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ESE 2024 : Mains Test Series

UPSC ENGINEERING SERVICES EXAMINATION

Electrical Engineering

Test-4 : Electrical Machines [All topics] + Power System-1 + Systems and Signal Processing-2 (Part Syllabus) + Microprocessor-2 (Part Syllabus)

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	
Q.2	
Q.3	
Q.4	
Section-B	
Q.5	
Q.6	
Q.7	
Q.8	
Total Marks Obtained	180

Signature of Evaluator Cross Checked by

Try to avoid calculation mistake

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 10 kVA single-phase transformer, rated for 2000/400 V has resistances and leakage reactance as follows.

Primary winding: $R_1 = 5.5\ \Omega$, $X_1 = 12\ \Omega$

Secondary winding: $R_2 = 0.2\ \Omega$, $X_2 = 0.45\ \Omega$.

Determine the approximate value of the secondary voltage at full-load 0.8 power-factor lagging when the primary voltage is 2000 V and also calculate the voltage regulation at this load.

[12 marks]

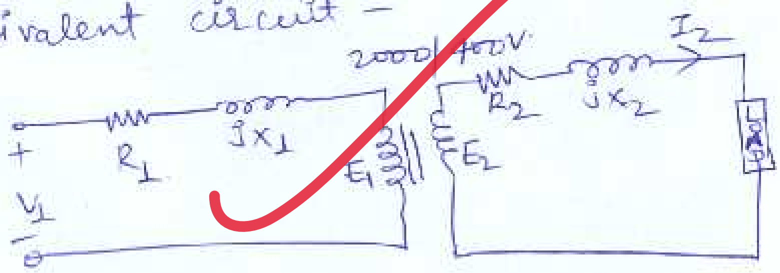
Ans Given informations are -

10kVA, 1-ϕ X-mer

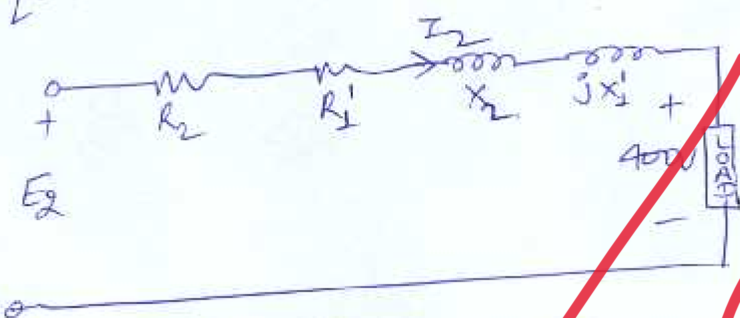
$V_1 = 2000\ V$

$V_2 = 400V$.

Equivalent circuit -



Equivalent circuit Referred secondary side.



where, $R_2 = 0.2\ \Omega$

$X_2 = 0.45$

$R_1' = 5.5\left[\frac{4}{20}\right]^2 = \frac{5.5}{25} = 0.22\Omega$

$X_1' = 0.48\ \Omega$

$E_2 = 400 + (j0.93 + 0.42)[I_2]$

$I_2 = \frac{10\times10^3}{400} = 25\ Amp$

$E_2 = 400\angle 0° + [0.42 + j0.93][25\angle -36.86°]$

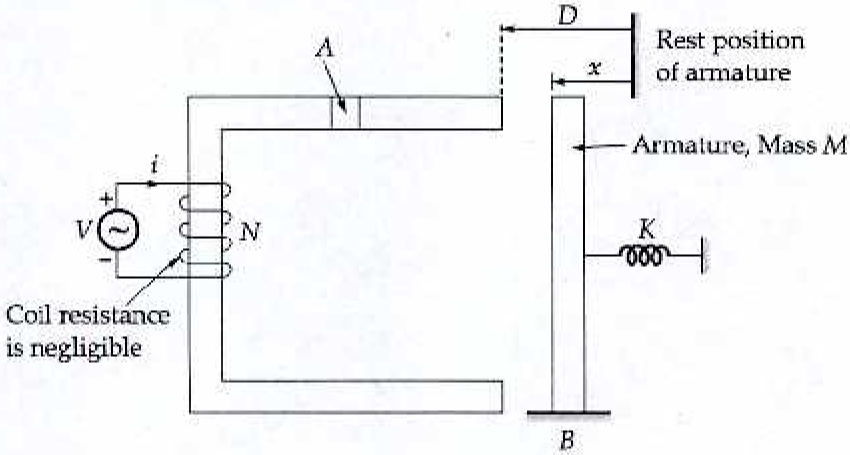
$E_2 = 422.527 \angle 1.6636$ volt.

$\%\text{voltage Regulation} = \frac{E_2 - V}{V} \times 100$

$= \frac{422.527 - 400}{400} \times 100$

$= 5.63\ \%$

Q.1 (b) 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]

Ans Given informations –

$B(t) = B_m \sin \omega t$

we know that, according to faraday's law of electromagnetic induction

$$E = -N \frac{d\phi}{dt}$$

Taking only magnitude

$$E = N \frac{d}{dt}(B \cdot A)$$

$$E = NA \frac{d}{dt}[B_m \sin \omega t]$$

$$E = NA\omega B_m \cos \omega t$$

$$\boxed{E = NA\omega B_m \cos \omega t} \text{ Volt}$$

(ii) we know that –

$$force = -\frac{dW_x}{dx}$$

$$W_x = Energy = \frac{1}{2} L I^2$$

$$L = \frac{N^2}{Reluctance(R)}$$

$$R = \frac{l}{\mu_0 \mu_r A}$$

where, $l = 2(D-x)$

$$R = \frac{2(D-x)}{\mu_0 \mu_r A}$$

$$L = \frac{N^2 \mu_0 \mu_r A}{2(D-x)}$$

$$W_x = \frac{1}{2} \times \frac{N^2 \mu_0 \mu_r A}{2(D-x)} \times i^2$$

$$F = -\frac{d}{dx}\left[\frac{N^2 \mu_0 \mu_r A i^2}{4(D-x)}\right] = \frac{N^2 \mu_0 \mu_r A i^2}{4(D-x)^2}$$

(ii) Drawing free Body Diagram –

$$M\frac{d^2[D-x]}{dt^2} + B\frac{d[D-x]}{dt} + K(D-x) = F$$

4

Q.1 (c) The power input to a 500 V, 50 Hz, 6-pole, 3-phase induction motor running at 975 rpm is 40 kW. The stator losses are 1 kW and friction and windage losses total 2 kW.

Calculate:

(i) the slip,

(ii) the rotor copper loss,

(iii) the output horsepower and

(iv) the efficiency.

[12 marks]

Ans Given informations are -

(i) Induction motor -

$N_r = 975$ rpm

$N_s = \frac{120 \times f}{P} = \frac{120 \times 50}{6} = 1000$ rpm.

$\% s = \frac{N_s - N_r}{N_s} = \frac{1000 - 975}{1000} \times 100$

$s = 0.025 = \frac{1}{40}$

$P_{in} = 40$ kW.

(ii) airgap power (P_g) = Rotor input = 40 − Stator loss

= 40 − 1

= 39 kW

rotor cu-loss $= s \times P_g = \frac{1}{40} \times 39$

= 975 Watt

(iii) mechanical output = rotor output

$P_m = (1-s) P_g = 39 [1 - 0.025]$

= 38.025 kW

P_{sh} (output power) = P_m − rotational loss

= 38.025 − 2

= 36.025 kW

Output power = 36.025 kW

In HP ⇒ $\frac{36.025 \text{ kW}}{746}$ HP

= 48.29 HP

(iv) % efficiency = $\frac{\text{Output power}}{\text{Input power}} \times 100$

$= \frac{36.025}{40} \times 100$

= 90.0625 %

11

Good Approach

Q.1 (d) A 240 V dc shunt motor runs on no-load at 800 rpm with no extra resistance in the field or armature circuit, the armature current being 2 A. Calculate the resistance required in series with the shunt winding so that the motor may run at 950 rpm when taking a line current of 30 A. Shunt winding resistance is 160 Ω, armature resistance is 0.4 Ω, Assume that flux is proportional to field current.

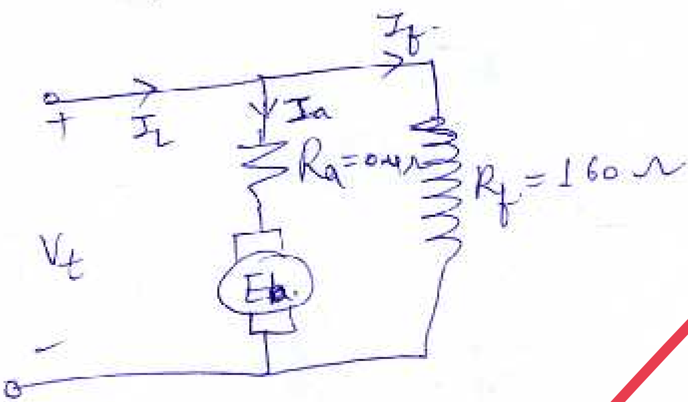
[12 marks]

Given informations are –

240V, dc shunt motor –

$N_0 = 800$ rpm.

$I_a = 2A$.



$\phi \propto I_f$.

1st case ⇒

$I_f = \frac{240}{160} = 1.5$ Amp

$E_0 = V - I_a R_a = 240 - 2 \times 0.4 = 239.2$ Volt

2nd case –

$I_a = 30 - \left(\frac{240}{160+R}\right)$

where, R ⇒ series Resistance in shunt field winding.

$E_1 = V - I_a R_a$.

$E \propto \phi N$

$\frac{E_0}{E_1} = \frac{\phi_0 N_1}{\phi_1 N_2} = \frac{\phi_0 \times 800}{950 \times I_{f_1}} = \frac{800}{950} \times \frac{I_{f_0}}{\left(\frac{240}{160+R}\right)}$

$\Rightarrow \frac{239.2}{E_1} = \frac{16}{19} \times \frac{1.5}{\left(\frac{240}{160+R}\right)} = \frac{24(160+R)}{19 \times 240}$

$$\Rightarrow \frac{239.2}{E_1} = \frac{(160+R)}{190}$$

$$\Rightarrow \boxed{E_1 = \frac{45448}{(160+R)}}$$

$$\Rightarrow \frac{45448}{(160+R)} = 240 - 0.4\times\left[30 - \frac{(240)}{(160+R)}\right]$$

$$\Rightarrow \frac{45448}{(160+R)} = 228 + \frac{96}{(160+R)}$$

$$\Rightarrow \frac{45448}{(160+R)} = \frac{[228[160+R] + 96]}{(160+R)}$$

$$\Rightarrow 45448 = 36480 + 228R + 96$$

$$\boxed{R = 38.912\,\Omega}$$

11

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Q.1 (e) Two transformers *A* and *B* each rated for 40 kVA have core-losses of 500 and 250 W respectively and full-load copper-losses of 500 and 750 W respectively. Compare the all-day efficiencies of the two transformers if they are to be used to supply a lighting load 'with outputs varying as follows:

Output-four hours at full-load, eight hours at half-load and the remaining 12 hours at no-load.

[12 marks]

Given informations—

for transformer A ⇒

$P_i = 500 W.$

$P_{cu} = 500 W.$

$$\% \text{ All-day efficiency} = \frac{kWh}{kWh + \text{losses in 24 hrs}} \times 100$$

$P_i = 24 \times 500 = 12000 \text{ Watt}$

$P_{cu}(\text{total}) = 500\left[4\times(1)^2 + 8\times\left(\frac{1}{4}\right) + 0\times 12\right]$

$= 3000 \text{ watt}$

Total output power $= 40\times(1)\times 4 + 400\times\frac{1}{2}\times 8 + 0$

$= 1760 \text{ KW.}$

$$\% \text{ All day efficiency} = \frac{1760}{1760+12+3}\times 100$$

$= 99.155 \%$

2

for transformer B ⇒

$(P_i)_{Total} = 250\times 24 = 6 KW.$

$(P_{cu})_{Total} = 750\left[4\times(1)^2 + 8\times\frac{1}{4} + 0\right] = 4.5 KW$

Do not write in this margin

% All day efficiency $= \frac{1760}{1760 + 6 + 4.5} \times 100$

$= \underline{\underline{99.4069\ \%}}$

efficiency of transformer B is more than X-mer A because of less number of losses in X-mer B.

Q.2 (a) A 50 kVA 13800/208 V, Δ-Y distribution transformers has a resistance of 1 percent and a reactance of 7 percent per unit.

(i) What is the transformer's phase impedance referred to high voltage side?

(ii) Calculate this transformer's voltage regulation at full load and 0.8 p.f. lagging using the calculated high voltage side impedance.

(iii) Calculate this transformer's voltage regulation under the same condition, using the per unit system.

[20 marks]

Given informations –

$R = 1\%$

$X = 7\%$

(i) $(Z_{HV})_\Delta = \frac{3V_{ph}^2}{S_{3\phi}} = \frac{3[13800]^2}{50\times 1000} = 11.4264\,k\Omega$

$(Z_{LV})_Y = \frac{(V_L)^2}{S_{3\phi}} = \frac{(208)^2}{50\times 1000} = 0.86528\,\Omega$

$(Z_{HV})_Y = \frac{(Z_{HV})_\Delta}{3} = 3.8088\,k\Omega$

$Z_{HV} = \frac{[1+j7]}{100}\times[3808.8] = 38.088 + j266.616$

$(Z_{HV})_{perphase} = 269.322\angle 81.87\ \Omega$

(ii) full load, 0.8 pf lagging

$(I_2)_{ph} = \frac{50\times 10^3}{3\times V_{ph}} = \frac{50\times 10^3}{3\times 13.8\times 10^3}$

$= 1.207$ Amp

$(V_2)_{ph} = 13.8\,kV$

% voltage Regulation = $\left[\frac{I_2 R_2 \cos\phi + I_2 X_2 \sin\phi}{V_2}\right] \times 100$

% VR = $\left[\frac{3\times[1.207 \times 38.088 \times 0.8 + 1.207 * 266.616 \times 0.6]}{13800}\right] \times 100$

$= 4.99658\,\%$

$\simeq 5\,\%$

(iii)

% VR = $[R_{pu}\cos\phi + X_{pu}\sin\phi] \times 100$

$= \frac{[1 \times 0.8 + 7 \times 0.6] \times 100}{100}$

$= 5\,\%$

Good Approach

18

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Q.2 (b) (i) A 70 MVA, 13.8 kV, 60 Hz, Y-connected, three-phase, salient-pole, synchronous generator has $X_d = 1.83\ \Omega$ and $X_q = 1.21\ \Omega$. It delivers the rated load at 0.8 pf lagging. The armature resistance is negligible. Determine :

1. the voltage regulation and
2. the power developed by the generator.

[10 marks]

Given informations are -

Salient pole synchronous generator -

$$\vec{E}_f' = V\angle 0^\circ + jI_a X_q + I_a R_a$$

$$|\vec{E}_f| = V\cos\delta + I_d X_d.$$

$$\tan\psi = \frac{V\sin\phi + I_a X_q}{V\cos\phi + I_a R_a}$$

let $V_{pu} = 1$ pu.

$I_{pu} = 1\angle -36.86^\circ$ pu.

$I_q = I_a \cos\psi$

$I_d = I_a \sin\psi.$

$$\tan\psi = \frac{(1)(0.6) + (1)\times X_q}{0.8}$$

$$Z_{Base} = \frac{(13.8)^2}{70} = 2.72\ \Omega$$

$X_q = 0.44$ pu.

$X_d = 0.672$ pu.

$$\tan\psi = \frac{0.6 + 0.44}{0.8} = 52.43^\circ$$

$\psi = \phi + \delta$

$\delta = 15.57^\circ$

$I_d = (1)\sin 52.43^\circ = 0.7926\ pu$

$I_q = 0.6097\ pu.$

$|\vec{E_f}| = (1)\cos(15.57^\circ) + (0.7926 \times 0.672)$

$|\vec{E_f}| = 1.4959\ pu$

$\%\ \text{Voltage Regulation} = \frac{|\vec{E_f}| - |V|}{|V|} \times 100$

$= 49.59\ \%$

$\text{power developed} = \frac{E_f V}{X_d}\sin\delta + \frac{V^2}{2}\left[\frac{1}{X_q} - \frac{1}{X_d}\right]\sin 2\delta$

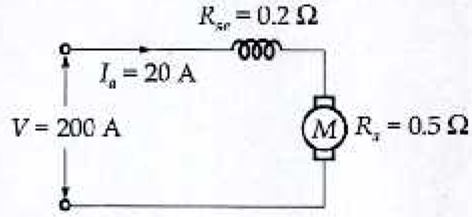
$P_g = \frac{1.4959 \times (1)}{0.672}\sin(15.57) + \frac{1}{2}\left[\frac{1}{0.44} - \frac{1}{0.672}\right] \times \sin(2 \times 15.57^\circ)$

$P_g = 0.5975 + 0.2029 = 0.8\ pu.$

$P_g = 56.026\ MW$

9

Q.2 (b) **(ii)** A dc series motor runs at 1000 rpm when taking 20 A at 200 V. The resistance of the armature circuit is 0.5 Ω and that of the field winding is 0.2 Ω. Find the speed for a total current of 20 A, 200 V, when a 0.2 Ω resistor is joined in parallel with the field winding. The flux for a field current of 10 A is 70% of that for 20 A.



[10 marks]

Given informations are -

DC series motor -

$E_1 = V - I_a(R_a + R_{se})$

$E_1 = 200 - 20[0.5 + 0.2] = \underline{186 V}$

~~series~~

when 0.2 Ω resistor is joined in parallel with field winding ⇒ $R_T = 0.1\ \Omega$

$\phi \propto I_{se}$

$\phi_1 \propto I_{se}$

$\phi_2 \propto \frac{I_{se}}{2}$

$E_2 = 200 - 20[0.5 + 0.1] = \underline{188 V}$

$E \propto \phi N$

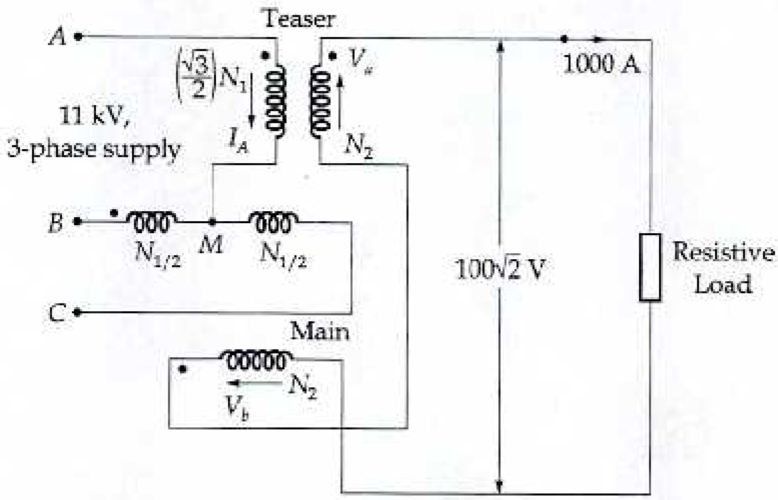
$\frac{E_1}{E_2} = \frac{\phi_1 N_1}{\phi_2 N_2} = \frac{\phi_1 \times 1000}{0.7\phi_1 \times N_2} = \frac{186}{188}$

$\Rightarrow \frac{1000}{0.7 \times N_2} = \frac{186}{188}$

$N_2 = 1443.932$ rpm

Q.2 (c) **(i)** Figure shows a Scott-connected transformer, supplied from 11 kV, 3-ϕ, 50 Hz mains. Secondaries are series-connected as shown, supply 1000 A at a voltage of $100\sqrt{2}$ V to a resistive load. The phase sequence of the 3-ϕ is *ABC*.

1. Calculate the turns ratio of the teaser transformer.
2. Calculate the line current I_B and its phase angle with respect to the voltage of phase *A* to neutral on the 3-ϕ side.



(ii) A 50 Hz, single-phase transformer draws a short circuit current of 30 A at 0.2 pf lag when connected to 16 V, 50 Hz source. What will be the short circuit current and its p.f. when the same transformer is energized from 16 V, 25 Hz source?

[12 + 8 marks]

(i) Given informations –

Scott connection X-mer

(i) Turns ratio of teaser X-mer.

$$N_{teaser} = 0.866\, N_{main}$$

$$\frac{N_1}{N_2} = \frac{2}{1}$$ → In teaser X-mer.

$$I_B = I_{BC} - \frac{I_A}{2}$$

$$I_A = I_B = I_C = 1.15\, I_{Teaser}$$

(ii) Given informations —

1-ϕ X-mer-

$I_{sc} = 30A$.

$pf = 0.2$ lag.

$V_{sc} = 16V$, 50Hz.

what is the short ckt current when — 16V, 25Hz.

$$I_{sc} = \frac{V}{|Z|}$$

$$I_{sc} \propto \frac{1}{f}$$

$$\frac{V}{f} \neq \text{constant}$$

$$Z_{sc} = \frac{16}{30} = 0.533\,\Omega$$

$$R_{sc} = 0.533 \cos\phi = 0.1066\,\Omega$$

$$X_{sc} = 0.522\,\Omega$$

At 25 Hz.

$$R_{sc} = 0.1066\,\Omega$$

$$X_{sc} = \frac{1}{2} \times 0.522 = 0.261\,\Omega$$

$$Z_{sc} = 0.282\,\Omega$$

$$I_{sc} = \frac{16}{Z_{sc}} = 56.73 \text{ Amp}$$

$$pf\ (\cos\phi_{sc}) = \left[\frac{R_{sc}}{Z_{sc}}\right] = 0.378 \text{ lag}$$

7

Q.3 (a) A 1200 KVA, 3300 V, 50 Hz, three-phase, star-connected alternator has armature resistance of 0.25 Ω per phase. A field current of 40 A produces a short circuit current of 200 A and an open-circuit emf of 1100 V line-to-line. Calculate the regulation on (i) full-load 0.8 power factor lagging; (ii) full-load 0.8 leading power-factor

[20 marks]

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Q.3 (b) A 11/0.4 kV, Y-Δ transformer is connected to 3-phase balanced load of 300 kVA at unity p.f. and also to a single phase load of 60 kVA at unity p.f. Determine the values of the current in each phase on the primary side. Neglect the no load current and the internal leakage impedance drop.

[20 marks]

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Q.3 (c) A 600 V, 6-pole, 3-phase, 50 Hz, star-connected synchronous motor has a resistance and synchronous reactance of 0.4 Ω and 7 Ω respectively. It takes a current of 15 A at UPF when operating with a certain field current. With the field current remaining constant, the load torque is increased until the motor draws a current of 50 A. Find the torque (gross) developed and the new power factor.

[20 marks]

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Q.4 (a) (i) The maximum efficiency of a 500 kVA, 3300/500 V, 50 Hz, single phase transformer is 97% and occurs at 75% of full-load, unity power factor. If the impedance is 10%, calculate the regulation at full-load power factor 0.8 lagging.

[10 marks]

Given informations are -

$$\Rightarrow 0.97 = \frac{0.75 \times 1 \times 500}{0.75 \times 500 \times 1 + 2P_i}$$

$$\Rightarrow 0.97 = \frac{375}{375 + 2P_i}$$

$$\boxed{P_i = 5.79896\ kW}$$

$$(P_{cu})_{full\ load} = \frac{P_i}{x^2} = \frac{5.79896}{(0.75)^2} = 10.31\ kW$$

$$\%\ Resistance\ drop = \frac{(P_{cu})_{fL} \times 100}{S_{3\phi}} = \frac{10.31}{500} \times 100$$

$$\%R = 2.0618\%$$

$$\%X_{pu} = \sqrt{Z_{pu}^2 - R_{pu}^2} = 9.785\%$$

$$\%\ Voltage\ Regulation = x[R_{pu}\cos\phi + X_{pu}\sin\phi] \times 100$$

$$= (1)[2.0618 \times 0.8 + 9.785 \times 0.6]$$

$$= 7.52\%$$

8

Q.4 (a) **(ii)** The resistance of the armature circuit of a 250 V dc shunt motor is 0.3 Ω and its full-load speed is 1000 rpm. Calculate the resistance required in series with the armature to reduce the speed with the full-load torque to 800 rpm, the full-load armature current being 50 A. If the load torque is then halved, at what speed will the motor run? The armature reaction effect is to be neglected.

[10 marks]

Given information-

DC Shunt Motor-

$R_a = 0.3\Omega$

$V_t = 250V$

$N_{fL} = 1000 rpm.$

$E_1 = V_t - I_a R_a = 250 - 50 \times 0.3 = 235V$

for shunt motor

$T \propto \phi I_a.$

$\phi =$ constant.

If $T =$ constant.

$I_{a_2} = 50A.$

$E \propto \phi N.$

$E_2 = \frac{800}{1000} \times 235 = 188V.$

$188 = 250 - 50[0.3 + R_{ext}]$

$\boxed{R_{ext} = 0.94\Omega}$

If load torque is halved

$T_{L_2} = \frac{T_{L_1}}{2}$

$\phi_1 I_{a_2} = \frac{\phi_1 I_{a_1}}{2}$

$I_{a_2} = \frac{I_{a_1}}{2} = 25 Amp$

$E_3 = 250 - 25[0.3 + 0.34] = 219$ Volt

$E \propto \phi N$

$N_1 = \frac{219}{235} \times 1000 = 931.9148$ rpm
(when Rext is connected)

$E_4 = 250 - 25[0.3] = 242.5$ Volt

$N_2 = 1000 \times \frac{242.5}{235} = 1031.9148$ rpm
when Rext is not connected.

0

Do not write in this margin

Q.4 (b) A 6 pole, 3 phase, 50 Hz alternator has 12 slots per pole and 4 conductors per slot. The winding is five-sixth pitch and the flux per pole is 1.5 wb. The armature coils are all connected in series with star connection. Calculate the induced emf per phase.

[20 marks]

Given informations are –

$\alpha = 180 - \left(\frac{5}{6} \times 180\right) = 30°$

$K_p = \cos(\alpha/2) = \underline{0.966}$

$\phi = 1.5\ Wb.$

$E_{ph} = 4.44 \times \phi \times N_{ph} \times f \times K_d \times K_p$ volt

$K_d = \frac{\sin\left(\frac{m\beta}{2}\right)}{m \sin(\beta/2)}$

$\beta = \frac{180}{(slot/pole)} = \underline{15°}$

$Z = 12 \times 6 \times 4 = 288$

$N = \frac{288}{2} = 144.$

$N_{ph} = 48$

$m = \frac{slots}{(pole/phase)} = \frac{12}{3} = 4$

$K_d = \frac{\sin\left(\frac{4 \times 15}{2}\right)}{4 \sin\left(\frac{15}{2}\right)} = \underline{0.966}$

putting all the values in above Emf equations

$E_{ph} = 4.44 \times 50 \times 1.5 \times 48 \times 0.966^2$

$E_{ph} = \underline{14.66\ KV}$ Ans

18

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Q.4 (c) A 7.5 hp, four pole, 208 V, 60 Hz, Y connected induction motor has rated current of 28 A. The following test data was recorded :

DC Test :	V_{DC} = 13.6 V,	I_{DC} = 28 A	
No Load Test :	V_T = 208 V,	f = 60 Hz,	P_{in} = 420 W
	I_A = 8.12 A,	I_B = 8.20 A,	I_C = 8.18 A
Blocked rotor test :			
	V_T = 25 V,	f = 15 Hz,	P_{in} = 920 W
	I_A = 28.1 V,	I_B = 28 A,	I_C = 27.6 A

Assume reactance value obtained by blocked rotor is equally divided between rotor and stator and neglect skin effect.

(i) Obtain induction motor per phase parameters and neatly draw per phase equivalent circuit of motor.

(ii) Calculate the slip at pull out torque and value of pull out torque also.

[20 marks]

Given informations are -

(i) $V_{ph} = 120.088$ Volt, 60 HZ, Y-connected IM.

$I_{rated} = 28$ Amp.

$R_1(DC) = 0.4857\Omega$

$R_1(ac) = R_1(DC)$ If skin effect is neglected.

$R_1 = 0.4857\Omega$

No-load test ⇒

⇒ $P_0 = \sqrt{3} V_0 I_0 \cos\phi_0$

⇒ $420 = \sqrt{3} \times 208 \times 8.166 \times \cos\phi_0$

⇒ $\cos\phi_0 = 0.14275°$

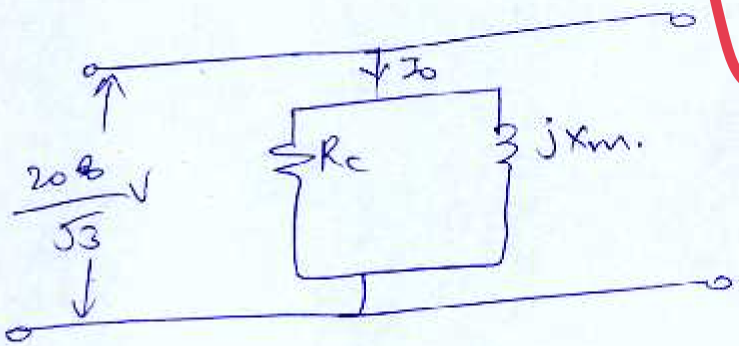
$\phi_0 = 81.79°$

$\sin\phi_0 = 0.9897$

$I_0 = \left[\frac{I_A + I_B + I_C}{3}\right] = 8.166$ Amp

$$X_m = \frac{V_{ph}}{I_0 \sin\phi_0} = \frac{120.088}{8.08189} = 14.8589\,\Omega$$

$$R_c = \frac{120.088}{I_0 \cos\phi_0} = 103.0182\,\Omega$$



Blocked Rotor test ⇒

$$I_{sc} = \frac{(I_A + I_B + I_C)}{3} = 27.9\text{ Amp.}$$

$$Z_B = \frac{V_{sc}}{I_{sc}} = \frac{25/\sqrt{3}}{I_{sc}} = 0.517\,\Omega$$

$$3 I_{sc}^2 R_{sc} = P_{sc} \Rightarrow R_{sc} = \frac{920}{3 \times (27.9)^2 \times 1}$$

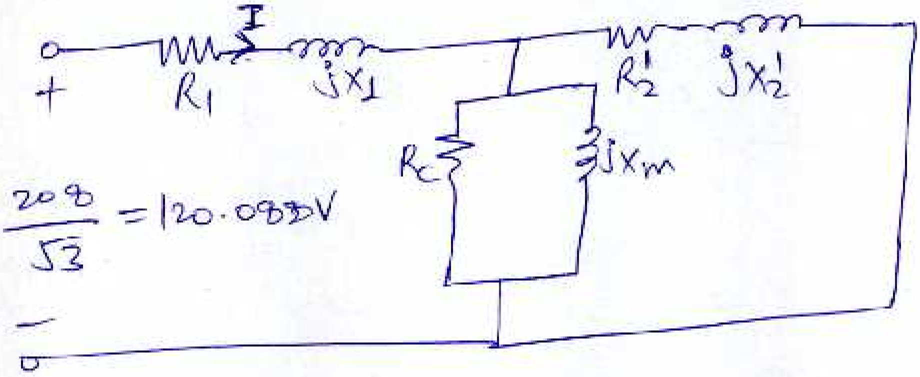
$$R_{sc} = 0.3939\,\Omega = R_1 + R_2'$$

$$X_{sc} = 0.3347\,\Omega = X_1 + X_2'$$

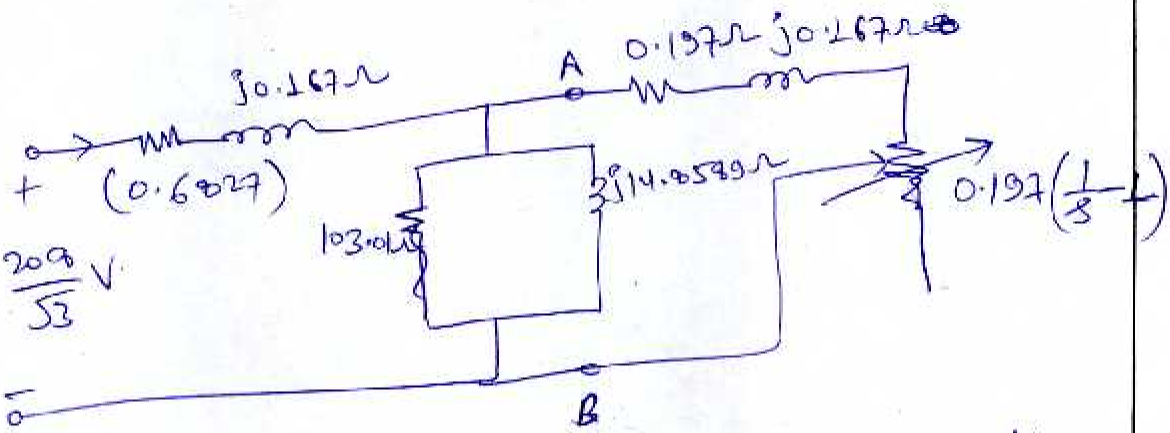
$$R_1 = R_2' = \frac{0.3939}{2} = 0.197\,\Omega$$

$$X_1 = X_2' = \frac{X_{sc}}{2} = 0.1674\,\Omega$$

per phase equivalent circuit Diagram of IM.



(ii) slip at maximum torque.



Thevenin equivalent circuit about AB terminals –

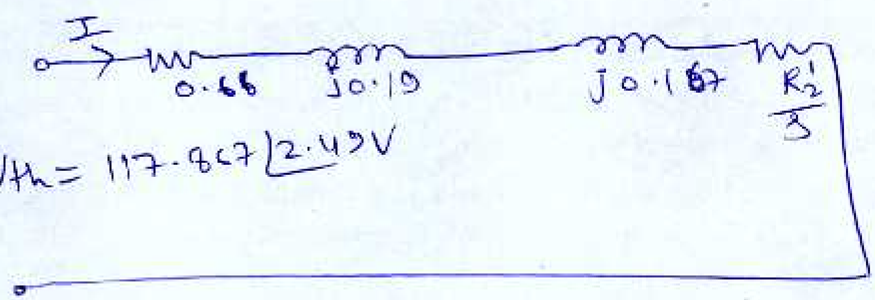
$$V_{th} = 120.088 \times \left[\frac{14.7\angle 81.79}{14.7\angle 81.79 + 0.7\angle 13.74^\circ}\right]$$

$$V_{th} = 117.867\angle 2.49^\circ \text{ Volt}$$

$$Z_{th} = 14.7\angle 81.79 \parallel (0.7\angle 13.74^\circ) = 0.687\angle 16.22\ \Omega$$

$$\boxed{Z_{th} = 0.66 + j0.19}$$

0.198



for maximum torque slip.

$$\frac{R_2'}{S_{mT}} = \sqrt{0.66^2 + (0.19+0.187)^2}$$

$$S_{mT} = \frac{0.197}{0.75} = 0.2625$$

$$P_{mT} = I^2 \times \left(\frac{R_2'}{S_{mT}}\right)$$

$$P_{mT} = \left[\frac{117.867\angle 2.49}{[1.41 + j0.357]}\right]^2 \times [0.75]$$

$$P_{mT} = (81.036)^2 \times 0.75 = 4925.1249 \text{ Watt}$$

$$(\text{Torque})_{max} = \frac{P_{mT}}{\omega} = 26.128 \text{ N-M}$$

$$\omega = \frac{2\pi \times N}{60} = \frac{2\pi \times 1800}{60} = 188.49 \text{ rad/sec.}$$

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

Q.5 (a) A 60 kV (rms) single-core metal sheathed cable is to be graded by means of a metallic intersheath. The safe electric stress of the insulating material is 4 kV/mm (rms).

(i) Calculate the diameter of the intersheath and the voltage at which it must be maintained in order to obtain minimum overall diameter. Calculate also the corresponding conductor diameter.

(ii) Compare the conductor diameter obtained in (i) with that of an ungraded cable working under the same conditions.

[12 marks]

Given informations are -

$V = 60 kV$

$E = 4 kV/mm$

$E = \frac{V}{r \ln(R/r)}$

$E_{min} = \frac{V}{R \ln(R/r)}$

$E_{max} = \frac{V}{r \ln(R/r)}$

$r = \frac{V}{E_{max}} = \frac{60}{4} = 15mm$

$Diameter = 2r = 30\ mm$

$R = r + t$

$\frac{R}{r} = e \Rightarrow R = 40.774\ mm$

$t = 25.77\ mm$

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Q.5 (b) A three-phase transmission line has a resistance 10 Ω per phase and a reactance of 30 Ω per phase.

(i) Determine the maximum power which may be transmitted if 132 kV were maintained at each end.

(ii) What is the phase difference between the receiving-end and sending-end voltages for maximum power transmitted?

(iii) Also, determine the rating of a synchronous phase modifier required to supply 100 MW at 0.9 power factor lagging at the receiving end.

[12 marks]

Given informations are -

$Z = (10 + j30) = 31.622 \angle 71.56^\circ \ \Omega$

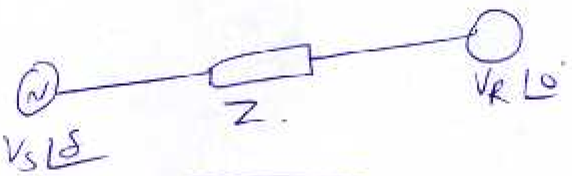
(i) $P_{max} \Big|_{at} \ \theta = \delta$.

$\theta = \delta = 71.565^\circ$.

$P_{max} = \left[\frac{VE}{Z} - \frac{V^2}{Z}\cos\theta\right]$

$P_{max} = \frac{V^2}{Z}[1 - \cos\theta] = 376.764 \text{ MW}$

(ii)



$\delta = 71.525^\circ$

(iii) ~~$Q_R = \frac{V^2}{Z}[1 - \sin\theta]$~~

$Q_R = \frac{V^2}{Z}\sin(\theta - \delta) - \frac{V^2}{Z}\sin\theta$

$Q_R = \frac{[132]^2}{31.622}\sin(71.535) = -522.735 \text{ MVAR}$

$Q_{line} = -Q_R = 522.735 \text{ MVAR}$

$Q_C = P_R \tan \phi_R = 100 \times \tan[\cos^{-1}(0.9)] = 48.43$ MVAR

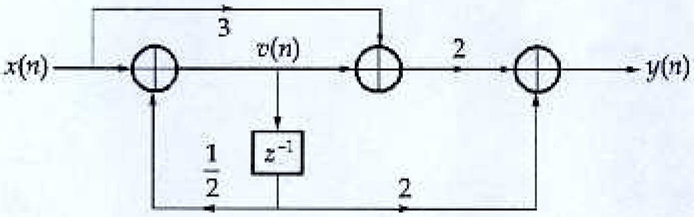
Rating of synchronous phase modifier $= Q_{line} - Q_C$

$Q_{C_1} = 522.735 - 48.43$

$\boxed{Q_{C_1} = 474.305 \text{ MVAR}}$

6

Q.5 (c) Determine the system function and the impulse response of the system shown in the figure below.



[12 marks]

By applying mason's gain formula –

$$\frac{y(n)}{x(n)} = \frac{2 + 3\times 2[1 - 0.5z^{-1}] + 2z^{-1}}{[1 - 0.5z^{-1}]}$$

$$\frac{y(n)}{x(n)} = \frac{2 + 6[1 - 0.5z^{-1}] + 2z^{-1}}{[1 - 0.5z^{-1}]}$$

$$\frac{Y(z)}{X(z)} = \frac{[2 + 6 - 3z^{-1} + 2z^{-1}]}{[1 - 0.5z^{-1}]}$$

$$= \frac{[8 + z^{-1}]}{[1 - 0.5z^{-1}]}$$

$$\frac{Y(z)}{X(z)} = \frac{[8z + 1]}{[z - 0.5]}$$

System function $= \frac{(8z+1)}{[z-0.5]}$

for impulse response – $\frac{y(z)}{z} = \frac{(8z+1)\times(1)}{z(z-0.5)}$

$y(n) = -\delta(n+1) + 10(1/2)^n u(n)$ Ans

2

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Q.5 (d) Find $y(n)$, $n \geq 0$ for the following difference equation :

(i) $$y(n) = \frac{1}{2}y(n-1) + x(n)$$

where $$x(n) = \left(\frac{1}{3}\right)^n u(n),\ y(-1) = 1$$

(ii) $$y(n) + \frac{1}{2}y(n-1) + \frac{1}{4}y(n-2) = 0$$

where, $$y(-1) = y(-2) = 1$$

[6 + 6 marks]

(i) Taking z-transform.

$$Y(z) = \frac{1}{2}z^{-1}Y(z) + \frac{1}{2}y(-1) + X(z)$$

$$Y(z)\left[1 - \frac{1}{2}z^{-1}\right] = \frac{1}{2} + X(z)$$

$$X(z) = \frac{z}{\left[z - \frac{1}{3}\right]} = \frac{1}{\left(1 - \frac{1}{3}z^{-1}\right)}$$

$$Y(z)\left[1 - \frac{1}{2}z^{-1}\right] = \frac{1}{2} + \frac{1}{\left(1 - \frac{1}{3}z^{-1}\right)}$$

$$Y(z)\left[1 - \frac{1}{2}z^{-1}\right] = \frac{\left(1 - \frac{1}{3}z^{-1}\right) + 2}{2\left(1 - \frac{1}{3}z^{-1}\right)}$$

$$Y(z) = \frac{\left[3 - \frac{1}{3}z^{-1}\right]}{2\left[1 - \frac{1}{3}z^{-1}\right]\left[1 - \frac{1}{2}z^{-1}\right]}$$

$$Y(z) = \frac{A}{\left(1 - \frac{1}{3}z^{-1}\right)} + \frac{B}{\left(1 - \frac{1}{2}z^{-1}\right)}$$

$$Y(z) = \frac{-2}{\left(1 - \frac{1}{3}z^{-1}\right)} + \frac{3.5}{\left(1 - \frac{1}{2}z^{-1}\right)}$$

3

taking inverse ~~laplac~~ z-transform -

$$y(n) = -2\left(\tfrac{1}{3}\right)^n u(n) + \tfrac{7}{2}\left(\tfrac{1}{2}\right)^n u(n)$$

(ii) Taking z-transform -

$$\Rightarrow Y(z) + \tfrac{1}{2}z^{-1}Y(z) + \tfrac{1}{2}y(-1) + \tfrac{1}{4}z^{-2}Y(z) + \tfrac{1}{4}z^{-1}y(-1) + \tfrac{1}{4}y(-2) = 0$$

1

$\Rightarrow$ putting all the values -

$$\Rightarrow Y(z)\left[1+\tfrac{1}{2}z^{-1}+\tfrac{1}{4}z^{-2}\right] + \tfrac{1}{2} + \tfrac{1}{4}z^{-1} + \tfrac{1}{4} = 0$$

$$\Rightarrow Y(z)\left[1+\tfrac{1}{2}z^{-1}+\tfrac{1}{4}z^{-2}\right] + \tfrac{3}{4} + \tfrac{1}{4}z^{-1} = 0$$

$$\Rightarrow Y(z)\left[4+2z^{-1}+z^{-2}\right] + (3+z^{-1}) = 0$$

$$\Rightarrow Y(z) = \frac{-(3+z^{-1})}{(4+2z^{-1}+z^{-2})}$$

$$Y(z) = \frac{-z(3z+1)}{(4z^2+2z+1)}$$

$$\frac{Y(z)}{z} = \frac{-(3z+1)}{(4z^2+2z+1)}$$

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Q.5 (e) Compare memory mapping and input-output mapping of input output devices in 8085 based system?

[12 marks]

memory mapping	Input-output mapping-
• 16-bit Address is required $2^{16} = 64KB$	8-bit Address is required $2^8 = 256Byte.$
• memory mapping is used when less Address is needed	• more Address is required.
• hardware cost is less because of easy design	• hardware cost is more because of complex design
• LDA 16-bit, MVI A, D } type instruction	• IN → 8 bit out → 8-bit type instructions

6

Q.6 (a) **(i)** A 20 MVA transformer which is used to operate at 30% overload feeding an 11 kV bus bar through a circuit breaker. The transformer circuit breaker is equipped with a 1000/5 current transformer and the feeder circuit breaker with 400/5 current transformer and both the current transformers feed IDMT relays having the following characteristics

Plug setting multiplier	2	3	5	10	15	20
Time (seconds)	10	6	4.1	3	2.5	2.2

The relay on the feeder circuit breaker has 125% plug setting and a 0.3 time multiplier setting. If a fault current of 5000 A flows from the transformer to the feeder, determine:

1. operating time of feeder relay.
2. suggest suitable plug setting and TMS of the transformer relay to ensure adequate discrimination of 0.5s between the transformer relay and feeder relay.
   [Given time for PSM of 3.33 = 5.6 *s*]

[10 marks]

Ans

$$PSM = \frac{\text{fault current}}{\text{pickup current}}$$

$$PSM = \frac{5000}{80 \times 1.25 \times 5} = 10$$

Q.6 (a) (ii) An industrial load of 4000 kW is supplied at 11 kV, the p.f. being 0.8 lagging. A synchronous motor is required to meet an additional load of 1103.25 kW and at the same time to raise the resultant power factor to 0.95 lagging. Determine the kVA capacity of the synchronous motor and the power factor at which it must operate. Take the efficiency of the synchronous motor as 80%.

[10 marks]

Given information-

synchronous Motor-

$P = \sqrt{3} V I \cos\phi$

$4000 = \sqrt{3} \times 11 \times 0.8 \times I$

$I = 262.43 \angle -36.86$ Amp

$P_{in} = \frac{4000}{0.8} = 5000$ kW.

$|Q_c| = [P_{in} \tan\phi_1 - (P_{in} + P_s) \tan\phi_2]$

$|Q_c| = 5000 \tan(36.86°) - (5000 + 1103.25) \tan(18.19)$

$|Q_c| = 1742.6093$ KVAR.

$Pf = \cos\left(\tan^{-1}\left(\frac{Q_c}{P_s}\right)\right)$

$Pf = \cos\left[\tan^{-1}\left[\frac{1742.6093}{1103.25}\right]\right]$

$Pf = \cos(57.662) = 0.5349$ leading

KVA rating of motor $= \sqrt{P_s^2 + Q_c^2}$

$= \sqrt{(1103.25)^2 + (1742.6093)^2}$

$S_{KVA} = 2062.4858$ (Motor)

Q.6 (b) Consider a discrete time system with the input-output relationship,

$$y(n)=\begin{cases} x(n); & n\geq 1 \\ 0; & n=0 \\ x(n+1); & n\leq -1 \end{cases}$$

where $x(n)$ is the input and $y(n)$ is the output of the given system. Check whether the system is (i) linear (ii) causal (iii) time-invariant (iv) stable.

[20 marks]

~~y(n) = x(n) u(n-1)~~

(i) $y(n) = x(n)\,u(n-1) + x(n+1)\,u(n+1)$

Taking, $y_1(n)$ output has $x_1(n)$ input

$y_1(n) = x_1(n)\,u(n-1) + x_1(n+1)\,u(n+1)$

Similarly, $y_2(n) \leftrightarrow x_2(n)$

$y_2(n) = x_2(n)\,u(n-1) + x_2(n+1)\,u(n+1)$

$y_1(n) + y_2(n) = [x_1(n) + x_2(n)]\,u(n-1) + u(n+1)[x_1(n+1) + x_2(n+1)]$ — (1)

for combined output,

$y_3(n) = y_1(n) + y_2(2)$

$x_3(n) = x_1(2) + x_2(n)$

$y_3(n) = [x_1(n) + x_2(n)]\,u(n-1) + (x_1(n+1) + x_2(n+1))\,u(n+1)$ — (2)

linear system.

according to above Eq^n ① and ②
it will follow Additive and homogeniety Property
so, that given system is linear as it
follow superposition theorem..

(ii) $y(n) = x(n)u(n-1) + x(n+1)u(n+1)$

according to this equation.

$y(n) \neq 0, \ n < -1.$

output of the system is depends upon
the future value of the input that's
why system is non-causal..

(iii) Time invariant condition ⇒

$y(n-n_0) \rightleftharpoons x(n-n_0)$

$y(n) \underset{\text{input shifting}}{\rightleftharpoons} x(n-n_0)$

if $y(n-n_0) = y(n)$ then only system
is Time-invariant otherwise time
variant so,

$y(n-n_0) = x(n-n_0)u(n-n_0-1) +$
$x(n-n_0+1)u(n-n_0+1)$ — ①

$y(n) = x(n-n_0)\, u(n-1) + x(n-n_0+1)\, u(n+1)$ — (2)

according to the equation (1) and equation (2)

$y(n-n_0) \neq y(n)$

so, system is <u>time-variant.</u>

<u>(iv)</u> $y(n) = x(n)\, u(n-1) + x(n+1)\, u(n+1)$

let $x(n) = \delta(n)$

$y(n) = \delta(n)\, u(n-1) + \delta(n+1)\, u(n+1)$

$$y(n) = u(n-1) + u(n+2)$$

let $x(n) = \delta(n+1)$

$y(n) = u(n-1)\, \delta(n+1) + u(n+1)\, \delta(n+2)$

$$y(n) = u(n) + u(n+3)$$

we are getting Bounded ~~output~~ output for bounded input so, that system is <u>stable</u>

18

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Q.6 (c) Determine the inverse z-transform of the following signals:

(i) $X(z) = \log(1 + az^{-1})$, $|z| > |a|$.

(ii) $X(z) = \dfrac{z^3 - 10z^2 - 4z + 4}{2z^2 - 2z - 4}$ with ROC $|z| > 2$.

[20 marks]

(i) $X(z) = \log\left[\frac{z+a}{z}\right]$

$X(z) = \log(a+z) - \log(z)$

differentiating both sides-

$\frac{dX(z)}{dz} = \frac{1}{(z+a)}(1) - \frac{1}{z}$

$\frac{dX(z)}{dz} = \frac{1}{(a+z)} - \frac{1}{z}$

we know, according to the z-transform property.

$nx(n) \xrightarrow{ZT} -z\frac{dX(z)}{dz}$.

$-z\frac{dX(z)}{dz} = 1 - \frac{z}{(z+a)}$

Taking inverse z-transform

$nx(n) = \delta(n) - (-a)^n u(n)$

$x(n) = \frac{1}{n}\left[\delta(n) - (-a)^n u(n)\right]$

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(ii) $X(z) = \frac{(z^3 - 10z^2 - 4z + 4)}{(2z^2 - 2z - 4)}$

$$2z^2 - 2z - 4 \,\big)\, z^3 - 10z^2 - 4z + 4 \,\big(\, \tfrac{z}{2} - \tfrac{9}{2}$$

$$z^3 - z^2 - 2z$$
$$- \quad + \quad +$$
$$-9z^2 - 2z + 4$$
$$-9z^2 + 9z + 18$$
$$+ \quad - \quad -$$
$$(-11z - 14)$$

$$X(z) = \frac{z}{2} - \frac{9}{2} - \frac{[11z + 14]}{(2z^2 - 2z - 4)}$$

$$X(z) = \frac{z}{2} - \frac{9}{2} - \frac{(11z + 14)}{2(z-2)(z+1)}$$

$$X(z) = \frac{z}{2} - \frac{9}{2} - \frac{1}{2}\left[\frac{12}{(z-2)} - \frac{1}{(z+1)}\right]$$

$$X(z) = \frac{z}{2} - \frac{9}{2} - \frac{6}{(z-2)} + \frac{0.5}{(z+1)}$$

taking inverse ~~by~~ z-transform -

$$x(n) = 0.5\delta(n+1) - 4.5\delta(n) - 6(2)^{n-1}u(n-1) + 0.5(-1)^{n-1}u(n-1)$$

14

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Q.7 (a) A three-phase, 50 Hz, transmission line, 40 km long delivers 36 MW at 0.8 power factor lagging at 60 kV (phase). The line constants per conductor are, $R = 2.5\ \Omega$, $L = 0.1$ H, $C = 0.25\ \mu F$. Shunt leakage may be neglected. Determine the voltage, current, power factor, active power and reactive volt-amperes at the sending end. Also, determine the efficiency and regulation of the line. Use (a) nominal *T* method, (b) nominal Π method.

[20 marks]

Q.7 (b) Using a rectangular window, design a low-pass filter with passband gain of unity, cut-off frequency of 1 kHz and working at a sampling frequency of 5 kHz. The length of the impulse response should be 7.

[20 marks]

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Q.7 (c) (i) In programming of 8085, what are main logic instructions related to command group 'ROTATE'? Describe briefly each instruction and their significance on register values with example, assuming accumulator content AAH and carry flag, CY = 0, before execution of instruction.

[10 marks]

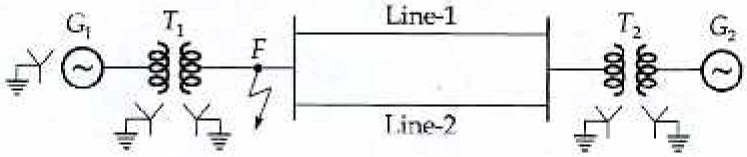
Q.7 (c) **(ii)** Write a program for transferring sixteen bytes of data stored in memory location at XX50H to XX5FH. Transfer the entire data set to new memory location starting at XX70H.

[10 marks]

Q.8 (a) Draw the sequence networks for the system shown in figure. Determine the fault current when **(i)** LLG and **(ii)** LL fault occurs at point F. The per unit reactances all referred to the same base are as follows:

	X_0	X_1	X_2
Generator G_1	0.05	0.3	0.2
Generator G_2	0.03	0.25	0.15
Line 1	0.70	0.3	0.3
Line 2	0.70	0.3	0.3
Transformer T_1	0.12	0.12	0.12
Transformer T_2	0.10	0.1	0.1

Both the generators are generating 1 p.u. voltage.



[20 marks]

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Q.8 (b) Find the voltage distribution and string efficiency of a three unit suspension insulator string if the capacitances of the link pins to earth and to the line are respectively 20 per cent and 10 per cent of the self capacitance of each unit. If a guard ring increases the capacitance to the line of lower link pin to 35 per cent of the self capacitance of each unit, find the redistribution of voltage and string efficiency.

[20 marks]

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Q.8 (c) (i) Write short notes on the following:

1. PROM
2. EPROM
3. EE-PROM
4. MASKED ROM
5. CONTROL BUS

[10 marks]

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Q.8 (c) **(ii)** What are the steps needed for data flow from memory to the MPU in 8085 microprocessor? Draw clear schematic timing diagram representing transfer of byte from memory to MPU.

[10 marks]

oooo

Space for Rough Work

Space for Rough Work

30 Hz

30x744 watt

7Hz

$\frac{A}{z} + \frac{B}{z-0.5}$

$\frac{1}{(1-az^{-1})}$

$\frac{-2z}{z} + \frac{10z}{(z-0.5)}$

$\frac{z}{(z-a)}$

-2

$-\delta(n+1) + 10(+0.5)^n u(n)$

$\frac{11z+14}{(z-2)(z+1)}$

$(2)^n u(n) \longrightarrow \frac{z}{(z-2)}$

$(2)^{n-1} u(n-1) \longrightarrow z^{-1}$