

P. NO 1

Department of Electrical Engineering

Final Assignment
Date 22/06/2020


Course Details

Course title :- Electrical Network Analysis
Module :- 4th
Instructor :- Dr Engr Shehryar Shajique
Total Marks :- 50

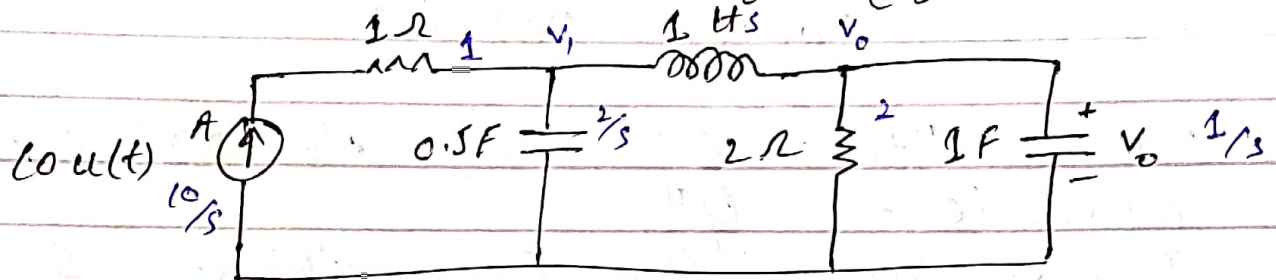
Student Details

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Q:-4 Apply Laplace transform and calculate the output voltage $V_o(t)$ in the circuit of figure below:



Sol. At Node 1,

$$\frac{10/s - V_1}{1} = \frac{V_1 - V_0}{s} + \frac{s V_0}{2}$$

$$\Rightarrow 10 = (s+1)V_1 + \left(\frac{s^2}{2} - 1\right)V_0 \rightarrow \textcircled{1}$$

At Node 2,

$$\frac{V_1 - V_0}{s} = \frac{V_0}{2} + sV_0$$

$$\Rightarrow V_1 = V_0 \left(\frac{s}{2} + s^2 + 1\right) \rightarrow \textcircled{2}$$

Substituting (2) into (1) gives

$$10 = (s+1) \left(s^2 + \frac{s}{2} + 1\right) V_0 + \left(\frac{s^2}{2} - 1\right) V_0 =$$

$$s(s^2 + 2s + 1.5) V_0$$

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$$V_0 = \frac{10}{s(s^2 + 2s + 1.5)} = \frac{A}{s} + \frac{Bs + C}{s^2 + 2s + 1.5}$$

$$10 = A(s^2 + 2s + 1.5) + Bs^2 + Cs$$

$$s^2 = 0 = A + B$$

$$s = 0 = 2A + C$$

$$\text{Constant} = 10 = 1.5A$$

$$A = \frac{20}{3}, \quad B = -\frac{20}{3}, \quad C = -\frac{40}{3}$$

$$V_0 = \frac{20}{3} \left[\frac{1}{s} - \frac{s+2}{s^2 + 2s + 1.5} \right]$$

$$= \frac{20}{3} \left[\frac{1}{s} - \frac{s+1}{(s+1)^2 + 0.7071^2} - 1.414 \frac{0.7071}{(s+1)^2 + 0.7071^2} \right]$$

Taking the inverse Laplace transform finally yields

$$V_0(t) = \frac{20}{3} \left[1 - e^{-t} \cos 0.7071t - 1.414 e^{-t} \sin 0.7071t \right] u(t) \text{ V.}$$

Q:-1 Assume that a 2000-KW turbine-generator of 0.85 power factor operates at the rated load. An additional load of 300 kW at 0.8 power factor is added. What KVAR of capacitor is required to operate the turbine generator but keep it from being overloaded?

Soln Original Load:

$$P_1 = 2000 \text{ kW}$$

$$\cos \theta_1 = 0.85$$

$$\theta_1 = 31.79^\circ$$

$$S_1 = \frac{P_1}{\cos \theta_1}, \quad Q_1 = S_1 \sin \theta_1$$

$$Q_1 = 1239.5 \text{ KVAR}$$

$$S_1 = 2352.94 \text{ KVA}$$

Additional Load:

$$P_2 = 300 \text{ kW}$$

$$\cos \theta_2 = 0.8$$

$$\theta_2 = 36.87^\circ$$

$$S_2 = \frac{P_2}{\cos \theta_2}, \quad Q_2 = S_2 \sin \theta_2$$

$$Q_2 = 225 \text{ KVAR}$$

$$S_2 = 375 \text{ KVA}$$

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Total Load:

$$S = S_1 + S_2$$

$$S = (P_1 + P_2) + j(Q_1 + Q_2)$$

$$S = P + jQ$$

$$P = 2000 + 300$$

$$P = 2300 \text{ KW}$$

$$Q = 1239.5 + 225$$

$$Q = 1464.5 \text{ KVAR}$$

Now,

The minimum operating P for a 2300 kW load and not exceeding the kVA rating of the generator is,

$$\cos \theta = \frac{P}{S_1}$$

$$\cos \theta = \frac{2300 \times 10^3}{2352.94 \times 10^3}$$

$$\cos \theta = 0.9775$$

$$\theta = 12.177$$

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Now,

The maximum load k VAR for these conditions,

$$Q_m = S, \sin \theta$$

$$Q_m = 2352.94 \sin(12.177^\circ)$$

$$Q_m = 496.313 \text{ k VAR.}$$

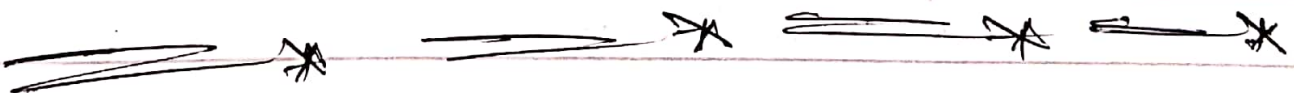
The capacitor must supply the difference between the total loads k VAR (i.e. Q) and the permissible generator k VAR (i.e. Q_m)

thus,

$$Q_c = Q - Q_m$$

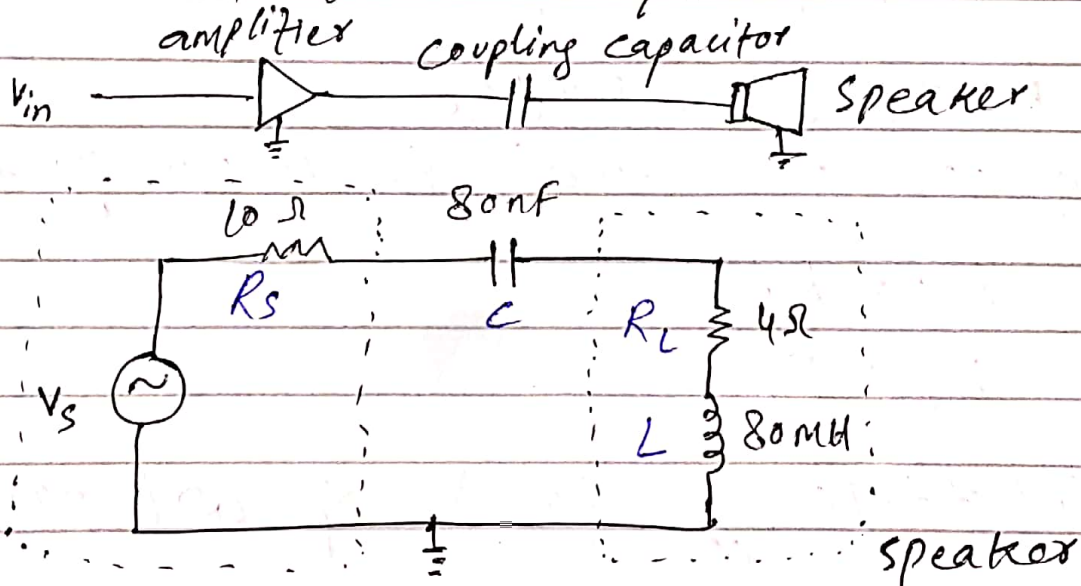
$$Q_c = 1464.5 - 496.313$$

$$Q_c = 968.2 \text{ k VAR.}$$



Q:-5 For the circuit given in figure below, the speaker works as load while the amplifier and the capacitor act as the source. To block dc current from amplifier, a coupling capacitor of 80 nF is used (see figure below) Calculate the following:

- (a) At what frequency is maximum power transfer to the speaker?
- (b) If $V_s = 5 \text{ V}_{\text{rms}}$, how much power is delivered to the speaker at that



Sol (a) Consider the following data:
 The amplifier and the capacitor act as a source. Hence the source impedance, $Z_s = R_s - jX_c$.
 The speaker acts as a load; Hence the load impedance, $Z_L = R_L + jX_L$

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The maximum power is transferred to the speaker or load when the load impedance is equal to the complex conjugate of the thevenin's impedance.

In this circuit, the thevenin's impedance is equal to the source impedance. Hence, maximum power is transferred to the speaker when,

$$Z_L = Z_S^*$$

$$R_L + jX_L = (R_S - jX_C)$$

$$R_L + jX_L = R_S + jX_C$$

Equate the real & imaginary terms

$$R_S = R_L$$

$$X_C = X_L$$

Substitute $\frac{1}{\omega C}$ for X_C & ωL for X_L .

$$X_C = X_L$$

$$\frac{1}{\omega C} = \omega L$$

$$1 = \omega^2 LC$$

$$\omega = \frac{1}{\sqrt{LC}}$$

Substitute the formula for angular frequency $2\pi f$ in place of ω

$$\omega = \frac{1}{\sqrt{LC}}$$

$$2\pi f = \frac{1}{\sqrt{LC}}$$

$$f = \frac{1}{2\pi\sqrt{LC}}$$

Now

Substitute 80 nF for C & 80 mH for L .

$$f = \frac{1}{2\pi\sqrt{(80 \times 10^{-3})(80 \times 10^{-9})}}$$

$$= \frac{1}{2(3.14)(80 \times 10^{-6})}$$

$$= 1990.44586$$

$$= 2.044 \text{ KHz}$$

Thus, the frequency, f , at which maximum power transfer to the speaker is $\boxed{2.044 \text{ KHz}}$.

(b) At the frequency $f = 2.044 \text{ kHz}$, the reactive powers are cancelled because they are in series. Calculate the power delivered to the speaker at the resonance frequency.

$$P = (I_s)^2 R_L$$

$$= \left[\frac{V_s}{(R_s + R_L)} \right]^2 R_L$$

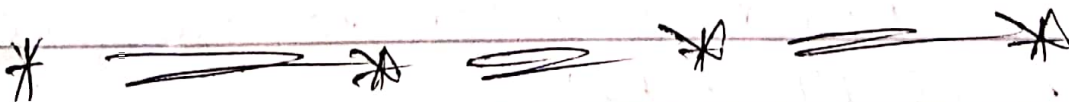
$$= \left(\frac{5}{10 + 4} \right)^2 4$$

$$= 0.51020 \text{ W}$$

$$= 510.20 \text{ mW}$$

Thus, The power, P , delivered to the speaker at the frequency $f = 2.044 \text{ kHz}$

is 510.20 mW



Q1.2 A balanced abc sequence, one line voltage of a balanced y-connected source is $V_{AB} = 180 \angle -20^\circ \text{ V}$. If the source is connected to a Δ -connected load of $20 \angle 40^\circ \Omega$, find the phase and line current.

Sol. Assume ABC sequence.

Line voltage $V_{AB} = 180 \angle -20^\circ \text{ V}$

$Z_{\Delta} = 20 \angle 40^\circ \Omega$

Using formula

$$V_L = \sqrt{3} V_p \angle 30^\circ$$

$$V_p = \frac{V_L}{\sqrt{3} \angle 30^\circ}$$

phase voltage

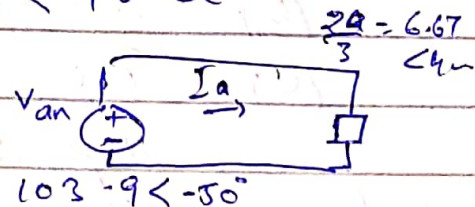
$$V_{an} = \frac{180 \angle -20^\circ}{\sqrt{3}} \angle -30^\circ = 103.9 \angle -50^\circ \text{ V}$$

$$Z_y = \frac{2\Delta}{3} = \frac{20 \angle 40^\circ}{3} = 6.67 \angle 40^\circ \Omega$$

Line current:

$$I_a = \frac{V_{an}}{\frac{2\Delta}{3}} = \frac{103.9 \angle -50^\circ}{6.67 \angle 40^\circ}$$

$$I_a = 15.57 \angle -90^\circ \text{ A}$$



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$$I_b = I_a \angle -120^\circ = 15.59 \angle 150^\circ \text{ A}$$

$$I_c = I_a \angle 120^\circ = 15.59 \angle 30^\circ \text{ A}$$

Phase current:

$$I_{AB} = \frac{15.57 \angle -90^\circ}{\sqrt{3}} \angle 30^\circ = 9 \angle -60^\circ \text{ A}$$

$$I_{BC} = I_{AB} \angle -120^\circ = 9 \angle -180^\circ \text{ A}$$

$$I_{CA} = I_{AB} \angle 120^\circ = 9 \angle 60^\circ \text{ A}$$

$$\Rightarrow * \rightleftharpoons * \rightleftharpoons * \rightleftharpoons * \rightleftharpoons *$$

Q:-3 Consider a load with value of,
 $V_{rms} = 110 \angle 85^\circ \text{ V}$, $I_{rms} = 0.4 \angle 15^\circ \text{ A}$.
Calculate the following:

- The complex and apparent powers.
- The real & reactive powers, and
- The power factor and the load impedance.

Sol:
=

Given

$$V_{rms} = 110 \angle 85^\circ \text{ V}$$

$$I_{rms} = 0.4 \angle 15^\circ \text{ A}$$

(a) The complex power is

$$S = V_{ms} I_{ms}^*$$

$$S = (110 \angle 85^\circ)(0.4 \angle -15^\circ)$$

$$S = 110 \times 0.4 \angle (85^\circ - 15^\circ)$$

$$\boxed{S = 44 \angle 70^\circ \text{ VA}}$$

The apparent power is

$$S = |S|$$

$$\boxed{S = 44 \text{ VA}}$$

(b) Express the complex power in rectangular form.

$$S = 44 \angle 70^\circ$$

$$S = 44 [\cos(70^\circ) + j \sin(70^\circ)]$$

$$S = 44 [0.3420 + j 0.9397]$$

$$S = 15.05 + j 41.35$$

Since $S = P + jQ$

The real power is

$$\boxed{P = 15.05 \text{ W}}$$

The reactive power is

$$Q = 41.35 \text{ VAR}$$

(C) The power factor is

$$PF = \cos(70^\circ)$$

$$PF = 0.342 \text{ (lagging)}$$

The power factor is lagging as the reactive power is positive.
The load impedance is

$$Z = \frac{V}{I}$$

$$V = \sqrt{2} V_{ms}$$

$$I = \sqrt{2} I_{ms}$$

$$Z = \frac{110\sqrt{2} \angle 85^\circ}{0.4\sqrt{2} \angle 15^\circ}$$

$$Z = 275 \angle 70^\circ \Omega$$

$$\bar{Z} = 275 [\cos(70^\circ) + j \sin(70^\circ)]$$

$$Z = 275 [0.342 + j 0.9397]$$

$$Z = 94.05 + j 258.4 \Omega$$