25
= 495.924 volts.

Now $E_b \propto \phi N$

$E_b \propto N$ (as ϕ is constant)

$\frac{E_{b_1}}{E_{b_2}} = \frac{N_1}{N_2} = \frac{N}{0.7N}$

$E_{b_2} = 0.7 \times E_{b_1}$ = 347.1469

$E_{b_2} = V - I_a(R_a + R_{ext})$ (given I_a is same)

347.1469 = 500 − 16.3029 (0.25 + R_{ext})

$R_{ext} = \frac{152.85}{16.3029} - .25$ = 9.1258 Ω

Total losses at full load
= 8776.47 − 7460
= 1316.47 W

1316.47 = $P_{cu_{Ar}} + P_{cu_{field}} + P_r$

P_r = 1316.47 − 16.3029^2 × .25 − $\frac{500^2}{400}$

P_r = 625.023 W

given that

$P_r \propto N$

$P_{r_2} = \left(\frac{N_2}{N_1}\right) P_{r_1}$

= (.7) × 625.023

= ~~306.2916 W~~

= 437.5 W

$P_{field} = \frac{500^2}{400} = 625 W$

$P_{cu(Ar)} = 16.3029^2 \times (9.1258 + .25)$

$= 2491.91 W$

$Input = V_t I_L = 500 \times (16.3029 + 1.25)$

$= 8776.47 W$

$\eta\% = \frac{Input - losses}{Input} \times 100 = \frac{8776.47 - 625 - 2491.91 - ~~308.29~~ 437.5}{8776.47} \times 100$

$=$ ~~30.99 ≈ 61%~~

$= 59.51\%$

Q.1 (b) A 3-ϕ, 460 V, 250 hp, 50 Hz, 8-pole wound rotor induction motor controls the speed of a fan. The torque required for the fan varies as the square of the speed. At full load the motor slip is 0.03 with the slip rings short circuited. The slip-torque relationship of the motor can be assumed to be linear from no load to full load. The resistance of each rotor phase is 0.02 Ω. Determine the value of resistance to be added to each rotor phase so that the fan runs at 600 rpm.

[12 marks]

$S_{fl} = 0.03$

$T_L \propto N^2$

$R_2 = 0.02\Omega$

$N_s = \frac{120 \times 50}{8}$

$N_s =$ ~~18000~~ 750 rpm

T_e v/s s is linear

at steady state

$T_e = T_L$

$T_e \propto \frac{s V^2}{R_2 f}$ (linear characteristics)

$T_e \propto \frac{s}{R_2}$

hence $\frac{T_{e1}}{T_{e2}} = \frac{S_{f1}}{R_2} \times \frac{R_2'}{s'}$ and $\left(\frac{T_{L1}}{T_{L2}}\right) = \frac{N_1^2}{N_2^2}$

Now at full load $S_{fl} = 0.03$

$N_1 = N_s(1 - S_{fl}) = 750(1 - 0.03)$

$= 727.5$ rpm

given $N_2 = 600$ rpm

hence $S' = \frac{N_s - N_2}{N_s} = 0.2$

Now $\frac{T_{e1}}{T_{e2}} = \frac{T_{L1}}{T_{L2}}$

$\frac{S_{fl}}{R_2} \times \frac{R_2'}{S'} = \left(\frac{N_1}{N_2}\right)^2$

$\frac{0.03}{0.02} \times \frac{R_2'}{0.2} = \left(\frac{727.5}{600}\right)^2$

$R_2' = 0.196\ \Omega$

hence $R_{ext} = R_2' - R_2$

$= 0.196 - 0.02$

$= \underline{\underline{0.176\ \Omega}}$

Q.1 (c) A single-phase 120 V, 50 Hz series motor gave the following standstill impedance,

$$Z_1 = (5 + j25)\ \Omega$$

The motor is connected to a 120 V, 50 Hz supply at 1800 rpm when loaded to draw a current of 1.6 A. The rotational loss is 30 W. Determine the efficiency and the starting torque. (Assume magnetic linearity)

[12 marks]

$V_t = 120\text{ V}$ $\quad P_r = 30\text{ W}$

$Z_1 = 5 + j25$

$N = 1800\text{ rpm}$

$I = 1.6\text{ A}$.

for 1ϕ series motor, if pf is $\cos\phi$ lagging then (or pf angle is $-\phi$)

$E\angle 0^\circ = V_t\angle\phi - I_a\angle 0^\circ\, \bar{Z}_1$ (E & I_a are in phase)

$E = 120\angle\phi - 1.6\,(5 + j25)$

$E = 120\cos\phi + j120\sin\phi - 1.6\,(5 + j25)$

Compare imaginary part

$120\sin\phi - 1.6 \times 25 = 0$

$\phi = \sin^{-1}\left(\frac{1.6 \times 25}{120}\right)$

$= 19.47^\circ$

hence

$E = 120\cos\phi - 1.6 \times 5$

$E = 120\cos 19.47 - 1.6 \times 5$

$E = 105.13$ Volts.

Power Output (developed) $= E I_a = 105.13 \times 1.6$

$= 168.219$

Shaft O/P

$P_{sh} = 168.219 - 30 = 138.22\text{ W}$

$\eta\% = \frac{P_{sh}}{P_{in}} = \frac{138.22}{120 \times 1.6 \cos 19.47} = 0.7635$ or 76.35%

Torque $\propto \phi I_a$

Torque $\propto I_a^2$

$I_a(start) = \frac{V_1}{Z_1}$ as $E = 0$

$= \frac{120}{5 + j25} = 4.706 \angle -78.7°$ Amp

at load

Torque = I_a^2

$\frac{T_{Load}}{T_{st}} = \left(\frac{1.6}{4.706}\right)^2$

$T_{st} = \left(\frac{4.706}{1.6}\right)^2 T_{Load} = 8.6509\ T_{Load}$

T_{st} (developed) $= 8.6509 \times \frac{168.219 \times 60}{1800 \times 2\pi} = 7.70$ Nm

~~Tst~~

1 (d) Two series motors are connected to the same supply system and coupled to the same load. The one when running at 600 rpm normally takes a current of 60 A; the other when taking 60 A, runs at 1200 rpm; in each case the supply being same 600 V. Neglect the effect of saturation, at what speed will the motor run when the load current is 120 A? Each motor has total resistance of 0.5 Ω. Also calculate the value of current in each motor under these conditions.

[12 marks]

Motor 1

$I_a = 60A$

$E_{b_1} = V - 60 \times 0.5$

$E_{b_1} = V - 30$

$E_{b_1} = 600 - 30$

$= 570V$

Motor 2

$I_a = 60A$

$E_{b_2} = V - 60 \times 0.5$

$E_{b_2} = 570$

Now $E_{b_1} = E_{b_2}$

$\phi_1 N_1 = \phi_2 N_2$

$\frac{\phi_1}{\phi_2} = \frac{1200}{600} = 2$ —— (1)

$\frac{Reluctance\ 2}{Reluctance\ 1} = 2$

Now load current = 120 A

$N_1 = N_2 = N$

hence ~~$\frac{E_{b1}}{E_{b2}} = \frac{N_1 \phi_1}{N_2 \phi_2} = \frac{\phi_1}{\phi_2} = 2$~~

$\frac{E_{b1}}{E_{b2}} = \frac{N}{N}\frac{\phi_1}{\phi_2} \Rightarrow \frac{I_{a1} \times R}{I_{a2} \times R}$

$\frac{E_{b1}}{E_{b2}} = 2\frac{I_{a1}}{I_{a2}}$ —— (a)

and $E_{b1}' = 600 - I_{a1} \times 0.5$ —— (I)

$E_{b2}' = 600 - I_{a2} \times 0.5$ —— (II)

and $I_{a1} + I_{a2} = 120\text{ A}$ —— (III)

$\frac{600 - \frac{I_{a1}}{2}}{600 - \frac{I_{a2}}{2}} = \frac{2 I_{a1}}{I_{a2}}$

~~$\frac{E_{b1}'}{E_{b2}} = \frac{600 - 0.5 I_{a1}}{570} = \frac{N}{600}$~~

$600 I_{a2} - \frac{I_{a1} I_{a2}}{2} = 1200 I_{a1} - I_{a1} I_{a2}$

adding eq (I) and (II)

$E_{b1}' + E_{b2}' = 1200 - 0.5 (I_{a1} + I_{a2})$

$= 1200 - 0.5 \times 120$

$= 1200 - 60 = 1140$ Volt. —— (b)

~~$= 1140$~~

$-600 I_{a2} + 1200 I_{a1} = + \frac{I_{a1} I_{a2}}{2}$

$-600 I_{a2} + 1200(120 - I_{a2}) = \frac{1}{2}(120 - I_{a2}) I_{a2}$

~~from (I), (II) & (a)~~

~~$\frac{600 - I_{a1}/2}{600 - I_{a2}/2} = 2\frac{I_{a1}}{I_{a2}}$~~

~~$-600 I_{a2} - \frac{I_{a1} I_{a2}}{2} = 600 I_{a1} - \frac{I_{a1} I_{a2}}{2}$~~

$\frac{I_{a2}^2}{2} - 1800 I_{a2} + 1200 \times 120 - 60 I_{a2} = 0$

$I_{a2} = 79.10\text{ A}$

$I_{a1} = 40.9\text{ A}$

~~from (a) and (b) $E_{b2} = 380\text{ V}$~~

~~$E_{b1} = 760\text{ V}$~~

~~$E_{b1} + E_{b2} =$~~

~~for motor~~

~~$E_{b1} = 570$~~

~~E_{b2}~~

N = ?? speed = ??

(e) A 4-pole, 3-phase, 50 Hz, star-connected alternator has 60 slots, with 2 conductors per slot and having armature winding of the two-layer type. Coils are short-pitched in such a way that if one coil side lies in slot number 1, the other lies in slot number 13. Determine the useful flux per pole required to generate a line voltage of 6000 V.

[12 marks]

$S = 60$

Slots per pole per phase $m = \frac{60}{4 \times 3} = 5$

β (Slot Angle) $= \frac{180}{\text{Slots / Pole}} = \frac{180}{(60/4)} = 12$

Distribution factor $\Rightarrow K_d = \frac{\sin m\beta/2}{m \sin \beta/2}$

$K_d = \frac{\sin\left(\frac{5 \times 12}{2}\right)}{5 \sin(12/2)}$

$K_d = 0.95667$

Angle of short pitch

$\alpha =$ Angle contribution by $(15 - 13) = 2$ Slots

$\alpha = 2\beta = 2 \times 12 = 24°$

Short pitch factor $K_c = \cos \alpha/2 = \cos 12 = 0.97814$

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Induced EMF

$E = \sqrt{2}\pi\, N_{ph}\, K_c\, K_d\, f\, \phi$

$\frac{6000}{\sqrt{3}} = \sqrt{2}\pi \times \frac{60 \times 2}{3 \times 2} \times 0.97814 \times .955667 \times 50\, \phi$

$\phi = \frac{3464.1}{\sqrt{2}\pi \times 20 \times 50 \times .97781 \times .95567}$

$\phi = 0.834$ Wb

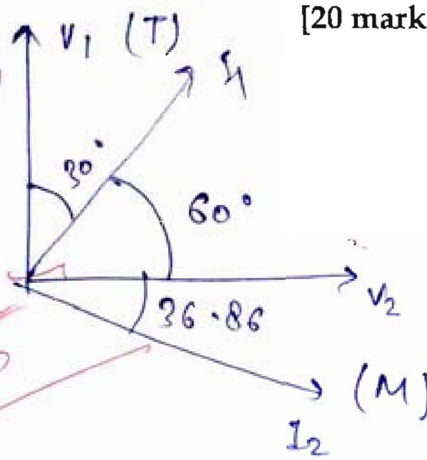
0.857 wb

Q.2 (a) Two single phase furnaces 1 and 2 are supplied at 220 V by means of two Scott-connected transformers with input voltage of 3-phase, 11 kV, 50 Hz. The voltage of furnace 1 is leading. Compute the currents on the 3-phase side if furnace 1 takes 500 kW at 0.866 pf lagging and furnace 2 takes 600 kW at 0.8 pf lagging. Also draw the phasor diagram.

[20 marks]

$I_1 = \frac{500 \times 10^3}{.866 \times 220} \angle -\cos^{-1} .866$

$I_1 = 2624.39 \angle -30° \text{ A}$



and $I_2 = \frac{600 \times 10^3}{\sqrt{3} \times 220} \angle -\cos^{-1} 0.8$

$I_2 = 3149.27 \angle -36.86 \text{ A}$

Ratio of main transformer $a_M = \frac{11000}{220} = 50$

Ratio of teaser transformer $a_T = \frac{\sqrt{3}}{2} a_M = 43.3$

Take V_2 as reference —

Now $\bar{I_a} = \frac{I_1}{a_T} = \frac{2624.39 \angle 60°}{43.3} = 60.60 \angle 60°$ A

$\bar{I_{bc}} = \frac{I_2}{a_m} = \frac{3149.27 \angle -36.86}{50} = 62.98 \angle -36.86$ A

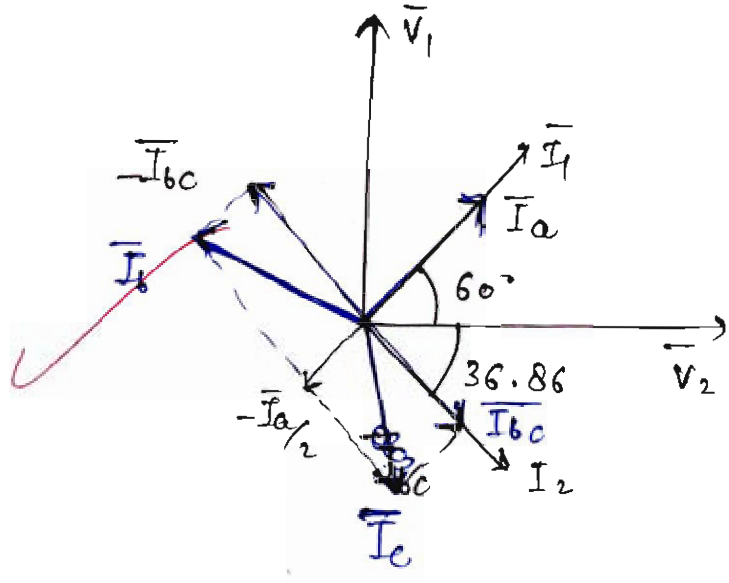
Now $\bar{I_a} = 60.6 \angle 60°$

$\bar{I_b} = -\frac{\bar{I_a}}{2} - \bar{I_{bc}} = -\frac{60.60 \angle 60°}{2} - 62.98 \angle -36.86$

$\bar{I_b} = 66.85 \angle 170°$ Amp

$\bar{I_c} = \bar{I_{bc}} - \frac{\bar{I_a}}{2} = 62.98 \angle -36.86 - \frac{60.60 \angle 60°}{2}$

$\bar{I_c} = 73.078 \angle -61.168$ A


$\bar{V}_1$
$\bar{I}_1$
$\bar{I}_a$
$-\bar{I}_{bc}$
$\bar{I}_b$
60°
36.86
$\bar{V}_2$
$-\bar{I}_a/2$
$\bar{I}_{bc}$
I_2
$\bar{I}_c$

Q.2 (b) A 400 V, 1450 rpm, 4-pole, 50 Hz wound-rotor induction motor has the following circuit model parameters.

$R_1 = 0.3\ \Omega$, $R_2' = 0.25\ \Omega$

$X_1 = X_2' = 0.6\ \Omega$ $X_m = 35\ \Omega$

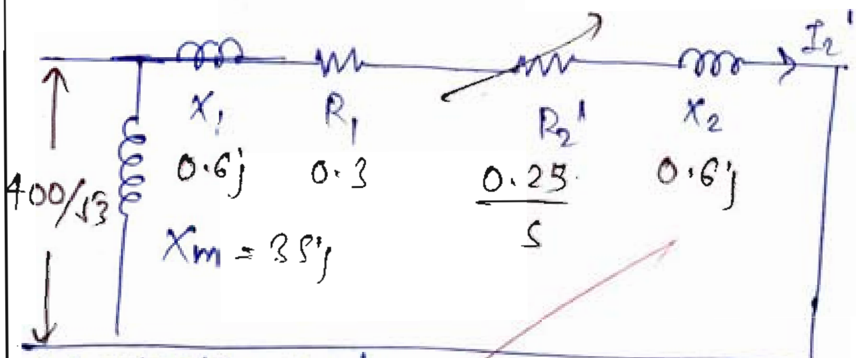
Rotational loss = 1500 W

(i) Calculate the starting torque and current when the motor is started directly on full voltage.

(ii) Calculate the full-load current, power factor and net torque. Also find internal efficiency and overall efficiency.

(iii) Find the slip for maximum torque and the value of maximum torque.

[20 marks]



assuming star

at starting $s = 1$

$$\bar{I_2}' = \frac{400/\sqrt{3}}{(0.3 + 0.25) + j(0.6 + 0.6)}$$

$$\bar{I_2}' = 174.949 \angle -65.37\ A$$

$$\bar{I_\phi} = \frac{400/\sqrt{3}}{jX_m} = \frac{400/\sqrt{3}}{35j} = 6.598 \angle -90^\circ\ \text{Amp}$$

Input current

$$\bar{I_1} = \bar{I_\phi} + \bar{I_2}'$$

$$\boxed{\bar{I_1} = 180.9678 \angle -66.29}\ \text{Amp.}$$

Now air gap power at starting $= 3 I_2'^2 R_2$

$$= 3 \times (174.949)^2 \times .25$$

$$= 22955.36\ W$$

$$T_{st} = \frac{P_g}{\omega_s} = \frac{22955.36}{\frac{120 \times 50}{4} \times \frac{2\pi}{60}} = 146.188\ \text{Nm}$$

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at full load $S = \frac{N_s - N_r}{N_s} = \frac{1500 - 1450}{1500} = 0.033$

here $\bar{I}_2' = \frac{400/\sqrt{3}}{\left(0.3 + \frac{0.25}{0.033}\right) + j\,1.2} = 28.988 \angle -8.66$ Amp

$\bar{I}_\phi = 6.598 \angle -90$ Amp

$\bar{I}_1 = \bar{I}_\phi + \bar{I}_2' = 30.68 \angle -20.936$ Amp.

Pf $= \cos(20.936) = 0.9339$ lagging

air gap power $= 3 I_2^2 R_2/s$

$P_g = 3 \times (28.988)^2 \times \frac{0.25}{.033} = 19097.82$

developed power

$P_m = (1-S) P_g = 18461.86$ W

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Shaft O/p

$P_{sh} = P_m - P_r$

$= 18461.86 - 1500$

$= 16961.86$ W

$T_{sh} = \frac{P_{sh}}{\omega_m} = \frac{16961.86}{1450 \times 2\pi/60} = 111.70$ Nm

Overall efficiency $= \frac{P_{sh}}{P_{in}} \times 100 = \frac{16961.86 \times 100}{\sqrt{3} \times 400 \times 30.68 \times .9339}$

$= 85.44\%$

Internal efficiency $= \frac{P_m}{P_g} = 1 - S = 0.9667$ or 96.67%

Slip at maximum torque

$$S_m = \frac{R_2}{\sqrt{R_1^2 + (X_2 + x_1)^2}}$$

$$= \frac{0.25}{\sqrt{.3^2 + 1.2^2}} = 0.2021 \text{ pu}$$

~~Tmax = $3I_2^2$~~

$$I_2' = \frac{400/\sqrt{3}}{.3 + \frac{.25}{.202} + j1.2} = 118.40\angle -37.96 \text{ Amp}$$

~~Tmax~~

air gap power

$$= 3 I_2'^2 R_2/s$$

$$= 3(118.4)^2 \times \frac{.25}{.2021} =$$

$$= 52023.354 \text{ W}$$

$$T_{max} = \frac{P_g}{\omega_s} = \frac{52023.354}{1500 \times \frac{2\pi}{60}}$$

$$= 331.19 \text{ Nm}$$

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2 (c) A salient pole synchronous machine delivers rated power to a load of unity power factor. The d-axis and q-axis reactances are:

$X_d = 0.95$ p.u, $X_q = 0.45$ p.u.

The power angle $\delta = 25°$

The stator winding resistance is negligible.

Calculate:

(i) the excitation voltage (E_f) and the terminal voltage (V_t).

(ii) the current I_a, I_d and I_q and draw the phasor diagram.

[20 marks]

$\delta = 25°$, ~~$I_a = 1\angle 0°$~~

q axis locator

$E_f' \angle \delta = \bar{V_t} + j \bar{I_a} X_q$

$E_f' \angle \delta = \bar{V_t} + j \frac{1\angle 0° \times 0.45}{V_t}$

$E_f' \angle \delta = \bar{V_t} + \frac{0.45}{V_t} j$

$E_f' \cos 25 + j E_f' \sin 25 = V_t + \frac{0.45}{V_t} j$

Rated power

$P = 1$ pu

$I_a = \frac{1}{V_t} \angle 0°$

hence

$E_f' \cos 25 = .98235$

$E_f' = 1.0839$ pu

~~$E_f' \cos 25 = 0.45/V_t$~~

~~$E_f' = 0.4965$~~

~~and $V_t = E_f' \sin 25$~~

~~$= 0.2098$ pu~~

$\tan 25 = \frac{0.45}{V_t \times V_t}$

$V_t^2 = \frac{0.45}{\tan 25}$

$V_t = 0.98235$

Now $I_d = I_a \sin \phi = \frac{1}{V_t} \sin(\delta + \phi)$

$= 1 \sin \delta / V_t$

$= 1 \sin 25 / V_t$

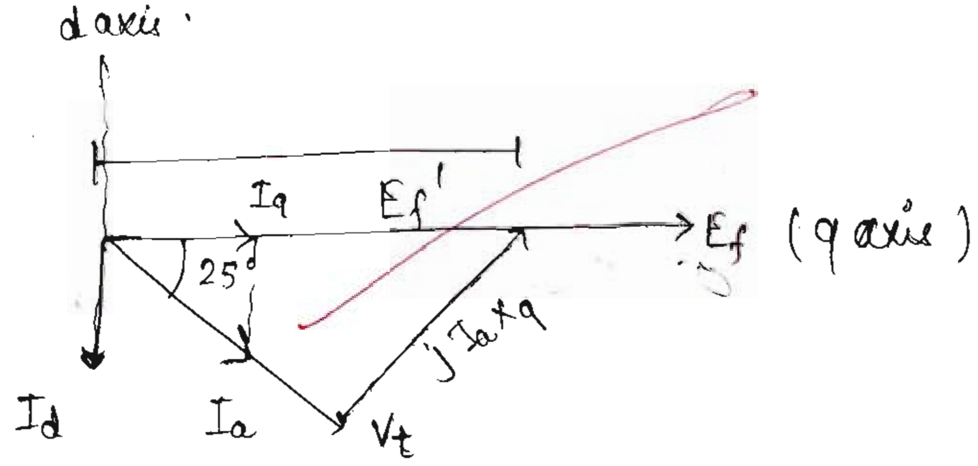
$= \frac{0.4226}{V_t}$ pu $= \frac{0.4226}{.98235} = 0.43019$ pu

I_q = ?

$E_f = E_f' + I_d (X_d - X_q)$

$E_f = 1.084 + .43019(.95 - .45)$

$E_f =$ ~~0.7078 pu~~ 1.299 pu


d axis
Iq
Ef'
Ef (q axis)
25°
j Ia Xq
Id
Ia
Vt

3 (a) Two separately excited dc generator operating in parallel, supply a total output current of 100 A. The terminal voltage of first machine falls from 270 V at no load to 250 V at an output current of 60 A. The terminal voltage of second machine falls from 280 V at no-load to 250 V at an output current of 80 A. Their external characteristics are linear.

Calculate:

(i) the output current of each machine.

(ii) the line voltage and total load in kW when first generator is floating.

[20 marks]

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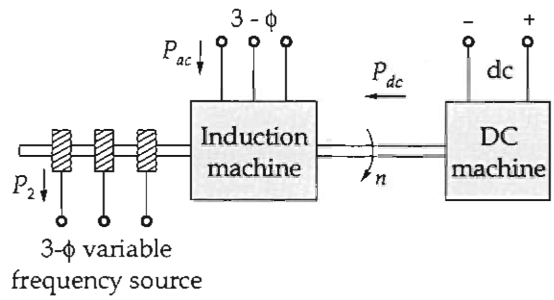
3 (b) A three phase source of variable frequency is required for an experiment. The frequency changer system is shown in figure. The induction machine is 3-ϕ, 6 pole wound rotor type whose stator terminals are connected to a three phase, 460 V, 50 Hz supply. The variable frequency output is obtained from the rotor terminals. The frequency is to be controlled over the range 10 - 100 Hz.



(i) Determine the speed in rpm of the system to give 10 Hz and 100 Hz.

(ii) If the open-circuit rotor voltage is 240 V when the rotor is at stand still, determine the rotor voltage available on open circuit with 10 Hz and 100 Hz.

(iii) If all the losses in the machine are neglected, what fraction of the output power is supplied by the ac supply and what fraction is supplied by the dc machine at 10 Hz and 100 Hz?

[20 marks]

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3 (c) A 3-ϕ, 230 V, 27 kVA, 0.9 power factor (lagging) load is supplied by three 10 kVA, 1330/230 V, 50 Hz transformers connected in Y-Δ by means of a common 3-ϕ feeder whose impedance is $(0.003 + j0.015)\Omega$ per phase. The transformers are supplied from a 3-phase source through a three phase feeder whose impedance is $(0.8 + j5.0)\Omega$ per phase. The equivalent impedance of one transformer referred to the low-voltage side is $(0.12 + j0.25)\Omega$. Determine the required supply voltage if the load voltage is 230 V. (Draw the relevant circuits wherever required)

[20 marks]

4 (a) A 6-pole, 240 V dc series motor has a flux per pole of 2 mWb/Amp over the working range of magnetizing curve which is assumed to be linear. The load torque is proportional to the speed squared and its value is 26 Nm at 1000 rpm. There are 440 wave connected conductors and total resistance of motor is 1 Ω. Determine the motor speed and current when this motor is connected to the rated supply voltage.

[20 marks]

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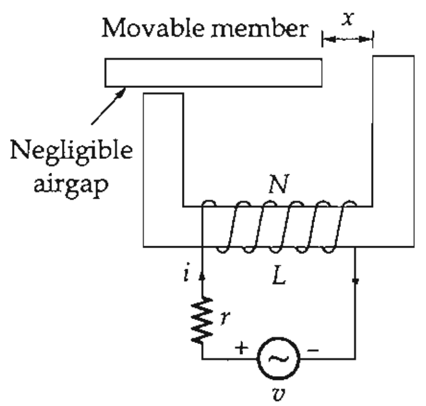
.4 (b) For the electromagnetic device shown in figure, the cross-sectional area normal to the flux is A and the reluctance is offered by air gap alone. Compute the average force on the movable member in terms of N, x, A, L etc.

When,

(i) $i = I_m \cos \omega t$

(ii) $v = V_m \cos \omega t$



[20 marks]

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.4 (c) A 3-ϕ cylindrical rotor synchronous machine and a shunt dc machine are mechanically coupled to transfer power from a dc source to an ac source and vice versa. The rating of the machines are

Synchronous machine: 12 kW, 208 V
$X_s = 3.0\ \Omega$

DC machine: 12 kW, 220 V

Neglect all losses

The dc machine is connected to a 220 V dc bus, and the synchronous machine is connected to a 3-ϕ, 208 V, 60 Hz bus. The excitation of the synchronous machine is made 1.25 p.u.

(i) For zero power transfer, determine the armature current in the dc machine and the current and power factor of the synchronous machine.

(ii) 8 kW is transferred from the dc bus to the ac bus through the two machines. What adjustment is necessary? Determine the armature current in the dc machine and the stator current and power factor of the synchronous machine.

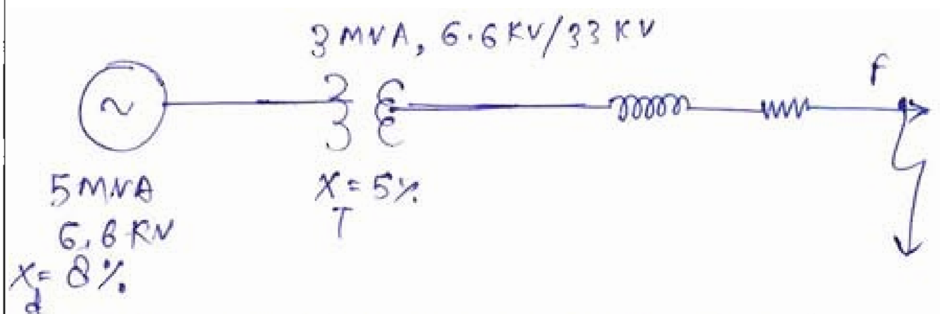
(iii) Repeat part (ii), if 8 kW is transferred from the ac bus to the dc bus.

[20 marks]

Section B : Power Systems - 1 + Electrical Circuits - 2 + Microprocessors - 2

.5 (a) A 3-phase, 5 MVA, 6.6 kV alternator with a reactance of 8% is connected to a feeder through transformer. The transformer is rated at 3 MVA, 6.6 kV/33 kV and has a reactance of 5% and feeder has a series impedance of $(0.12 + j0.48)\Omega$/ph/km. If a 3-phase symmetrical fault occurs at a point 15 km along the feeder, then determine the fault current supplied by the generator operating under no load with a voltage of 6.9 kV.

[12 marks]



Let the per unit base on generator side is

$V_B = 6.6$ KV

$S_B = 5$ MVA

hence pu reactance of transformer at New base

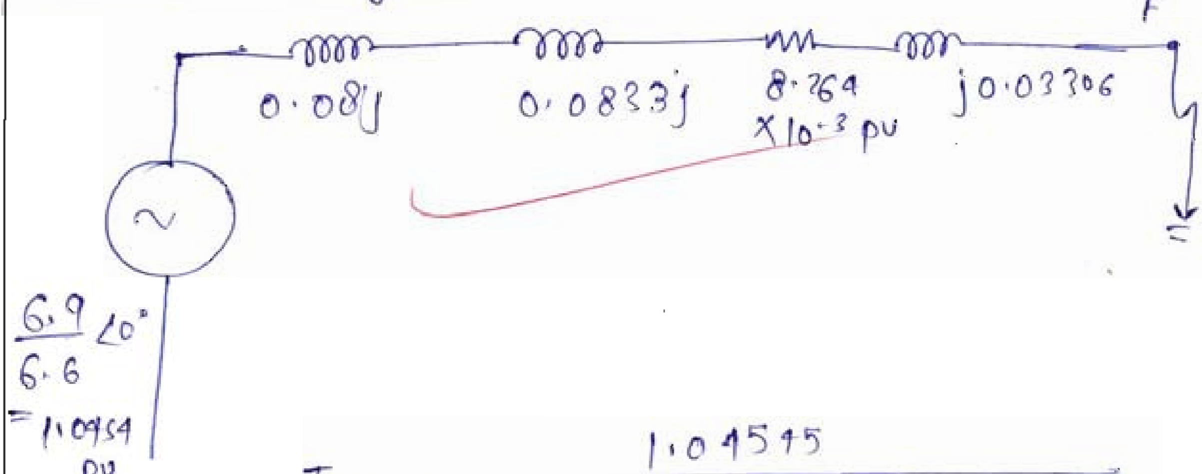
$$X_T = 0.05 \times \left(\frac{5}{3}\right) = 0.0833 \text{ pu}$$

pu impedance of feeder upto fault point

$$Z_F = (0.12 + j\,0.48) \times 15 \times \frac{5}{(33)^2}$$

$$Z_F = 8.264 \times 10^{-3} + j\,0.03306 \text{ pu}$$

Reactance diagram :- Fault point voltage (prefault) $= V_{Th} = \frac{6.9}{6.6}$ pu



$$I_{F(pu)} = \frac{1.04545}{0.08j + 0.0833j + 8.264 \times 10^{-3} + 0.03306j}$$

$I_{F(pu)} = 5.3194 \angle -87.59$ pu

I_F in ampere (for generator side)

$I_{Base} = \frac{5 \times 10^3}{\sqrt{3} \times 6.6} = 437.386$ A

$I_{F(g)} = 437.386 \times 5.3194$
$= 2326.63$ Amp

(on fault side)

$I_{Base} = \frac{5 \times 10^3}{\sqrt{3} \times 33}$
$= 87.477$ A

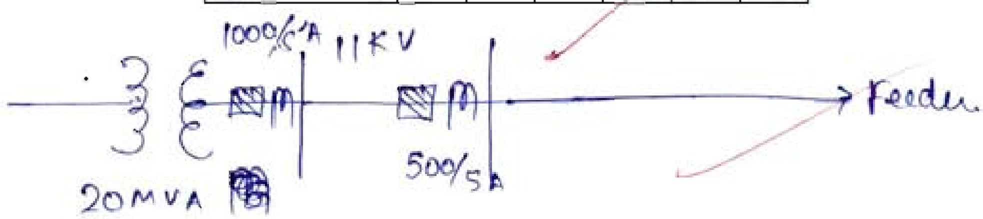
$I_{F(fault side)}$
$= 87.477 \times 5.3194$
$= 465.326$ Amp.

Q.5 (b) A 20 MVA transformer, which may be called upon to operate at 25% overload, feeds 11 kV bus bars through a circuit breaker; other circuit breakers supply outgoing feeders. The transformer circuit breaker is equipped with 1000/5 A CT's and the feeder circuit breakers with 500/5 A CT's and all sets of CT's feed induction type over-current relays. The relays on the feeder circuit breakers have a 125% plug setting and a 0.4 time setting. If a three phase fault current of 7500 A flows from the transformer to one of the feeders, find the operating time of the feeder relay, the minimum plug setting of the transformer relay and its time setting assuming a discriminative time margin of 0.5 second.

PSM	2	4	5	8	12	20
Operating time (in seconds)	10	5	4.7	3	2.8	2.4

For TMS = 1 second

[12 marks]



$I_F = 7500$ A

→ for feeder side relay.

Pickup setting / Plug setting $= 1.25 \times 5 = 6.25$ A

$PSM = \frac{7500 \times 5}{500 \times 6.25} = 12$

hence operating time corresponding to TMS = 1

$T_{op} = 2.8$ sec

Actual operating time of feeder relay

- $T_{op}' = 0.4 \times 2.8$

$T_{op}' = 1.12$ sec

→ for transformer relay -

Operating time (Actual)

$= 1.12 + 0.5$

$= 1.62$ sec

Now plug setting of Transformer relay

$= \dfrac{I_{rated} \times 1.25}{CT\ ratio}$ × ~~CT ratio~~

$= \dfrac{\dfrac{20000}{\sqrt{3} \times 11} \times 1.25}{(1000/5)}$

$= \dfrac{1312.159 \times 5}{1000}$

$= 6.5607$ Amp

% PS $= \dfrac{6.5607}{5} = 1.3121$ or 131.21%

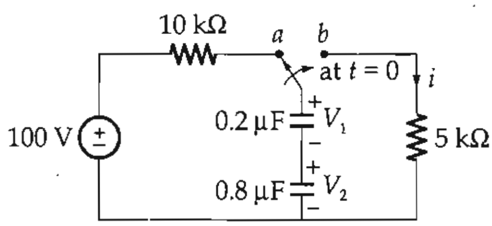
Now PSM of Transformer relay $= \dfrac{7500 \times 5}{1000 \times 6.5607}$

$= 5.$

TMS = ??

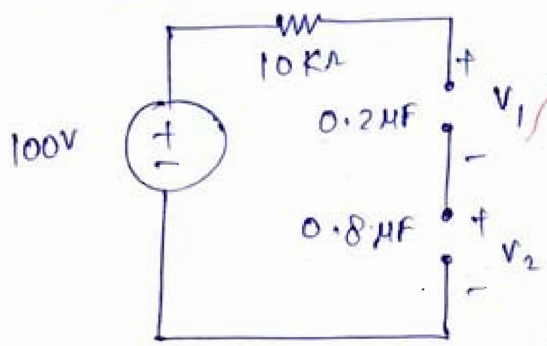
Do not write in this margin

Q.5 (c) The switch in the circuit shown has been in position-*a* for long time, At $t = 0$, the switch is thrown to position-*b*. Find the time-domain expression for the current *i*.



[12 marks]

for $t<0$,

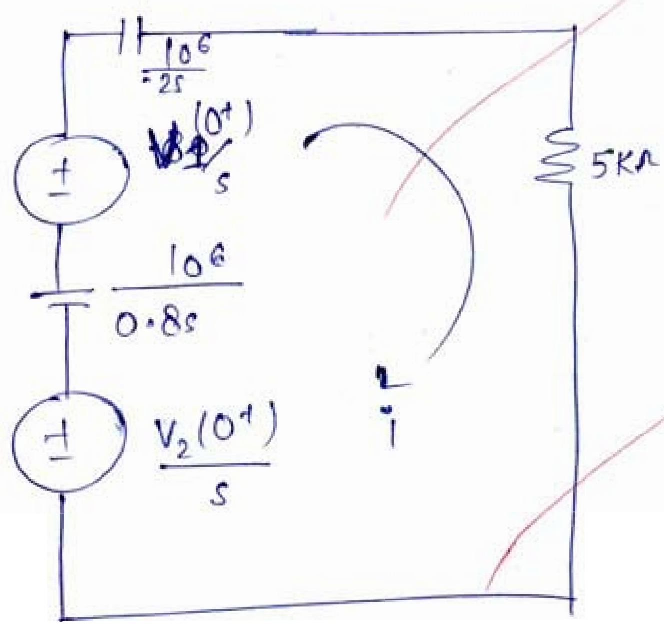


$$V_1 = \frac{100 \times 0.8}{0.8 + 0.2} = 80\,V$$

$$V_2 = \frac{100 \times 0.2}{0.8 + 0.2} = 20\,V$$

$V_1(0^-) = V_1(0^+) = 80V$, $V_2(0^-) = V_2(0^+) = 20V$

for $t>0$ transformed ckt is



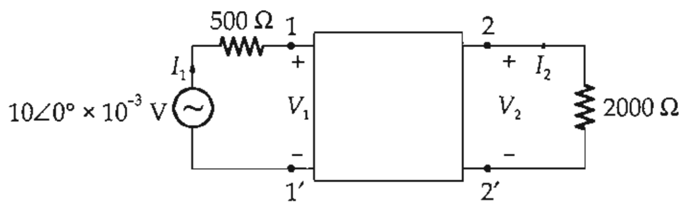
$$\frac{V_1(0^+) + V_2(0^+)}{s} = \left(\frac{10^6}{0.2s} + \frac{10^6}{0.8s}\right) I(s) + 5000 I(s)$$

$$I(s) = \frac{100}{s\left[\frac{10^6}{0.2s} + \frac{10^6}{0.8s} + 5000\right]} = \frac{100}{\left[\frac{10^7}{2} + \frac{10^7}{8} + 5000s\right]}$$

$$I(s) = \frac{100/5000}{\left(\frac{10^7}{10^4} + \frac{10^7}{4 \times 10^4} + s\right)} = \frac{0.02}{s + 1250}$$

Taking laplace inverse $i(t) = 0.02e^{-1250t}$ for $t>0$

5 (d) The hybrid parameters of a two-port network shown in figure are $h_{11} = 1000\ \Omega$, $h_{12} = 0.003$, $h_{21} = 100$ and $h_{22} = 50\ \mu℧$. Find V_2.



[12 marks]

System equation in terms of h parameters

$V_1 = h_{11}I_1 + h_{12}V_2 = 1000 I_1 + 0.003 V_2$ —— (I)

$I_2 = h_{21}I_1 + h_{22}V_2 = 100 I_1 + 50\times10^{-6} V_2$ —— (II)

from the given circuit

$V_2 = -2000 I_2$ —— (III)

Substituting value of V_2 in eq (III)

$I_2 = 100 I_1 + 50\times10^{-6}(-2000 I_2)$

$I_2 + 50\times2000\times10^{-6} I_2 = 100 I_1$

$I_2(1 + 0.1) = 100 I_1$

$I_1 = \dfrac{1.1 I_2}{100}$ —— (IV)

Subtituting I_1 and V_2 value in eq (I)

$V_1 = 1000\times\dfrac{1.1 I_2}{100} + 0.003\times(-2000) I_2$

$V_1 = \dfrac{1000}{100}\times 1.1 I_2 - 3\times2 I_2$

$V_1 = 11 I_2 - 6 I_2 = 5 I_2$ —— (V)

from the ckt $V_1 = 10\times10^{-3}\angle 0° - 500 I_1$

Putting in eq (V)

$10\times10^{-3} - 500 I_1 = 5 I_2$

$10\times10^{-3} - \dfrac{500\times1.1}{100} I_2 = 5 I_2$ $\Rightarrow I_2 = \dfrac{10\times10^{-3}}{5 + 5.5}$

$I_2 = \dfrac{1}{1050}$ A

hence from eq (iii)

$V_2 = -2000 I_2$

$V_2 = -2000 \times \frac{1}{1050}$

$V_2 = -1.90476$ volts

Q.5 (e) Calculate the delay produced by the following subroutine program of an 8085 microprocessor, which is operating with a clock frequency of 2 MHz.

```
DELAY  : MVI B, 02H    —  7T
LOOP2:   MVI C, FFH    —  7T
LOOP1:   DCR C         —  4T
         JNZ LOOP1     —  10 / 7T
         DCR B         —  4T
         JNZ LOOP2     —  10 / 7T
         RET           —  10T
```

[12 marks]

~~loop 2 MVI C FF~~
loop (1) ~~DCR C~~
JNZ loop 1
~~DCR B~~

Inner loop ~~delay~~ T'states (loop 1)

$= (4+10) \times 254 + (4+10)$

$= 3570\ T$

Total loop (2) ~~delay~~ Tstates $= (7T + 3570T + 4T + 10T) + (7T + 3570T + 4T + 7T)$

$= 7179\ T$

~~Delay~~ both
Outside loop T states = 7T + 10T
= 17T

total T states = 17T + 7179 T

= 7196 T

hence
Total time delay

$$= \frac{\text{total T states}}{\text{Clock frequency}}$$

$$= \frac{7196}{2 \times 10^6} \text{ sec}$$

= 3.598 msec

Q.6 (a) A 3-phase transmission line 50 km long consists of three hard drawn copper conductors in a 1.2 m delta. Load conditions at receiving end are: 10000 kVA at 0.8 pf lagging 33000 volts, 50 Hz. Line is designed so that transmission loss is approximately 10%.

Calculate:

(i) The sending end voltage and power factor,

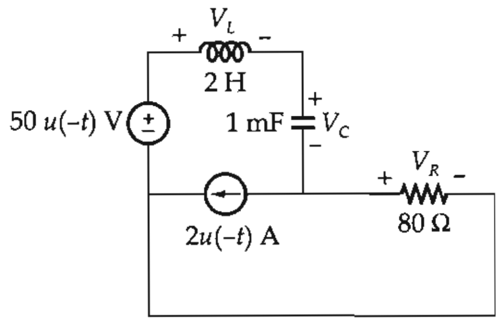
(ii) Efficiency and

(iii) Voltage regulation.

(Assume $\rho = 1.73 \times 10^{-6}\ \Omega$–cm)

[20 marks]

Q.6 (b) Find the expression of V_C, V_R and V_L for $t > 0$ in the circuit shown in figure.



[20 marks]

Q.6 (c) **(i)** Give detailed description of the bits of the control word of intel 8255.

(ii) Find control word for the following configuration of the ports of intel 8255 for mode-2 operation;

Port A - bidirectional

Mode of port A - Mode-2

Port B - input

Mode of port B - Mode 0.

The remaining pins of PORT C_{lower}, i.e.

P_{C0}, P_{C1}, P_{C2} - output.

[15 + 5 marks]

7 (a) A single core lead sheathed cable has a conductor of 1 cm diameter and a sheath of 5 cm inside diameter. Two dielectric materials having permittivity of 4 and 2.5 and permissible potential gradients of 60 kV/cm and 50 kV/cm respectively are used. Determine the thickness of the dielectric materials and the maximum safe working voltage. **[20 marks]**

for capacitance grading

$g_1 \varepsilon_1 = 60 \times 4 = 240$

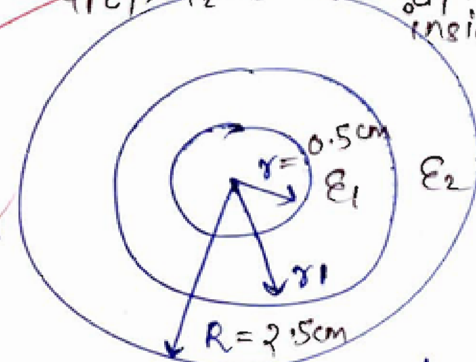
$g_2 \varepsilon_2 = 50 \times 2.5 = 125$ (outside)

$g_1 \varepsilon_1 > g_2 \varepsilon_2$ hence ε_1 is inside

$$g_1 \varepsilon_1 r = g_2 \varepsilon_2 r_1$$

$$60 \times 4 \times \frac{1}{2} = 50 \times 2.5\, r_1$$

$$r_1 = \frac{1.92\ \text{cm}}{2} = 0.96\ \text{cm}$$



→ hence thickness of first dielectric which is inside (ε_1)

$$2(r_1 - r) = 1.92 - 1$$
$$= 0.92\ \text{cm}$$

as $E = \dfrac{q}{2\pi\varepsilon_0 r \varepsilon_r}$

$\dfrac{q}{2\pi\varepsilon_0} = \varepsilon_r\, r\, E = \text{constant}$

This is used above

→ thickness of second dielectric

$$= 2(R - r_1)$$
$$= 2R - 2r_1$$
$$= 5 - 1.92$$
$$= 3.08\ \text{cm}$$

→ Safe working ~~work~~ voltage

$$V_{max} = \text{~~E max~~}\ g_1 r \ln\left(\frac{r_1}{r}\right) + g_2 r_1 \ln\left(\frac{R}{r}\right)$$

$$= 60 \times \frac{\cdot 96}{0.5} \ln\left(\frac{0.96}{0.5}\right) + 50 \times \cdot 96 \ln\left(\frac{2.5}{\cdot 96}\right)$$

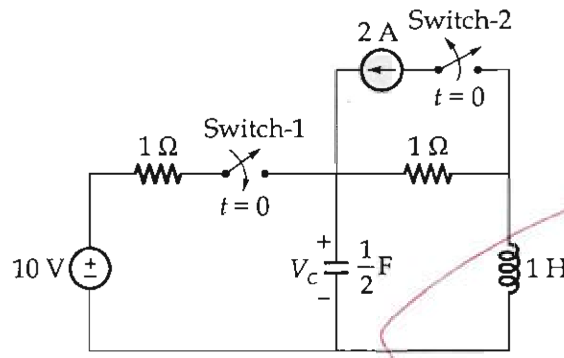
$$\simeq 65.51\ \text{KV (max)}.$$

$$V_{max(rms)} = \frac{65.51}{\sqrt{2}} = 46.32\ \text{KV (rms)}$$

18

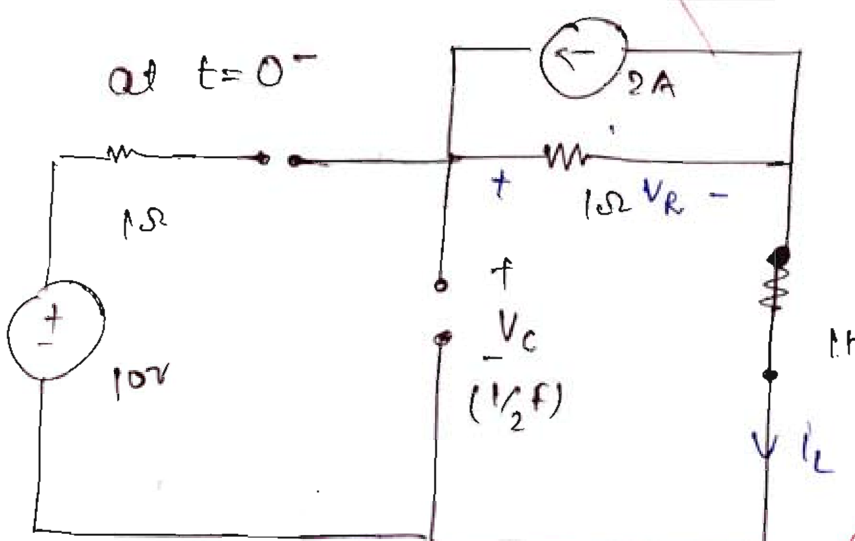
Do not write in this margin

7 (b) (i) Find $i_L(0^+)$, $V_C(0^+)$, $\frac{dV_C(0^+)}{dt}$ and $\frac{di_L(0^+)}{dt}$ for the circuit shown below. Use $\frac{dV_C(0^+)}{dt}$ to denote $\left.\frac{dV_C(t)}{dt}\right|_{t=0^+}$. Assume that switch-1 has been opened and switch-2 has been closed for a long time and steady state condition prevails at $t = 0^-$.



[12 marks]

at $t=0^-$

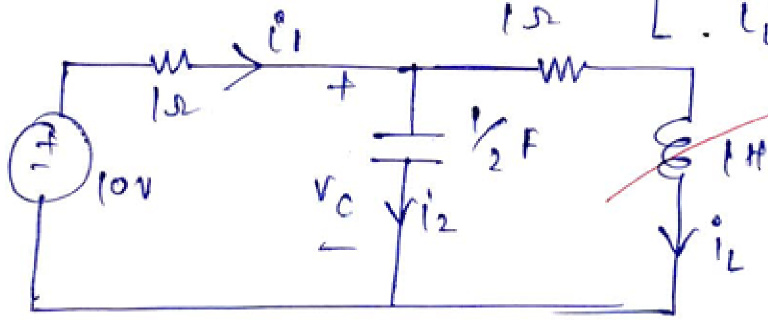


at $t=0^-$ $\quad i_L(0^-)=0$

$V_C(0^-) = V_R(0^-) = 2\times 1 = 2V$

→ at $t=0^+$ ckt is

$\left[\begin{array}{l} V_C(0^+)=V_C(0^-)=2V \\ i_L(0^+)=i_L(0^-)=0 \end{array}\right.$



$i_L(0^+) = 0 = i_L(0^-)$

$V_C(0^+) = 2V$

Do not write in this margin

$$i_1(0^+) = \frac{10 - V_c(0^+)}{1} = \frac{10-2}{1} = 8\,A.$$

KCL:-

$$i_1(0^+) = i_L(0^+) + i_2(0^+)$$

$$i_1(0^+) = i_2(0^+) \quad \text{as} \quad i_L(0^+) = 0$$

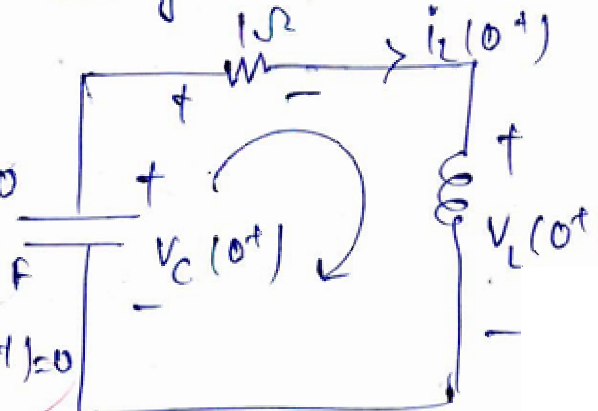
$$i_2(0^+) = C\frac{dV_c(0^+)}{dt} = 8$$

8

$$\boxed{\frac{dV_c}{dt}(0^+) = \frac{8}{(1/2)} = 16\ V/sec}$$

Since $i_L(0^+)$ zero hence voltage drop across 1Ω is zero

KVL in the loop shown



$$V_c(0^+) + V_R(0^+) + V_L(0^+) = 0$$

$$V_c(0^+) + 1\, i_L(0^+) + L\frac{di_L(0^+)}{dt} = 0$$

$$L\frac{di_L(0^+)}{dt} = -2$$

(because $V_c(0^+) = 2V$, $i_L(0^+) = 0\,A$)

$$\boxed{\frac{di_L(0^+)}{dt} = -2\ A/sec}$$

2 A/sec

Do not write in this margin

7 (b) (ii) A linear graph has five nodes and seven branches. The reduced incidence matrix for this graph is given below:

Nodes ↓, Branches →

	1	2	3	4	5	6	7
a	1	1	0	0	0	0	1
b	−1	−1	−1	0	0	0	0
c	0	0	−1	1	0	0	0
d	0	0	0	−1	−1	−1	0

It is claimed that the set of branches {1, 3, 4, 5} constitutes a tree. Without drawing the graph, verify the truth of this claim.

[8 marks]

Incidence matrix

A =	1	2	3	4	5	6	7
a	1	1	0	0	0	0	1
b	−1	−1	1	0	0	0	0
c	0	0	−1	1	0	0	0
d	0	0	0	−1	−1	−1	0
ref	0	0	0	0	1	1	−1

(c) (i) Compare the memory mapped I/O and peripheral I/O.

[10 marks]

Memory mapped I/O	I/O mapped I/O
16 bit address for devices	8 bit address for devices
65536 devices and memory locations can be addressed	256 I/O devices can be addressed
Used for small memory systems	Used for large memory systems.
Instructions used as LDA, STA etc. MOV M, R	Instruction used are IN 8 bit, OUT 8 bit for I/O operation and LDA, STA, MOV M, R etc for memory operation
Control signals IO/$\overline{M}$ = 0, $\overline{RD}$ = 0 ($\overline{MEMR}$), $\overline{WR}$ = 0 ($\overline{MEMW}$)	IO/$\overline{M}$ = 1, $\overline{RD}$ = 0 ($\overline{IOR}$), $\overline{WR}$ = 0 ($\overline{IOW}$)
Some operation can be done directly on I/O devices	Operations can't be done on I/O device.
More hardware	Less hardware.

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Q.7 (c) **(ii)** Write the different types of 8085 hardware vectored interrupts and mention the type of triggering, vectored address and dependency on EI and DI.

[10 marks]

Hard ware Interrupts.

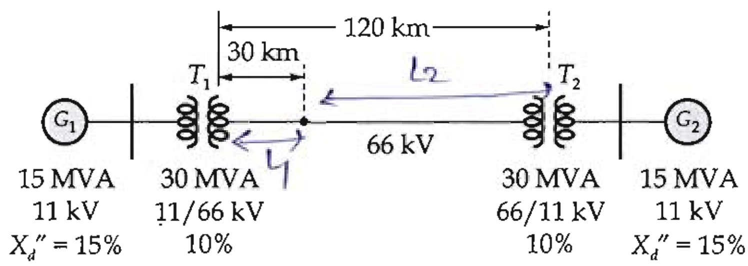
		Triggering	Vector address
1)	TRAP	Edge + Level	0024 H
2)	RST 7.5	Edge	003C H
3)	RST 6.5	level	0034 H
4)	RST 5.5	level	002C H
5)	INTR	level	Non Vectored.

→ Trap can't be disabled/Enabled by EI /DI because it is non maskable

→ RST 7.5, RST 6.5, RST 5.5, INR can be enabled /Disabled simultaneously by EI/ DI.

There is nothing like single interrupt masking using EI /DI. for individual masking use SIM instruction.

(a) Two generators rated 15 MVA, 11 kV, having 15% subtransient reactance are interconnected through transformers and a 120 km long line as shown in figure. The reactance of the line is 0.12 ohms/km. The transformer near the generators are rated 30 MVA, 11/66 kV with leakage reactance of 10% each. A three-phase symmetrical fault occurs at a distance of 30 km from one end of the line when the system is on no load but at rated voltage. Determine the fault current and the fault MVA.



[20 marks]

Ref system base is 11 kV, 30 MVA on generator side.

$X_{d_1}'' = \frac{0.15 \times 30}{15} = 0.3 \text{ pu}$

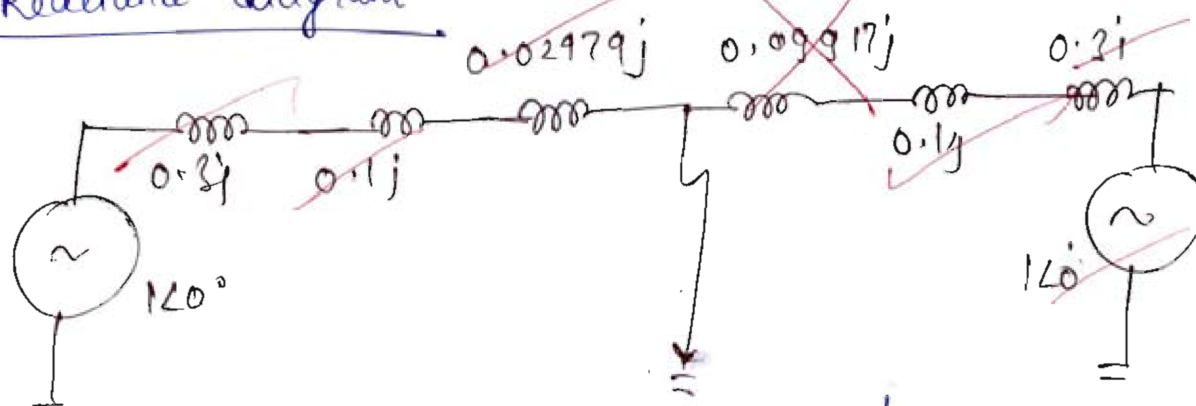
$X_{d_2}'' = \frac{0.15 \times 30}{15} = 0.3 \text{ pu}$

$X_{T_1} = X_{T_2} = 0.1 \text{ pu}$

$X_{line}(L_1) = \frac{30 \times 0.12 \times 30}{(66)^2} = 0.02479 \text{ pu}$

$X_{line}(L_2) = \frac{\cancel{120}\,90 \times 0.12 \times 30}{(66)^2} = 0.09917 \text{ pu}$

Reactance diagram



$I_f(\text{pu}) = \frac{1}{(0.3+0.1+0.02479)j} + \frac{1}{(0.3+0.1+0.09917)j}$

$I_f (pu) = -j\, 4.7936$ pu

I_{Base} on line $= \dfrac{30 \times 10^3}{\sqrt{3} \times 66} = 262.43$ A

Hence I_f (Amp) $= 262.43 \times 4.7936$

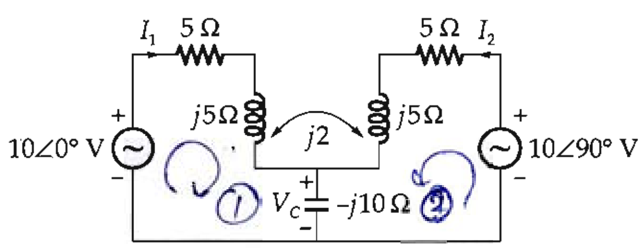
$= 1257.99375$ A

fault MVA $= I_f (pu) \times (MVA)_{Base}$ (as $V = 1$ pu)

$= 4.7936 \times 30$

$= 143.808$ MVA

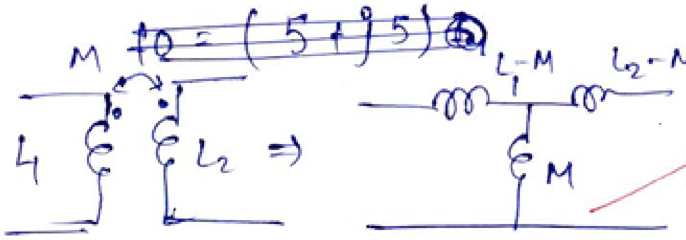
Q.8 (b) (i) Obtain the dotted equivalent circuit for the coupled circuit and hence find the voltage across the capacitor.

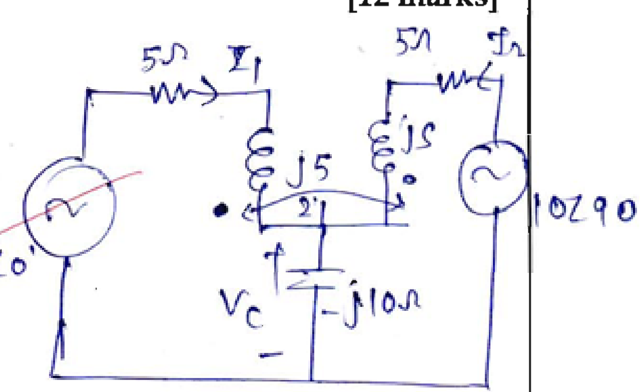


[12 marks]

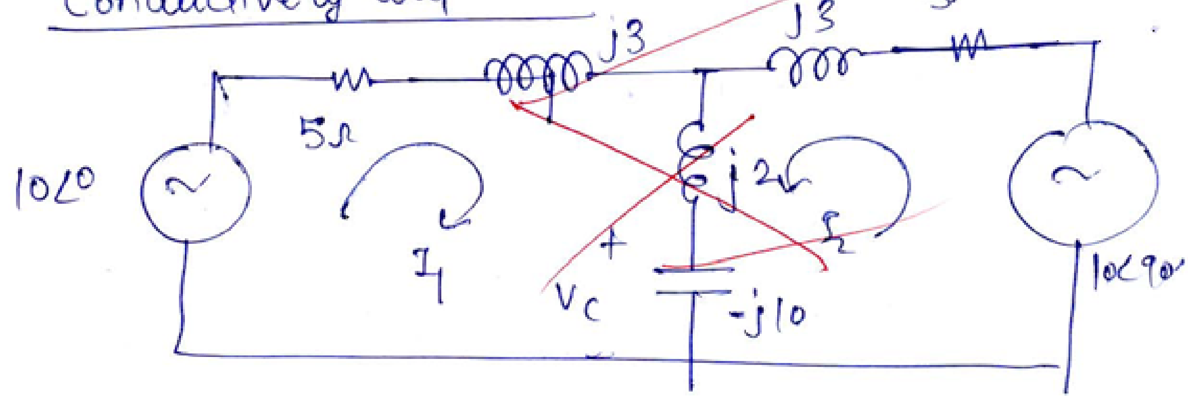
~~KVL in loop (1)~~

~~10 = (5 + j5)~~





Conductively coupled ckt



$10\angle 0^\circ = (5+j5) I_1 + (-8j)(I_1 + I_2)$

$10\angle 0^\circ = (5-3j) I_1 - 8j I_2$ —— (i)

KVL in loop (2)

$10\angle 90 = (5+j5) I_2 - 8j (I_1 + I_2)$

$10\angle 90 = (5-j3) I_2 - 8j I_1$ —— (ii)

$$I_1 = \frac{10\angle 90 - (5-j3) I_2}{-8j}$$

Putting value of I_1 in eq (1)

$$10\angle 0^\circ = \frac{(5-3j)\left[(5-3j) I_2 - 10\angle 90\right]}{8j} - 8j I_2$$

$$10\angle 0^\circ - \frac{10\angle 90 (5-3j)}{8j} = I_2 \left(\frac{(5-3j)^2}{8j} - 8j \right)$$

$5.303\angle 45 = I_2 [10.68\angle -110.556]$

$\bar{I_2} = 0.49653 \angle 155.55^\circ$ Amp

hence $I_1 = \dfrac{10\angle 90 - (5-j3) \times .49653\angle 155.53}{-8j}$

$\bar{I_1} = 0.9739 \angle 167.82^\circ$ Amp.

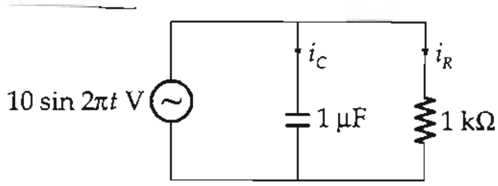
hence voltage across capacitor

$V_c = -10j (\bar{I_1} + \bar{I_2})$

$V_C = -10j\,[0.49658\angle 155.55 + 0.9739\angle 167.82]$

$V_C = 14.628\angle 78.68^\circ$ Volts

3 (b) (ii) A sinusoidal voltage source is applied to the parallel RC network as shown in figure below. Find the energy stored in the capacitor and energy dissipated by the resistor over the interval $0 < t < 0.5$ sec.



[8 marks]

Current in resistor

$i_R(t) = \dfrac{10\sin 2\pi t}{1000} = \dfrac{1}{100}\sin 2\pi t$

Energy dissipated in resistance

$E_R = \int_0^{0.5} R\, i_R^2(t)\, dt = \int_0^{0.5} \dfrac{1}{10000}\sin^2 2\pi t \times 1000\, dt$

$E_R = \int_0^{0.5} \dfrac{1}{10}\sin^2 2\pi t\, dt$

$E_R = 0.025$ Joule

Current in capacitor

$i_c = C\frac{dv}{dt} = 1\times10^{-6}\frac{d}{dt}(10\sin 2\pi t)$

$i_c = 10\times10^{-6}\times 2\pi \cos 2\pi t$

$i_c(t) = 2\pi\times10^{-5}\cos 2\pi t$

Energy stored in capacitor

$E_c = \int_0^{0.5} v(t)\, i_c(t)\, dt$

$= \int_0^{0.5} 10\sin 2\pi t \times 2\pi\times10^{-5}\cos 2\pi t\, dt$

$= 2\pi\times10^{-4}\int_0^{0.5}\sin 2\pi t\cos 2\pi t\, dt$

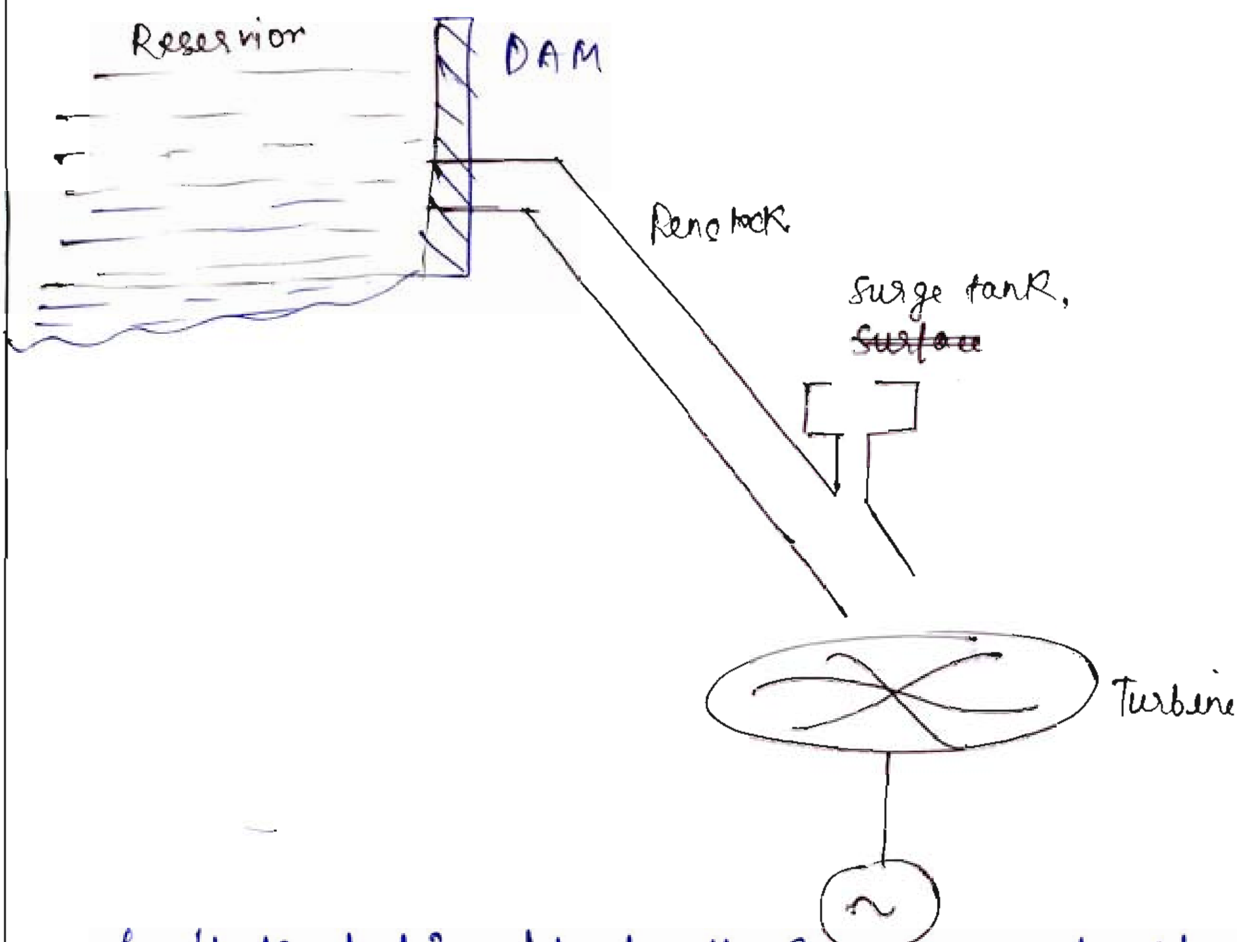
$E_c = \underline{\underline{0}}$ $\underline{\underline{\text{Joule}}}$

7

(c) (i) Draw a schematic arrangement of Hydroelectric plant and explain its working in brief.

[10 marks]

Hydroelectric plant



→ In Hydroelectric plant, there is a reservior at a location generally far from generator. This stores the water in huge amount with the help of DAM

→ Penstock is a pipe which connects reservior to the ~~gate~~ turbine gate. Penstock is made up of Hard concrete material and equipped with surge tank, which regulates water pressure inside the penstock and avoids water hammer during load decrement and supplies water during load increment

→ There are generally three types of turbines

Do not write in this margin

(1) Pelton wheel

(2) Francis

(3) Kaplan.

→ Turbine room is equipped which gate values to regulate water input

→ Water discharged to tail race, from exhaust of turbine.

→ Water forces moves the turbine and voltage is generated at the generator

→ To avoid debris there are some stoppers made up of steel Net like structure.

c) (ii) A 1000 MW control area (1) is interconnected with a 5000 MW control area (2). The 1000 MW area has the system parameters given below,

$$R = 2 \text{ Hz/p.u. MW}$$
$$B = 0.01 \text{ p.u. MW/Hz}$$

and increase in load,

$$\Delta P_{D1} = 0.05 \text{ p.u. MW}$$

Area 2 has the same parameters R and B but in terms of the 5000 MW base. Calculate the static frequency drop.

[10 marks]

Actual values of R and B

$R_1 = \frac{2 \text{ Hz}}{\text{pu MW}} = \frac{2}{1000} = 2 \times 10^{-3} \frac{\text{Hz}}{\text{MW}}$.

$B_1 = 0.01 \text{ puMW/Hz} = 0.01 \times 1000$
$= 10 \text{ MW/Hz}$

$R_2 = 2 \times \frac{1}{5000} = 4 \times 10^{-4} \text{ Hz/MW}$

$B_2 = 0.01 \times 5000 = 50 \text{ MW/Hz}$

$\beta_1 = B_1 + \frac{1}{R_1} = 10 + \frac{1}{2 \times 10^{-3}} = 510 \text{ MW/Hz}$

$\beta_2 = B_2 + \frac{1}{R_2} = 50 + \frac{1}{4 \times 10^{-4}} = 2550 \text{ MW/Hz}$

Now $a_{12} = \frac{P_1}{P_2} = \frac{S_1}{S_2} = \frac{1000}{5000} = 0.2$

$\Delta P_{D1} = 0.05 \times 1000 = 50 \text{ MW}$, $\Delta P_{D2} = 0$

$\Delta f = -\frac{\left[\Delta P_{D1} + a_{12} \Delta P_{D2}\right]}{\beta_2 + a_{12}\beta_1}$

$= -\frac{[50 + 0.2 \times 0]}{2550 + 510 \times 0.2} = 0.01885 \text{ Hz}$

Do writ this

$$\Delta f = -\frac{(P_{D_1} + P_{D_2} a_{12})}{\beta_2 + a_{12}\beta_1}$$

$$\Delta f = -\frac{\times 50}{2550 + 0.2 \times 510} = 0.01885 \text{ Hz.}$$

Space for Rough Work

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