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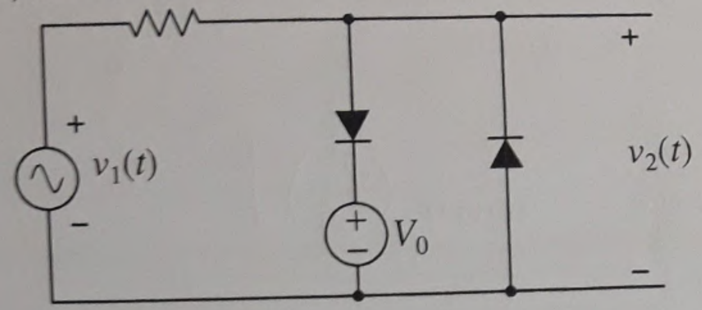
Indian Institute of Technology, Delhi
ELL 100: Introduction to Electrical Engineering
Minor 2: March 26, 2018

Instructions:

Answer all questions. Answers written only in the space provided will be checked.

1. In the circuit shown below, the two diodes are ideal with zero cut-in voltage. The voltage source $v_1(t)$ is $10\sin(100\pi t)$ volts. V_0 is 5 volts.



$100\pi t = \frac{\pi}{6}$

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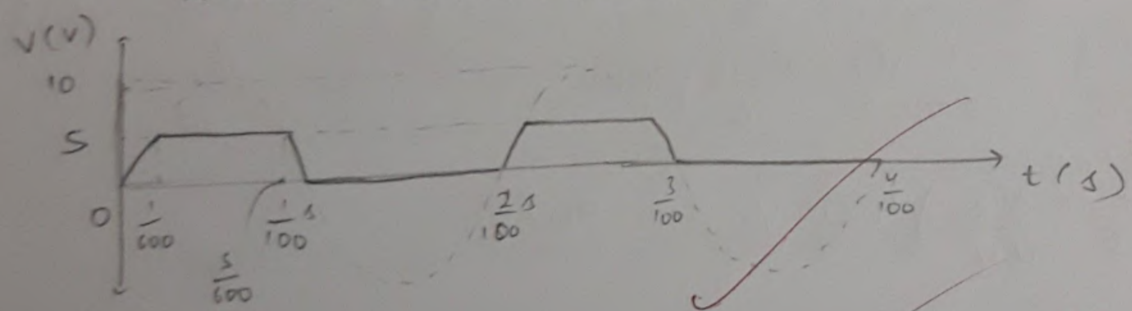
(a) Sketch $v_2(t)$ for two periods, labelling the relevant portions. (2 marks)
(b) In the first period, find the values of t at which $v_1(t) = V_0$. (2 marks)
(c) What is the average value of $v_2(t)$? (3 marks)
(d) What is the RMS (root mean-squared) value of $v_2(t)$? (3 marks)

a)



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b) $t = \frac{1}{600}$ s and $t = \frac{5}{600}$ s.

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c) $\dfrac{\int_0^{1/600} 10\sin(100\pi t)}{1/100} = \frac{10}{100\pi}\left(\cos(100\pi t)\right)^{1/600}$

$= \frac{1}{10\pi}\left(\frac{\sqrt{3}}{2} - 1\right)$

?

1

Average $= \dfrac{\frac{2}{10\pi}\left(1-\frac{\sqrt{3}}{2}\right) + \frac{4}{600}\times 5}{1/100} = \left(\frac{20}{\pi}\left(1-\frac{\sqrt{3}}{2}\right) + \frac{20}{6}\right)$ V

$= 4.186$ V

Ans

d) $\int_0^{1/600} 100 \sin^2(100\pi t)\, dt$

$= 50 \int_0^{1/600} (1 - \cos(200\pi t))\, dt$

$= 50 \left[t - \frac{1}{200\pi} \sin(200\pi t) \right]_0^{1/600}$

$= 50 \left[\frac{1}{600} - \frac{4}{200\pi} \left(\frac{\sqrt{3}}{2} \right) \right]$ (1)

$RMS = \sqrt{\dfrac{100\left[\frac{1}{600} - \frac{1}{200\pi}\left(\frac{\sqrt{3}}{2}\right)\right] + 25\left(\frac{4}{600}\right)}{1/100}}$

$= \sqrt{\left(\frac{1}{6} - \frac{1}{2\pi \times 2}\frac{\sqrt{3}}{2} + \frac{1}{6} \right) 100}$

$= \sqrt{\left(\frac{1}{3} - \frac{\sqrt{3}}{4\pi} \right) 100}$ V Ans

$= 4.42$ V ?

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2. A 3-phase 50-Hz voltage source with $V_{an} = 230\angle 0°$ volts, $V_{bn} = 230\angle -120°$ volts, and $V_{cn} = 230\angle 120°$ volts feeds an inductive load with $Z = 5\angle 75°$ ohm, as shown in the schematic below. All voltages are RMS quantities. A capacitor bank is installed to improve the power factor to 1.00, as seen by the source. Assume that the potential at n is the same as at n'.

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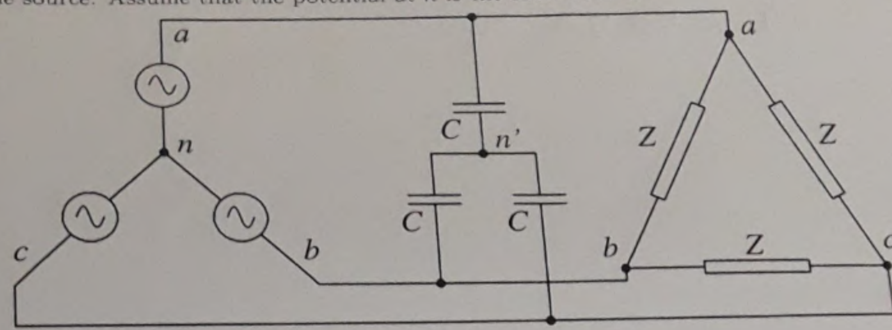

(a) What is the three-phase apparent power (active plus reactive) absorbed by the inductive load? (4 marks)

(b) What is the value of C? (4 marks)

(c) What is the three-phase apparent power absorbed by the capacitor bank? (2 marks)

(d) What is the three-phase apparent power supplied by the source? (2 marks)

By Z load

$V_{ab} = V_a - V_b = 230\sqrt{3}\angle 30°$

$I_{ab} = \frac{V_{ab}}{Z} = \frac{230\sqrt{3}\angle 30°}{5\angle 75°} =$

$= 46\sqrt{3}\angle -45°$

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Power $= (31.74\angle 75°$ kVA$) \times 3 = 95.22\angle 75°$ kVA Ans

By C load

$V_{an} = 230\angle 0°$

$Z = \frac{1}{\omega C}\angle -90°$

$I_{an} = \frac{230\angle 0°}{\frac{1}{\omega C}\angle -90°}$

$= 230\omega C\angle 90°$

Power $= 3 V_{an} I_{an}$

$= 3(230\angle 0°)(230\omega C\angle 90°)$

$= 158.7\omega C\angle -90°$ kW $= 95.22\sin 75°$

4

$\omega C = 0.58$

$C = \frac{0.58}{2\pi f} = 1.84$ mF Ans

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c) ~~98~~ −91.97 ~~kVAR~~ kW = −95.22 sin75°

(2)

d) +24.64 ~~kVA~~ kW

(2)

$\frac{5\angle 75^\circ (\angle -90^\circ)}{0.58\left(-\frac{3\angle 90^\circ}{0.58} \times 2\right)}$

$\begin{bmatrix} 3.1\angle 54^\circ & 1.55\angle 54^\circ \end{bmatrix}$

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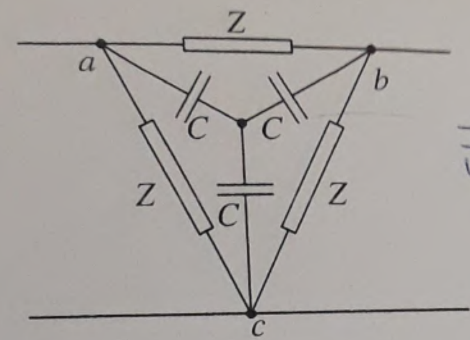
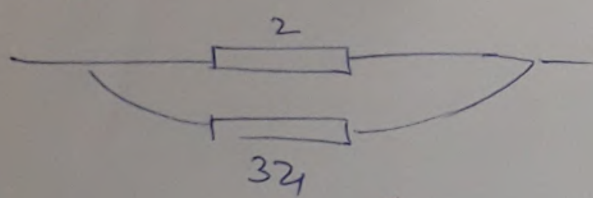
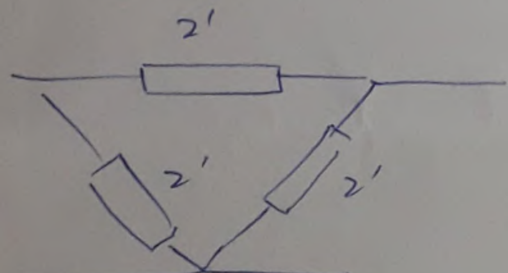
(c) The inductive load and the capacitor bank are redrawn below. Visualize the schematic as a two-port network, with the two ports as ac and bc. Calculate the Z-parameters of the two-port network. ($4\times 2 = 8$ marks)



$\frac{-j}{\omega C} = Z_1$



$\frac{3Z_1 Z}{3Z_1+Z} = Z'$ ✓



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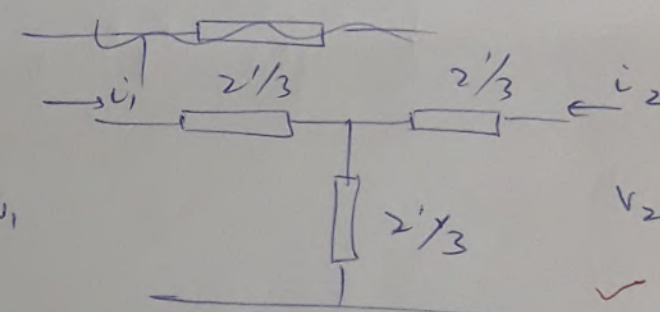

✓

$$\begin{bmatrix} V_1 \\ V_2 \end{bmatrix} = \begin{bmatrix} 2Z'/3 & Z'/3 \\ Z'/3 & 2Z'/3 \end{bmatrix} \begin{bmatrix} i_1 \\ i_2 \end{bmatrix}$$

$$\frac{Z_1 Z}{3Z_1+Z} = \frac{-jZ}{\omega C\left(\frac{-3j}{\omega C}+Z\right)}$$

$$Z = \begin{bmatrix} \frac{2Z_1 Z}{3Z_1+Z} & \frac{Z_1 Z}{3Z_1+Z} \\ \frac{Z_1 Z}{3Z_1+Z} & \frac{2Z_1 Z}{3Z_1+Z} \end{bmatrix} = \begin{bmatrix} \frac{-2jZ}{-3j+Z\omega C} & \frac{-jZ}{-3j+Z\omega C} \\ \frac{-jZ}{-3j+Z\omega C} & \frac{-2jZ}{-3j+Z\omega C} \end{bmatrix}$$

✓

$$\begin{bmatrix} 3.1\angle 54^\circ & 1.55\angle 54^\circ \\ 1.55\angle 54^\circ & 3.1\angle 54^\circ \end{bmatrix}$$

Ans

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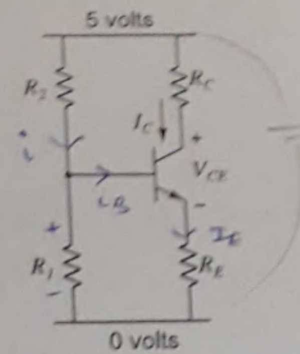
3. In the BJT biasing circuit shown below, I_C is to be set to 2 mA, and V_{CE} is to be set to 2 volts. The ratio of R_C and R_E is to be set to 5, i.e., $R_C/R_E = 5$. The β of the device is 200. Assume V_{BE} is 0.7 volts.



(a) What is the value of R_E? (2 marks)

(b) What is the value of R_C? (2 marks)

(c) The value of $R_1 \parallel R_2$ is 100 kΩ. What are the values of R_1 and R_2? (3 + 3 = 6 marks)

$-5 + i_C R_C + V_{CE} + i_E R_E = 0$

Now, $R_C = 5R_E$

$-3 + 5 i_C R_E + i_E R_E = 0$

$i_E = i_B + i_C = \frac{2mA}{200} + 2mA$

$R_E = \frac{3}{5i_C + i_E} = \frac{3}{12.0\cancel{1}}\ k\Omega$

$i_E = 2mA = 2.0\cancel{1}\ mA$

a) $R_E = 0.25\ k\Omega$ Ans

b) $R_C = 5R_E = 1.25\ k\Omega$ Ans

$0 - iR_1 + 0.7 - i_E R_E = 0$

$iR_1 = 0.7 - \frac{1}{4}(2) = 0.2V$

considering i_B to be small

$-5 + i(R_1 + R_2) = 0$

$iR_1 + iR_2 = 5$

$iR_2 = 4.8$

$\frac{R_2}{R_1} = 24$

$\frac{R_1 R_2}{R_1 + R_2} = 100$

$\left(\frac{0.2}{i}\right)\left(\frac{4.8}{i}\right)\left(\frac{i}{5}\right) = 100 \Rightarrow i = 0.192\ mA$

$R_1 = \frac{0.2}{0.192} = 1.042\ k\Omega$ Ans

$R_2 = 25\ k\Omega$ Ans

current in the branch.

~~Now ow~~

Since 0.01 mA can be considered small in respect to 0.2mA, our assumption was valid.