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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 ☑	
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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	
Q.2	
Q.3	
Q.4	
Section-B	
Q.5	
Q.6	
Q.7	
Q.8	
Total Marks Obtained	213

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.

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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]

Sol:

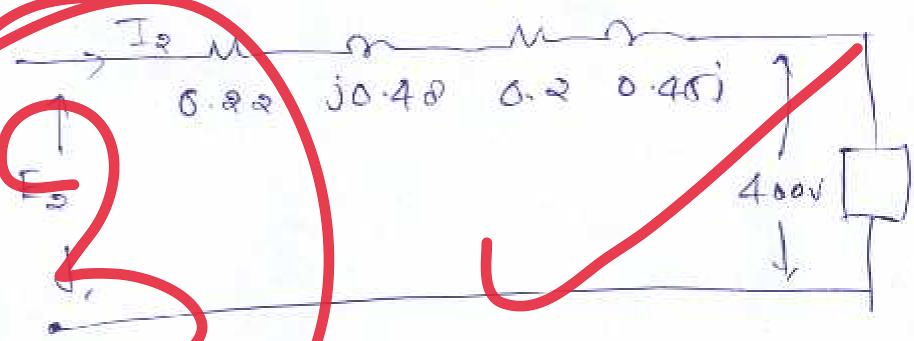
Transformation Ratio $= \frac{2000}{400} = 5$

Referred primary impedance towards Secondary side

$R_1' = \frac{(5.5 + 12j)}{25}$

$\Rightarrow R_1' = 0.22 + 0.48i$

then Equivalent circuit refered to Secondary side



3

Full Load Current $I_2 = \frac{10000}{400}$

$I_2 = 25\ A$

$\Rightarrow \vec{I_2} = 25\angle -36.87°\ A$

Now $E_2 = 400 + 25\angle -36.87\ (0.42 + 0.93j)$

$\Rightarrow \vec{E}_2 = 422.53 \angle 1.668^\circ$ V

So Secondary Voltage = 422.53 V

and voltage regulation

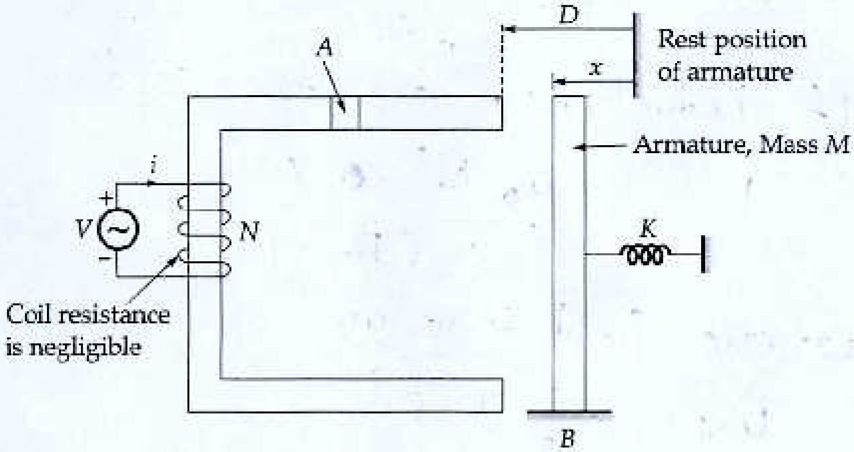
$$\% VR = \frac{E_2 - V_2}{V_2} \times 100$$

$$= \frac{422.53 - 400}{400} \times 100$$

$$\boxed{\% VR = 5.6325 \%}$$

Good through the made easy solution

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]

(i) induced emf in the coil

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

$$\Rightarrow e_c = -N \frac{d}{d\phi}(B_m \sin \omega t\ A)$$

$$\Rightarrow e_c = -N B_m A \omega \cos \omega t$$

Now $V = iR + e_c$

$$\Rightarrow i = \frac{V - e_c}{R}$$

Now induced current

$$\Rightarrow i = \frac{V + N B_m A \omega \cos \omega t}{R}$$

(ii) Reluctance offered by air gap

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

Now self inductance of the configulati

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

Now, magnetic field energy

$$W_f = \frac{1}{2} L i^2$$

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

magnetic force

$$f_e = -\frac{\partial W_f}{dx} = \frac{1}{4} \frac{\mu_0 N^2 A i^2}{(D-x)^2}$$

∴ Since $H \cdot 2(D-x) = Ni$

$$\frac{B}{\mu_0} 2(D-x) = Ni$$

Now

$$f_e = \frac{1}{4} \frac{\mu_0 A}{(D-x)^2} \frac{B^2}{\mu_0^2} 4 (D-x)^2$$

$$f_e = \frac{A B^2}{\mu_0} = \frac{A}{\mu_0} B_m^2 \sin^2 wt$$

$$\Rightarrow \boxed{f_e = \frac{A}{\mu_0} B_m^2 \sin^2 wt}$$

(iii) Magnetic force is overcome by spring force

$$f_e = Kx$$

$$\Rightarrow \frac{A}{\mu_0} B_m^2 \sin^2 wt = Kx \Rightarrow \boxed{x = \frac{A}{\mu_0 K} B_m^2 \sin^2 wt}$$

5

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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]

Sol:

(i) motor Speed = 975 RPM

Synchronous Speed $N_s = \frac{120 \times 50}{6}$

$= 1000$ RPM

Now Slip $s = \frac{N_s - N_r}{N_s}$

$= \frac{1000 - 975}{1000}$

$\boxed{S = 0.025}$

(ii) power input $P_{in} = 40$ kW

Stator Losses $= 1$ kW

then air gap power $P_g = 40 - 1$

$= 39$ kW

rotor Copper loss $P_{cu} = S P_g$

$= 0.025 \times 39$

$= 0.975$ kW

$P_{cu} = 975$ watts

(iii) power developed

$$P_d = (1-s) P_g$$

$$= (1-0.025) 39$$

$$\Rightarrow P_d = 38.025 \text{ kW}$$

and power output $= P_d - P_{rotational}$

$$= 38.025 - 2$$

$$\boxed{P_{out} = 36.025 \text{ kW}}$$

we know that $1 \text{ hp} = 746 \text{ W}$

So, output horse power,

$$P_{out} = \frac{36025}{746} = 48.29 \text{ hp}$$

(iv) Efficiency $= \frac{P_{out}}{P_{in}} \times 100$

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

$$\boxed{\% \text{ efficiency} = 90.0625 \%}$$

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Good Approach

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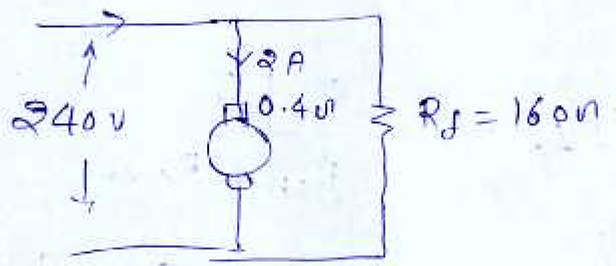
Q.1 (d) A 240 V dc shunt motor runs on no-load at 800 rpm with no extra resistance in the field or armature circuit, the armature current being 2 A. Calculate the resistance required in series with the shunt winding so that the motor may run at 950 rpm when taking a line current of 30 A. Shunt winding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

[12 marks]

Case-1



Now induced emf $E = 240 - 2(0.4)$

$E = 239.2 V$

and $I_{f_1} = \frac{240}{160} = 1.5 A$

Now speed becomes 950 RPM

$I_L = 30 A = I_a + I_{f_2}$ $\phi \propto I_f$

Now

$$\frac{E_1}{E_2} = \frac{I_{f1}}{I_{f2}} \frac{N_1}{N_2}$$

$$\Rightarrow \frac{239.2}{240-(30-I_{f_2})0.4} = \frac{1.5}{I_{f_2}} \times \frac{800}{950}$$

$$\Rightarrow \frac{239.2}{228+0.4I_{f_2}} = \frac{1.5 \times 800}{950 I_{f_2}}$$

$$\frac{239.2}{228+0.4I_{f_2}} = \frac{24}{19 I_{f_2}}$$

$$\Rightarrow 4544.8 I_{f_2} = 5472 + 9.6 I_{f_2}$$

$\Rightarrow (4535.2) I_{f_2} = 5472$

$\Rightarrow \boxed{I_{f_2} = 1.20656\ A}$

Now $I_{f_2} = \dfrac{240}{R_{sh} + R_{ext}}$

$\Rightarrow R_{sh} + R_{ext} = 198.912$

$\Rightarrow \boxed{R_{ext} = 38.912\ \Omega}$

So external resistance added in the series is $R_{ex} = 38.912$ ohm

11

Good Approach

Do not write in this margin

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]

for Transformer – A , S = 40 KVA

P_i = 500 W

P_{cu} = 500 W

Now output KWH in 24 hours

$= 40 \times 4 + \frac{1}{2} \times 8 \times 40$

$= 320$ KWH

and P_i in 24 h = 500×24

$= 12000$ WH

and

$P_{cu} = 4 \times 500 + 8 \times \left(\frac{1}{2}\right)^2 \times 500$

$= 3000$ WH

then all day efficiency for TF – A

$= \frac{320 \times 10^3}{320 \times 10^3 + 12000 + 3000}$

$\% \eta_A = 95.5223 \%$

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Similary for TF-B

$P_i = 250\ W$

$P_{cu} = 750\ W$

Output KWH in 24 hours = 320 KWH

P_i in WH $= 250 \times 24$

$= 6000$ WH

P_{cu} in WH $= 250 \times 4 + 0\left(\frac{1}{2}\right)^2 \times 250$

$= 1500$ WH

Now all day efficiency

$$\%\eta_B = \frac{320 \times 10^3}{320 \times 10^3 + 1500 + 6000}$$

$$\boxed{\%\eta_B = 97.71\%}$$

So Transformer - B has higher efficiency compare to Transformer-A

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]

Sol: Given Δ-Y Distribution Transformer having 50 KVA, 13800/208 V

per unit Impedance : $(0.01 + j0.07)$ pu

(i) for High voltage Side

Base KVA = 50 KVA

Base Voltage = 13800

$$Z_{base} = \frac{3(13800)^2}{50 \times 10^3}$$

$Z_{base} = 11426.4$ ohm

Now per phase impedance referred to H.V. Side

$Z_{actual} = (0.01 + j0.07)(11426.4)$

$Z_{actual} = (114.264 + j800)\Omega$
on HV Side

(ii) full load Current

$$I_2 = \frac{50 \times 10^3}{\sqrt{3} \times 208} = 138.786 A$$

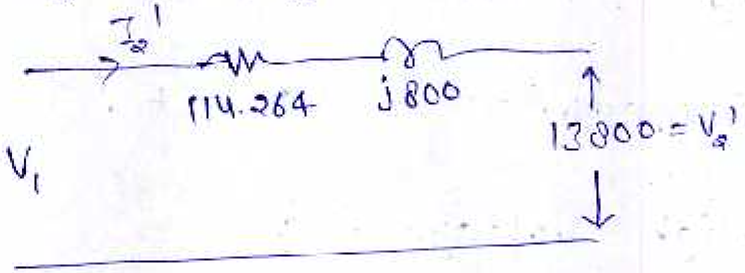
Now $\vec{I_2} = 138.786 \angle -36.87^\circ$ A

Now Current referred to primary Side

$$I_2' = 138.786 \times \frac{208}{13800 \times \sqrt{3}}$$

$$I_2' = 1.2077 \text{ A}$$

Now Equivalent Circuit Referred to high voltage Side



Now $V_1 = 13800 + 1.2077 \angle -36.87 \, (114.264 + j800)$

$$\Rightarrow V_1 = 14506.519 \angle 2.7868 \text{ V}$$

Now Voltage Regulation (VR)

$$\% \text{ VR} = \frac{V_1 - 13800}{13800} \times 100$$

$$= \frac{14506.519 - 13800}{13800} \times 100$$

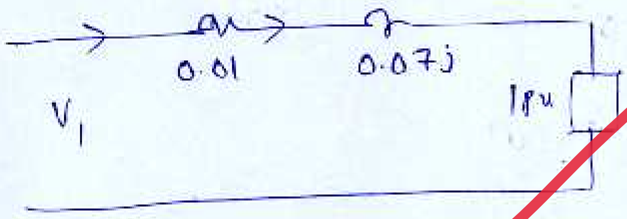
$$= 5.119\%$$

$\% \text{ VR} \simeq 5.12\%$

(iii) By using per unit system

$I_2' = 1 \angle -36.87°$

and $V_2' = 1$ pu



then

$V_1 = 1\angle 0° + 1\angle -36.87 (0.01 + 0.07j)$

$= 1.05119 \angle 2.72$ V

Now voltage regulation

$\% VR = \frac{1.05119 - 1}{1} \times 100$

$= 5.119 \%$

$\boxed{\% VR = 5.12 \%}$

So, Voltage Regulation calculated in actual ohms system and ~~at~~ per unit system are exactly same, as they should be

Good Approach

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Do not write in this margin

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]

Sol:

$X_d = 1.83\ \Omega$ power factor : 0.8

$\phi = \cos^{-1}(0.8)$

$= 36.87$

$X_q = 1.21\ \Omega$

full load current $I_a = \frac{70 \times 10^3}{\sqrt{3} \times 13.8}$

$I_a = 2928.5883\ A$

Now, $\vec{I_a} = 2928.5883 \angle -36.87°$

Now,

$E_f' = V_t + j I_a X_q$

$= \frac{13800}{\sqrt{3}} + j(2928.5883 \angle -36.87)$
1.21

$\Rightarrow E_f' = 10484.136 \angle 15.6878$

power angle $\delta = 15.6878$

Now, $\psi = \delta + \phi$

$= 15.6878 + 36.87$

$\psi = 52.5578°$

then Direct Axis current, $I_d = I_a \sin\psi$

$= 2928.58 \sin(52.55)$

$I_d = 2325.2\ A$

Now, induced emf

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

$$= 10484.136 + 2325.2(1.83 - 1.21)$$

$$E_f = 11925.76 \text{ V}$$

per phase terminal voltage

$$V_t = \frac{13800}{\sqrt{3}}$$

(i) Voltage regulation

$$\% VR = \frac{E_f - V_t}{V_t} \times 100$$

$$= \frac{11925.76 - \frac{13800}{\sqrt{3}}}{\frac{13800}{\sqrt{3}}} \times 100$$

$$\boxed{\% VR = 49.68 \%}$$

(ii) Power developed by Generator:

$$P_{dev} = S\cos\theta$$

$$= 70(0.8)$$

[There is no other losses due to negligible resistance]

$$\boxed{P_{dev} = 56 \text{ MVA}}$$

5

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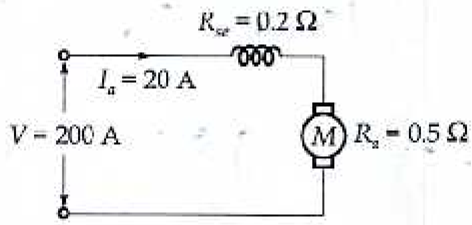
Q.2 (b) (ii) A dc series motor runs at 1000 rpm when taking 20 A at 200 V. The resistance of the armature circuit is 0.5 Ω and that of the field winding is 0.2 Ω. Find the speed for a total current of 20 A, 200 V, when a 0.2 Ω resistor is joined in parallel with the field winding. The flux for a field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



[10 marks]

Sol.

initial operation $I_a = 20$ A

$V = 200$ A

and $N_1 = 1000$ RPM, $R_T = 0.2 + 0.5 = 0.7\ \Omega$

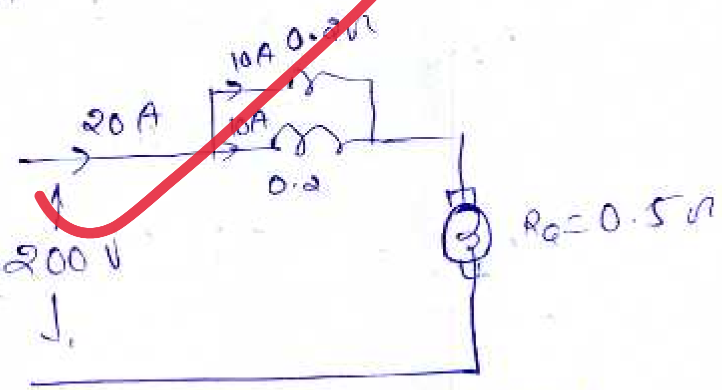
Then induced emf,

$$E_1 = V - I_a(R_T) \quad \dots (1)$$

$$= 200 - 20(0.7)$$

$$\Rightarrow \boxed{E_1 = 186\ V}$$

Now when $0.2\ \Omega$ resistor is connected in parallel with field winding then



Now $R_T = 0.5 + \frac{0.2 \times 0.2}{0.4}$

$R_T = 0.6\ \Omega$

then Corresponding induced emf, from eq. (1)

$$E_2 = 200 - 20(0.6)$$

$$\Rightarrow \boxed{E_2 = 188\ V}$$

given when parallel resistance connected then I_f becomes 10 A So corresponding flux 0.7 of initial flux

$$\phi_2 = 0.7\,\phi_1$$

Now

$$\frac{E_1}{E_2} = \frac{N_1\ \phi_1}{N_2\ \phi_2}$$

$$\frac{186}{188} = \frac{1000}{N_2} \times \frac{\phi_1}{0.7\,\phi_1}$$

$$\Rightarrow \boxed{N_2 = 1443.932\ RPM}$$

So New Speed is 1443.932 RPM, after parallel connection of resistance

05

Good Approach

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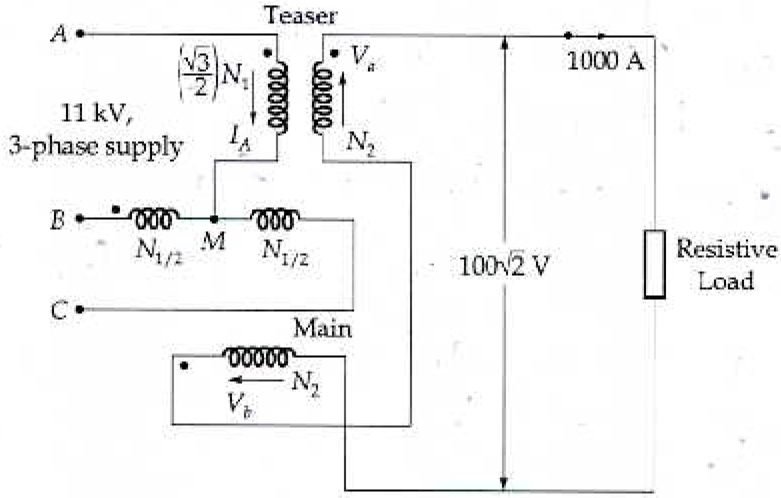
Q.2 (c) **(i)** Figure shows a Scott-connected transformer, supplied from 11 kV, 3-ϕ, 50 Hz mains. Secondaries are series-connected as shown, supply 1000 A at a voltage of $100\sqrt{2}$ V to a resistive load. The phase sequence of the 3-ϕ is *ABC*.

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]

Sol (i)

$$V_a = V_b = \frac{100\sqrt{2}}{\sqrt{2}} = 100\text{ V}.$$

~~Turn~~ Turns Ratio of Main Transformer

$$a_M = \frac{11000}{100} = 110$$

and Turns Ratio of Teaser Transformer is given by,

Now, $a_T = \frac{\sqrt{3}}{2} a_M = \frac{\sqrt{3}}{2} \times 110$

$a_T = 55\sqrt{3}$

$a_T \approx 95.26 \approx 96$

(b) (2) Current in phase A

$$I_A = \frac{I_a}{a_T} = \frac{1000}{\frac{\sqrt{3}}{2} \times 110}$$

$$\boxed{I_a = 10.5 \ A}$$

∵ Since Secondary winding are in series so $I_a = I_b$

and $$I_{BC} = \frac{I_b}{a_M} = \frac{1000}{110}$$

$$= 9.0909 \ A$$

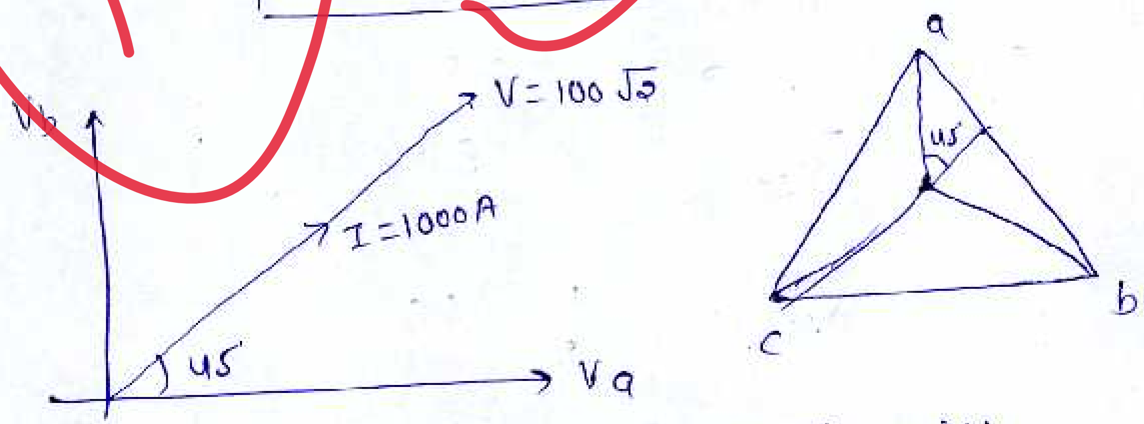
then Line Current

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

$$= 9.0909 - \frac{10.5}{2}$$

$$\boxed{I_B = 3.84 \ A}$$

11



So Current I_B lags by 45° with respect to the voltage of phase A to Neutral.

(iii) given
short circuit current 30 A at 0.2 p.f Lag when connected to 16 V, 50 Hz Source

then $I_{sc} = 30A \angle -78.463$

then $Z_{sc} = \frac{V_{sc}}{I_{sc}}$

$\Rightarrow Z_{sc} = \frac{16}{30\angle -78.463}$

$Z_{sc} = (0.10667 + j\,0.5225)\,\Omega$

Now at 25 Hz, 16 V
Re Leakage reactance will change
So, $\frac{X'_{sc}}{X_{sc}} = \frac{25}{50}$

$\Rightarrow X'_{sc} = \frac{1}{2} X_{sc}$

$\Rightarrow \boxed{X'_{sc} = 0.26127\ \Omega}$

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then New current is given as

$$I'_{sc} = \frac{V}{Z_{sc}'}$$

$$= \frac{16}{0.10667 + j\,0.26187}$$

$$\Rightarrow \quad I'_{sc} = 56.696 \angle -67.8^{\circ}\ A$$

Now Short Circuit Current = 56.696 A

and operating power factor = $\cos(67.8)$

= 0.3778 (Lagging)

Do not write in this margin

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]

Sol: for $I_f = 40$ A

$I_{sc} = 200$ A and $V_{oc} = 1100$ V

then ~~Sho~~ Sychronous Impedance is given by

$$Z_s = \frac{V_{oc(ph)}}{I_{sc}}$$

$$= \frac{1100}{\sqrt{3}\,(200)}$$

$$Z_s = 3.1754 \text{ ohm}$$

and per phase Resistance $R = 0.25$

then Synchronous Reactance $X_s = \sqrt{Z_s^2 - R^2}$

$$\boxed{X_s = 3.165\,\Omega}$$

(i) full load 0.8 power factor

full load Current $I_a = \dfrac{1200 \times 10^3}{3300 \times \sqrt{3}}$

$= 209.945$ A

$\vec{I_a} = 209.945 \angle -36.87°$ A

then induced emf

$$\vec{E_f} = \vec{V_t} + \vec{I_a}(R_a + jX_s) \quad \ldots (1)$$

$$= \frac{3300}{\sqrt{3}} + 209.945\angle{-36.87^\circ}\,(0.25 + j3.165)$$

$$\vec{E_f} = 2398.64\angle 12.03^\circ \text{ V}$$

then voltage regulation:

$$\% VR = \frac{E_f - \frac{3300}{\sqrt{3}}}{\frac{3300}{\sqrt{3}}} \times 100$$

$$= \frac{2398.64 - \frac{3300}{\sqrt{3}}}{\frac{3300}{\sqrt{3}}} \times 100$$

$$\boxed{\% V.R. = 25.89\ \%}$$

(ii) full load 0.8 leading power factor

then full load current

$$\vec{I_a} = 209.945\angle 36.87^\circ \text{ A}$$

then from Eq. (1), induced emf

$$\vec{E_f} = \frac{3300}{\sqrt{3}} + 209.945\angle 36.87^\circ\,(0.25 + j3.165)$$

$$= 1647.75\angle 19.98^\circ \text{ V}$$

then voltage regulation

$$\% VR = \frac{E_f - V_t}{V_t} \times 100$$

$$= \frac{1647.75 - 3300/\sqrt{3}}{3300/\sqrt{3}} \times 100$$

$$\boxed{\% VR = -13.51\ \%}$$

So with

0.8 p.f Lagging → % VR = 25.89%

0.8 p.f leading → % VR = −13.51%

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Good Approach

 Do not write in this margin

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]

Sol. Since Load is connected on Δ - Side then

for 3- phase balanced Load of 300kVA

Load current

$$I_{L1} = \frac{300 \times 10^3}{\sqrt{3} \times 0.4 \times 10^3}$$

$$I_{L1} = 433 \text{ A}$$

and Single phase Load of 60kVA then

$$I_{1\phi} = \frac{60 \times 10^3}{0.4 \times 10^3}$$

$$I_2 = 150 \text{ A}$$

by Energy balance Equati

$$S_T = S_1 + S_2$$

$$= 300 + 60$$

$$S_T = 360 \text{ kVA}$$

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phase current at primary side in phase - A

$$I_A = \frac{360 \times 10^3}{\sqrt{3} \times 11 \times 10^3}$$

$$\Rightarrow \quad I_A = 18.895 \text{ A}$$

Similary for phase- B

$$\vec{I_B} = 18.895 \angle -120^\circ \text{ A}$$

$$\vec{I_C} = 18.895 \angle -240^\circ \text{ A}$$

So phase current are

$$\vec{I_A} = 18.895 \angle 0^\circ \text{ A}$$

$$\vec{I_B} = 18.895 \angle -120^\circ \text{ A}$$

$$\vec{I_C} = 18.895 \angle -240^\circ \text{ A}$$

Do not write in this margin

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]

Sol.

given motor current

$\vec{I}_a = 15 A \angle 0°$

Synchronous Impedance

$Z_s = (0.4 + 7j)\ \Omega$

$= 7.0114 \angle 86.73\ \Omega$

~~then~~ and phase terminal voltage

$V_t = \frac{600}{\sqrt{3}}$

$= 346.41\ V$

Now induced Emf is given as

$\vec{E}_f = V_t - \vec{I}_a \vec{Z}_s \quad \dots (1)$

$\vec{E}_f = \frac{600}{\sqrt{3}} - 15(0.4 + 7j)$

$\Rightarrow \vec{E}_f = 356.236 \angle -17.1424\ V$

given now, field current remains constant

means excitation constant

so $\vec{E}_f = 356.236\ V$ (phase)

but current now, $I_a = 50\ A$

then from Eq. (i)

$$(I_a Z_s)^2 = (E_f)^2 + (V_t)^2 - 2 E_f V_t \cos\delta$$

$$(50(7.01))^2 = (356.236)^2 + (346.41)^2 - 2(356.23)(346.41)\cos\delta$$

by solving

$\Rightarrow$ $\boxed{\delta = 58.841^\circ}$

Now $$\vec{I_a} = \frac{\vec{V_t} - \vec{E_f}\angle -58.841}{(0.4+7j)}$$

$\Rightarrow$ $\vec{I_a} = 50\angle -25.258^\circ$ A

So New power factor : $\cos(25.258)$

$\boxed{p.f. = 0.9044 \text{ (Lagging)}}$

Part - II

Input power $P_{in} = \sqrt{3} \times 600 \times 50 \times 0.9044$

$= 47$ KW

and Resistance Cu Loss $= 3 I^2 R$

$= 3(50)^2(0.4)$

$= 3$ KW

So power developed $= P_{in} - P_{loss}$

$= 47 - 3$

$\boxed{P_{dev} = 44 \text{ KW}}$

Now, Sychronous Speed :,

~~$\omega_s = 4\pi$~~ $N_s = \frac{120 \times 50}{6}$

$N_s = 1000$ RPM

$\Rightarrow \quad \omega_s = \frac{2\pi \times 1000}{60} = 104.719$ rad/sec

Now, Torque developed $= \frac{P_{dev}}{\omega_s}$

$= \frac{44000}{104.719}$

| T_{gross} / T_{dev} = 420.172 N-m |

So New power factor : 0.904 lagging

and T_{dev} = 420.172 N-m

Good Approach

18

Do not write in this margin

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]

Do not write in this margin

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]

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]

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]

Do not write in this margin

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]

(i) given voltage Rating = 60 kV/RMS

safe electric stress g = 4 kV/mm

$V = g\, r \ln\left(\frac{R}{r}\right)$

for minimum overall diameter

$\frac{R}{r} = e$

$\Rightarrow 60 = 4r$

$\Rightarrow r = 15$ mm

Radius of inter sheath

R = 40.77 mm

and Diameter is D = 81.548 mm

10

Do not write in this margin

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]

Sol:

$$Z_{Line} = (10 + 30j)$$

$$= 31.6227 \angle 71.565$$

(i) for maximum power ~~δ = θ~~ β = δ

then P_{max} is

$$P_{max} = \frac{V_s V_R}{|Z|} - \frac{V_R^2}{|Z|} \cos(\beta)$$

$$= \frac{132 \times 132}{31.6227} - \frac{132^2}{31.6227} \times \frac{10}{31.6227}$$

$$\boxed{P_{max} = 376.755 \text{ MW}}$$

(ii) phase difference b/w V_s and V_R under max. power transmitted is 71.565

(iii) $P_R = 100\ MW = P_{Load}$ $Q_{Load} = 48.4322$ MVAR

Now

$$100 = \frac{132\times132}{31.6227}\cos(\beta-\delta) - \frac{132\times132}{31.6227}\times\frac{10}{31.6227}$$

by solving

$\Rightarrow$ $\cos(\beta-\delta) = 0.4977$

$\Rightarrow$ $\beta-\delta = 60.152$

Now

$$Q_R = \frac{132\times132}{31.6227}\sin(60.152) - \frac{132\times132}{31.6227}\times\frac{30}{31.6227}$$

$Q_R = -44.8162$ MVAR

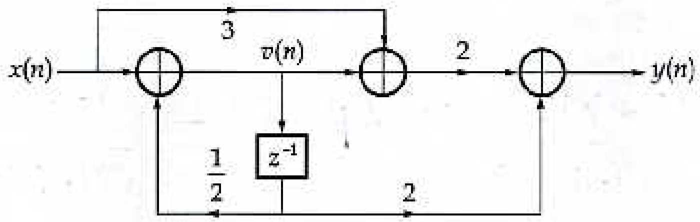
Now Rating of Synchronous phase modifier is $= |Q_R| + Q_{Load}$

$\boxed{Q_{SPM} = 93.24\ MVAR}$

11

Good Approach

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



[12 marks]

Sol: for obtaining TF,

$$(1-\tfrac{1}{2}z^{-1})$$

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

then by solving, Transfer function:

$$\Rightarrow \frac{Y(z)}{X(z)} = \frac{8-z^{-1}}{1-\frac{1}{2}z^{-1}}$$

$$\Rightarrow \frac{Y(z)}{X(z)} = H(z) = \frac{8}{1-\frac{1}{2}z^{-1}} - \frac{z^{-1}}{1-\frac{1}{2}z^{-1}}$$

taking inverse ZT we have

$$h(n) = 8\left(\tfrac{1}{2}\right)^n u(n) - \left(\tfrac{1}{2}\right)^{n-1} u(n-1)$$

for Right side signal

11

Good Approach

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]

Sol: (i) given difference equation $x(n) \rightleftharpoons X(z)$

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

by applying ZT, we have

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

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

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

for $n \geq 0$, means Right-sided Signal

So ROC is outside to the outermost pole

So ROC: $|z| > \frac{1}{2}$

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

by taking inverse ZT we have

$$y(n) = \frac{1}{4}\left(\frac{1}{2}\right)^{n+1} u(n) + 3\left(\frac{1}{2}\right)^{n} u(n) - 2\left(\frac{1}{3}\right)^{n} u(n)$$

$n \geq 0$

(ii) for given difference equation applying ZT

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

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

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

$$\Rightarrow Y(z) = \frac{-0.75 - 0.25z^{-1}}{1 + \frac{1}{2}z^{-1} + \frac{1}{4}z^{-2}}$$

by Long division method,

$1 + \frac{1}{2}z^{-1}$)

$$1+\frac{1}{2}z^{-1}+\frac{1}{4}z^{-2} \overline{) -0.75 - 0.25z^{-1}} \left(-0.75+0.125z^{-1}\right.$$

$$-0.75 - 0.375z^{-1} - 0.1875z^{-2}$$

$$+ \quad\quad +$$

$$0.125z^{-1} + 0.1875z^{-2}$$

$$0.125z^{-1} + 0.0625z^{-2} + 0.03125z^{-3}$$

$$-$$

$$0.125z^{-2} - 0.03125z^{-3}$$

So

$$Y(z) = -0.75 + 0.125z^{-1} - - -$$

taking inverse Z-Transform

$$y(n) = -0.75\,\delta(n) + 0.125\,\delta(n-1) + - - -$$

16

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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
(i) 16-bit Address	(i) 8-bit Address
(ii) all instruction related to memory can be used EX: MOV A,M, STA, LDA, STAX, LDAX etc.	(ii) a instruction used all IN and OUT
(iii) Data transfer beween memory and any register	(iii) Data transfer between accumulator and I/O devices only.
(iv) More hardware is required to decode 16-bit address.	(iv) Less hardware to decode 8-bit address required
(v) Control Signals $\overline{MEMW}$ $\overline{MEMR}$ are used	(v) Control Signal $\overline{IOR}$ and $\overline{IOW}$ are used to read and write data

(vi) Arithmatic and Logical operation can performed directly on data	(vi) There is no such provision in I-O mapping in 8085
(vii) Memory map is shared b/w memory and I/o devices	(vii) I/o map is independent of mainmemory

10

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]

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]

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]

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]

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]

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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]

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]

Do not write in this margin

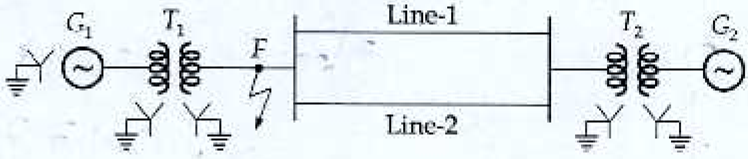
Q.7 (c) (ii) Write a program for transferring sixteen bytes of data stored in memory location at XX50H to XX5FH. Transfer the entire data set to new memory location starting at XX70H.

[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:

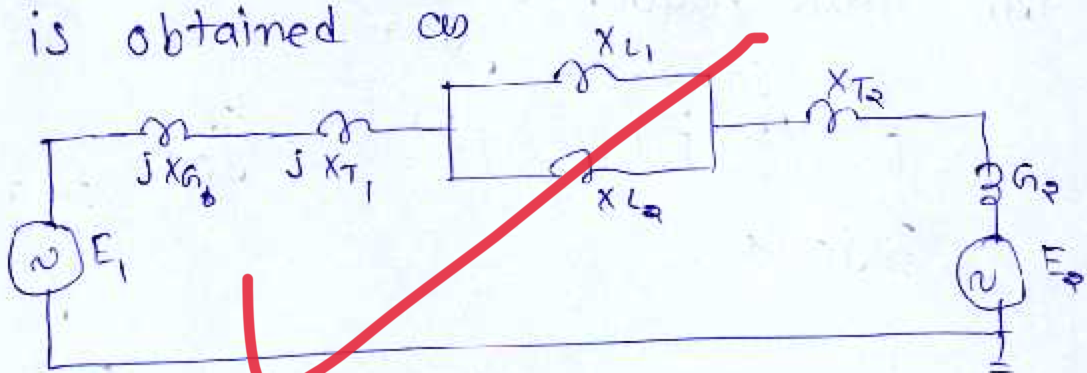
	X_0	X_1	X_2
Generator G_1	0.05	0.3	0.2
Generator G_2	0.03	0.25	0.15
Line 1	0.70	0.3	0.3
Line 2	0.70	0.3	0.3
Transformer T_1	0.12	0.12	0.12
Transformer T_2	0.10	0.1	0.1

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

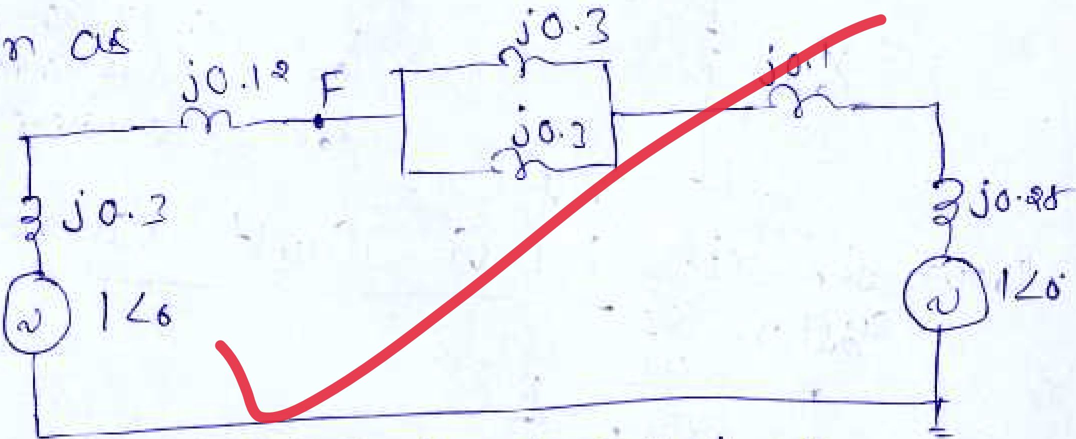


[20 marks]

Sol: Single-line Diagram of above system is obtained as



Now positive Sequence Network is Drawn as

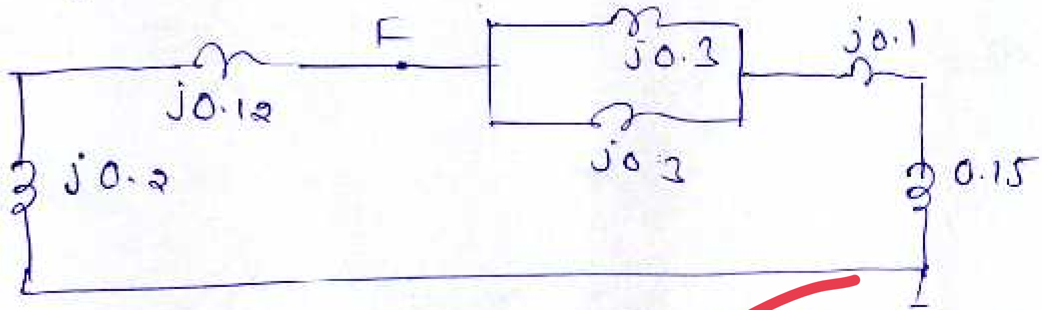


Equivalent Network at point - F

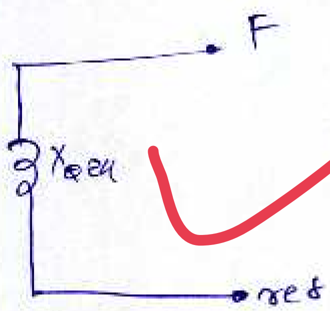
j0.22896 pu

1∠0

then Negative Sequence ~~Imq~~ Network



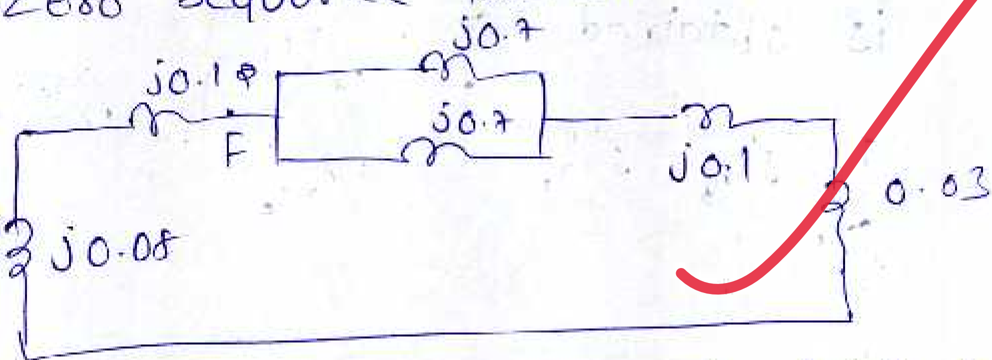
Now Equivalent Network at fault point - F



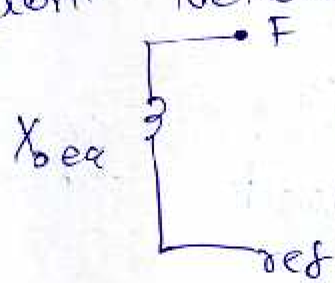
$$X_{2eq} = \frac{0.32 \times 0.4}{0.4 + 0.32}$$

$$= j\,0.1778 \text{ pu}$$

Now Zero Sequence Network of system



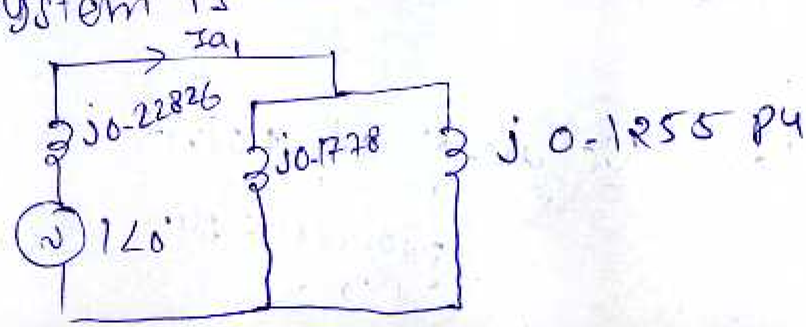
Equivalent Network at fault point - F



$$X_{0eq} = \frac{0.17\,(0.48)}{0.17 + 0.48}$$

$$X_{0eq} = 0.1255 \text{ pu}$$

Now for (i) LLG fault Connected system is



Now positive sequence current

$$I_{a_1} = \frac{1}{0.22826 + \left(\frac{0.1770 \times 0.1255}{0.1255 + 0.1770}\right)}$$

$$I_{a_1} = -j3.3325 \text{ pu}$$

Now $$I_{a_0} = 3.3325 \left(\frac{0.1770}{0.1770 + 0.1255}\right)$$

$$= -j1.9536 \text{ pu}$$

So fault current $|I_f| = 3 I_{a_0}$

$$\Rightarrow |I_f| = 5.86 \text{ pu}$$

(ii) Now for L-L fault

fault current is given by

$$I_f = \frac{\sqrt{3}}{Z_1 + Z_2} = \frac{\sqrt{3}}{X_1 + X_2}$$

$$I_f = -j\,4.2655 \text{ pu}$$

$$\Rightarrow |I_f| = 4.265 \text{ pu}$$

12

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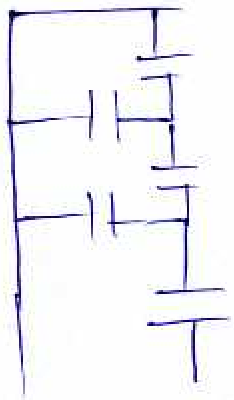
Q.8 (b) Find the voltage distribution and string efficiency of a three unit suspension insulator string if the capacitances of the link pins to earth and to the line are respectively 20 per cent and 10 per cent of the self capacitance of each unit. If a guard ring increases the capacitance to the line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

Sol:



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]

Sol:

(i) PROM: (Programmable Read only memory)

- By using the programmed code it help to read the memory in better and effecient way.

(ii) EPROM: [Electrically Programmed Read only memory]

- In this the information transfer is by Electrically programmed code that causes fast memory read operation.

(iii) EEPROM: (Electrically Erasable Programmed Read only memory)

- Data can be erased by electrical phenoman that is stored in ROM.

(iv)(4) ~~ASI~~ MASK ROM: It Signifies that memory operation is unaffected by the ongoing processor operation So It has no effect by ~~mem~~ processor operation

(5) CONTROL BUS: It is a 16-bit bus having direct control over data or memory address used by either data bus or address bus during execution of an program.

- It provides control over instruction ~~Sequ~~ address that has to be fetched from memory.

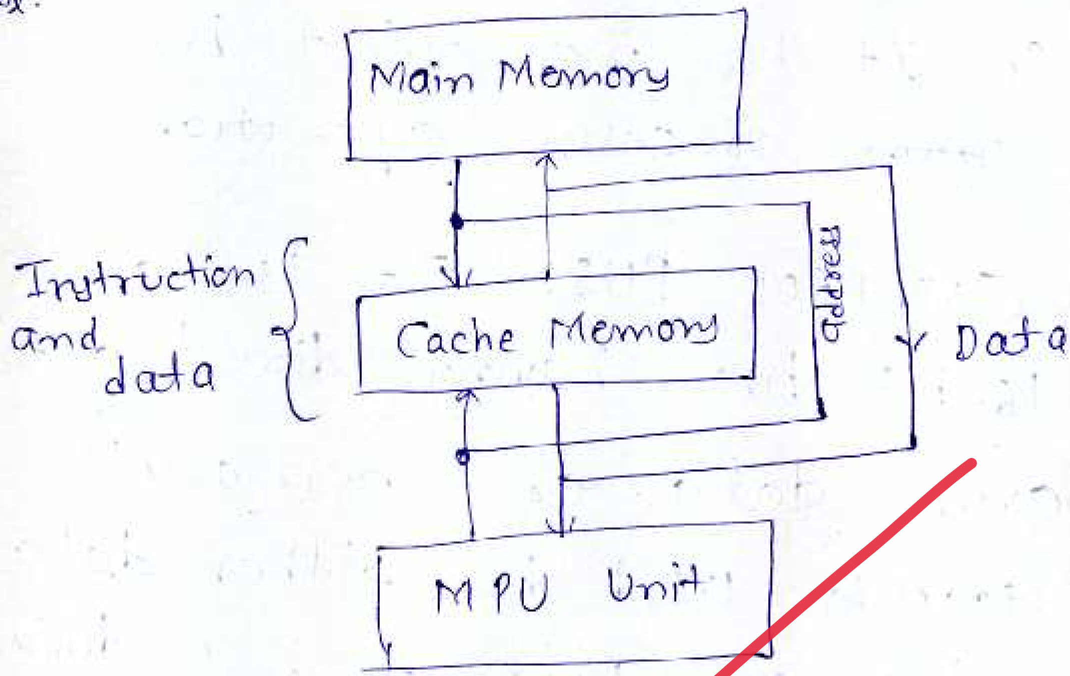
6

Elaborate it more

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]

Sol:



Steps needed for data flow:

(i) There are several steps are taken for transferring data from main memory to MPU unit.

(i) Processor issues a address to memory register through address bus.

(ii) Processor gives read command through control bus.

(iii) Memory accepts it and retrive data through data bus.

→ Data Transfer can be from memory to processor (read) and data Transfer from processor to memory.

→ Main Concern in data transfer is speed mismatch b/w MPU unit and Memory So fast and small memory cache memory is used to eliminating the Speed mismatch issue.

2

Elaborate it more

Space for Rough Work

Space for Rough Work

Space for Rough Work

$\frac{13800}{200/\sqrt{3}}$