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ESE 2026 : Mains Test Series

UPSC ENGINEERING SERVICES EXAMINATION

Electrical Engineering

Test-3 : Power Systems
+ Digital Electronics-1 + Microprocessor-1
+ Electrical Circuits-2 + Systems and Signal Processing-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	43
Q.2	56
Q.3	
Q.4	
Section-B	
Q.5	14
Q.6	13
Q.7	45
Q.8	
Total Marks Obtained	171

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.

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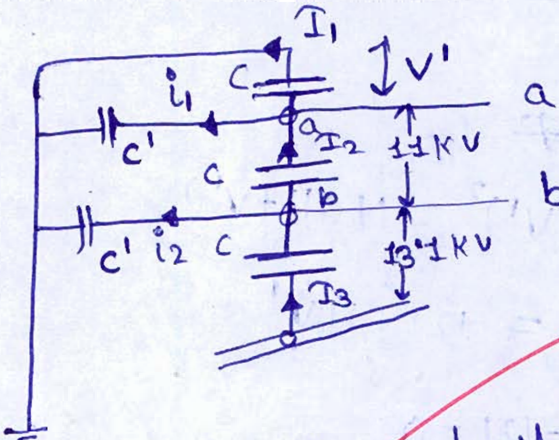
Section A : Power Systems

(a) The three bus-bar conductors in an outdoor substation are supported by units of post type insulators. Each unit consists of a stack of 3-pin type insulators fixed one on the top of the other. The voltage across the lower insulator is 13.1 kV and that across the next is 11 kV. Find the bus-bar voltage of the station.

[12 marks]



Assume c' be the capacitance between pin to earth

by KCL at a,

$$i_1 + I_1 = I_2$$

$$V'\omega c' + V'\omega C = (11K)\omega C$$

$$V'(c'+C) = (11K)C$$

$$V'\left(\frac{c'}{C}+1\right) = 11 \quad \text{—①}$$

(let V' is also in KV)

by KCL at b,

$$I_3 = i_2 + I_2$$

$$(13.1)\omega C = (11 + V')\omega c' + (11)\omega C$$

$$13.1\,C = 11c' + V'c' + 11C$$

$$2.1\,C = (11 + V')c'$$

$$\frac{2.1}{11+V'} = \frac{c'}{C} \quad \text{—②}$$

substituting ② in ①',

$$V'\left(\frac{2.1}{11+V'}+1\right)=11$$

$$2.1V'+11V'+(V')^2=11(11+V')$$

$$(V')^2+13.1V'=121+11V'$$

$$(V')^2+2.1V'-121=0$$

$$\boxed{V'=10\,KV}$$

hence phase voltage is,

$$V_{ph}=V'+11+13.1$$

$$V_{ph}=10+11+13.1$$

$$\boxed{V_{ph}=34.1\,KV}$$

line voltage is $V_{l-l}=V_{ph}\times\sqrt{3}$

$$\boxed{V_{l-l}=59.06\,KV}$$

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Good Approach

Do not write in this margin

(b) A certain 3-phase equilateral transmission line has a total corona loss of 53 kW at 106 kV and a loss of 98 kW at 110.9 kV. What is the disruptive critical voltage? What is the corona loss at 113 kV?

[12 marks]

(b) $P_L = 53\,kW$ @ $106\,kV$

$P_L = 98\,kW$ @ $110.9\,kV$

as we know;

$$P_L = 242\times10^{-5} \times \left(\frac{f+25}{\delta}\right)\times\sqrt{\frac{r}{d}} \times (V_c - V_{ph})^2 \; kW/km/ph$$

$\Rightarrow$ $P_L \propto (V_c - V_{ph})^2$ —(a)

case① | $V_{l-l} = 106\,kV$

$\therefore V_{ph} = 61.2\,kV$

$P_{L_1} \propto (V_c - 61.2\times10^3)^2$ —①

case② | $V_{l-l} = 110.9\,kV$

$\therefore V_{ph} = 64.02\,kV$

$\therefore P_{L_2} \propto (V_c - 64.02\times10^3)^2$ —②

① ÷ ②,

$$\frac{P_{L_1}}{P_{L_2}} = \left(\frac{V_c - 61.2\times10^3}{V_c - 64.02\times10^3}\right)^2$$

$$\frac{53}{98} = \left(\frac{V_c - 61.2\times10^3}{V_c - 64.02\times10^3}\right)^2$$

$$0.735\,V_c - 47.08\times10^3 = V_c - 61.2\times10^3$$

$$\boxed{\therefore V_c = 53.28\,kV}$$

$\therefore P_L \propto (53.28 - V_{ph})^2$ (V_{ph} in kV)

$P_L = a(53.28 - V_{ph})^2$ — (a)

for $V_{ph} = 61.2$ kV, $P_L = 53$ kW

$\frac{53 \times 10^3}{(53.28 - 61.2)^2} = a$

$\boxed{a = 844.94}$

substituting in (a),

$P_L = 844.94(53.28 - V_{ph})^2$ in watts

for $V_L = 113$ kV

$P_L = 844.94\left(53.28 - \frac{113}{\sqrt{3}}\right)^2$

$P_L = 120873.3$

$\therefore$ Power loss due to corona = 120.87 kW at 113 kV

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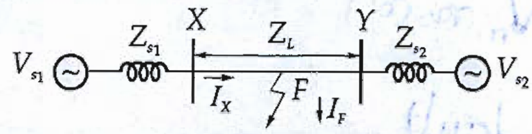
Good Approach

(c) Given that: $V_{s1} = V_{s2} = 1 + j0$ p.u, +ve sequence impedance are:
$Z_{s1} = Z_{s2} = 0.001 + j0.01$ p.u and $Z_L = 0.006 + j0.06$ p.u, 3-ϕ. Base MVA = 100, voltage base = 400 kV(L – L). Nominal system frequency = 50 Hz.

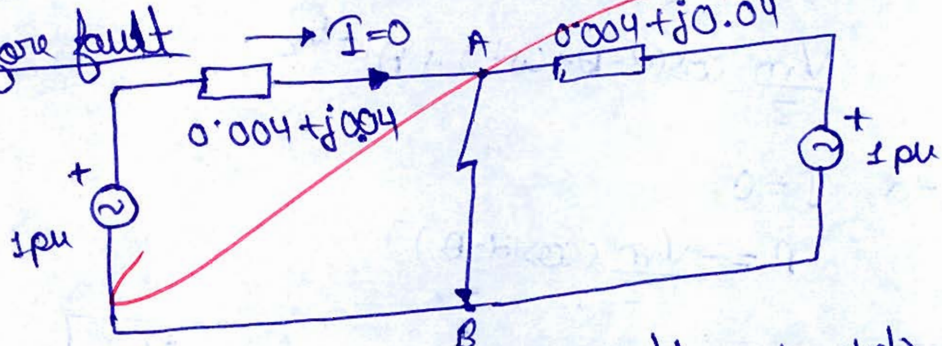


The reference voltage for phase 'a' is defined as $V(t) = V_m \cos(\omega t)$. A symmetrical 3-ϕ fault occurs at centre of the line, i.e. at point 'F' at time 't_0' the +ve sequence impedance from source S_1 to point 'F' equals (0.004 + j0.04) p.u. The wave form corresponding to phase 'a' fault current from bus X reveals that decaying d.c. offset current is –ve and in magnitude at its maximum initial value. Assume that the negative sequence are equal to +ve sequence impedances and the zero sequence impedance (Z) are 3 times +ve sequence (Z). Find the instant (t_0) of the fault.

[12 marks]

As both side of fault is symmetric, hence, for a 3-ϕ fault at F, equivalent per unit per phase circuit can be developed as,

Before fault

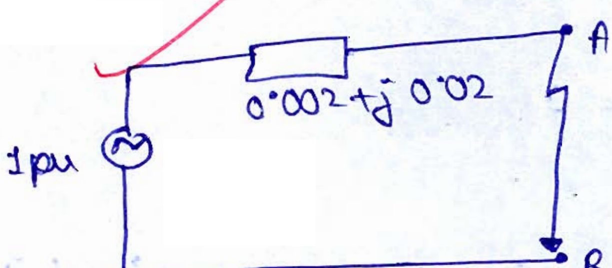


thevenin across AB, (Before fault unloaded)

$V_{th} = 1$ pu

$Z_{th} = (0{\cdot}004 + j0{\cdot}04) \,||\, (0{\cdot}004 + j0{\cdot}04)$

$Z_{th} = 0{\cdot}002 + j0{\cdot}02$



let at the instant of fault,

$$V_{AB} = V_m \cos(\alpha)$$

∴ t=0 instant of fault

$$I_{s.s.} = \frac{V_m}{Z}\cos(\alpha - \theta + \omega t)$$

— (steady state)

for transient,

$$I_{tr} = Ae^{-t/\tau}$$

$$\therefore\ I = I_{ss} + I_{tr}$$

$$I = \frac{V_m}{Z}\cos(\alpha - \theta + \omega t) + Ae^{-t/\tau}$$

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as $t=0$, $I=0$

$$A = -\frac{V_m}{Z}(\cos(\alpha - \theta))$$

Good Approach

$$\boxed{I = \frac{V_m}{Z}\cos(\alpha - \theta + \omega t) - \frac{V_m}{Z}e^{-t/\tau}\cos(\alpha-\theta)}$$

as said DC offset current is at it's negative Maximum,

at $t=0$, $\frac{V_m}{Z}\cos(\alpha - \theta + \omega t)$ should be at its positive peak,

$$\Rightarrow\ \alpha - \theta + \omega t = 0$$

$$\alpha = \theta$$

$$\therefore\ \alpha = \tan^{-1}\left(\frac{0.04}{0.004}\right) = 84.29^\circ = 1.471 \text{ radian}$$

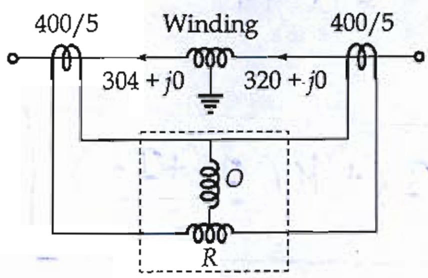
~~$\omega t_0 = 84.29$~~

~~$\therefore\ t_0 = \frac{84.29}{2\pi \times 50}$~~

$$\omega t_0 = 1.471$$

$$\boxed{t_0 = \frac{1.471}{2\pi \times 50} = 4.68 \text{ mS}}$$

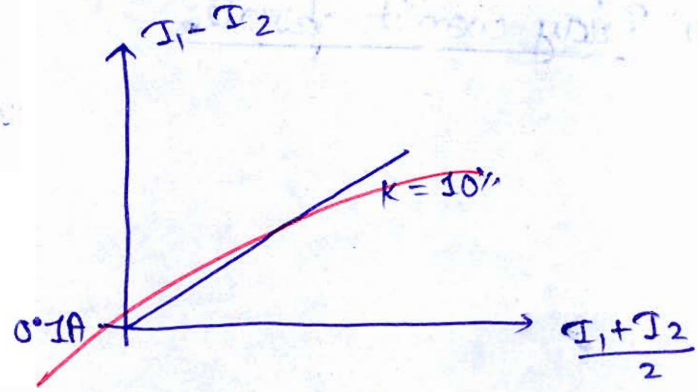
(d) The figure given below shows percentage differential relay applied to the protection of an alternator winding. The relay has 0.1 ampere minimum pick-up and 10% slope of characteristic $(I_1 - I_2)$ vs $(I_1 + I_2)/2$. A high-resistance ground fault occurred near the grounded neutral end of generator winding, while the generator is carrying load. As a consequence, the currents in ampere flowing at each end of the winding are shown in the figure. Assume CT ratio of 400/5. Will the relay operate to trip the breaker?

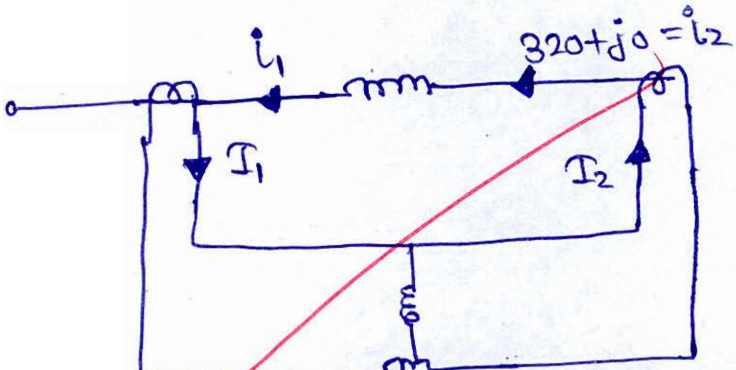


[12 marks]

$I_{pk} = 0.1A$

$K = 10\%$





$I_1 = $ C.T. Ratio (i_1)

$I_1 = \frac{5}{400} \times 304$

$I_1 = 3.8\ A$

$I_2 = $ C.T. Ratio (i_2)

$I_2 = \frac{5}{400} \times 320$

$I_2 = 4A$

from characteristics,

for Relay operation,

$(I_2 - I_1) \geq I_0 + K\left(\frac{I_1 + I_2}{2}\right)$

$I_2 - I_1 = 0.2A$

$$I_0 + K\left(\frac{I_1+I_2}{2}\right) = 0.1 + 0.1\left(\frac{3.8+4}{2}\right)$$

$$= 0.49$$

as

$$(I_2 - I_1) \leqslant I_0 + K\left(\frac{I_1+I_2}{2}\right)$$

hence Relay won't operate.

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1 (e) A synchronous generator of reactance 1.20 p.u. is connected to an infinite bus bar ($|V| = 1.0$ p.u.) through transformers and a line of total reactance of 0.60 p.u. The generator no-load voltage is 1.20 p.u. and its inertia constant is $H = 4$ MW s/MVA. The resistance and machine damping may be assumed negligible. The system frequency is 50 Hz. Calculate the frequency of natural oscillations if the generator is loaded to 80% of its maximum power limit.

[12 marks]

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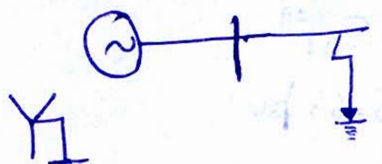
2 (a) (i) A three-phase, 100 MVA, 25 kV generator has solidly grounded neutral. The positive, negative and the zero sequence reactances of the generator are 0.2 pu, 0.2 pu and 0.05 pu, respectively, at the machine base quantities. If a bolted single phase to ground fault occurs at the terminal of the unloaded, generator. Find the fault current in amperes immediately after the fault.

[10 marks]

(2)(a)(i)

100 MVA, 25 KV



$X_g^{(1)} = 0.2$ pu

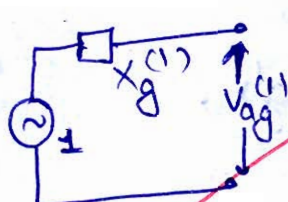
$X_g^{(2)} = 0.2$ pu

$X_g^{(0)} = 0.05$ pu

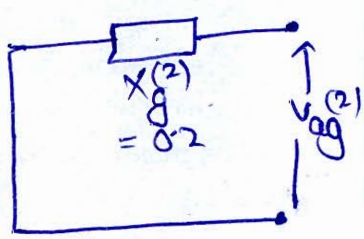
Positive sequence,

Let $S_{Base} = 100$ MVA

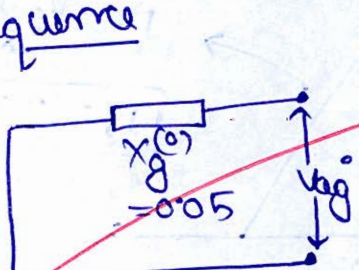
$V_{Base} = 25$ KV



Negative Sequence

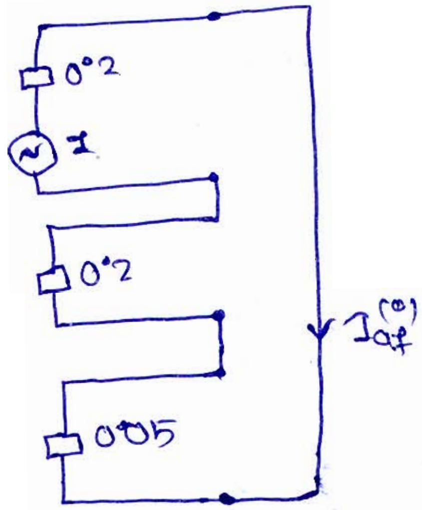


Zero sequence



connecting all the three impedance network in series and as we know,

$$\boxed{I_F = 3I_{af}^{(0)}} \quad -(1)$$



$I_{af}^{(0)} = \frac{1}{0.2 + 0.2 + 0.05}$

$I_{af}^{(0)} = \frac{1}{0.45} = 2.22$ pu

$\therefore I_F = 3 I_{af}^{(0)}$

$= 6.66$ pu

$I_{Base} = \frac{S_{Base}}{\sqrt{3}\, V_{Base}} = \frac{100 \times 10^6}{\sqrt{3} \times 25 \times 10^3} = 2.31$ KA

$\therefore$ $I_f = 15.380$ KA

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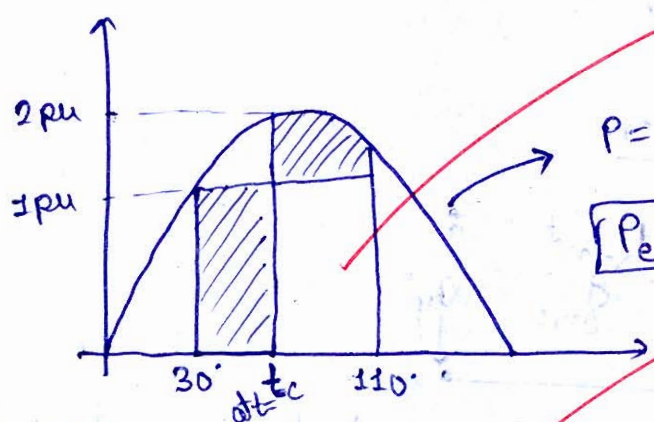
Q.2 (a) **(ii)** A generator delivers power of 1.0 p.u. to an infinite bus through a purely reactive network. The maximum power that could be delivered by the generator is 2.0 p.u. A three-phase fault occurs at the terminals of the generator which reduces the generator output to zero. The fault is cleared after t_c second. The original network is then restored. The maximum swing of the rotor angle is found to be δ_{max} = 110 electrical degree. Calculate the rotor angle in electrical degrees at $t = t_c$.

[10 marks]

for above Power (vs) load angle,



$P = \frac{V_S V_R}{X_S} \sin\delta$

$P_e = 2 \sin\delta$

$P = \frac{V_S V_R}{X_S} \sin(\delta)$

at $\delta = 90$

$P = 2$ $\therefore$ $X_S = 0.5$ (assuming $1 = V_S = V_R$)

∴ at normal state, P = 1 pu

$$1 = \frac{V_S V_R}{X_S} \sin\delta_1$$

$$\sin\delta_1 = X_S = 0.5$$

$$\therefore \boxed{\delta_1 = 30}$$

by equal Area criteria, area of both shaded region should be equal,

let δ_c be angle bo clearing,

$$\int_{\delta_1}^{\delta_c} (P_M - P_e)\, d\delta = \int_{\delta_c}^{110} (P_e - P_m)\, d\delta$$

as $P_M = 1$ PU

$$\int_{\frac{\pi}{6}=\delta_1}^{\delta_c} 1\, d\delta = \int_{\delta_c}^{1.92} (2\sin\delta - 1)\, d\delta$$

$$[\delta_c - \frac{\pi}{6}] = [-2\cos\delta]_{\delta_c}^{1.92} - [\delta]_{\delta_c}^{1.92}$$

$$\delta_c - \frac{\pi}{6} = [2\cos\delta_c - 2\cos(1.92)] - 1.92 + \delta_c$$

$$2\cos(1.92) + 1.396 = 2\cos\delta_c$$

$$\boxed{\delta_c = 1.2069 \text{ radian}}$$

$$\delta_c = 1.2069 \times \frac{180}{\pi} \text{ degree}$$

$$\boxed{\delta_c = 69.15^\circ}$$

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Good Approach

Q.2 (b) A 50 Hz, 3 phase transmission line 300 km long has total series impedance of (40 + *j*125) ohm and a total shunt admittance of 10^{-3} mho. The receiving end load is 50 MW at 220 kV with 0.8 lagging power factor. Calculate the sending end voltage, current, power and power factor using:

(i) Short line approximation.

(ii) Nominal π method.

(iii) Exact transmission line equation of long line.

(iv) Approximation of long line.

[20 marks]

$l = 300\text{ Km}$

$Z = 40 + j125$

$Y = 10^{-3} j$

$P_R = 50 \times 10^6$ W

$V_R = 220 \times 10^3$ V

$\therefore |I_R| = \dfrac{P_R}{\sqrt{3}\, V_R \times \cos\phi}$

$|I_R| = 164.02$ A

$\therefore I_R = |I_R| \angle -\cos^{-1}(0.8)$

$I_R = 164.02 \angle -36.87$ A

(i) short line Model,

$V_S = A V_R + B I_R$

$A = 1,\ B = Z = 40 + j125$

$(V_R)_{ph} = 127$ KV

on solving

$(V_S)_{ph} = 145.08 \angle 4.92$

$(I_S) = (I_R) = 164.02 \angle -36.87$

$(V_S)_{L-L} = 145.08 \times \sqrt{3}$

$(V_S)_{L-L} = 251.297$ KV

$I_S = 164.02 \angle -36.87$ A

power factor $= \cos(4.92 + 36.87)$
$= 0.745$ lagg

Power at sending end $= \sqrt{3}\ V_S I_S \cos\phi$

$P_S = 53.184$ KW

(ii) Nominal π-model,

$D = A = 1 + \frac{YZ}{2} = 0.9377 \angle 1.222$

$B = Z = 40 + 125j$

$C = Y\left(1 + \frac{YZ}{4}\right) = 9.688 \times 10^{-4} \angle 90.59$

$\therefore V_S = AV_R + BI_R$

$V_S = A(127 \times 10^3) + (164.02 \angle -36.87) B$

$(V_S)_{ph} = 137.43 \angle 6.28$

$\therefore (V_S)_{L-L} = 238.04$ kV

$I_S = CV_R + DI_R$

$I_S = 128.14 \angle 15.11$ A

~~∴ power factor = cos(15.11 + 36.87)~~

~~= [illegible]~~

$\therefore$ power factor $= \cos(15.11 - 6.268)$
$= 0.988$ lead

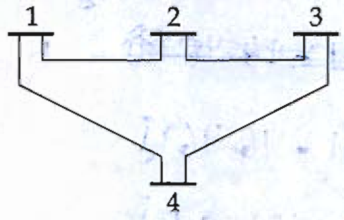
$P_S = \sqrt{3}\ V_S I_S \cos\phi$

$P_S = 52.197$ KW

18

Try to avoid over writing

.2 (c) The figure below shows a four-bus system.



The shunt admittances at the buses are negligible. The line impedances are as under:

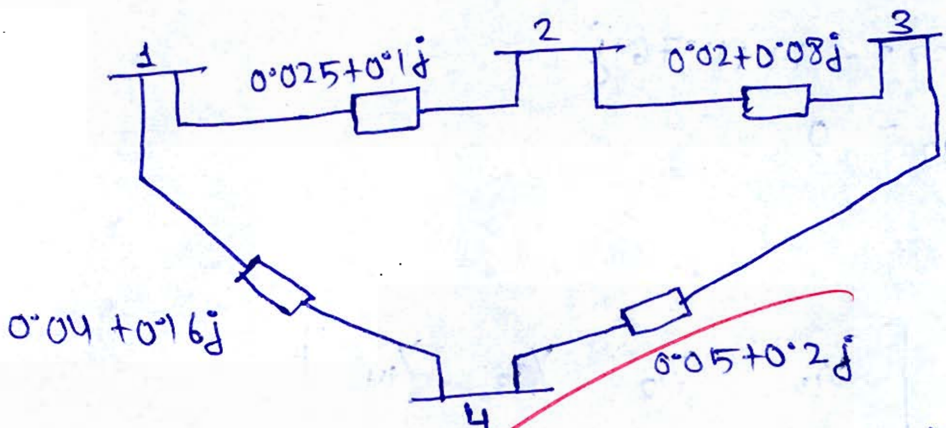
Line (bus to bus)	:	1 - 2	2 - 3	3 - 4	4 - 1
R(p.u.)	:	0.025	0.02	0.05	0.04
X(p.u.)	:	0.10	0.08	0.20	0.16

(i) Formulate Y_{bus}.

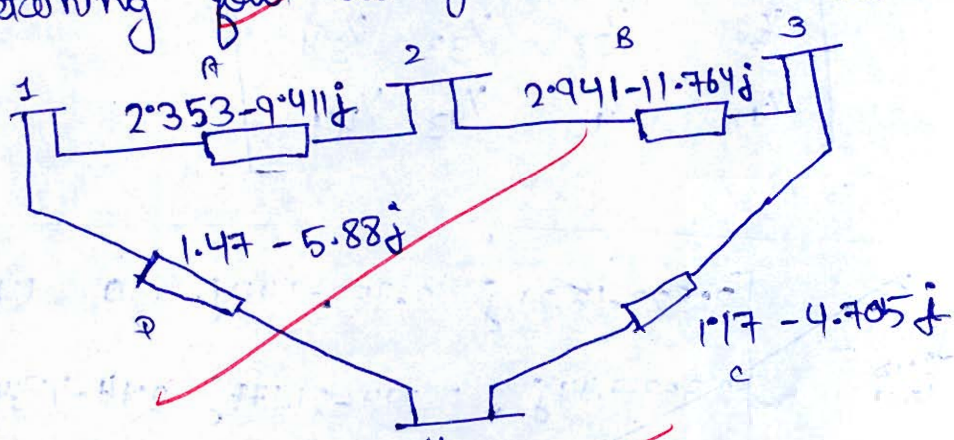
(ii) Which elements of the Y_{bus} obtained in (i) are affected when a new line from bus 1 to bus 3 is added?

[20 marks]

Q2 (c)



(i) obtaining four bus system in Admittance values



for 4 bus system:

size of Y-bus : 4×4

diagonal elements : sum of Admittances connected to Bus

off diagonal elements : Admittance between 2 Buses multiplied -1

$[Y_{11}] = Y_{12} + Y_{14} = 3.823 - 15.291j$

$[Y_{22}] = Y_{21} + Y_{23} = 5.294 - 21.175j$

$[Y_{33}] = Y_{23} + Y_{34} = 4.111 - 16.469j$

$[Y_{44}] = Y_{41} + Y_{43} = 2.64 - 10.585j$

$Y_{12} = Y_{21} = -2.353 + 9.411j$

$Y_{13} = Y_{31} = 0$

$Y_{14} = Y_{41} = -1.47 + 4.705j \quad Y_{43} = Y_{34} = -1.17 + 4.705j$

$Y_{23} = Y_{32} = -2.94 + 11.764j$

$Y_{24} = Y_{42} = 0$

Y- Bus,

$$[Y] = \begin{bmatrix} Y_{11} & Y_{12} & Y_{13} & Y_{14} \\ Y_{21} & Y_{22} & Y_{23} & Y_{24} \\ Y_{31} & Y_{32} & Y_{33} & Y_{34} \\ Y_{41} & Y_{42} & Y_{43} & Y_{44} \end{bmatrix}$$

$$\therefore [Y]_{Bus, 4\times4} = \begin{bmatrix} 3.823-15.291j & 2.353-9.411j & 0 & 1.47-4.705j \\ 2.353-9.411j & 5.294-21.175j & 2.94-11.764j & 0 \\ 0 & 2.94-11.764j & 4.111-16.469j & \\ 1.47-4.705i & 0 & 1.17-4.705j & 2.64-10.585j \end{bmatrix}$$

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$$[Y]_{Bus\ 4\times4} = \begin{bmatrix} 3.823-15.291j & -2.353+9.411j & 0 & -1.47+4.705j \\ -2.353+9.411j & 5.294-21.175j & -2.94+11.764j & 0 \\ 0 & -2.94+11.764j & 4.111-16.469j & -1.17+4.705j \\ -1.47+4.705j & 0 & -1.17+4.705j & 2.64-10.585j \end{bmatrix}$$

(ii) As we know adding an element between two Buss is done as, (let's say ① & ③)

$$[Y]_{Bus_{new}} = [Y]_{Bus_{old}} + \begin{matrix} \text{①} \\ \text{①} \end{matrix}\overset{\text{①} \quad \text{③}}{\begin{bmatrix} 1 & -1 \\ -1 & 1 \end{bmatrix}} [Y] \text{ element}$$

∴ $y_{11}, y_{13}, y_{31}, y_{33}$ these 4 element will get affected by addition of new element.

18

Good Approach

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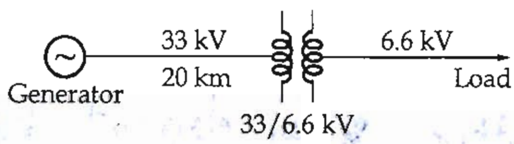
Q.3 (a) (i) A 3-phase load of 2000 kVA, 0.8 power factor is supplied at 6.6 kV, 50 Hz means of a 33 kV transmission line 20 km long and 33/6.6 kV step-down transformer. The resistance and reactance of each conductor are 0.4 Ω and 0.5 Ω per km respectively. The resistance and reactance of transformer primary are 7.5 Ω and 13.2 Ω, while those of secondary are 0.35 Ω and 0.65 Ω respectively. Find the voltage necessary at sending end of transmission line when 6.6 kV is maintained at the receiving end. Determine also the sending end power factor and transmission efficiency.



[15 marks]

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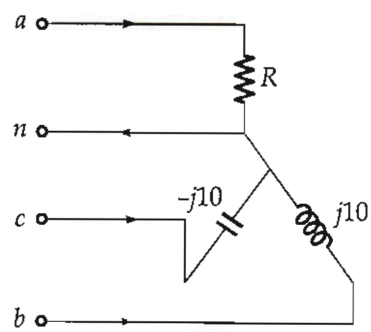
Q.3 (a) **(ii)** A three-phase load is connected to a three-phase balanced supply as shown in the figure. If $V_{an} = 100\angle 0°$ V, $V_{bn} = 100\angle -120°$ V and $V_{cn} = 100\angle -240°$ V (angles are considered positive in the anti-clockwise direction), find the value of R for zero current in the neutral wire.

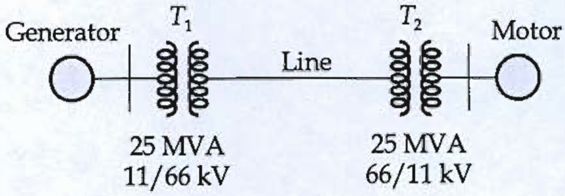


[5 marks]

.3 (b) (i) Derive an expression for the critical clearing angle for a power system consisting of a single machine supplying to an infinite bus, for a sudden load increment.

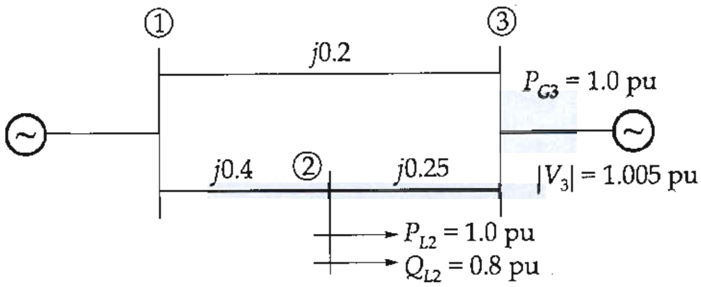
[10 marks]

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



[10 marks]

.3 (c) For the power system network shown in figure, compute the bus voltages using the Gauss-Seidel iteration method. Line reactances and loads are shown in figure. Bus-1 is the slack bus ($V_1 = 1.04\angle 0°$) and bus-2 and bus-3 are the load and voltage-control buses respectively. Assume tolerance equal to 1×10^{-5}.



Compute V_1, V_2 and V_3 upto one iteration.

[20 marks]

Q.4 (a) (i) The insulation resistance of a single-core cable is 495 MΩ per km. If the core diameter is 2.5 cm and resistivity of insulation is 4.5×10^{14} Ω-cm. Find the insulation thickness.

[10 marks]

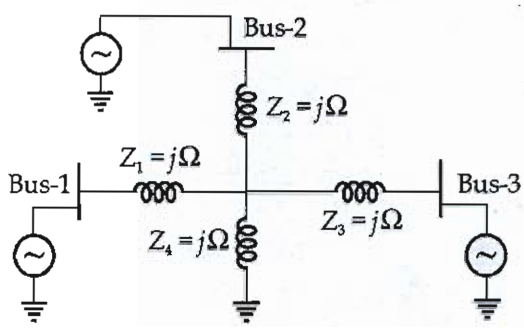
Q.4 (a) (ii) A 3-phase, 2-pole, 50 Hz, synchronous generator has a rating of 250 MVA, 0.8 pf lagging. The kinetic energy of the machine at synchronous speed is 1000 MJ. The machine is running steadily at synchronous speed and delivering 60 MW power at a power angle of 10 electrical degrees. If the load is suddenly removed, assuming the acceleration is constant for 10 cycles, find the value of the power angle after 5 cycles in electrical degrees.

[10 marks]

Q.4 (b) (i) What is the effect of fault impedance on the performance of distance protection? Suggest a method for overcoming this effect.

[14 marks]

Q.4 (b) (ii) A 3 Bus network is shown below. Consider generators as an ideal voltage sources. If rows 1, 2 and 3 of the Y_{Bus} matrix correspond to Bus 1, 2 and 3 respectively, find Y_{Bus} of the network shown.



[6 marks]

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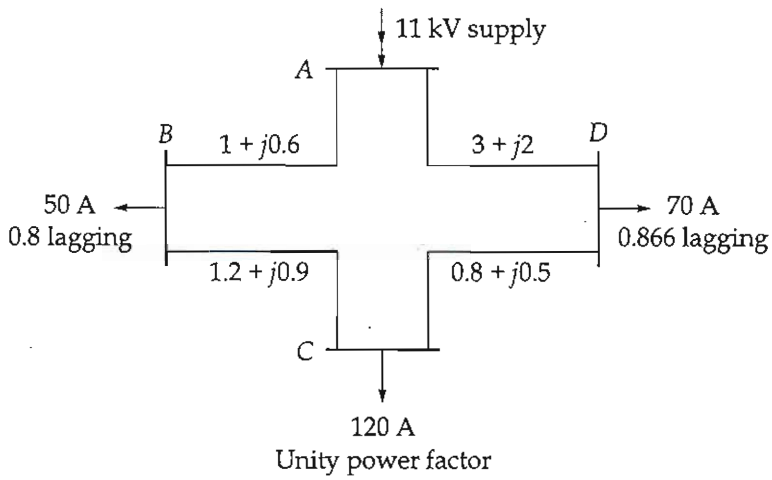
Q.4 (c) A 3-phase ring main *ABCD* fed at *A* at 11 kV supplies balanced loads of 50 A at 0.8 p.f. lagging at *B*. 120 A at unity power factor at *C* and 70 A at 0.866 lagging at *D*, the load currents being referred to the supply voltage at *A*. The impedances of the various sections are:

Section *AB* = $(1 + j0.6)\Omega$; Section *BC* = $(1.2 + j0.9)\Omega$

Section *CD* = $(0.8 + j0.5)\Omega$; Section *BC* = $(1.2 + j0.9)\Omega$

Calculate the currents in various sections and station bus-bar voltages at *B*, *C* and *D*.



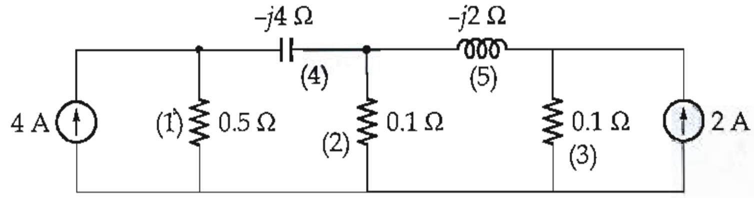
[20 marks]

Section B : Digital Electronics-1 + Microprocessor-1 + Electrical Circuits-2 + Systems and Signal Processing -2

Q.5 (a) For the circuit diagram shown below, draw its graph and

(i) Obtain incidence matrix and cut-set matrix.

(ii) How many trees are possible for this circuit?



[12 marks]

Q.5 (b) Find the z-transform $X(z)$ and sketch the pole-zero plot with the ROC for each of the following sequences :

(i) $x[n] = \left(\frac{1}{2}\right)^n u[n] + \left(\frac{1}{3}\right)^n u[n]$.

(ii) $x[n] = \left(\frac{1}{3}\right)^n u[n] + \left(\frac{1}{2}\right)^n u[-n-1]$.

(iii) $x[n] = \left(\frac{1}{2}\right)^n u[n] + \left(\frac{1}{3}\right)^n u[-n-1]$.

[12 marks]

(b) (i) $x[n] = (1/2)^n u(n) + (1/3)^n u(n)$

as we know

$$(a)^n u(n) \xrightarrow{Z.T.} \frac{1}{1-az^{-1}}, \quad |z| > |a|$$

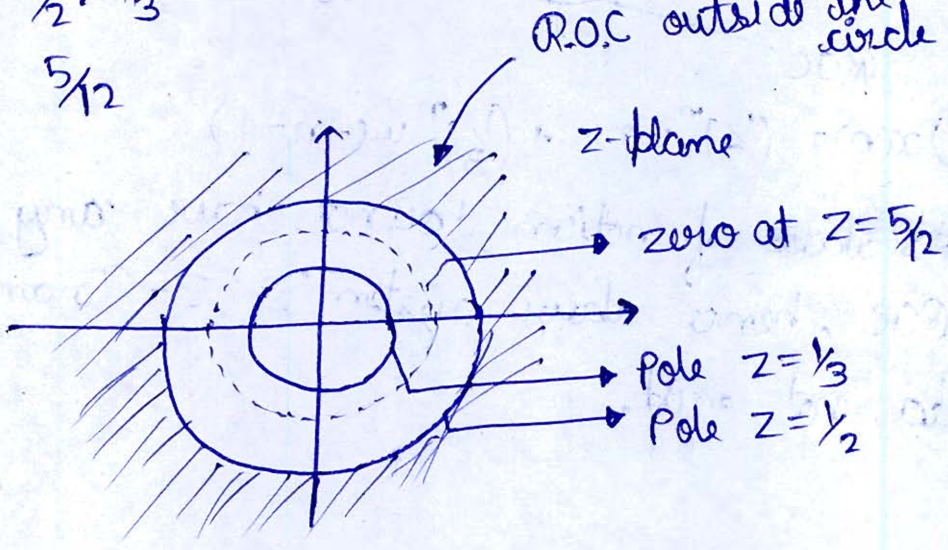
$$\therefore X(z) = \frac{1}{1-\frac{1}{2}z^{-1}} + \frac{1}{1-\frac{1}{3}z^{-1}}$$

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

$$X(z) = \frac{\left(2-\frac{5}{6}z^{-1}\right)}{(1-\frac{1}{2}z^{-1})(1-\frac{1}{3}z^{-1})}$$

Pole: $1/2, 1/3$

zero: $5/12$



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

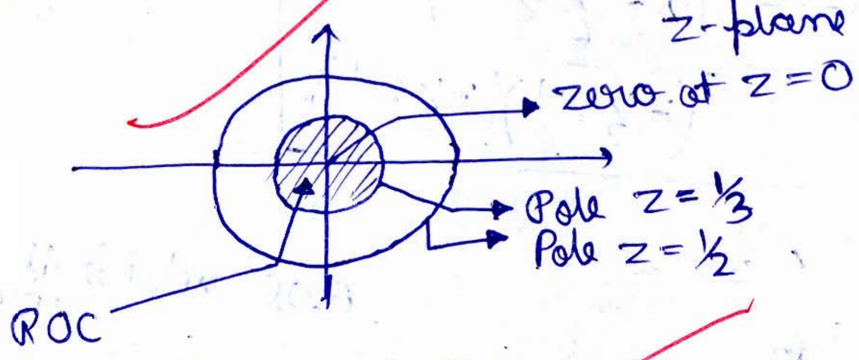
$\left(\frac{1}{3}\right)^n u(n) \xrightleftharpoons{Z.T.} \frac{1}{1-\frac{1}{3}z^{-1}}, \quad |z| > \frac{1}{3}$

$\left(\frac{1}{2}\right)^n u(-n-1) \rightleftharpoons -\frac{1}{1-\frac{1}{2}z^{-1}}, \quad |z| < \frac{1}{2}$

$\therefore X(z) = \frac{1}{1-\frac{1}{3}z^{-1}} - \frac{1}{1-\frac{1}{2}z^{-1}}, \quad \frac{1}{3} < |z| < \frac{1}{2}$

$X(z) = \frac{1-\frac{1}{2}z^{-1} - 1 + \frac{1}{3}z^{-1}}{\left(1-\frac{1}{3}z^{-1}\right)\left(1-\frac{1}{2}z^{-1}\right)} = \frac{-\frac{1}{6}z^{-1}}{\left(1-\frac{1}{3}z^{-1}\right)\left(1-\frac{1}{2}z^{-1}\right)}$

$\therefore \boxed{X(z) = \frac{-\frac{1}{6}z^{-1}}{\left(1-\frac{1}{3}z^{-1}\right)\left(1-\frac{1}{2}z^{-1}\right)}}$ ROC: $\frac{1}{3} < |z| < \frac{1}{2}$



10

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

As above function does not have any common ROC, hence above system's Z-Transform do not exist.

Try to avoid over writing

$8z^2 - 6z + 1$

Q.5 (c) $y(n+2) - \frac{3}{4}y(n+1) + \frac{1}{8}y(n) = x(n+2) + x(n+1)$.

Solve the above difference equation using z-transform if it is given that $y(-1) = 0$, $y(-2) = -1$ and input is $x(n) = u(n)$ and calculate zero input response and zero state response separately.

[12 marks]

(c) Applying z- transform on above differential equation,

~~$z^2 Y(z) - z z^{-1} y(-1) - z^2 y(-2)$~~

case (1) zero state Response,

$y(-1) = 0 \quad y(-2) = 0$

$x(n) = u(n)$

as $x(n) = u(n)$

$$X(z) = \frac{1}{1 - z^{-1}} = \frac{z}{z-1}$$

$$z^2 Y(z) - \frac{3}{4} z^1 Y(z) + \frac{1}{8} Y(z) = (z^2 + z) X(z)$$

$$Y(z) = \left(\frac{z^2 + z}{z^2 - \frac{3}{4}z + \frac{1}{8}}\right)\left(\frac{z}{z-1}\right)$$

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

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

$$\frac{Y(z)}{z} = \frac{5/3}{z - \frac{1}{4}} + \frac{-6}{z - \frac{1}{2}} + \frac{16/3}{z - 1}$$

$$Y(z) = \frac{5/3}{1 - \frac{1}{4}z^{-1}} - \frac{6}{1 - \frac{1}{2}z^{-1}} + \frac{16/3}{1 - z^{-1}}$$

Applying inverse z-transform,

$$y_{ZSR}(n) = \left[\frac{5}{3}\left(\frac{1}{4}\right)^n - 6\left(\frac{1}{2}\right)^n + \frac{16}{3}\right]u(n)$$

case ②

zero input response,

$x(n) = 0$

$y(-1) = 0 \; , \; y(-2) = -1$

$$z^2 Y(z) - z^2(y(-1)) - z(y(-2)) - \frac{3}{4} z Y(z) + z\, y(-1) \times \frac{3}{4} + \frac{1}{8} Y(z) = 0$$

as $y(-1) = 0$

$$\left(z^2 - \frac{3}{4} z + \frac{1}{8}\right) Y(z) = -z$$

$$Y(z) = \frac{-z}{\left(z^2 - \frac{3}{4}z + \frac{1}{8}\right)}$$

④

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

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

Applying inverse z-transform,

$$y_{ZIR}(n) = 4\left[\left(\frac{1}{4}\right)^n - \left(\frac{1}{2}\right)^n\right]u(n)$$

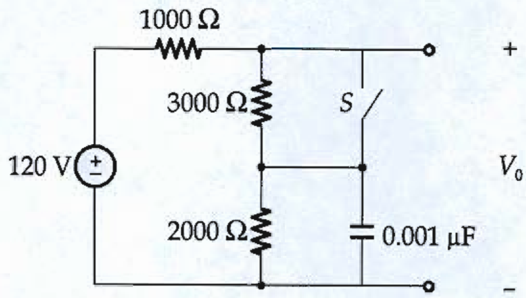
Q.5 (d) Specify the truth table of an octal to binary priority encoder. Provide an output V to indicate that atleast one of the inputs is present. The input with highest subscript number has the highest priority. What will be the values of four outputs if inputs D_2 and D_6 are 1 at the same time?

[12 marks]

Q.5 (e) Set of three 8-bit data readings are stored in memory starting at XX50 H. Sort the readings in ascending order using assembly level program on an 8085 microprocessor.

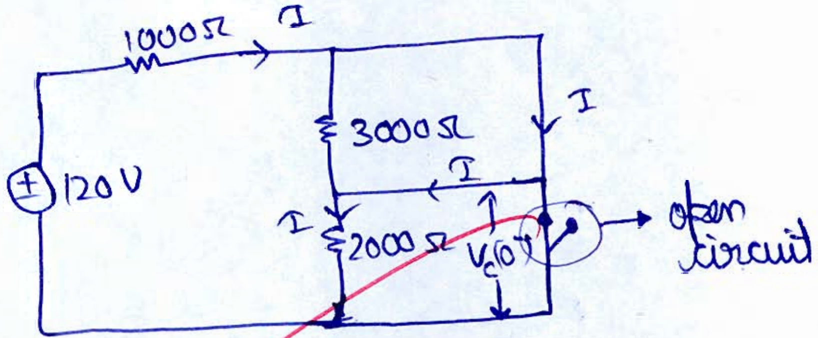
[12 marks]

Q.6 (a) In the network of figure below, the switch *S* has been closed for a long time. The switch is suddenly opened at $t = 0$ and reclosed at $t = 20$ μs. Find the expression for the voltage V_0 for $t \leq 20$ μs and $t > 20$ μs.



[20 marks]

at $t = 0^{-}$



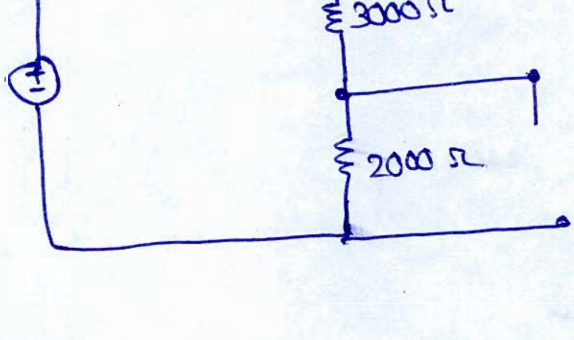
$$I = \frac{120}{3000}$$

$$\therefore V_C(0^-) = I \times 2000$$

$$V_C(0^-) = \frac{120}{3000} \times 2000$$

$$\boxed{V_C(0^-) = 80\,V}$$

at $t = 20\,\mu s$ switch is open



4

Incomplete solution

Q.6 (b) The instruction code 0100 1111 (4FH) is stored in memory location 2005H. Illustrate the data flow and list the sequence of events when the instruction code is fetched by the 8085 microprocessor.

[20 marks]

Q.6 (c) (i) Implement the following Boolean function with a 4 × 1 multiplexer and external gates :

$$F(A, B, C, D) = \Sigma(1, 3, 4, 11, 12, 13, 14, 15)$$

Connect inputs A and B to the selection lines. The input requirements for the four data lines will be a function of variables C and D. These values are obtained by expressing F as a function of C and D for each of the four cases when AB equals 00, 01, 10 and 11. This function may have to be implemented with external gates.

[12 marks]

$F(A,B,C,D) = \Sigma(1,3,4,11,12,13,14,15)$

A	B	C	D	F
0	0	0	0	0
0	0	0	1	1
0	0	1	0	0
0	0	1	1	1
0	1	0	0	1
0	1	0	1	0
0	1	1	0	0
0	1	1	1	0
1	0	0	0	0
1	0	0	1	0
1	0	1	0	0
1	0	1	1	1
1	1	0	0	1
1	1	0	1	1
1	1	1	0	1
1	1	1	1	1

$D = I_0$

$\overline{C+D} = I_1$

$CD = I_2$

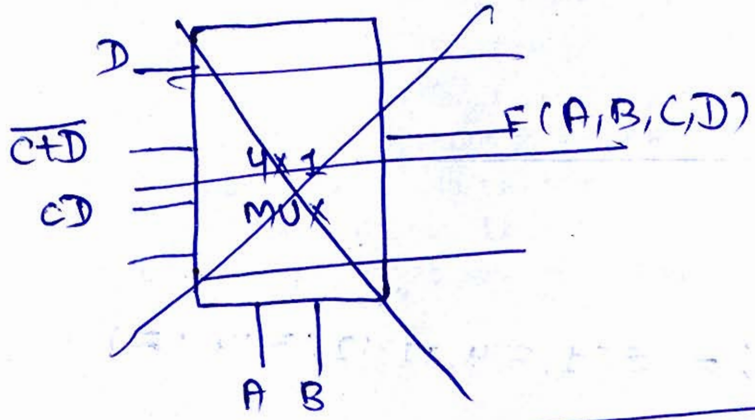
$1 = I_3$

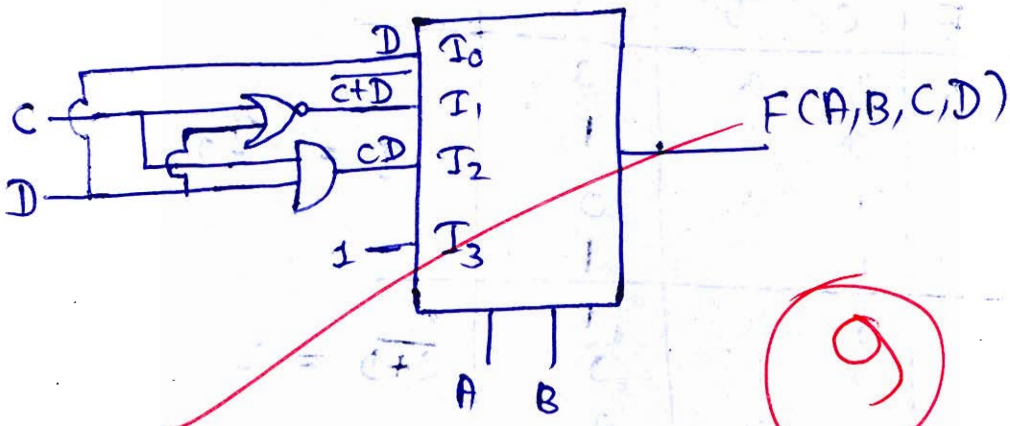
$\therefore I_0 = D$

$I_1 = \overline{C+D}$

$I_2 = CD$

$I_3 = 1$





9

Incomplete Solution

Q.6 (c) (ii) Write an assembly language program to obtain 2's complement of a 16-bit number.

[8 marks]

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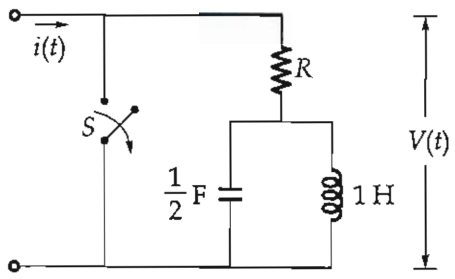
Q.7 (a) The circuit shown below has zero initial energy. At $t = 0$, the switch 'S' is opened. Find the value of resistor R for the given excitation such that the response is $V(t) = 0.5 \sin \sqrt{2} t\, u(t)$.



The excitation is $i(t) = te^{-\sqrt{2}t}\, u(t)$.

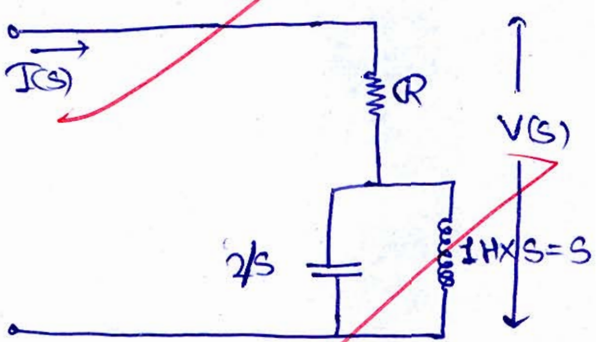
[20 marks]

⇒ Initial energy = 0

$\therefore \; V_C(0^-) = 0$

$i_L(0^-) = 0$

Applying laplace transform,



$\therefore \; V_R(s) = I(s) R \quad — ①$

by current division,

$I_L(s) = I(s) \left(\frac{2/s}{s + 2/s} \right)$

$I_L(s) = I(s) \left(\frac{2}{s^2 + 2} \right)$

$\therefore \; V_L(s) = s \times I_L(s)$

$$V_L(S) = S \times I(S)\left(\frac{2}{S^2+2}\right)$$

$$V_L(S) = I(S)\ \frac{2S}{S^2+2}$$

as $i(t) = te^{-\sqrt{2}t}\ u(t)$

$$\therefore I(S) = \frac{1}{(S+\sqrt{2})^2}$$

$$\therefore V_L(S) = \frac{1}{(S+\sqrt{2})^2} \times \frac{2S}{S^2+2} \quad \text{—②}$$

$$V(S) = V_R(S) + V_L(S)$$

$$\therefore V(S) = I(S)R + \frac{1}{(S+\sqrt{2})^2} \times \frac{2S}{S^2+2}$$

$$V(S) = \frac{1}{(S+\sqrt{2})^2}\left(R + \frac{2S}{S^2+2}\right)$$

$$V(S) = \frac{1}{S^2+2+2\sqrt{2}S}\left(\frac{RS^2+2R+2S}{S^2+2}\right) \quad \text{—③}$$

18

Now $V(t) = 0.5 \sin\sqrt{2}t\ u(t)$

$$\therefore V(S) = \frac{1}{2}\ \frac{\sqrt{2}}{S^2+2} \quad \text{—④}$$

Good Approach

by ③ & ④,

$$\frac{1}{\sqrt{2}}\ \frac{1}{S^2+2} = \left(\frac{RS^2+2R+2S}{S^2+2+2\sqrt{2}S}\right) \times \frac{1}{S^2+2}$$

$$S^2+2\sqrt{2}S+2 = \sqrt{2}RS^2 + 2\sqrt{2}R + 2\sqrt{2}S$$

by comparing both side

$$R = \frac{1}{\sqrt{2}} = 0.707\,\Omega$$

Q.7 (b) **(i)** For the second order FIR lattice filter with reflection coefficients $K_1 = \frac{1}{2}$, $K_2 = \frac{1}{4}$, find the FIR system.

(ii) Obtain a lattice filter implementation of the FIR filter $H(z) = 8 + 4z^{-1} + 2z^{-2} + z^{-3}$.

[10 + 10 marks]

(b)(i) As we know,

$$A_m = A_{m-1} + K_m z^{-1} B_{m-1} \quad \text{--- (1)}$$

let $A_0 = 1$, $B_0 = 1$

put $m = 1$,

$$A_1 = A_0 + K_1 z^{-1} B_0$$

$$A_1 = 1 + \tfrac{1}{2} z^{-1}$$

B_1 = Reverse polynomial by A_1

$$B_1 = \tfrac{1}{2} + z^{-1}$$

put $m = 2$,

$$A_2 = A_1 + K_2 z^{-1} B_1$$

$$A_2 = (1 + \tfrac{1}{2} z^{-1}) + \tfrac{1}{4} z^{-1} (\tfrac{1}{2} + z^{-1})$$

$$A_2 = 1 + \tfrac{5}{8} z^{-1} + \tfrac{1}{4} z^{-2}$$

$\therefore$ FIR filter is $\boxed{H(z) = 1 + \frac{5}{8} z^{-1} + \frac{1}{4} z^{-2}}$

order of filter = 2

length of filter = 3

9

Good Approach

(ii) $H(z) = 8+4z^{-1}+2z^{-2}+z^{-3}$

from above,

order of filter = 3

length of filter = 4

~~as we know~~, ∴ it will have 3 lattice coefficient K_1, K_2, K_3

as we know,

$$A_{m-1}(z) = \frac{A_m - K_m B_m}{1-K_m^2} \quad —①$$

from $H(z) = A_3(z) = 8+4z^{-1}+2z^{-2}+z^{-3}$

$B_3(z)$ = Reverse polynomial of $A_3(z)$

$B_3(z) = 1+2z^{-1}+4z^{-2}+8z^{-3}$

and $\boxed{K_3 = 1}$

put $m=3$,

$$A_2(z) = \frac{8+4z^{-1}+2z^{-2}+z^{-3} - 1(1+2z^{-1}+4z^{-2}+8z^{-3})}{1-(-1)^2}$$

3

Incomplete Solution

Q.7 (c) Design a synchronous 3-bit gray code up-counter using J-K flip-flop.

[20 marks]

Binary code			Gray code			Next state		
A'	B'	C'	A	B	C	A^+	B^+	C^+
0	0	0	0	0	0	0	0	1
0	0	1	0	0	1	0	1	1
0	1	0	0	1	1	0	1	0
0	1	1	0	1	0	1	1	0
1	0	0	1	1	0	1	1	1
1	0	1	1	1	1	1	0	1
1	1	0	1	0	1	1	0	0
1	1	1	1	0	0	0	0	0

Rearranging

Present state			Next state								
Q_A	Q_B	Q_C	Q_A^+	Q_B^+	Q_C^+	J_A	K_A	J_B	K_B	J_C	K_C
0	0	0	0	0	1	0	X	0	X	1	X
0	0	1	0	1	1	0	X	1	X	X	0
0	1	0	1	1	0	1	X	X	0	0	X
0	1	1	0	1	0	0	X	X	0	X	1
1	0	0	0	0	0	X	1	0	X	0	X
1	0	1	1	0	0	X	0	0	X	X	1
1	1	0	1	1	1	X	0	X	0	1	X
1	1	1	1	0	1	X	0	X	1	X	0

Excitation Table of JK,

Q	Q^+	J	K
0	0	0	X
0	1	1	X
1	0	X	1
1	1	X	0

Improve presentation

J_A

	$\bar{Q}_B\bar{Q}_C$	$\bar{Q}_BQ_C$	Q_BQ_C	$Q_B\bar{Q}_C$
$\bar{Q}_A$		1	●	●
Q_A	X	X	X	X

$J_A = \bar{Q}_B Q_C$

K_A

	$\bar{Q}_B\bar{Q}_C$	$\bar{Q}_BQ_C$	Q_BQ_C	$Q_B\bar{Q}_C$
$\bar{Q}_A$	X	X	X	X
Q_A	1			

$K_A = \bar{Q}_B \bar{Q}_C$

J_B

	$\bar{Q}_B\bar{Q}_C$	$\bar{Q}_BQ_C$	Q_BQ_C	$Q_B\bar{Q}_C$
$\bar{Q}_A$		1	X	X
Q_A			X	X

$J_B = \bar{Q}_A Q_C$

K_B

	$\bar{Q}_B\bar{Q}_C$	$\bar{Q}_BQ_C$	Q_BQ_C	$Q_B\bar{Q}_C$
$\bar{Q}_A$	X	X		
Q_A	X	X	1	

$K_B = Q_A Q_C$

J_C

	$\bar{Q}_B\bar{Q}_C$	$\bar{Q}_BQ_C$	Q_BQ_C	$Q_B\bar{Q}_C$
$\bar{Q}_A$	1	X	X	
Q_A		X	X	1

$J_C = \bar{Q}_A\bar{Q}_B + Q_A Q_B$

$J_C = Q_A \odot Q_B$

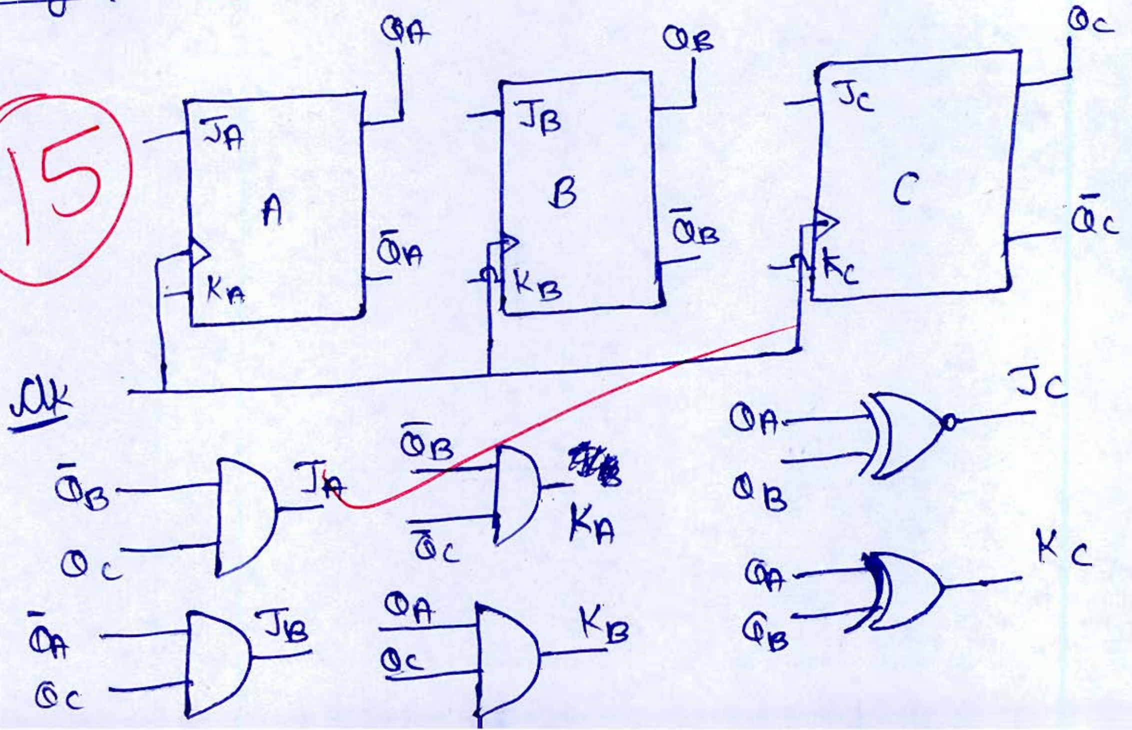
K_C

	$\bar{Q}_B\bar{Q}_C$	$\bar{Q}_BQ_C$	Q_BQ_C	$Q_B\bar{Q}_C$
$\bar{Q}_A$	X	●	1	X
Q_A	X	1		X

$K_C = Q_A\bar{Q}_B + \bar{Q}_A Q_B$

$K_C = Q_A \oplus Q_B$

Design:-

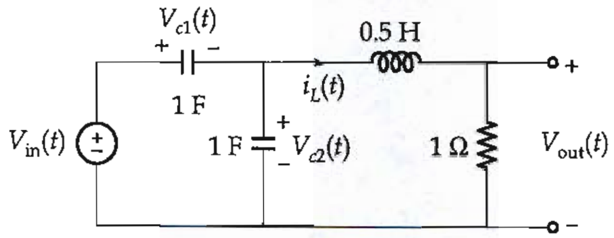


15

Q.8 (a) Design a sequential circuit with two J-K flip-flops A and B and two inputs E and F. If $E = 0$, the circuit remains in the same state regardless of the value of F. When $E = 1$ and $F = 1$, the circuit goes through the state transitions from 00 to 01, to 10, to 11, back to 00, and repeat. When $E = 1$ and $F = 0$, the circuit goes through its state transitions from 00 to 11, to 10, to 01, to 00, and repeats.

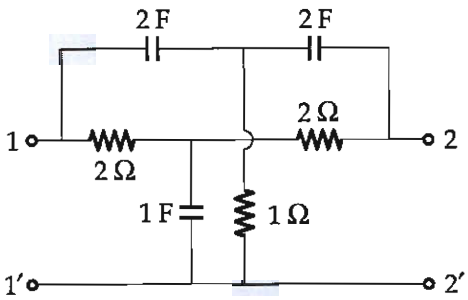
[20 marks]

Q.8 (b) (i) Consider the circuit below in which $V_{in}(t) = 5u(t)$ V, $V_{c1}(0^-) = 3$ V, $V_{c2}(0^-) = 0$ V and $i_L(0^-) = 2$ A. Find $V_{out}(t)$ and also obtain V_{out} at $t = 1$ sec.



[10 marks]

Q.8 (b) (ii) Determine the Y-parameters of given network.



[10 marks]

Do not write in this margin

.8 (c) A sequential circuit has two J-K flip-flops A and B, two inputs x and y, and one output z. The flip-flop input equations and circuit output equation are:

$J_A = \overline{A}Bx$; $K_A = A + Bx\overline{y}$; $J_B = B\overline{x} + y$; $K_B = \overline{B}\overline{y}$; $Z = Axy + B\overline{x}\,\overline{y}$

(i) Draw the logic diagram of the circuit.

(ii) Tabulate the state table.

(iii) Derive the state equations for A and B.

[20 marks]

OOOO

Space for Rough Work

Space for Rough Work

$te^{-\sqrt{2}t}$

$\frac{d}{ds}\left(\frac{1}{s+\sqrt{2}}\right)$

$\frac{1}{(s+\sqrt{2})^2}$

$z^2 - \frac{1}{4} - \frac{1}{2}z$

$(z-\frac{1}{4})(z-\frac{1}{2})$

$8+4z^{-1}+2z^{-2}+z^{-3}-1-2z^{-1}-4z^{-2}-8z^{-3}$

2

	$\bar{D}$	D
$\bar{C}$	0	1
C	2	1 3

Space for Rough Work