. practice those question you left in Test.

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ESE 2023 : Mains Test Series

UPSC ENGINEERING SERVICES EXAMINATION

Electrical Engineering

Test-4 : Electrical Machines + Power Systems-1 + Systems and Signal Processing-2 + Microprocessors-2

Name : ....

Roll No :

Test Centres				Student's Signature
Delhi ☑	Bhopal ☐	Jaipur ☐		
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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	36
Q.2	46
Q.3	
Q.4	
Section-B	
Q.5	49
Q.6	31
Q.7	
Q.8	35
Total Marks Obtained	197

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.

Section A : Electrical Machines

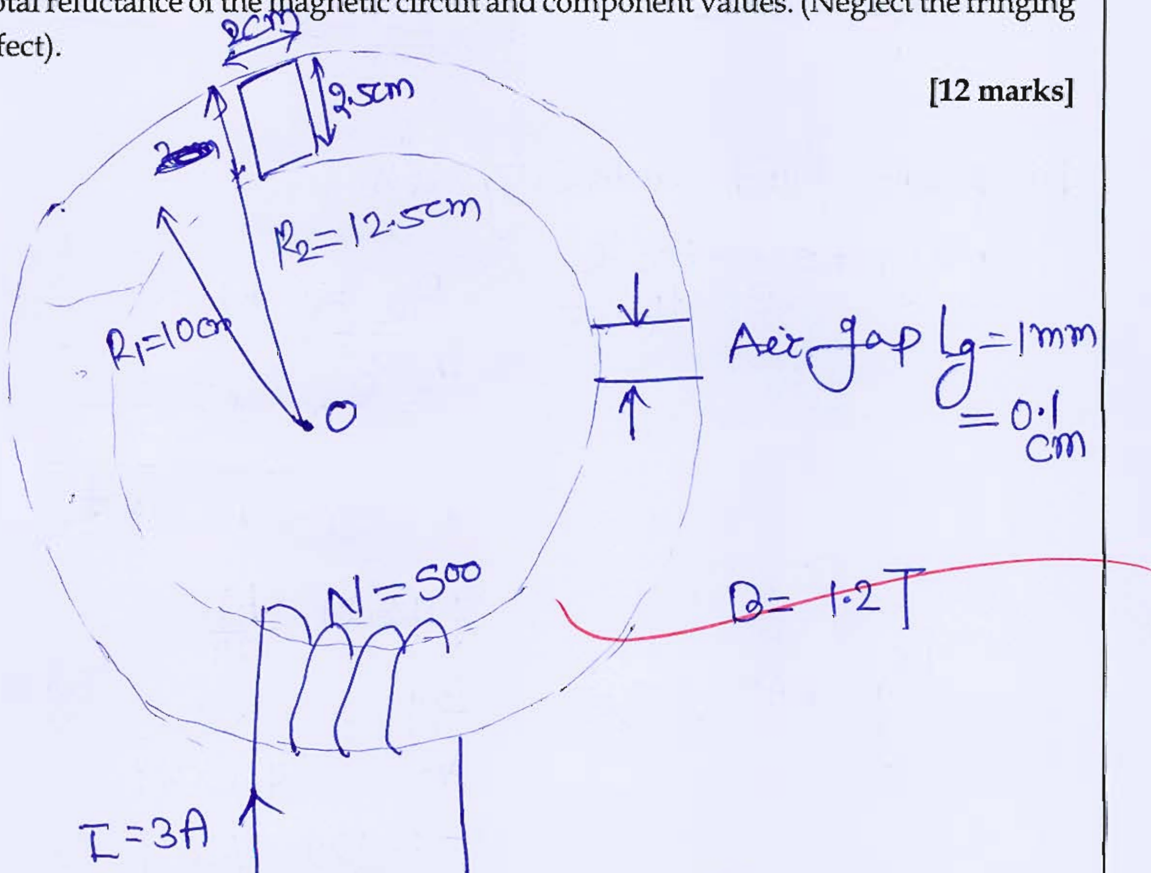
Q.1 (a) A ring of magnetic material has a rectangular cross-section. The inner diameter of ring is 20 cm and outer diameter is 25 cm, its thickness being 2 cm. An air-gap of 1 mm length is cut across the ring. The ring is wound with 500 turns and carrying a current of 3 A producing a flux density of 1.2 T in the air gap. Find :

(i) Magnetic field intensity in the magnetic material and in air-gap.

(ii) Relative permeability of the magnetic material.

(iii) Total reluctance of the magnetic circuit and component values. (Neglect the fringing effect).

[12 marks]



Mean length of Core, $L_C = 2\pi\left(\frac{R_1+R_2}{2}\right) - 0.1\ cm$

$= 70.586\ cm$

Length of Air gap $= L_g = 0.1\ cm$

Area of Cross Section, $A = 2.5cm \times 2cm = 5cm^2$

Thus,

$$\phi = \frac{NI}{\frac{L_c}{\mu_r \mu_0 A} + \frac{L_g}{\mu_0 A}}$$

$$\Rightarrow B = \frac{\phi}{A} = \frac{\mu_0 N I}{\frac{L_c}{\mu_r} + \frac{L_g}{1}}$$

Do not write in this margin

$$\Rightarrow 1.2 = \frac{4\pi \times 10^{-7} \times 500 \times 3}{\frac{70.586 \times 10^{-2}}{\mu_r} + \frac{0.1 \times 10^{-2}}{1}}$$

we found Relative permeability of Core = 1236.62

Magnetic field intensity in magnetic material,

$$H_c = \frac{B_c = (B)}{\mu_r \mu_0}$$

$$= \frac{1.2}{1236.62 \times 4\pi \times 10^{-7}}$$

$$= 772.21 \ \frac{AT}{m}$$

$$H_g \text{ (Air gap)} = \frac{B_g}{\mu_0} = \frac{1.2}{4\pi \times 10^{-7}}$$

$$= 954.929 \ \frac{KAT}{m}$$

$$\text{Total Reluctance} = \frac{MMF}{flux}$$

$$= \frac{NI}{\phi}$$

$$= \frac{NI}{BA}$$

$$= \frac{500 \times 3}{1.2 \times 5 \times 10^{-4}}$$

$$= 2.5 \times 10^{6} \left(\frac{AT}{web}\right)$$

11

Do not write in this margin

Q.1 (b) The core-loss (hysteresis + eddy-current loss) for a given specimen of magnetic material is found to be 2000 W at 50 Hz. Keeping the flux density constant, the frequency of supply is raised to 75 Hz resulting in a core loss of 3200 W. Compute separately hysteresis and eddy current losses at both the frequencies.

[12 marks]

Since $P_{eddy} \propto B^2 f^2$

and hysteresis $\propto B^{1.6} f$

For constant flux density,

$P_{core} = P_{hysterisis} + P_{eddy}$ [where A & B are constant]

$= Af + Bf^2$

At 50 Hz

$2000 = 50A + 2500B$ — (1)

At 75 Hz

$3200 = 75A + 5625B$ — (2)

We get $A = \frac{104}{3}$, $B = \frac{8}{75}$

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Good Approach

At 50 HZ

Eddy Current loss $= \frac{8}{75} \times 50^2 = 266.67$ W

Hysteris loss $= \frac{104}{3} \times 50 = 1733.33$ W

At 75 HZ

Eddy Current loss $= \frac{8}{75} \times 75^2 = 600$ W

hysteris loss $= \frac{104}{3} \times 75 = 2600$ W

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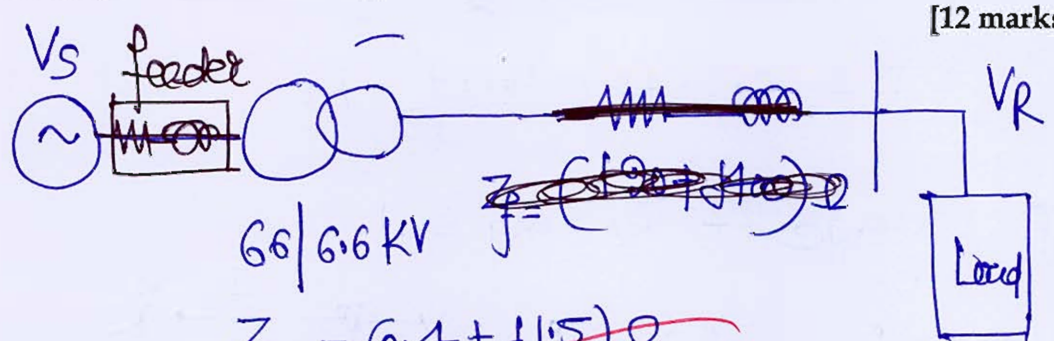
Q.1 (c) A single phase load is fed through a 66 kV feeder whose impedance is (120 + *j*400) Ω and a 66/6.6 kV transformer of equivalent impedance (referred to LV) (0.4 + *j*1.5) Ω. The load is 250 kW at 0.8 leading power factor at 6 kV. Compute :

(i) the voltage at sending end of the feeder.

(ii) the voltage at the primary terminals of the transformer.

(iii) complex power at the sending end of the feeder.

[12 marks]



$Z_{LV} = (0.4 + j1.5)\,\Omega$

Analyzing the above circuit on a Base of 66 KV and 500 KVA on high voltage side of transformer.

$Z_{Base\,66kV} = \frac{66\,kV^2}{0.5\,MVA}\,\Omega = 8712\,\Omega$

$Z_{Base\,LV} = \frac{(6.6\times10^3)^2}{500\times10^3} = 87.12\,\Omega$

Pu impedance of Trans $= \frac{(0.4 + j1.5)\,\Omega}{87.12}$

$Z_T = 0.0178\angle 75.07^\circ$ pu

for feeder, pu impedance on 66 kV $= \frac{120 + j400}{8712}$

$Z_F = 0.0479\angle 73.3^\circ$ pu

For Load

$P_{Load} = \frac{250\,kW}{500\,kVA} = 0.5$ pu

$V_R = \frac{6\,kV}{6.6\,kV} = 0.909\angle 0^\circ$ pu

$P_{Road} = V_R I \cos\phi$

$\Rightarrow 0.5 = 0.909 \times I \times 0.8$

$I = 0.6875$ pu

At 0.8 pf leading

$I = 0.6875 \angle 36.87^\circ$ pu

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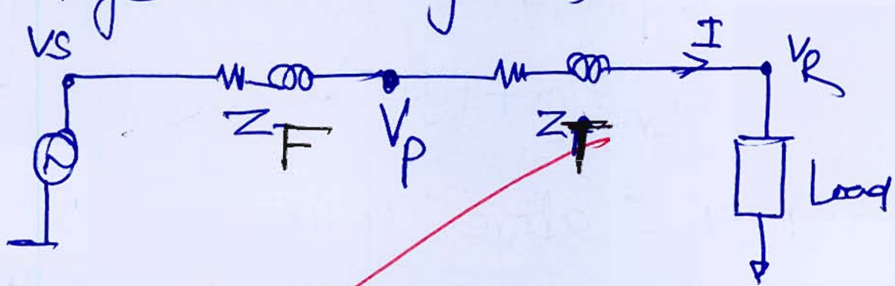
Good Approach

(i) Voltage at sending end,



$V_S = V_R + I(Z_T + Z_F)$

$= 0.909\angle 0^\circ + (0.6875\angle 36.87^\circ)(0.0178\angle 75.07^\circ + 0.0479\angle 73.3^\circ)$

$=$ ~~3.11 ∠ 94.26°~~ pu

$= 0.8941 \angle 2.71^\circ$ pu

$V_{sending\ end} = 0.8941 \times 66$ KV $= 59$ KV

(ii) Voltage at primary terminals

$V_P = V_R + I Z_T$

$= 0.909\angle 0^\circ + (0.6875\angle 36.87^\circ)(0.0178\angle 75.07^\circ)$

$= 0.9045 \angle 0.719^\circ$

$= 0.9045 \times 66$ KV $= 59.696$ KV

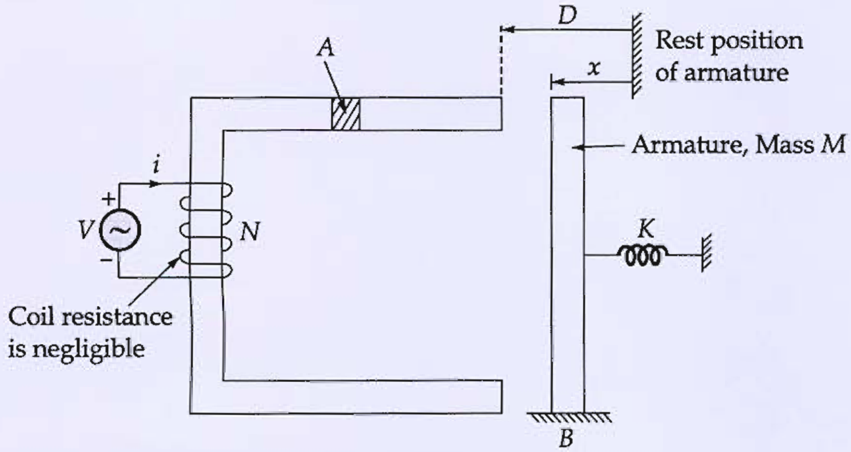
(iii) Complex Power at sending end

$= V_S I^*$

$= (0.8941\angle 2.71)\times(0.6875\angle 36.87^\circ)\times 500$ KVA

$= 254.32$ KW $- j\,172.577$ KVA

Q.1 (d) For electromechanical system shown in figure, the air-gap flux density under steady operating condition is $B(t) = B_m \sin \omega t$.



Find :

(i) coil voltage

(ii) the force of field origin as a function of time.

(iii) the motion of armature as a function of time.

[12 marks]

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Q.1 (e) The following data pertain to a 250 V DC series motor :

$$Z = 180, \frac{P}{A} = 1$$

$$\text{Flux/pole} = 3.75 \text{ mWb/field amp}$$

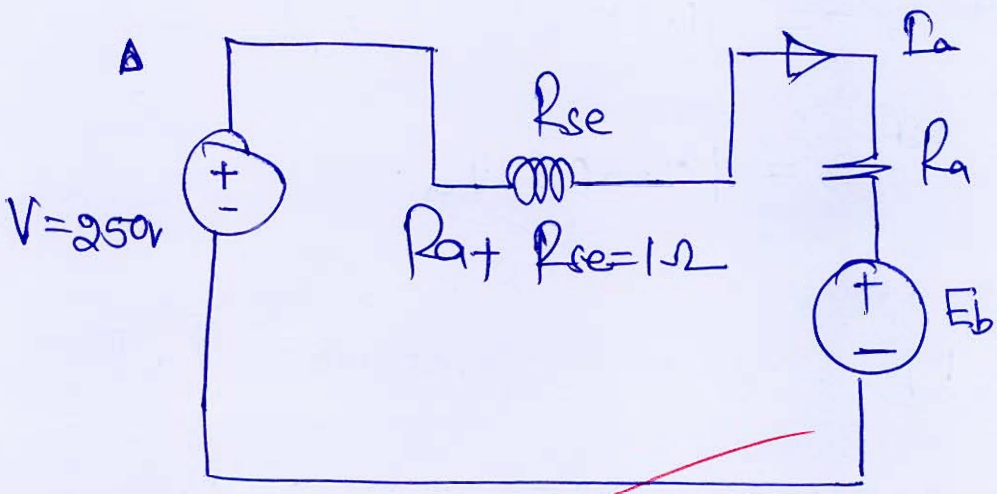
Total armature circuit resistance = 1 Ω

The motor is coupled to a centrifugal pump whose load torque is

$$T_L = 10^{-4}n^2 \text{ Nm where } n = \text{Speed in rpm}$$

Calculate the current drawn by the motor and the speed at which it will run for given load.

[12 marks]



$$E_b = \frac{ZP}{2\pi A}\phi\omega_m = \frac{ZP}{60A}\phi n \quad \text{—(1)}$$

$$T = \frac{ZP}{60A}\phi I_a \quad \text{—(2)}$$

ϕ = flux per field amp × field amp

$$= 3.75 \frac{m\,Wb}{\text{field amp}} \times I_a \quad [I_f = I_a]$$

$$\phi = 3.75 I_a \text{ mweb} \quad \text{—(3)}$$

$$= 3.75 \times 10^{-3} I_a \text{ (web)}$$

$$\frac{ZP}{60A} = \frac{180 \times 1}{60} = 3$$

Thus $E_b = 11.25\, I_a n \times 10^{-3}$ [using (1) and (3)]

$$T = 11.25\, I_a^2 \times 10^{-3} \text{ [in Nm]}$$

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From circuit,

$E_b = V - (R_a + R_{se}) I_a$

$E_b = 250 - I_a$ —— (4)

given $T_L = 10^{-4} n^2$ (Nm)

$T = T_L$

$10^{-4} n^2 = 11.25 \times 10^{-3} I_a^2$

we get $n = 10.606 I_a$

As

$E_b = 250 - I_a = 11.25 \times 10^{-3} I_a n$

$\Rightarrow 250 - I_a = 11.25 \times 10^{-3} \times 10.606 I_a^2$

$[n = 10.606]$

Solving for I_a,

$I_a = 41.77$ A

Thus $n = 10.606 I_a$

$= 443.01$ rpm

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Q.2 (a) A 3-ϕ, 12 kV, 15 MVA, 60 Hz, salient pole synchronous motor is run from a 12 kV, 60 Hz, balanced 3-ϕ supply. The machine reactances are X_d = 1.2 pu, X_q = 0.6 pu (with the machine rating as base). Neglect rotational losses and armature resistance losses. The machine excitation and load are varied to obtain the following conditions :

(i) Maximum power input is obtained with no field excitation. Determine the value of this power, armature current and the power factor of this condition.

(ii) Rated power output is obtained with minimum excitation. Determine this minimum value of excitation emf.

[20 marks]

(i) For Synchronous motor

$$V = E_f + j I_d X_d + j I_q X_q + I_a r_a$$

Without field excitation,

$$E_f = 0$$

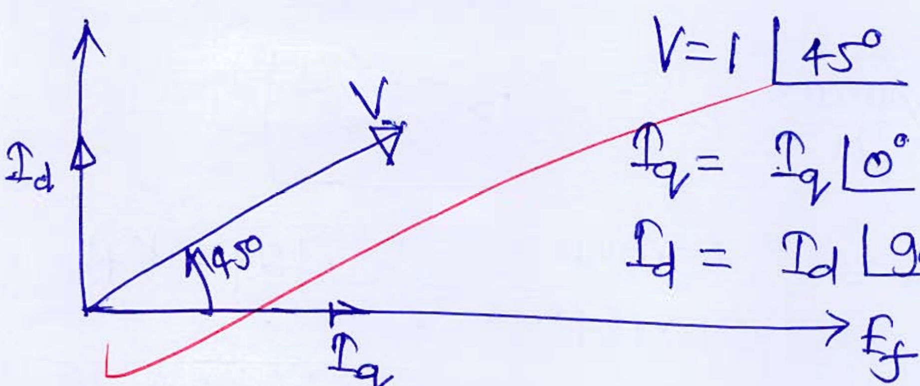
and $r_a = 0$,

Thus $V = j I_d X_d + j I_q X_q$

For maximum power input,

As $P = \frac{V E_f}{X_d}\sin\delta + \frac{V^2}{2}\left(\frac{1}{X_q} - \frac{1}{X_d}\right)\sin 2\delta$

$$\delta = 45^\circ$$



$V = 1\angle 45^\circ$ pu

$I_q = I_q \angle 0^\circ$

$I_d = I_d \angle 90^\circ$

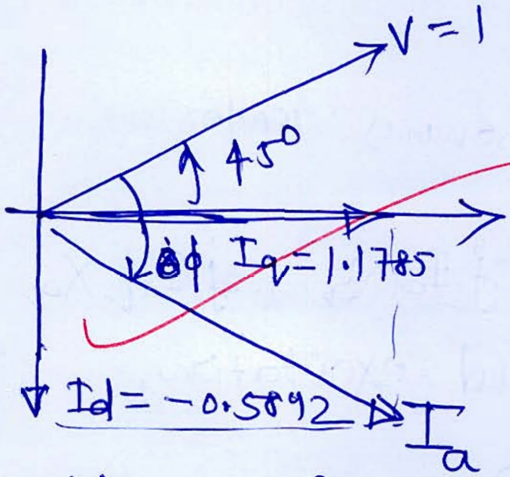
$$1\angle 45^\circ = j(I_d\angle 90^\circ)(1.2) + j(I_q\angle 0^\circ)(0.6)$$

$$\frac{1}{\sqrt{2}} + j\frac{1}{\sqrt{2}} = -1.2\, I_d + j\, 0.6\, I_q$$

Seperating Real and Imaginary Part we get

$I_d = -0.5892$ pu

$I_q = 1.1785$ pu



Lagging pf angle $= 45^\circ + \tan^{-1}\left(\frac{0.5892}{1.1785}\right)$

$= 71.56^\circ$

$pf = \cos(71.56^\circ) = 0.3162$ lag

Maximum Power $= \frac{V^2}{2}\left(\frac{1}{X_q} - \frac{1}{X_d}\right)$

$= \frac{1^2}{2}\left(\frac{1}{0.6} - \frac{1}{1.2}\right)$

$= 0.4167$ pu × 15 MVA

Maximum Power = 6.25 MVA

I_a base $= \frac{15 MVA}{\sqrt{3} \times 12 KV} = 0.7217$ KA

$I_a = \sqrt{I_d^2 + I_q^2} = \sqrt{0.5892^2 + 1.1785^2}$

$= 1.3175$ pu × 0.7217 KA

$I_a = 950.9$ A

(ii) For $P = 1$ pu

$$P = \frac{VE_f}{X_d}\sin\delta + \frac{V^2}{2}\left(\frac{1}{X_q} - \frac{1}{X_d}\right)\sin 2\delta$$

$$\Rightarrow 1 = \frac{1 \times E_f}{1.2}\sin\delta + \frac{1^2}{2}\left(\frac{1}{0.6} - \frac{1}{1.2}\right)\sin 2\delta$$

$$\Rightarrow 1 = \frac{E_f \sin\delta}{1.2} + \frac{5}{12}\sin 2\delta$$

$$\Rightarrow 12 = 10E_f \sin\delta + 5\sin 2\delta$$

$$E_f = \frac{12 - 5\sin 2\delta}{10\sin\delta}$$

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For minimum E_f

$$\frac{dE_f}{d\delta} = 0$$

$$\Rightarrow \frac{d}{d\delta}(12 - 5\sin 2\delta)\, 10\sin\delta - (12 - 5\sin 2\delta)\frac{d}{d\delta}(10\sin\delta) = 0$$

$$\Rightarrow -100\cos 2\delta \sin\delta - 120\cos\delta + 50\sin 2\delta\cos\delta = 0$$

δ $\delta = 58.688^\circ$

So

$$E_{f\,min} = \frac{12 - 5 \times \sin(2 \times 58.688)}{10 \times \sin(58.688)}$$

$= 0.88$ pu $= 10.56$ KV

Q.2 (b) A 3-ϕ, 250 kW, 460 V, 60 Hz, 8-pole induction machine is driven by a wind turbine. The induction machine has the following parameters :

$$R_1 = 0.015\ \Omega,\ R_2' = 0.035\ \Omega$$
$$L_1 = 0.385\text{ mH},\ L_2' = 0.358\text{ mH},\ L_m = 17.24\text{ mH}$$

The induction machine is connected to 460 V infinite bus through a feeder having a resistance of 0.01 Ω and inductance of 0.08 mH. The wind turbine drives the machine at a slip of –2.5%. Determine :

(i) the speed of turbine.

(ii) the voltage at the terminals of induction machine.

(iii) the power delivered to infinite bus and the power factor.

(iv) the efficiency of the system. Assume the rotational and core losses to be 3 kW.

[20 marks]

(i) Synchronous Speed,

$N_s = \frac{120f}{P} = \frac{120 \times 60}{8}$

$= 900$ rpm

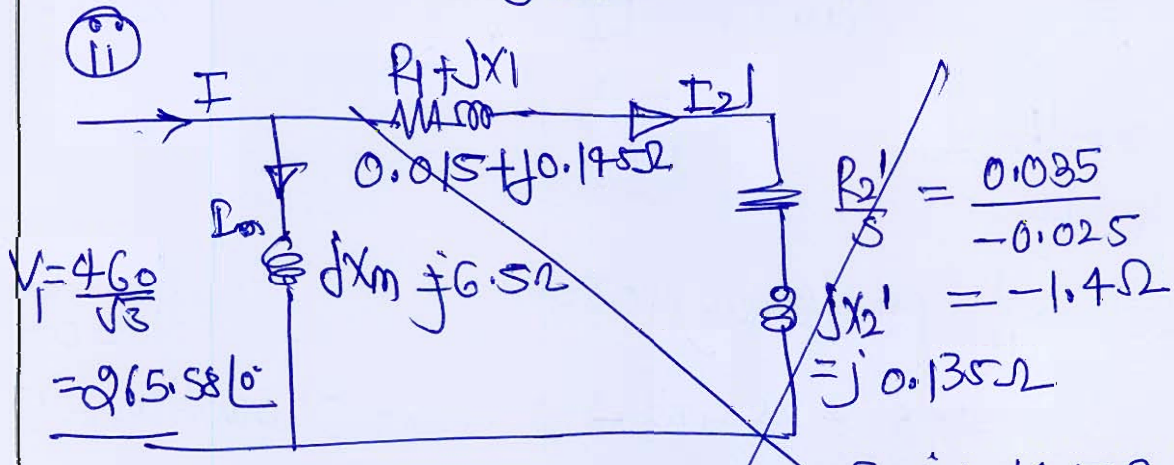
Speed of Turbine,

$N = (1-s)(N_s)$

$= (1 - -0.025)(900)$

$= 922.5$ rpm

(ii)



$\therefore X_1 = j(120\pi) \times 0.385 \times 10^{-3} = j0.145\ \Omega$

$\therefore X_2' = j(120\pi) \times 0.358 \times 10^{-3} = j0.135\ \Omega$

$jX_m = j(120\pi) \times 17.24 \times 10^{-3} = j6.5\ \Omega$

Try to avoid

$$I_2' = \frac{265.58\angle 0^\circ}{0.015 + j0.145 + j0.135 - 1.4} = 187.95\angle -168.57^\circ \text{ A}$$

$$I_m = \frac{265.58\angle 0^\circ}{j6.5} = 40.86\angle -90^\circ \text{ A}$$

$$I = I_2' + I_m$$
$$= 200\angle -157^\circ \text{ A}$$

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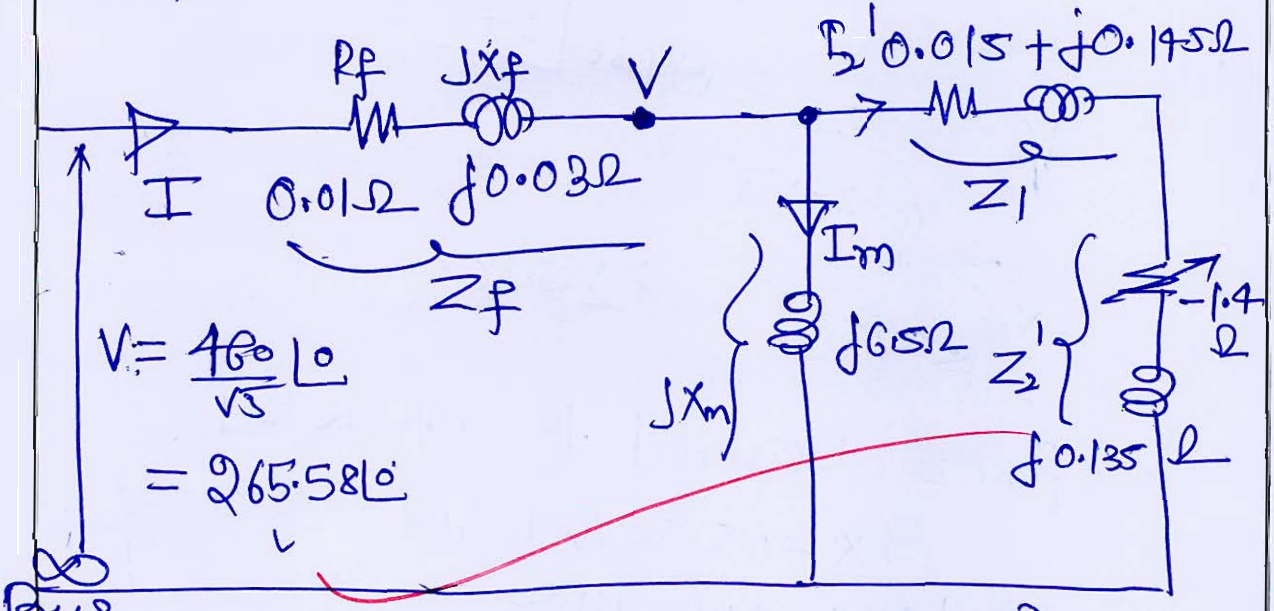
Equivalent Circuit :-



$$V = \frac{400}{\sqrt{3}}\angle 0 = 265.58\angle 0^\circ$$

$$Z_{eq} = Z_f + jX_m \parallel (Z_1 + Z_2')$$
$$= (0.01 + j0.03) + j6.5 \parallel \underbrace{(1.413\angle 168.57^\circ)}_{Z_1 + Z_2'}$$
$$= (0.01 + j0.03) + 1.327\angle 157^\circ$$
$$= 1.33\angle 155.67^\circ \ \Omega$$

$$I = \frac{V}{Z_{eq}} = 199.66\angle -155.67^\circ \text{ A}$$

$$I_m = I \times \left(\frac{Z_1 + Z_2'}{Z_1 + Z_2' + jX_m} \right) = 40.77 \angle -88.69^\circ \ A$$

$$I_2' = I - I_m = 187.54 \angle -167.21^\circ$$

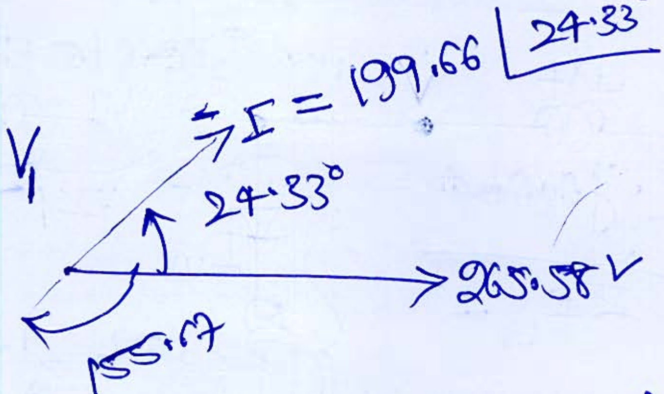
(ii) voltage at terminal of Xm

$$= jX_m I_m = (j6.5)(40.77 \angle -88.69^\circ)$$

$$= 265.005 \angle 1.36^\circ \text{ (phase)}$$

$$= 459 \ V$$

(iii)



∴ Power delivered to infinite Bus

$$= 3 \times 265.58 \times 199.66 \times \cos 24.33$$

$$= 144.949 \ KW$$

18

Good Approach

(iv) $P_{air\ gap} = 3 \times I_2'^2 \times R_2' = 3 \times 187.54^2 \times -1.4$

$$= -147.719 \ KW$$

$P_{gross} = (1-s)(P_{air gap}) = -151.412 \ KW$

$P_{net mech} = P_{gross} - P_{rot} = -154.412 \ KW$

$$\eta = \frac{P_{out}}{P_{in}} = \frac{144.949}{154.412} = 93.87\%$$

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Q.2 (c) A 10 kW, 100 V, 1000 rpm dc machine has armature resistance, $R_a = 0.1\ \Omega$ and is connected to 100 V dc supply.

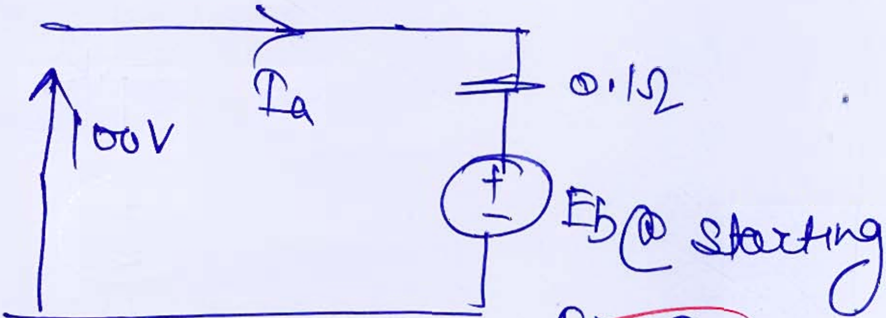
(i) Determine the starting current if no starting resistance is used in the circuit.

(ii) Determine the starting resistance if the starting current is limited to twice the rated current.

(iii) This dc machine is to be run as a motor, using a starter box. Determine the values of resistance required in (3-section) starter box such that the armature current I_a is constrained within 100 to 200% of its rated value (i.e., 1 to 2 pu) during start-up.

[2 + 2 + 16 marks]

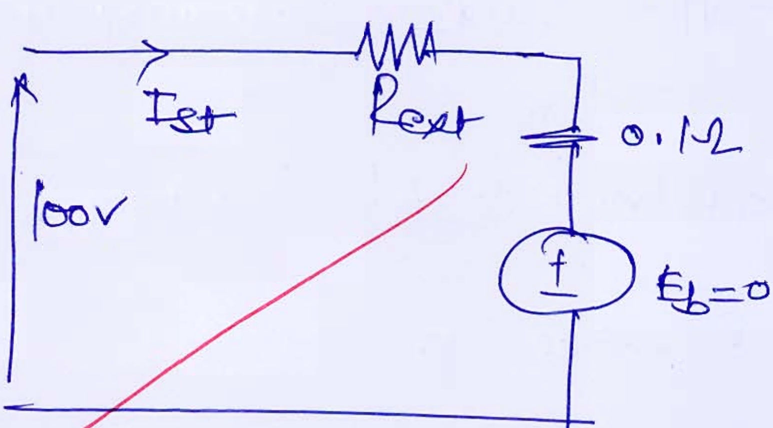
(i)



$E_b = 0$

Starting Current $= \frac{100}{0.1} = 1000\,A$

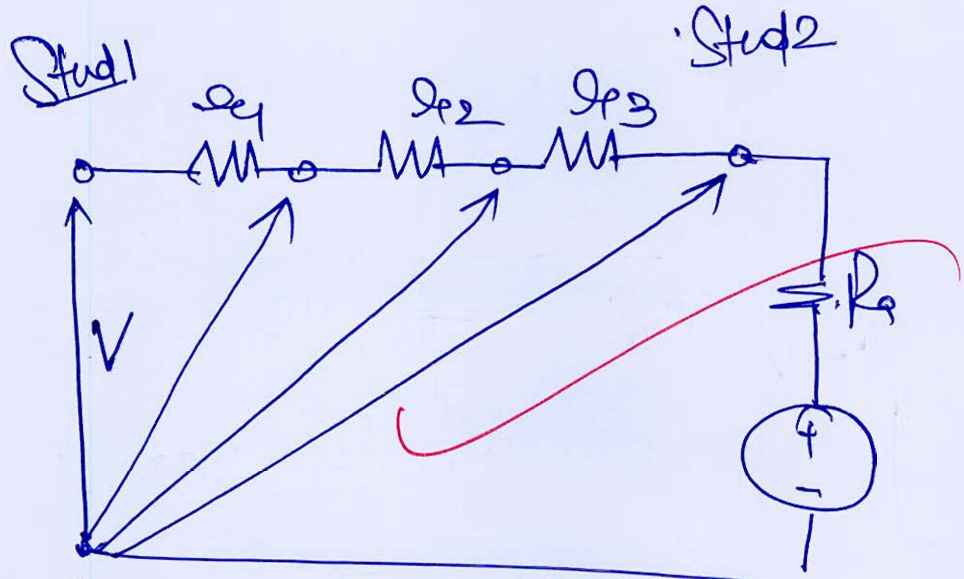
(ii) Rated Current $= \frac{10\,kW}{100\,V} = 100\,A$



$I_{st} = 2 \times 100\,A = \frac{100}{0.1 + R_{ext}}$

$R_{ext} = 0.4\ \Omega$

(11) For 3- Section Starter



we have at stud1,

$V = (r_1 + r_2 + r_3 + R_a) I_{max}$

When stud1 — stud2, (assuming current = I_{min})

So $V = (r_1 + r_2 + r_3 + R_a) I_{min} + E_{b@stud1-2}$

Instant E_b does not change.

So

$V = (r_2 + r_3 + R_a) I_{max} + E_{b@stud1-2}$

Thus $\frac{r_1 + r_2 + r_3 + R_a}{r_2 + r_3 + R_a} = \frac{I_{max}}{I_{min}} = 2$

or if $R_1 = r_1 + r_2 + r_3 + R_a$

$R_2 = r_2 + r_3 + R_a$

$R_3 = r_3 + R_a$

$R_4 = R_a$

we get

$$\frac{R_1}{R_2} = \frac{R_2}{R_3} = \frac{R_3}{R_4} = 2$$

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$$\Rightarrow \frac{R_1}{R_4} = 2^3$$

$R_1 = 2^3 \times R_a = 0.8\,\Omega$ $\quad R_a = 0.1\,\Omega$

$R_2 = \frac{R_1}{2} = 0.4\,\Omega$

$R_3 = \frac{R_2}{2} = 0.2\,\Omega$

$R_4 = R_a = \frac{R_3}{2} = 0.1\,\Omega$ [verified]

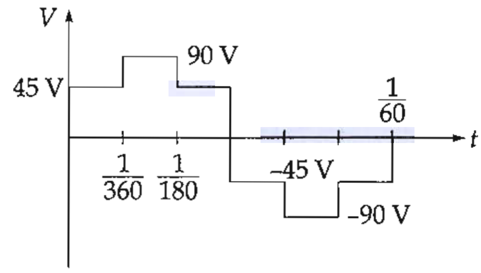
now

Section 1, $r_1 = R_2 - R_1 = 0.4\,\Omega$

Section 2, $r_2 = R_2 - R_3 = 0.2\,\Omega$

Section 3, $r_3 = R_3 - R_4 = 0.1\,\Omega$

Q.3 (a) (i) A six-step voltage of frequency 60 Hz, as shown in figure, is applied on a coil wound on a magnetic core. The coil has 500 turns. Find the maximum value of flux and sketch the waveforms of voltage and flux as a function of time.



(ii) Find the number of series turns required for each phase of a 3-ϕ, 50 Hz, 10-pole alternator with 90 slots. Winding is to be connected to give a line voltage of 11 kV. The flux/pole is 0.16 Wb.

[15 + 5 marks]

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Q.3 (b) Tests are performed on a 1-ϕ, 10 kVA, 2200/220 V, 50 Hz transformer and the following results are obtained :

	Open Circuit Test (HV side open)	Short Circuit Test (LV side shorted)
Voltmeter	220 V	150 V
Ammeter	2.5 A	4.55 A
Wattmeter	100 W	215 W

(i) Derive the parameters for approximate equivalent circuit referred to LV side and the HV side.

(ii) Determine the power factor for no-load and short-circuit tests.

(iii) Determine voltage regulation at 75% full load, 0.6 power factor lagging.

[10 + 2 + 8 marks]

Q.3 (c) A test on $\frac{1}{4}$ hp, 120 V, 60 Hz, 1725 rpm single phase induction motor reveals the following results :

Stator resistance : 2 Ω

Rotor resistance referred to stator : 4 Ω

Stator leakage reactance : 3 Ω

Stator leakage reactance referred to stator : 3 Ω

Resistance corresponding to the windage, friction and iron losses : 600 Ω

Magnetizing reactance : 60 Ω

Draw the equivalent circuit diagram of motor and determine the forward and backward branch rotor power, power output, efficiency and power factor of motor when it runs at 1725 rpm.

[20 marks]

Q.4 (a) (i) A 230 V, 250 rpm, 100 A separately excited dc motor has armature resistance of 0.5 Ω. The motor is connected to 230 V dc supply and rated dc voltage applied to field winding. It is driving a load whose torque speed characteristics is given by $T_L = 500 - 10\omega$, where ω is the rotational speed in rad/sec and load torque in N-m. Find the steady state speed at which motor will drive the load and armature current drawn by it from source. Neglect the rotational losses of the machine.

(ii) A 200 V dc shunt motor takes 22 A at rated voltage and runs at 1000 rpm. Its field resistance is 100 Ω and armature circuit resistance (including brushes) is 0.1 Ω. Compute the value of additional resistance required in armature circuit to reduce its speed to 800 rpm, when

(a) load torque is independent of speed.

(b) load torque is proportional to speed.

[10 + 5 + 5 marks]

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Q.4 (b) A 3-ϕ, 25 kW, 400 V, 50 Hz, 8-pole induction motor has rotor resistance of 0.08 Ω and standstill reactance of 0.4 Ω. The effective stator/rotor turns ratio is 2.5/1. The motor is to drive a constant-torque load of 25 Nm. Neglect stator impedance.

(i) Calculate the minimum resistance to be added in rotor circuit for motor to start-up on load.

(ii) At what speed would the motor run, if the added resistance is (a) left in the circuit, and (b) subsequently short circuited?

[20 marks]

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Q.4 (c) (i) The following data are taken from the open circuit and short circuit characteristics of a 45 kVA, 3-ϕ, Y-connected, 220 V(L-L), 6 pole, synchronous machine. From the open circuit characteristics :

Line-to-line voltage (V_L) = 220 V

Field current (I_f) = 2.84 A

From the short circuit characteristics :

Armature current (A)	118	152
Field current (A)	2.20	2.84

From the air gap line :

Field current (I_f) = 2.20 A; Line to line voltage (V_L) = 202 V

Compute the unsaturated value of synchronous reactance, its saturated value at rated voltage and short circuit ratio.

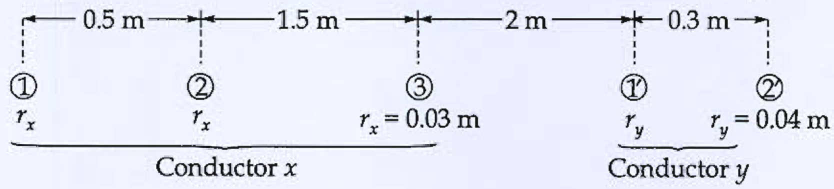
Express the synchronous reactance in ohm per phase and in per unit on machine rating as base.

(ii) A 325 MVA, 26 kV, 60 Hz, 3-ϕ, salient synchronous generator is observed to be operating at power output of 250 MW and a lagging power factor of 0.89 at a terminal voltage of 26 kV. The generator synchronous reactances are $X_d = 1.95$ and $X_q = 1.18$, both in per unit. Calculate generated emf and load angle between the generator terminal voltage and generated emf.

[12 + 8 marks]

Section B : Power Systems-1 + Systems and Signal Processing-2 + Microprocessors-2

Q.5 (a) Evaluate the inductance of phase 'X' and 'Y' for the single phase two conductor line shown in figure and therefore calculate the total inductance of given line.



[12 marks]

Mutual GMD of x and y

$$GMD_{xy} = \sqrt[6]{D_{11'} D_{12'} D_{21'} D_{22'} D_{31'} D_{32'}}$$

$$= \sqrt[6]{4m \times 4.3m \times 3.5m \times 3.8m \times 2m \times 2.3m}$$

$$= 3.1892\ m$$

Self GMD of Conductor x

$$GMD_x = \sqrt[9]{(r')^3 \times D_{12} \times D_{13} \times D_{21} \times D_{23} \times D_{31} \times D_{32}}$$

$$= \sqrt[9]{(0.7788 \times 0.03)^3 \times 0.5 \times 2 \times 0.5 \times 1.5 \times 2 \times 1.5}$$

$$= 0.3128\ m$$

Do not write in this margin

Self GMD of Conductor y

$$GMD_y = \sqrt[4]{(0.7788 \times 0.04)^2 \times 0.3 \times 0.3}$$

$$= 0.09667 \ m$$

$$L_{phase\,x} = 0.2 \ln\left(\frac{GMD_{xy}}{GMD_x}\right) \frac{mH}{km}$$

$$= 0.2 \ln\left(\frac{3.1892}{0.3128}\right) \frac{mH}{km}$$

$$= 0.4644 \frac{mH}{km}$$

$$L_{phase\,y} = 0.2 \ln\left(\frac{GMD_{xy}}{GMD_y}\right) \frac{mH}{km}$$

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Good Approach

$$= 0.2 \ln\left(\frac{3.1892}{0.09667}\right) \frac{mH}{km}$$

$$= 0.6992 \frac{mH}{km}$$

Total Inductance $= L_{phase\,x} + L_{phase\,y}$

$$= 0.4644 + 0.6992$$

$$= 1.1636 \frac{mH}{km}$$

Q.5 (b) A 3-ϕ, 400 kV, 50 Hz transmission line has a series inductive reactance of 0.30 Ω/km and shunt susceptance of 3.75×10^{-6} S/km. If the line is 400 km long, then determine its

(i) Surge impedance

(ii) Propagation constant

(iii) ABCD constant

(iv) Wavelength

(v) SIL

[12 marks]

(i) given,

$z = j\,0.30\ \frac{\Omega}{km}$

$y = j\,3.75 \times 10^{-6}\ \frac{S}{km}$

Surgece Impedance = Charact. Imp. as line is Lossless

$= \sqrt{\frac{z}{y}}$

$= \sqrt{\frac{j0.30}{j3.75 \times 10^{-6}}} =$

$= 282.842\ \Omega$

(ii) Propagation Constant

$\gamma = \sqrt{yz}$

$= j\,1.06 \times 10^{-3}$ /km

Q.7 (b) **(i)** A star connected 3-ϕ, 12 MVA, 11 kV alternator has a reactance of 10%. It is protected by Merz-price circulating current scheme which is set to operate for fault current not less than 200 A. Calculate the value of earthing resistance to be provided in order to ensure that only 15% of alternator winding remain unprotected.

(ii) For a 132 kV, 50 Hz system reactance and capacitance upto the location of circuit breaker is 3 Ω and 0.015 μF respectively. Calculate, frequency of transient oscillation, maximum value of restriking voltage across the contacts of circuit breaker and maximum value of RRRV.

[10 + 10 marks]

Q.7 (c) Write a program for 8085 microprocessor to provide signal for ON/OFF time to three traffic lights (Green, Red, Yellow) and two pedestrian signs (walk and don't walk). The traffic lights and signs are turned ON/OFF by the data bits of output port as given below :

S.No.	Signal	Data Bits	On Time
1.	Green	D_0	15 sec
2.	Yellow	D_2	5 sec
3.	Red	D_4	20 sec
4.	Walk	D_6	15 sec
5.	Don't Walk	D_7	25 sec

Use one second delay subroutine program for interval. Assume traffic and pedestrian flow are in same direction, the pedestrian should cross the road when green light is ON. Also draw neat flow chart for execution of program by traffic signal controller.

[20 marks]

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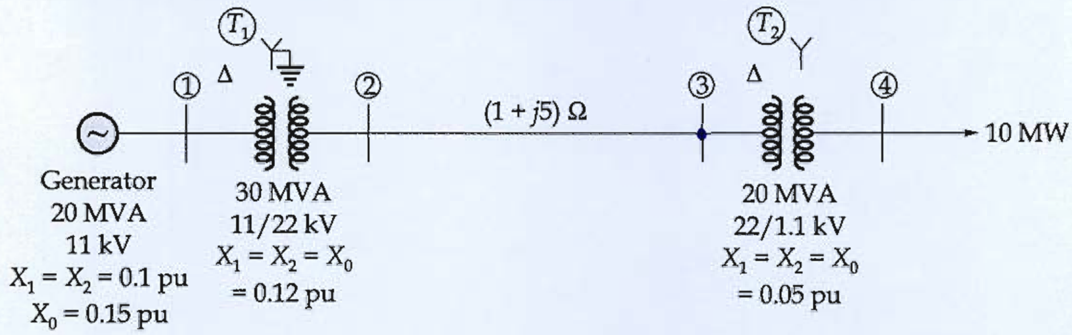
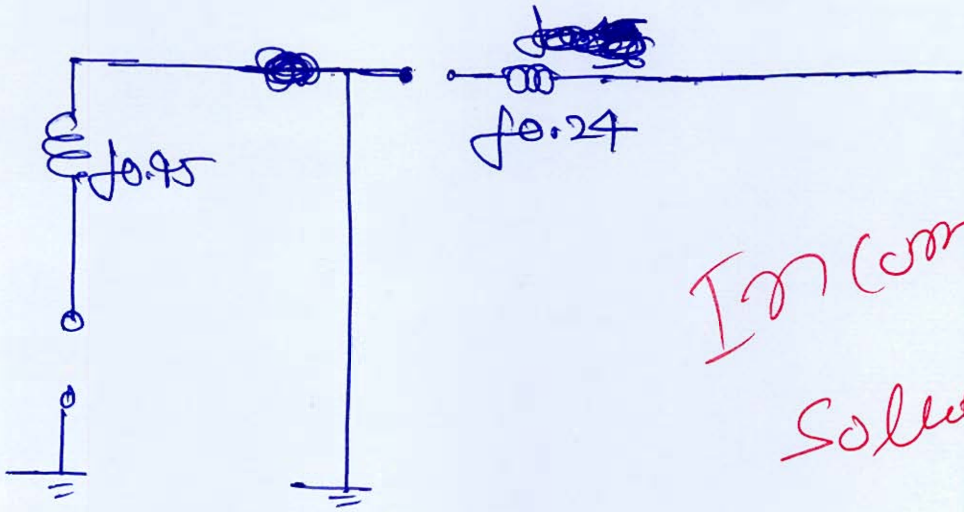
Q.8 (a) The power system shown in figure is supplying 10 MW UPF load at 1.10 kV. An SLG fault occurs at bus-3. Determine the fault current. Assuming that fault resistance is 6.6 Ω. The equipment parameters are shown in figure :



[20 marks]

Assuming a Base of 60 MVA
11 kV on Generator Side.

On new Base,
Zero Sequence Circuit,



Incomplete Solution

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Q.8 (b) A second-order transfer function is given as

$$H(z) = \frac{(1-0.25z^{-2})}{1+0.9z^{-1}+0.18z^{-2}}$$

Perform the filter realizations to obtain

(i) Direct form I and direct form II.

(ii) Cascade form via first order section.

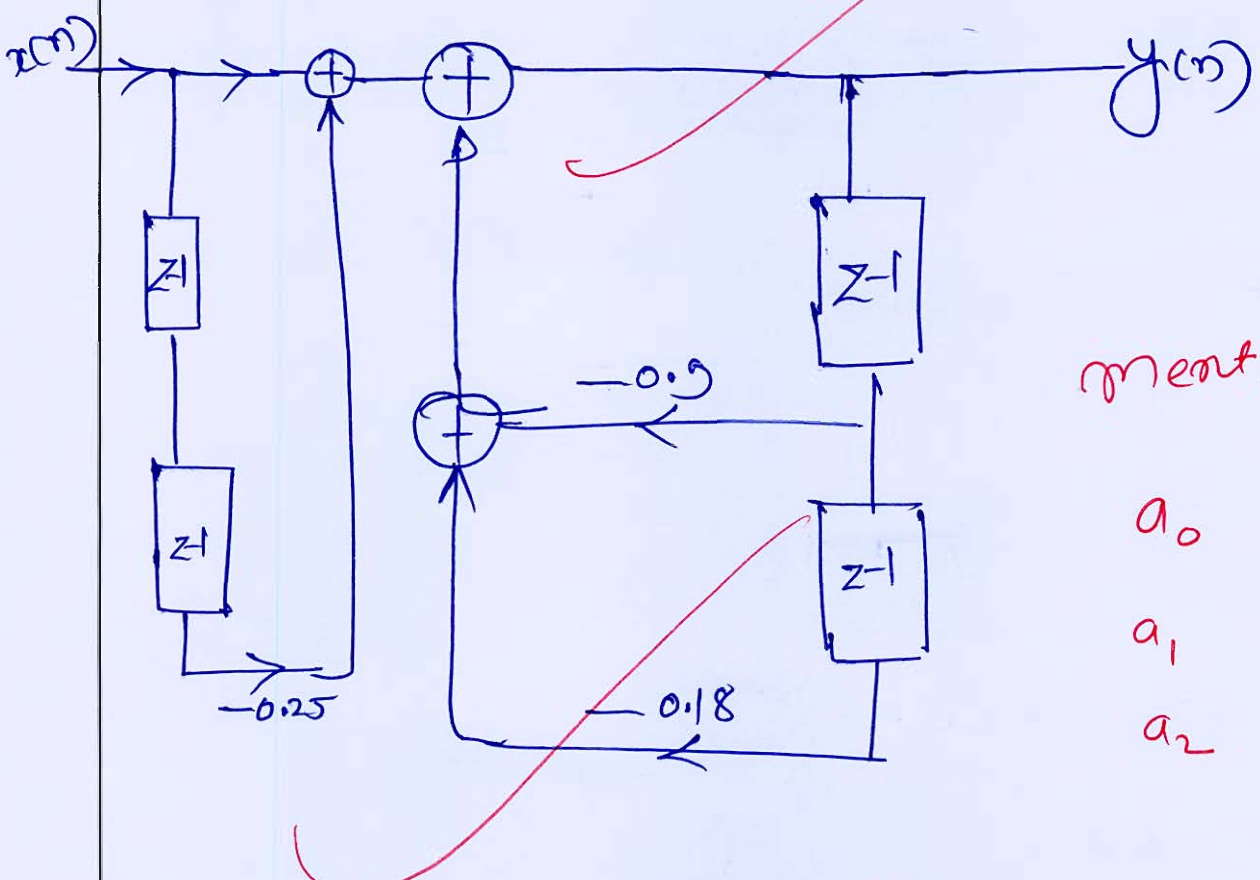
(iii) Parallel form via first order section.

[20 marks]

(i)

$$H(z) = \frac{1-0.25z^{-2}}{1-(-0.9z^{-1}-0.18z^{-2})}$$

Direct form I :-



mention

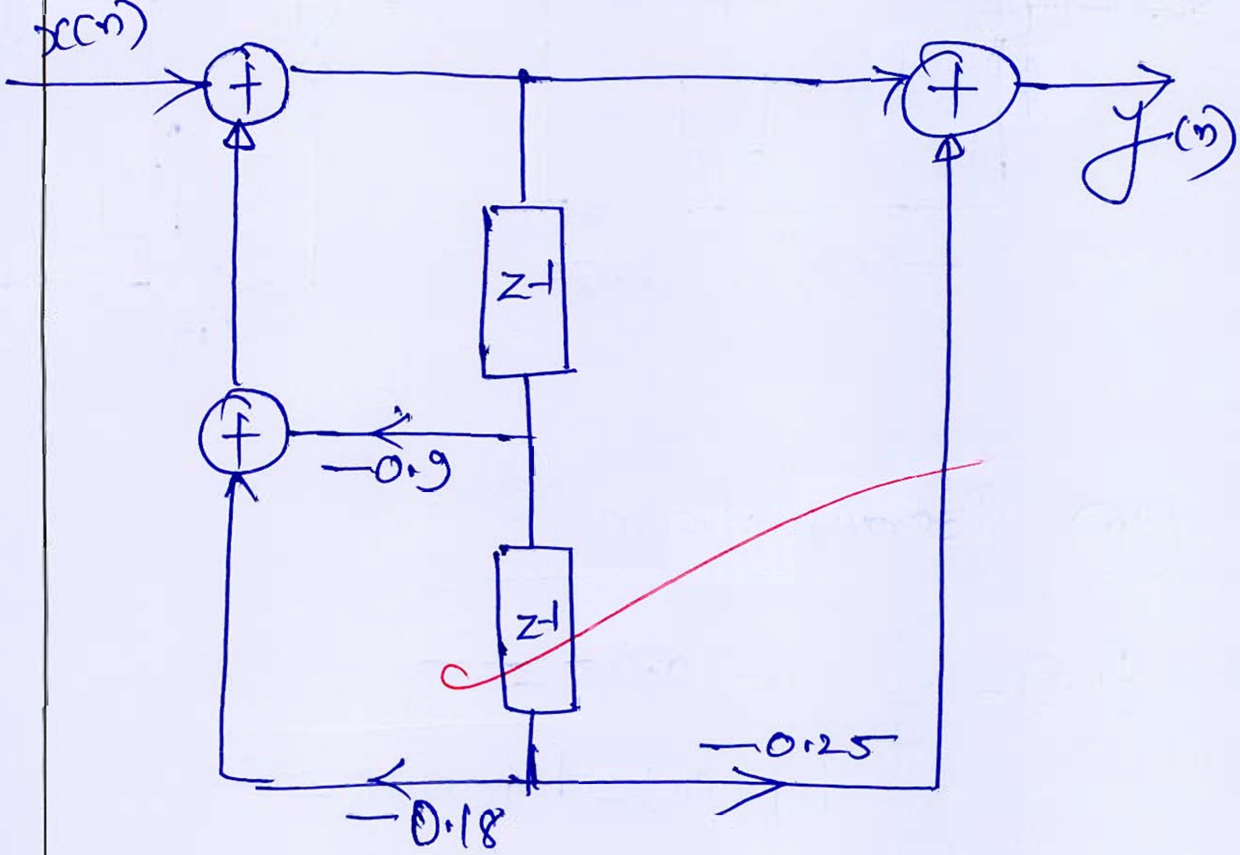
a_0 b_0

a_1 b_1

a_2 b_2

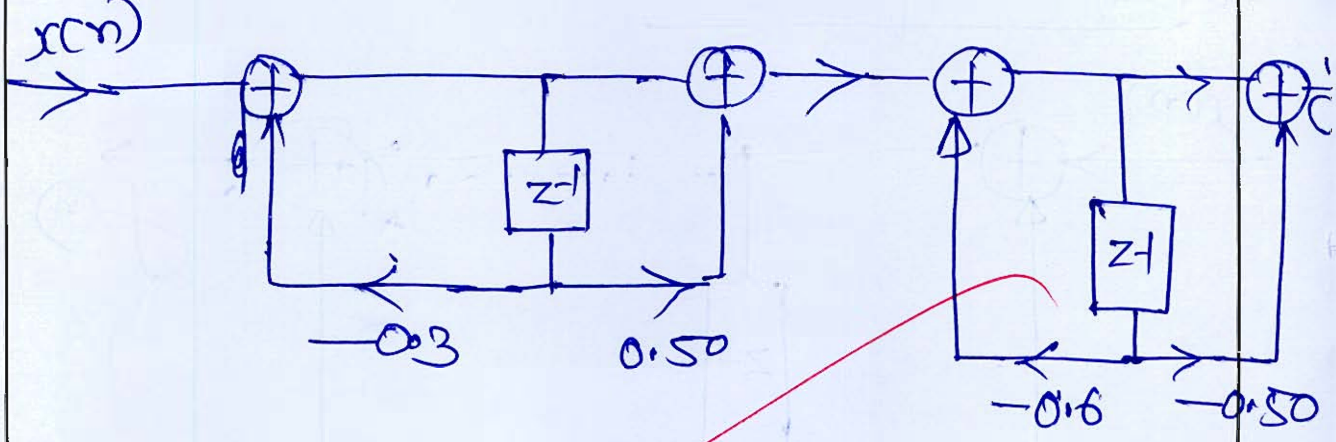
Write in detail

Direct form 2



(ii) $H(z) = \dfrac{(1 - 0.25 z^{-2})}{(1 + 0.3 z^{-1})(1 + 0.6 z^{-1})}$

$$= \underbrace{\frac{(1 + 0.50 z^{-1})}{(1 + 0.3 z^{-1})}}_{H_1(z)} \underbrace{\frac{(1 - 0.50 z^{-1})}{(1 + 0.6 z^{-1})}}_{H_2(z)}$$



(iii) Parallel form

$$H(z) = \frac{1 - 0.25 z^{-2}}{1 + 0.9 z^{-1} + 0.18 z^{-2}}$$

$$= \frac{z^2 - 0.25}{z^2 + 0.9z + 0.18}$$

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$$= 1 + \frac{-0.9z - 0.43}{(z+0.3)(z+0.6)}$$

$$= 1 - \frac{8/15}{z+0.3} - \frac{11/30}{z+0.6}$$

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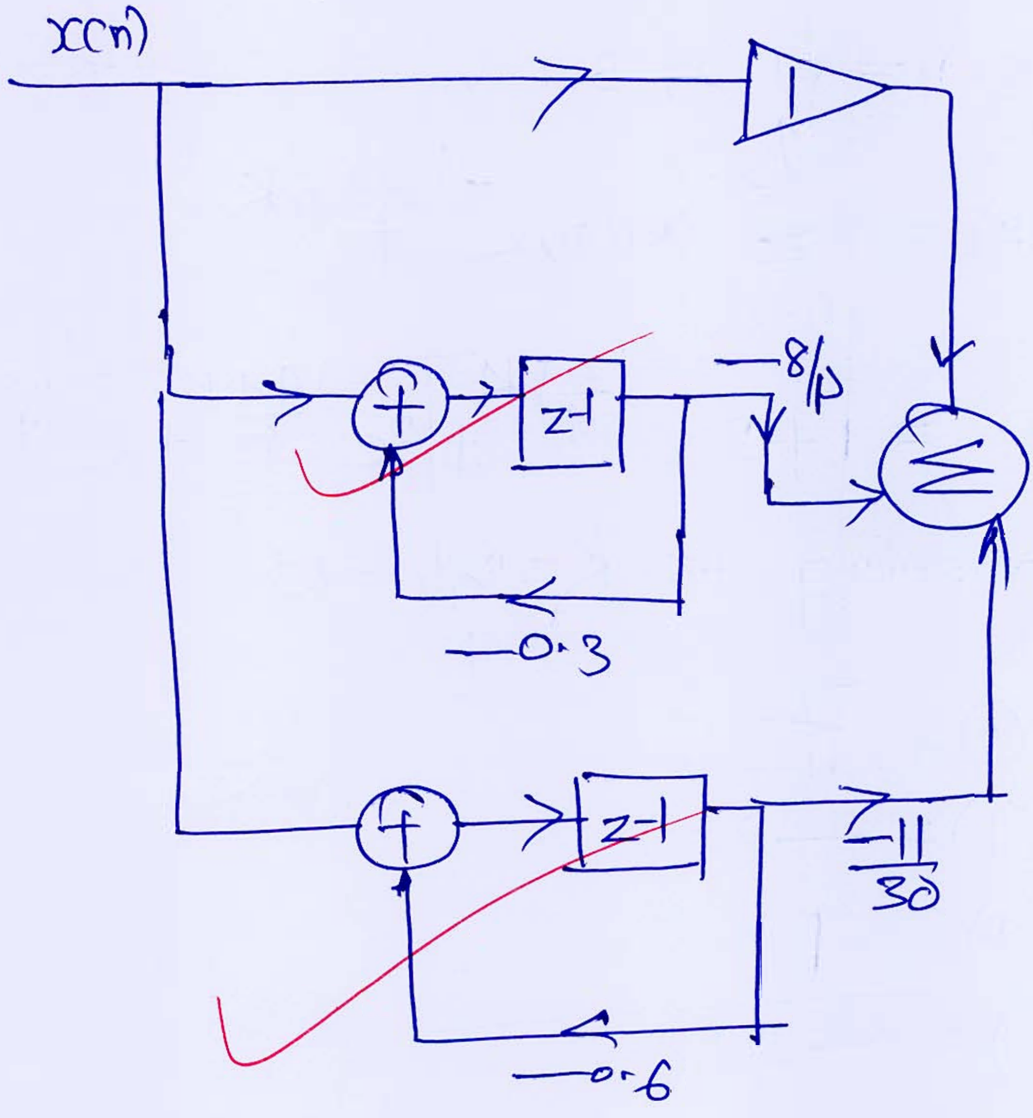
Parrall form



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Q.8 (c) Use four point DFT and IDFT to determine the circular convolution of following sequences :

$$x_1(n) = \{\underset{\uparrow}{1},2,3,1\} \text{ and } x_2(n) = \{\underset{\uparrow}{4},3,2,2\}$$

[20 marks]

$x_1(n) = \{\underset{\uparrow}{1}, 2, 3, 1\}$

$X_1(K) = \sum_{n=0}^{3} x_1(n) e^{-j\frac{2\pi}{4}nK}$

$= 1 + 2e^{-j\frac{2\pi}{4}K} + 3e^{-j\frac{4\pi}{4}K} + e^{-j\frac{6\pi}{4}K}$

Computing for $K = 0, 1, 2, 3$

$X_1(0) = 7$

$X_1(1) = -2-j$

$X_1(2) = 1$

$X_1(3) = -2+j$

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Similarly

$X_2(K) = 4 + 3e^{-j\frac{2\pi}{4}K} + 2e^{-j\frac{4\pi}{4}K} + 2e^{-j\frac{6\pi}{4}K}$

we get

$X_2(K) = \{11, 2-j, 1, 2+j\}$

$x_1(n) * x_2(n) = y(n)$

$X_1(K)\ X_2(K) = Y(K)$

$Y(K) = \{77, -5, 1, -5\}$

$$y(n) = \frac{1}{4}\sum_{K=0}^{3} Y(K) e^{j\frac{2\pi}{4}Kn}$$

$$= \frac{77 - 5e^{j\frac{2\pi}{4}n} + e^{j\frac{4\pi}{4}n} - 5e^{j\frac{6\pi}{4}n}}{4}$$

$y(0) = 17$

$y(1) = 19$

$y(2) = 22$

$y(3) = 19$

Thus

$x_1(n) * x_2(n) = \{17, 19, 22, 19\}$

Space for Rough Work

Space for Rough Work