Chapter 11, Solution 1.

$$v(t) = 160\cos(50t)$$
$$i(t) = -20\sin(50t - 30°) = 2\cos(50t - 30° + 180° - 90°)$$
$$i(t) = 20\cos(50t + 60°)$$

$$p(t) = v(t)\,i(t) = (160)(20)\cos(50t)\cos(50t + 60°)$$
$$p(t) = 1600\left[\cos(100t + 60°) + \cos(60°)\right] \text{ W}$$
$$p(t) = \underline{\mathbf{800 + 1600\cos(100t + 60°)\ W}}$$

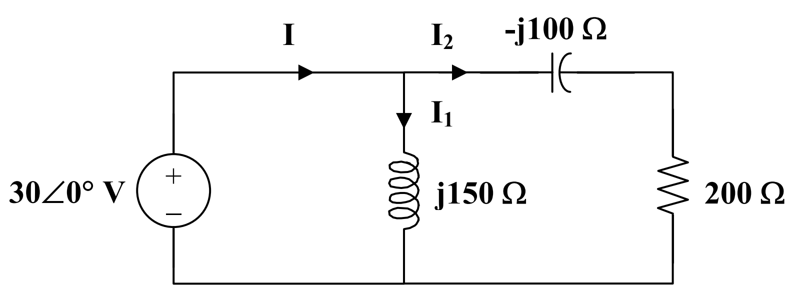
$$P = \frac{1}{2}V_m I_m \cos(\theta_v - \theta_i) = \frac{1}{2}(160)(20)\cos(60°)$$

$$P = \underline{\mathbf{800\ W}}$$

Chapter 11, Solution 2.

First, transform the circuit to the frequency domain.

$$30\cos(500t) \longrightarrow 30\angle 0°, \qquad \omega = 500$$
$$0.3 \text{ H} \longrightarrow j\omega L = j150$$
$$20\mu\text{F} \longrightarrow \frac{1}{j\omega C} = \frac{-j}{(500)(20)(10^{-6})} = -j100$$



$$\mathbf{I}_1 = \frac{30\angle 0°}{j150} = 0.2\angle -90° = -j0.2$$

$$i_1(t) = 0.2\cos(500t - 90°) = 0.2\sin(500t)$$

$$\mathbf{I}_2 = \frac{30\angle 0°}{200 - j100} = \frac{0.3}{2 - j} = 0.1342\angle 26.56° = 0.12 + j0.06$$

$$i_2(t) = 0.1342\cos(500t + 25.56°)$$

$$\mathbf{I} = \mathbf{I}_1 + \mathbf{I}_2 = 0.12 - j0.14 = 0.1844\angle\text{-}49.4°$$
$$i(t) = 0.1844\cos(500t - 35°)$$

For the voltage source,

$$p(t) = v(t)\,i(t) = [\,30\cos(500t)\,] \times [\,0.1844\cos(500t - 35°)\,]$$

At $t = 2$ s,

$$p = 5.532\cos(1000)\cos(1000 - 35°)$$
$$p = (5.532)(0.5624)(0.935)$$
$$p = \underline{\mathbf{2.91\ W}}$$

For the inductor,

$$p(t) = v(t)\,i(t) = [\,30\cos(500t)\,] \times [\,0.2\sin(500t)\,]$$

At $t = 2$ s,

$$p = 6\cos(1000)\sin(1000)$$
$$p = (6)(0.5624)(0.8269)$$
$$p = \underline{\mathbf{2.79\ W}}$$

For the capacitor,

$$\mathbf{V}_c = \mathbf{I}_2\,(\text{-}j100) = 13.42\angle\text{-}63.44°$$
$$p(t) = v(t)\,i(t) = [\,13.42\cos(500 - 63.44°)\,] \times [\,0.1342\cos(500t + 25.56°)$$

At $t = 2$ s,

$$p = 18\cos(1000 - 63.44°)\cos(1000 + 26.56°)$$
$$p = (18)(0.991)(0.1329)$$
$$p = \underline{\mathbf{2.37\ W}}$$

For the resistor,

$$\mathbf{V}_R = 200\,\mathbf{I}_2 = 26.84\angle 25.56°$$
$$p(t) = v(t)\,i(t) = [\,26.84\cos(500t + 26.56°)\,] \times [\,0.1342\cos(500t + 26.56°)\,]$$

At $t = 2$ s,

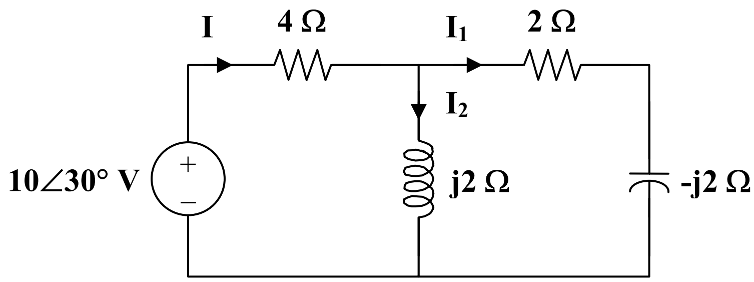
$$p = 3.602\cos^2(1000 + 25.56°)$$
$$p = (3.602)(0.1329^2$$
$$p = \underline{\mathbf{0.0636\ W}}$$

Chapter 11, Solution 3.

$$10\cos(2t+30°) \longrightarrow 10\angle 30°, \qquad \omega = 2$$

$$1\text{ H} \longrightarrow j\omega L = j2$$

$$0.25\text{ F} \longrightarrow \frac{1}{j\omega C} = -j2$$



$$j2 \,||\, (2 - j2) = \frac{(j2)(2-j2)}{2} = 2 + j2$$

$$\mathbf{I} = \frac{10\angle 30°}{4 + 2 + j2} = 1.581\angle 11.565°$$

$$\mathbf{I}_1 = \frac{j2}{2}\mathbf{I} = j\mathbf{I} = 1.581\angle 101.565°$$

$$\mathbf{I}_2 = \frac{2 - j2}{2}\mathbf{I} = 2.236\angle 56.565°$$

For the source,

$$\mathbf{S} = \mathbf{V}\mathbf{I}^* = \frac{1}{2}(10\angle 30°)(1.581\angle\text{-}11.565°)$$

$$\mathbf{S} = 7.905\angle 18.43° = 7.5 + j2.5$$

The average power supplied by the source $=$ **7.5 W**

For the 4-Ω resistor, the average power absorbed is

$$P = \frac{1}{2}|\mathbf{I}|^2 R = \frac{1}{2}(1.581)^2(4) = \mathbf{5\ W}$$

For the inductor,

$$\mathbf{S} = \frac{1}{2}|\mathbf{I}_2|^2 \mathbf{Z}_L = \frac{1}{2}(2.236)^2(j2) = j5$$

The average power absorbed by the inductor $=$ **0 W**

For the 2-Ω resistor, the average power absorbed is

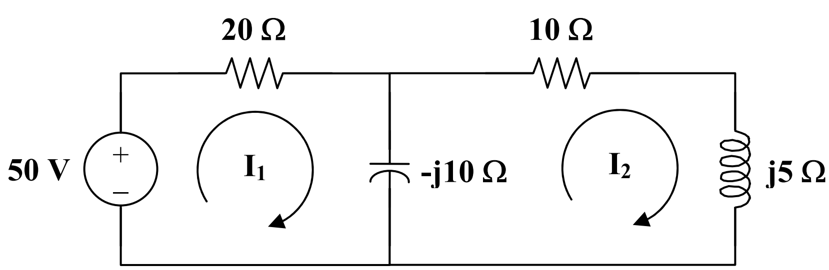
$$P = \frac{1}{2}|\mathbf{I}_1|^2 R = \frac{1}{2}(1.581)^2(2) = \underline{\mathbf{2.5\ W}}$$

For the capacitor,

$$\mathbf{S} = \frac{1}{2}|\mathbf{I}_1|^2 \mathbf{Z}_c = \frac{1}{2}(1.581)^2(\text{-j}2) = \text{-j}2.5$$

The average power absorbed by the capacitor $= \underline{\mathbf{0\ W}}$

Chapter 11, Solution 4.



For mesh 1,

$$50 = (20 - \text{j}10)\mathbf{I}_1 + \text{j}10\mathbf{I}_2$$
$$5 = (2 - \text{j})\mathbf{I}_1 + \text{j}\mathbf{I}_2 \qquad (1)$$

For mesh 2,

$$0 = (10 + \text{j}5 - \text{j}10)\mathbf{I}_2 + \text{j}10\mathbf{I}_1$$
$$0 = (2 - \text{j})\mathbf{I}_2 + \text{j}2\mathbf{I}_1 \qquad (2)$$

In matrix form,

$$\begin{bmatrix} 5 \\ 0 \end{bmatrix} = \begin{bmatrix} 2-\text{j} & \text{j} \\ \text{j}2 & 2-\text{j} \end{bmatrix} \begin{bmatrix} \mathbf{I}_1 \\ \mathbf{I}_2 \end{bmatrix}$$

$$\Delta = 5 - \text{j}4, \qquad \Delta_1 = 5(2 - \text{j}), \qquad \Delta_2 = \text{-j}10$$

$$\mathbf{I}_1 = \frac{\Delta_1}{\Delta} = \frac{5(2-\text{j})}{5-\text{j}4} = 1.746\angle 12.1°$$

$$\mathbf{I}_2 = \frac{\Delta_2}{\Delta} = \frac{\text{-j}10}{5\text{-j}4} = 1.562\angle 128.66°$$

For the source,

$$\mathbf{S} = \frac{1}{2}\mathbf{V}\mathbf{I}_1^* = 43.65\angle\text{-}12.1°$$

The average power supplied $= 43.65\cos(12.1°) = \underline{\mathbf{42.68\ W}}$

For the 20-Ω resistor,

$$P = \frac{1}{2}|\mathbf{I}_1|^2 R = \underline{\mathbf{30.48\ W}}$$

For the inductor and capacitor,

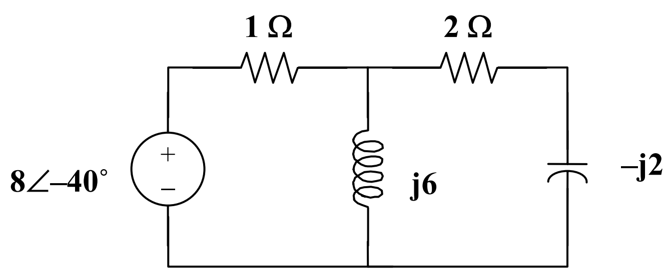
$$P = \underline{\mathbf{0\ W}}$$

For the 10-Ω resistor,

$$P = \frac{1}{2}|\mathbf{I}_2|^2 R = \underline{\mathbf{12.2\ W}}$$

Chapter 11, Solution 5.

Converting the circuit into the frequency domain, we get:



$$I_{1\Omega} = \frac{8\angle -40°}{1 + \frac{j6(2-j2)}{j6+2-j2}} = 1.6828\angle -25.38°$$

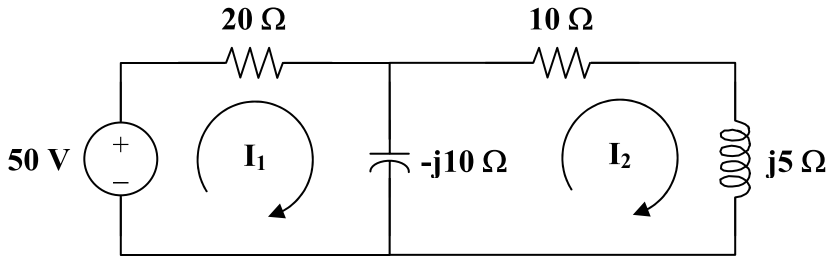
$$P_{1\Omega} = \frac{1.6828^2}{2}1 = \underline{1.4159\ W}$$

$$P_{3H} = P_{0.25F} = \underline{\mathbf{0}}$$

$$|I_{2\Omega}| = \left|\frac{j6}{j6+2-j2}1.6828\angle -25.38°\right| = 2.258$$

$$P_{2\Omega} = \frac{2.258^2}{2}2 = \underline{5.097\ W}$$

Chapter 11, Solution 6.



For mesh 1,

$$(4 + j2)\mathbf{I}_1 - j2(4\angle 60°) + 4\mathbf{V}_o = 0 \quad (1)$$

$$\mathbf{V}_o = 2(4\angle 60° - \mathbf{I}_2) \quad (2)$$

For mesh 2,

$$(2 - j)\mathbf{I}_2 - 2(4\angle 60°) - 4\mathbf{V}_o = 0 \quad (3)$$

Substituting (2) into (3),

$$(2 - j)\mathbf{I}_2 - 8\angle 60° - 8(4\angle 60° - \mathbf{I}_2) = 0$$

$$\mathbf{I}_2 = \frac{40\angle 60°}{10 - j}$$

Hence,

$$\mathbf{V}_o = 2\left(4\angle 60° - \frac{40\angle 60°}{10 - j}\right) = \frac{-j8\angle 60°}{10 - j}$$

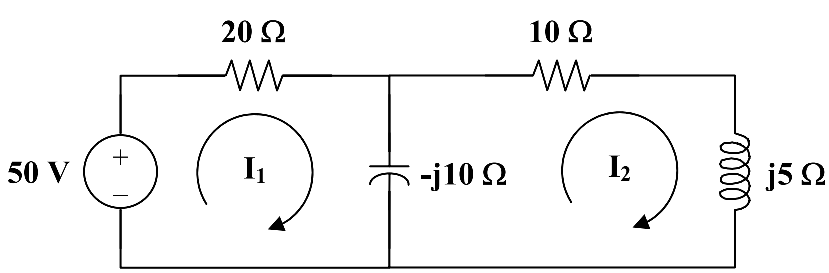
Substituting this into (1),

$$(4 + j2)\mathbf{I}_1 = j8\angle 60° + \frac{j32\angle 60°}{10 - j} = (j8\angle 60°)\left(\frac{14 - j}{10 - j}\right)$$

$$\mathbf{I}_1 = \frac{(4\angle 60°)(1 + j14)}{21 + j8} = 2.498\angle 125.06°$$

$$P_4 = \frac{1}{2}\left|\mathbf{I}_1\right|^2 R = \frac{1}{2}(2.498)^2(4) = \underline{\mathbf{12.48\ W}}$$

Chapter 11, Solution 7.



Applying KVL to the left-hand side of the circuit,

$$8\angle 20° = 4\mathbf{I}_o + 0.1\mathbf{V}_o \tag{1}$$

Applying KCL to the right side of the circuit,

$$8\mathbf{I}_o + \frac{\mathbf{V}_1}{j5} + \frac{\mathbf{V}_1}{10 - j5} = 0$$

But, $$\mathbf{V}_o = \frac{10}{10 - j5}\mathbf{V}_1 \longrightarrow \mathbf{V}_1 = \frac{10 - j5}{10}\mathbf{V}_o$$

Hence, $$8\mathbf{I}_o + \frac{10 - j5}{j50}\mathbf{V}_o + \frac{\mathbf{V}_o}{10} = 0$$

$$\mathbf{I}_o = j0.025\,\mathbf{V}_o \tag{2}$$

Substituting (2) into (1),

$$8\angle 20° = 0.1\mathbf{V}_o\,(1 + j)$$

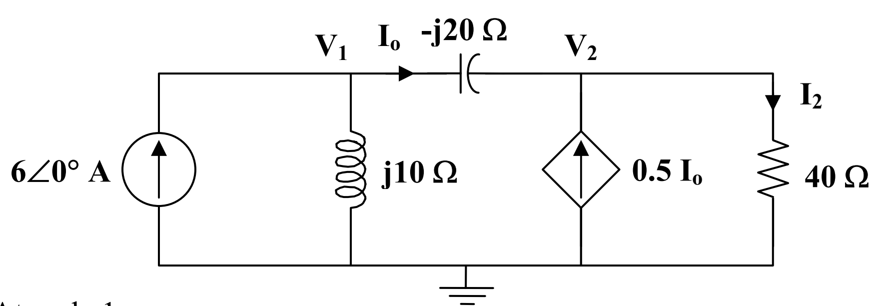
$$\mathbf{V}_o = \frac{80\angle 20°}{1 + j}$$

$$\mathbf{I}_1 = \frac{\mathbf{V}_o}{10} = \frac{10}{\sqrt{2}}\angle -25°$$

$$P = \frac{1}{2}\left|\mathbf{I}_1\right|^2 R = \left(\frac{1}{2}\right)\left(\frac{100}{2}\right)(10) = \underline{\mathbf{250\ W}}$$

Chapter 11, Solution 8.

We apply nodal analysis to the following circuit.



At node 1,

$$6 = \frac{\mathbf{V}_1}{j10} + \frac{\mathbf{V}_1 - \mathbf{V}_2}{-\,j20} \quad \mathbf{V}_1 = j120 - \mathbf{V}_2 \tag{1}$$

At node 2,

$$0.5\mathbf{I}_o + \mathbf{I}_o = \frac{\mathbf{V}_2}{40}$$

But, $$\mathbf{I}_o = \frac{\mathbf{V}_1 - \mathbf{V}_2}{\text{- j20}}$$

Hence, $$\frac{1.5(\mathbf{V}_1 - \mathbf{V}_2)}{\text{- j20}} = \frac{\mathbf{V}_2}{40}$$

$$3\mathbf{V}_1 = (3 - \text{j})\mathbf{V}_2 \qquad (2)$$

Substituting (1) into (2),

$$\text{j}360 - 3\mathbf{V}_2 - 3\mathbf{V}_2 + \text{j}\mathbf{V}_2 = 0$$

$$\mathbf{V}_2 = \frac{\text{j}360}{6 - \text{j}} = \frac{360}{37}(\text{-}1 + \text{j}6)$$

$$\mathbf{I}_2 = \frac{\mathbf{V}_2}{40} = \frac{9}{37}(\text{-}1 + \text{j}6)$$

$$P = \frac{1}{2}\left|\mathbf{I}_2\right|^2 R = \frac{1}{2}\left(\frac{9}{\sqrt{37}}\right)^2(40) = \underline{\mathbf{43.78\ W}}$$

Chapter 11, Solution 9.

$$V_o = \left(1 + \frac{6}{2}\right)V_s = (4)(2) = 8\text{ V rms}$$

$$P_{10} = \frac{V_o^2}{R} = \frac{64}{10}\text{ mW} = \underline{\mathbf{6.4\ mW}}$$

The current through the 2 -kΩ resistor is

$$\frac{V_s}{2k} = 1\text{ mA}$$

$$P_2 = I^2 R = \underline{\mathbf{2\ mW}}$$

Similarly,

$$P_6 = I^2 R = \underline{\mathbf{6\ mW}}$$

Chapter 11, Solution 10.

No current flows through each of the resistors. Hence, for each resistor, $P = \underline{\mathbf{0\ W}}$.

Chapter 11, Solution 11.

$$\omega = 377, \qquad R = 10^4, \qquad C = 200 \times 10^{-9}$$
$$\omega RC = (377)(10^4)(200 \times 10^{-9}) = 0.754$$
$$\tan^{-1}(\omega RC) = 37.02°$$

$$Z_{ab} = \frac{10k}{\sqrt{1 + (0.754)^2}} \angle -37.02° = 6.375 \angle -37.02° \text{ k}\Omega$$

$$i(t) = 2\sin(377t + 22°) = 2\cos(377t - 68°) \text{ mA}$$
$$I = 2 \angle -68°$$

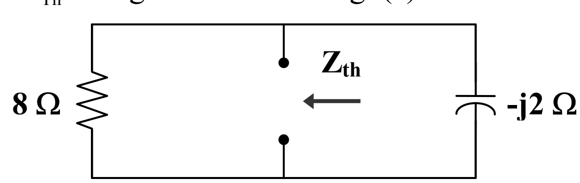
$$S = I_{rms}^2 Z_{ab} = \left(\frac{2 \times 10^{-3}}{\sqrt{2}} \right)^2 (6.375 \angle -37.02°) \times 10^3$$

$$S = 12.751 \angle -37.02° \text{ mVA}$$

$$P = |S| \cos(37.02) = \underline{\mathbf{10.181\ mW}}$$

Chapter 11, Solution 12.

(a) We find $\mathbf{Z}_{Th}$ using the circuit in Fig. (a).

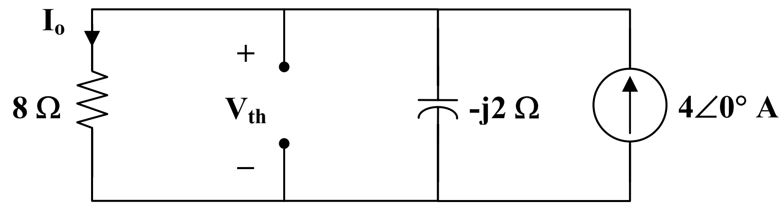


(a)

$$\mathbf{Z}_{Th} = 8 \,||\, -j2 = \frac{(8)(-j2)}{8 - j2} = \frac{8}{17}(1 - j4) = 0.471 - j1.882$$

$$\mathbf{Z}_L = \mathbf{Z}_{Th}^* = \underline{\mathbf{0.471 + j1.882\ \Omega}}$$

We find $\mathbf{V}_{Th}$ using the circuit in Fig. (b).



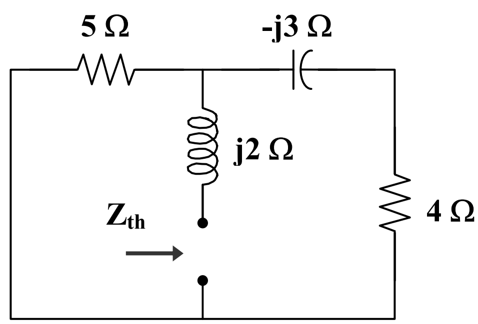
(b)

$$\mathbf{I}_o = \frac{-j2}{8-j2}(4\angle 0°)$$

$$\mathbf{V}_{Th} = 8\mathrm{I}_o = \frac{-j64}{8-j2}$$

$$\mathrm{P}_{max} = \frac{|\mathbf{V}_{Th}|^2}{8\mathrm{R}_L} = \frac{\left(\dfrac{64}{\sqrt{68}}\right)^2}{(8)(0.471)} = \underline{\mathbf{15.99\ W}}$$

(b) We obtain $\mathbf{Z}_{Th}$ from the circuit in Fig. (c).



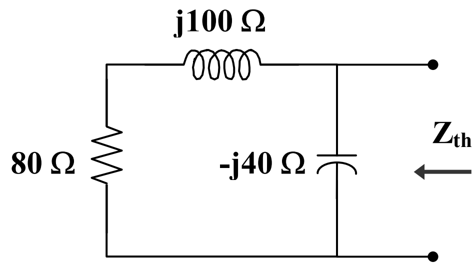
(c)

$$\mathbf{Z}_{Th} = j2 + 5 \,||\, (4-j3) = j2 + \frac{(5)(4-j3)}{9-j3} = 2.5 + j1.167$$

$$\mathbf{Z}_L = \mathbf{Z}_{Th}^* = \underline{\mathbf{2.5 - j1.167\ \Omega}}$$

Chapter 11, Solution 13.

(a) We find $\mathbf{Z}_{Th}$ at the load terminals using the circuit in Fig. (a).

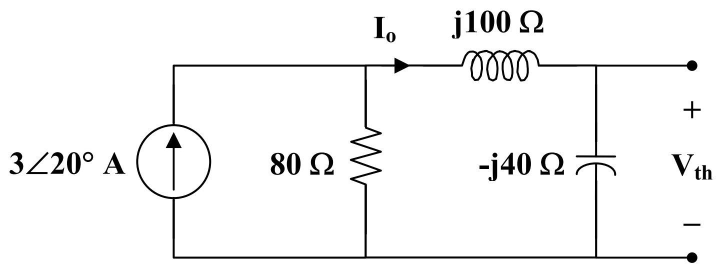


(a)

$$\mathbf{Z}_{Th} = \text{-j}40 \,||\, (80 + \text{j}100) = \frac{(\text{-j}40)(80 + \text{j}100)}{80 + \text{j}60} = 51.2 - \text{j}1.6$$

$$\mathbf{Z}_L = \mathbf{Z}_{Th}^* = \underline{\mathbf{51.2 + j1.6\,\Omega}}$$

(b) We find $\mathbf{V}_{Th}$ at the load terminals using Fig. (b).



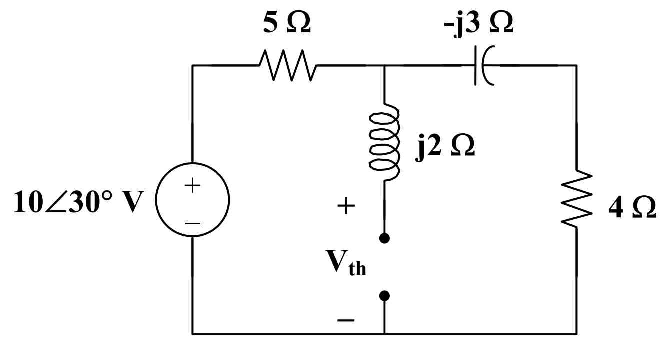
(b)

$$\mathbf{I}_o = \frac{80}{80 + \text{j}100 - \text{j}40}(3\angle 20°) = \frac{(8)(3\angle 20°)}{8 + \text{j}6}$$

$$\mathbf{V}_{Th} = \text{-j}40\,\mathbf{I}_o = \frac{(\text{-j}40)(24\angle 20°)}{8 + \text{j}6}$$

$$P_{max} = \frac{|\mathbf{V}_{Th}|^2}{8R_L} = \frac{\left(\frac{40}{10}\cdot 24\right)^2}{(8)(51.2)} = \underline{\mathbf{22.5\ W}}$$

From Fig.(d), we obtain $\mathbf{V}_{Th}$ using the voltage division principle.

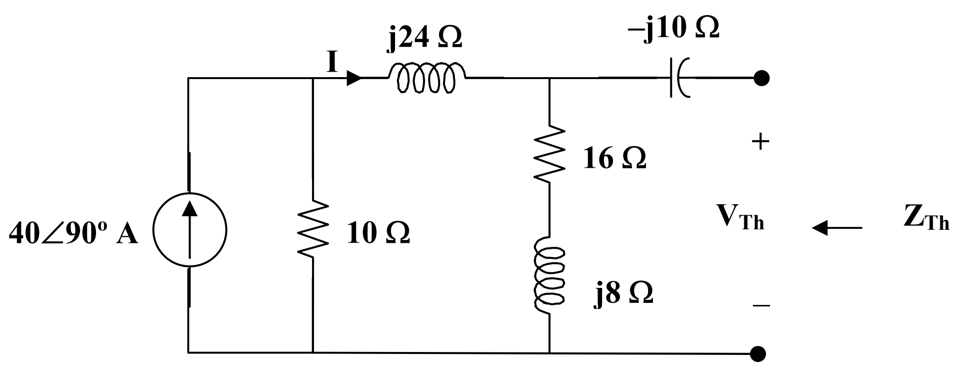


(d)

$$\mathbf{V}_{Th} = \left(\frac{4 - j3}{9 - j3}\right)(10\angle 30°) = \left(\frac{4 - j3}{3 - j}\right)\left(\frac{10}{3}\angle 30°\right)$$

$$P_{max} = \frac{|\mathbf{V}_{Th}|^2}{8R_L} = \frac{\left(\frac{5}{\sqrt{10}} \cdot \frac{10}{3}\right)^2}{(8)(2.5)} = \underline{\mathbf{1.389\ W}}$$

Chapter 11, Solution 14.



$$Z_{Th} = -j10 + \frac{(10 + j24)(16 + j8)}{10 + j24 + 16 + j8} = -j10 + 8.245 + j7.7 = 8.245 - j2.3\Omega$$

$$Z = Z_{Th}^* = \underline{8.245 + j2.3\Omega}$$

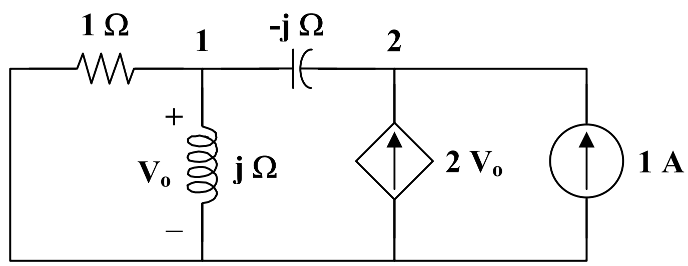
$$V_{Th} = I(16 + j8) = \frac{10}{10 + j24 + 16 + j8} j40(16 + j8)$$

$$= 173.55\angle 65.66° = 71.53 + j158.12 \text{ V}$$

$$P_{max} = \left|I_{rms}^2\right| 8.245 = \frac{\dfrac{\left|V_{Th}^2\right|}{\sqrt{2}^2}}{(2x8.245)^2} 8.245 = \underline{456.6 \text{ W}}$$

Chapter 11, Solution 15.

To find $\mathbf{Z}_{Th}$, insert a 1-A current source at the load terminals as shown in Fig. (a).



(a)

At node 1,

$$\frac{\mathbf{V}_o}{1} + \frac{\mathbf{V}_o}{j} = \frac{\mathbf{V}_2 - \mathbf{V}_o}{-j} \longrightarrow \mathbf{V}_o = j\mathbf{V}_2 \qquad (1)$$

At node 2,

$$1 + 2\mathbf{V}_o = \frac{\mathbf{V}_2 - \mathbf{V}_o}{-j} \longrightarrow 1 = j\mathbf{V}_2 - (2 + j)\mathbf{V}_o \qquad (2)$$

Substituting (1) into (2),

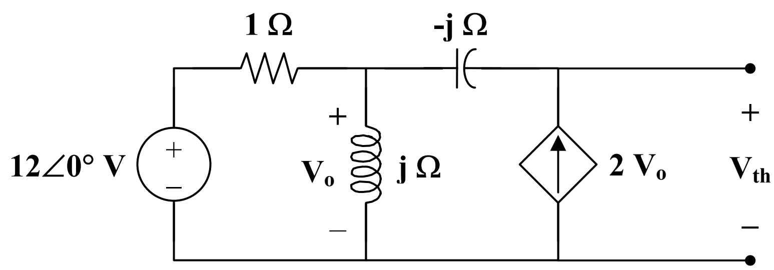
$$1 = j\mathbf{V}_2 - (2 + j)(j)\mathbf{V}_2 = (1 - j)\mathbf{V}_2$$

$$\mathbf{V}_2 = \frac{1}{1 - j}$$

$$\mathbf{V}_{Th} = \frac{\mathbf{V}_2}{1} = \frac{1 + j}{2} = 0.5 + j0.5$$

$$\mathbf{Z}_L = \mathbf{Z}_{Th}^* = \underline{\mathbf{0.5 - j0.5\,\Omega}}$$

We now obtain $\mathbf{V}_{Th}$ from Fig. (b).



(b)

$$2\mathbf{V}_o + \frac{12 - \mathbf{V}_o}{1} = \frac{\mathbf{V}_o}{j}$$

$$\mathbf{V}_o = \frac{-12}{1+j}$$

$$\mathbf{V}_o - (-j \times 2\mathbf{V}_o) + \mathbf{V}_{Th} = 0$$

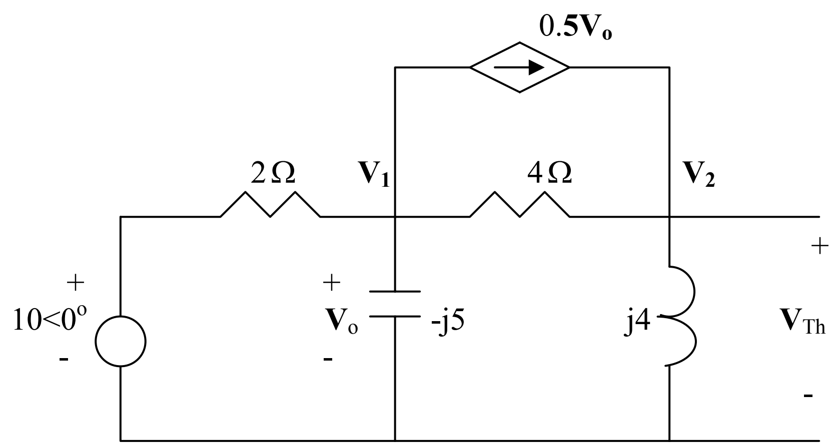
$$\mathbf{V}_{Th} = -(1+j2)\mathbf{V}_o = \frac{(12)(1+j2)}{1+j}$$

$$P_{max} = \frac{|\mathbf{V}_{Th}|^2}{8R_L} = \frac{\left(\frac{12\sqrt{5}}{\sqrt{2}}\right)^2}{(8)(0.5)} = \underline{\mathbf{90\ W}}$$

Chapter 11, Solution 16.

$$\omega = 4, \quad 1\text{H} \longrightarrow j\omega L = j4, \quad 1/20\text{F} \longrightarrow \frac{1}{j\omega C} = \frac{1}{j4x1/20} = -j5$$

We find the Thevenin equivalent at the terminals of Z_L. To find V_{Th}, we use the circuit shown below.



At node 1,

$$\frac{10-V_1}{2}=\frac{V_1}{-j5}+0.25V_1+\frac{V_1-V_2}{4} \longrightarrow 5=V_1(1+j0.2)-0.25V_2 \qquad (1)$$

At node 2,

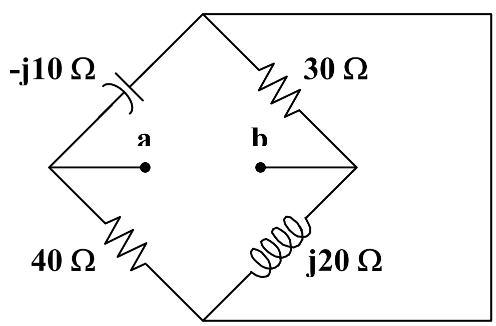
$$\frac{V_1-V_2}{4}+0.25V_1=\frac{V_2}{j4} \longrightarrow 0=0.5V_1+V_2(-0.25+j0.25) \qquad (2)$$

Solving (1) and (2) leads to

$V_{Th}=V_2=6.1947+j7.0796=\underline{9.4072\angle 48.81^o}$

Chapter 11, Solution 17.

We find R_{Th} at terminals a-b following Fig. (a).

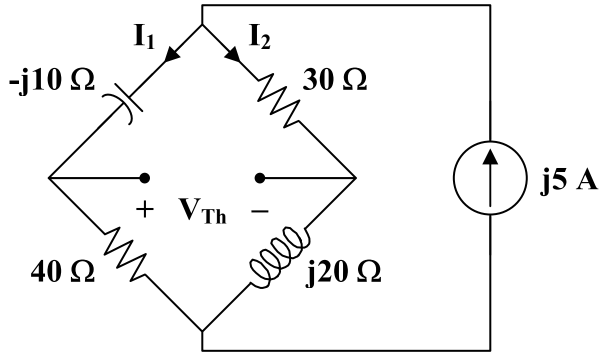


(a)

$$\mathbf{Z}_{\mathrm{Th}}=30\,||\,\mathrm{j}20+40\,||\,(\text{-j}10)=\frac{(30)(\mathrm{j}20)}{30+\mathrm{j}20}+\frac{(40)(\text{-j}10)}{40-\mathrm{j}10}$$

$$\mathbf{Z}_{\mathrm{Th}}=9.23+\mathrm{j}13.85+2.353-\mathrm{j}9.41$$
$$\mathbf{Z}_{\mathrm{Th}}=11.583+\mathrm{j}4.44\,\Omega$$
$$\mathbf{Z}_{\mathrm{L}}=\mathbf{Z}^*_{\mathrm{Th}}=\underline{\mathbf{11.583-j4.44\,\Omega}}$$

We obtain $\mathbf{V}_{\mathrm{Th}}$ from Fig. (b).



(b)

Using current division,

$$\mathbf{I}_1 = \frac{30 + j20}{70 + j10}(j5) = -1.1 + j2.3$$

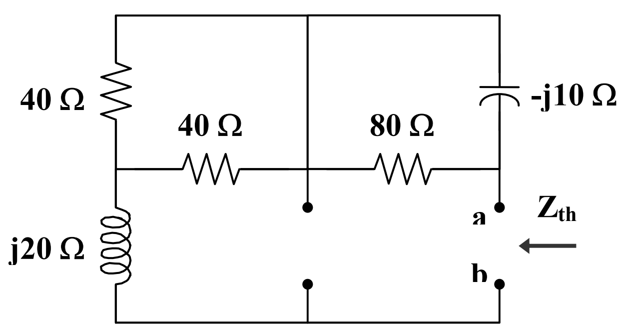
$$\mathbf{I}_2 = \frac{40 - j10}{70 + j10}(j5) = 1.1 + j2.7$$

$$\mathbf{V}_{Th} = 30\mathbf{I}_2 + j10\mathbf{I}_1 = 10 + j70$$

$$P_{max} = \frac{\left|\mathbf{V}_{Th}\right|^2}{8R_L} = \frac{5000}{(8)(11.583)} = \underline{\mathbf{53.96\ W}}$$

Chapter 11, Solution 18.

We find $\mathbf{Z}_{Th}$ at terminals a-b as shown in the figure below.



$$\mathbf{Z}_{Th} = j20 + 40 \,||\, 40 + 80 \,||\, (-j10) = j20 + 20 + \frac{(80)(-j10)}{80 - j10}$$

$$\mathbf{Z}_{Th} = 21.23 + j10.154$$

$$\mathbf{Z}_L = \mathbf{Z}_{Th}^* = \underline{\mathbf{21.23 - j10.15\ \Omega}}$$

Chapter 11, Solution 19.

At the load terminals,

$$\mathbf{Z}_{Th} = -j2 + 6 \,||\, (3 + j) = -j2 + \frac{(6)(3 + j)}{9 + j}$$

$$\mathbf{Z}_{Th} = 2.049 - j1.561$$

$$R_L = \left|\mathbf{Z}_{Th}\right| = 2.576\ \Omega$$

To get $\mathbf{V}_{Th}$, let $\mathbf{Z} = 6 \,||\, (3 + j) = 2.049 + j0.439$.

By transforming the current sources, we obtain

$$\mathbf{V}_{Th} = (4\angle 0°)\mathbf{Z} = 8.196 + j1.756$$

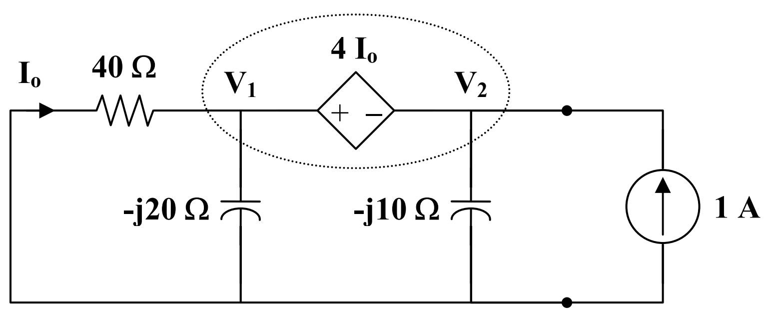
$$P_{max} = \frac{|\mathbf{V}_{Th}|^2}{8R_L} = \frac{70.258}{20.608} = \underline{\mathbf{3.409\ W}}$$

Chapter 11, Solution 20.

Combine j20 Ω and -j10 Ω to get

$$j20 \,||\, \text{-}j10 = \text{-}j20$$

To find $\mathbf{Z}_{Th}$, insert a 1-A current source at the terminals of R_L, as shown in Fig. (a).



(a)

At the supernode,

$$1 = \frac{\mathbf{V}_1}{40} + \frac{\mathbf{V}_1}{\text{-}j20} + \frac{\mathbf{V}_2}{\text{-}j10}$$

$$40 = (1 + j2)\mathbf{V}_1 + j4\mathbf{V}_2 \qquad (1)$$

Also, $\mathbf{V}_1 = \mathbf{V}_2 + 4\mathbf{I}_o$, where $\mathbf{I}_o = \dfrac{\text{-}\mathbf{V}_1}{40}$

$$1.1\mathbf{V}_1 = \mathbf{V}_2 \longrightarrow \mathbf{V}_1 = \frac{\mathbf{V}_2}{1.1} \qquad (2)$$

Substituting (2) into (1),

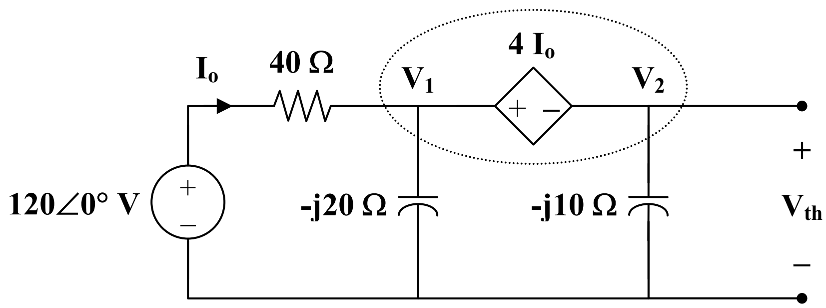
$$40 = (1 + j2)\left(\frac{\mathbf{V}_2}{1.1}\right) + j4\mathbf{V}_2$$

$$\mathbf{V}_2 = \frac{44}{1 + j6.4}$$

$$\mathbf{Z}_{Th} = \frac{\mathbf{V}_2}{1} = 1.05 - j6.71\,\Omega$$

$$R_L = \left| \mathbf{Z}_{Th} \right| = \underline{\mathbf{6.792\,\Omega}}$$

To find $\mathbf{V}_{Th}$, consider the circuit in Fig. (b).



(b)

At the supernode,

$$\frac{120 - \mathbf{V}_1}{40} = \frac{\mathbf{V}_1}{-j20} + \frac{\mathbf{V}_2}{-j10}$$

$$120 = (1 + j2)\,\mathbf{V}_1 + j4\,\mathbf{V}_2 \qquad (3)$$

Also, $\mathbf{V}_1 = \mathbf{V}_2 + 4\,\mathbf{I}_o$, where $\mathbf{I}_o = \dfrac{120 - \mathbf{V}_1}{40}$

$$\mathbf{V}_1 = \frac{\mathbf{V}_2 + 12}{1.1} \qquad (4)$$

Substituting (4) into (3),

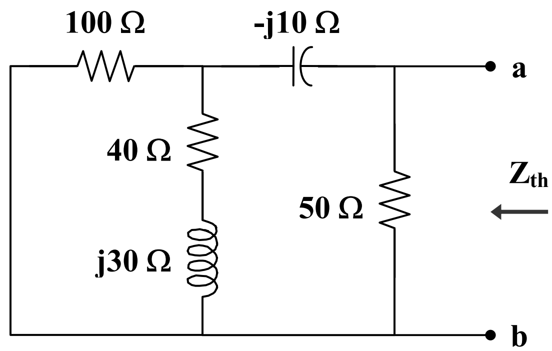
$$109.09 - j21.82 = (0.9091 + j5.818)\,\mathbf{V}_2$$

$$\mathbf{V}_{Th} = \mathbf{V}_2 = \frac{109.09 - j21.82}{0.9091 + j5.818} = 18.893\angle -92.43°$$

$$P_{max} = \frac{\left| \mathbf{V}_{Th} \right|^2}{8\,R_L} = \frac{(18.893)^2}{(8)(6.792)} = \underline{\mathbf{6.569\ W}}$$

Chapter 11, Solution 21.

We find $\mathbf{Z}_{Th}$ at terminals a-b, as shown in the figure below.



$$\mathbf{Z}_{Th} = 50 \,||\, [\,-\,j10 + 100 \,||\, (40 + j30)\,]$$

where $100 \,||\, (40 + j30) = \dfrac{(100)(40 + j30)}{140 + j30} = 31.707 + j14.634$

$$\mathbf{Z}_{Th} = 50 \,||\, (31.707 + j4.634) = \frac{(50)(31.707 + j4.634)}{81.707 + j4.634}$$

$$\mathbf{Z}_{Th} = 19.5 + j1.73$$

$$R_L = \left| \mathbf{Z}_{Th} \right| = \underline{\mathbf{19.58\ \Omega}}$$

Chapter 11, Solution 22.

$$i(t) = 4\sin t, \qquad 0 < t < \pi$$

$$I^2_{rms} = \frac{1}{\pi}\int_0^{\pi} 16\sin^2 t\,dt = \frac{16}{\pi}\left(\frac{t}{2} - \frac{\sin 2t}{4}\right)\Big|_0^{\pi} = \frac{16}{\pi}\left(\frac{\pi}{2} - 0\right) = 8$$

$$I_{rms} = \sqrt{8} = \underline{2.828\ \text{A}}$$

Chapter 11, Solution 23.

$$v(t) = \begin{cases} 15, & 0 < t < 2 \\ 5, & 2 < t < 6 \end{cases}$$

$$V_{rms}^2 = \frac{1}{6}\left[\int_0^2 15^2 \ dt + \int_2^6 5^2 \ dt\right] = \frac{550}{6}$$

$$V_{rms} = \underline{\mathbf{9.574\ V}}$$

Chapter 11, Solution 24.

$$T = 2, \qquad v(t) = \begin{cases} 5, & 0 < t < 1 \\ -5, & 1 < t < 2 \end{cases}$$

$$V_{rms}^2 = \frac{1}{2}\left[\int_0^1 5^2 \ dt + \int_1^2 (-5)^2 \ dt\right] = \frac{25}{2}[1+1] = 25$$

$$V_{rms} = \underline{\mathbf{5\ V}}$$

Chapter 11, Solution 25.

$$f_{rms}^2 = \frac{1}{T}\int_0^T f^2(t)dt = \frac{1}{3}\left[\int_0^1 (-4)^2 dt + \int_1^2 0dt + \int_2^3 4^2 dt\right]$$
$$= \frac{1}{3}[16+0+16] = \frac{32}{3}$$

$$f_{rms} = \sqrt{\frac{32}{3}} = \underline{3.266}$$

Chapter 11, Solution 26.

$$T = 4, \qquad v(t) = \begin{cases} 5 & 0 < t < 2 \\ 10 & 2 < t < 4 \end{cases}$$

$$V_{rms}^2 = \frac{1}{4}\left[\int_0^2 5^2\ dt + \int_2^4 (10)^2\ dt\right] = \frac{1}{4}[50 + 200] = 62.5$$

$$V_{rms} = \underline{\mathbf{7.906\ V}}$$

Chapter 11, Solution 27.

$$T = 5, \qquad i(t) = t, \quad 0 < t < 5$$

$$I_{rms}^2 = \frac{1}{5}\int_0^5 t^2\ dt = \frac{1}{5}\cdot\frac{t^3}{3}\Big|_0^5 = \frac{125}{15} = 8.333$$

$$I_{rms} = \underline{\mathbf{2.887\ A}}$$

Chapter 11, Solution 28.

$$V_{rms}^2 = \frac{1}{5}\left[\int_0^2 (4t)^2\ dt + \int_2^5 0^2\ dt\right]$$

$$V_{rms}^2 = \frac{1}{5}\cdot\frac{16t^3}{3}\Big|_0^2 = \frac{16}{15}(8) = 8.533$$

$$V_{rms} = \underline{\mathbf{2.92\ V}}$$

$$P = \frac{V_{rms}^2}{R} = \frac{8.533}{2} = \underline{\mathbf{4.267\ W}}$$

Chapter 11, Solution 29.

$$T = 20, \qquad i(t) = \begin{cases} 20 - 2t & 5 < t < 15 \\ -40 + 2t & 15 < t < 25 \end{cases}$$

$$I_{eff}^2 = \frac{1}{20}\left[\int_5^{15} (20 - 2t)^2 \, dt + \int_{15}^{25} (-40 + 2t)^2 \, dt\right]$$

$$I_{eff}^2 = \frac{1}{5}\left[\int_5^{15} (100 - 20t + t^2) \, dt + \int_{15}^{25} (t^2 - 40t + 400) \, dt\right]$$

$$I_{eff}^2 = \frac{1}{5}\left[\left(100t - 10t^2 + \frac{t^3}{3}\right)\Bigg|_5^{15} + \left(\frac{t^3}{3} - 20t^2 + 400t\right)\Bigg|_{15}^{25}\right]$$

$$I_{eff}^2 = \frac{1}{5}[83.33 + 83.33] = 33.332$$

$$I_{eff} = \underline{\mathbf{5.773\ A}}$$

$$P = I_{eff}^2 R = \underline{\mathbf{400\ W}}$$

Chapter 11, Solution 30.

$$v(t) = \begin{cases} t & 0 < t < 2 \\ -1 & 2 < t < 4 \end{cases}$$

$$V_{rms}^2 = \frac{1}{4}\left[\int_0^2 t^2 \, dt + \int_2^4 (-1)^2 \, dt\right] = \frac{1}{4}\left[\frac{8}{3} + 2\right] = 1.1667$$

$$V_{rms} = \underline{\mathbf{1.08\ V}}$$

Chapter 11, Solution 31.

$$V^2{}_{rms} = \frac{1}{2}\int_0^2 v(t) dt = \frac{1}{2}\left[\int_0^1 (2t)^2 \, dt + \int_1^2 (-4)^2 \, dt\right] = \frac{1}{2}\left[\frac{4}{3} + 16\right] = 8.6667$$

$$V_{rms} = \underline{2.944\ \text{V}}$$

Chapter 11, Solution 32.

$$I_{rms}^2 = \frac{1}{2}\left[\int_0^1 (10t^2)^2\ dt + \int_1^2 0\ dt\right]$$

$$I_{rms}^2 = 50\int_0^1 t^4\ dt = 50 \cdot \frac{t^5}{5}\Big|_0^1 = 10$$

$$I_{rms} = \underline{\mathbf{3.162\ A}}$$

Chapter 11, Solution 33.

$$i(t) = \begin{cases} 10 & 0 < t < 1 \\ 20 - 10t & 1 < t < 2 \\ 0 & 2 < t < 3 \end{cases}$$

$$I_{rms}^2 = \frac{1}{3}\left[\int_0^1 10^2\ dt + \int_1^2 (20 - 10t)^2\ dt + 0\right]$$

$$3I_{rms}^2 = 100 + 100\int_1^2 (4 - 4t + t^2)\ dt = 100 + (100)(1/3) = 133.33$$

$$I_{rms} = \sqrt{\frac{133.33}{3}} = \underline{\mathbf{6.667\ A}}$$

Chapter 11, Solution 34.

$$f_{rms}^2 = \frac{1}{T}\int_0^T f^2(t)dt = \frac{1}{3}\left[\int_0^2 (3t)^2 dt + \int_2^3 6^2 dt\right]$$

$$= \frac{1}{3}\left[\frac{9t^3}{3}\Bigg|_0^2 + 36\right] = 20$$

$$f_{rms} = \sqrt{20} = \underline{4.472}$$

Chapter 11, Solution 35.

$$V_{rms}^2 = \frac{1}{6}\left[\int_0^1 10^2\ dt + \int_1^2 20^2\ dt + \int_2^4 30^2\ dt + \int_4^5 20^2\ dt + \int_5^6 10^2\ dt\right]$$

$$V_{rms}^2 = \frac{1}{6}[100 + 400 + 1800 + 400 + 100] = 466.67$$

$$V_{rms} = \underline{\mathbf{21.6\ V}}$$

Chapter 11, Solution 36.

(a) $I_{rms} = \underline{10\ \text{A}}$

(b) $V^2{}_{rms} = 4^2 + \left(\frac{3}{\sqrt{2}}\right)^2 \longrightarrow V_{rms} = \sqrt{16 + \frac{9}{2}} = \underline{4.528\ \text{V}}$ (checked)

(c) $I_{rms} = \sqrt{64 + \frac{36}{2}} = \underline{9.055\ \text{A}}$

(d) $V_{rms} = \sqrt{\frac{25}{2} + \frac{16}{2}} = \underline{4.528\ \text{V}}$

Chapter 11, Solution 37.

$$i = i_1 + i_2 + i_3 = 8 + 4\sin(t + 10^o) + 6\cos(2t + 30^o)$$

$$I_{rms} = \sqrt{I^2{}_{1rms} + I^2{}_{2rms} + I^2{}_{3rms}} = \sqrt{64 + \frac{16}{2} + \frac{36}{2}} = \sqrt{90} = \underline{9.487\ \text{A}}$$

Chapter 11, Solution 38.

$$0.5\ \text{H} \longrightarrow j\omega L = j(2\pi)(50)(0.5) = j157.08$$

$$\mathbf{Z} = R + jX_L = 30 + j157.08$$

$$\mathbf{S} = \frac{|\mathbf{V}|^2}{\mathbf{Z}^*} = \frac{(210)^2}{30 - j157.08}$$

$$\text{Apparent power } = |\mathbf{S}| = \frac{(210)^2}{160} = \underline{275.6 \text{ VA}}$$

$$\text{pf} = \cos\theta = \cos\left(\tan^{-1}\left(\frac{157.08}{36}\right)\right) = \cos(79.19°)$$

$$\text{pf} = \underline{\mathbf{0.1876 \quad (lagging)}}$$

Chapter 11, Solution 39.

$$\mathbf{Z}_T = j4 \,||\, (12 - j8) = \frac{(j4)(12 - j8)}{12 - j4}$$

$$\mathbf{Z}_T = 0.4(3 + j11) = 4.56\angle 74.74°$$

$$\text{pf} = \cos(74.74°) = \underline{\mathbf{0.2631}}$$

Chapter 11, Solution 40.

At node 1,

$$\frac{120\angle 30^o - V_1}{20} = \frac{V_1}{j30} + \frac{V_1 - V_2}{50} \longrightarrow$$

$$103.92 + j60 = V_1(1.4 - j0.6667) - 0.4V_2 \qquad (1)$$

At node 2,

$$\frac{V_1 - V_2}{50} = \frac{V_2}{10} + \frac{V_2}{-j40} \longrightarrow \qquad 0 = -V_1 + (6 + j1.25)V_2 \qquad (2)$$

Solving (1) and (2) leads to

$$\mathbf{V}_1 = 45.045 + j66.935, \quad \mathbf{V}_2 = 9.423 + j9.193$$

(a) $\underline{P_{j30\Omega} = 0 = P_{-j40\Omega}}$

$$P_{10\Omega} = \frac{V^2{}_{rms}}{R} = \frac{1}{2}\frac{|V_2|^2}{R} = 173.3/20 = \underline{8.665\ \text{W}}$$

$$P_{50\Omega} = \frac{1}{2}\frac{|V_1 - V_2|^2}{R} = 4603.1/100 = \underline{46.03\ \text{W}}$$

$$P_{20\Omega} = \frac{1}{2}\frac{|120\angle 30^o - V_1|^2}{R} = 3514/40 = \underline{87.86\ \text{W}}$$

(b) $I = \dfrac{120\angle 30^o - V_1}{20} = 2.944 - j0.3467, \qquad V_s = 120\angle 30^o = 103.92 + j60$

$$\overline{S} = \frac{1}{2}V_s I^{\bullet} = 142.5 - j106.3, \qquad S = |\overline{S}| = \underline{177.8\ \text{VA}}$$

(c) pf = 142.5/177.8 = **<u>0.8015 (leading).</u>**

Chapter 11, Solution 41.

(a) $$\text{- j2} \,||\, (\text{j5} - \text{j2}) = \text{-j2} \,||\, \text{-j3} = \frac{(\text{-j2})(\text{-j3})}{\text{j}} = \text{-j6}$$

$$\mathbf{Z}_T = 4 - \text{j6} = 7.211\angle\text{-}56.31°$$

pf = cos(-56.31°) = **<u>0.5547 (leading)</u>**

(b) $$\text{j2} \,||\, (4 + \text{j}) = \frac{(\text{j2})(4 + \text{j})}{4 + \text{j3}} = 0.64 + \text{j}1.52$$

$$\mathbf{Z} = 1 \,||\, (0.64 + \text{j}1.52 - \text{j}) = \frac{0.64 + \text{j}0.44}{1.64 + \text{j}0.44} = 0.4793\angle 21.5°$$

pf = cos(21.5°) = **<u>0.9304 (lagging)</u>**

Chapter 11, Solution 42.

$$\text{pf} = 0.86 = \cos\theta \longrightarrow \theta = 30.683°$$

$$Q = S\sin\theta \longrightarrow S = \frac{Q}{\sin\theta} = \frac{5}{\sin(30.683°)} = 9.798 \text{ kVA}$$

$$\mathbf{S} = \mathbf{V}\,\mathbf{I}^* \longrightarrow \mathbf{I}^* = \frac{\mathbf{S}}{\mathbf{V}} = \frac{9.798\times10^3\angle 30.683°}{220} = 44.536\angle 30.683°$$

Peak current $= \sqrt{2}\times 44.536 =$ $\underline{\mathbf{62.98\ A}}$

Apparent power = S = $\underline{\mathbf{9.798\ kVA}}$

Chapter 11, Solution 43.

(a) $V_{rms} = \sqrt{V^2_{1rms} + V^2_{2rms} + V^2_{3rms}} = \sqrt{25 + \frac{9}{2} + \frac{1}{2}} = \sqrt{30} = \underline{5.477\text{ V}}$

(b) $P = \dfrac{V^2_{rms}}{R} = 30/10 = \underline{3\text{ W}}$

Chapter 11, Solution 44.

$$pf = 0.65 = \cos\theta \longrightarrow \theta = 49.46^o$$

$$\overline{S} = S(\cos\theta + j\sin\theta) = 50(0.65 + j0.7599) = 32.5 + j38 \quad \text{kVA}$$

Thus,

$\underline{\text{Average power} = 32.5\text{ kW}, \quad \text{Reactive power} = 38\text{ kVAR}}$

Chapter 11, Solution 45.

(a) $V^2{}_{rms} = 20^2 + \dfrac{60^2}{2} = 2200 \quad \longrightarrow \quad V_{rms} = \underline{46.9\text{ V}}$

$$I_{rms} = \sqrt{1^2 + \frac{0.5^2}{2}} = \sqrt{1.125} = \underline{1.061A}$$

(b) $P = V_{rms} I_{rms} = \underline{49.74\text{ W}}$

Chapter 11, Solution 46.

(a) $\mathbf{S} = \mathbf{V}\,\mathbf{I}^* = (220\angle 30°)(0.5\angle -60°) = 110\angle -30°$

$\mathbf{S} = \underline{\mathbf{95.26 - j55\ VA}}$

Apparent power = $\underline{\textbf{110 VA}}$

Real power = $\underline{\textbf{95.26 W}}$

Reactive power = $\underline{\textbf{55 VAR}}$

pf is **leading** because current leads voltage

(b) $\mathbf{S} = \mathbf{V}\,\mathbf{I}^* = (250\angle -10°)(6.2\angle 25°) = 1550\angle 15°$

$\mathbf{S} = \underline{\mathbf{1497.2 + j401.2\ VA}}$

Apparent power = $\underline{\textbf{1550 VA}}$

Real power = $\underline{\textbf{1497.2 W}}$

Reactive power = $\underline{\textbf{401.2 VAR}}$

pf is **lagging** because current lags voltage

(c) $\mathbf{S} = \mathbf{V}\,\mathbf{I}^* = (120\angle 0°)(2.4\angle 15°) = 288\angle 15°$

$\mathbf{S} = \underline{\mathbf{278.2 + j74.54\ VA}}$

Apparent power = $\underline{\textbf{288 VA}}$

Real power = $\underline{\textbf{278.2 W}}$

Reactive power = $\underline{\textbf{74.54 VAR}}$

pf is **lagging** because current lags voltage

(d) $\mathbf{S} = \mathbf{V}\,\mathbf{I}^* = (160\angle 45°)(8.5\angle -180°) = 1360\angle -135°$

$\mathbf{S} = \underline{\mathbf{-961.7 - j961.7\ VA}}$

Apparent power = $\underline{\mathbf{1360\ VA}}$

Real power = $\underline{\mathbf{-961.7\ W}}$

Reactive power = $\underline{\mathbf{-961.7\ VAR}}$

pf is **leading** because current leads voltage

Chapter 11, Solution 47.

(a) $\mathbf{V} = 112\angle 10°, \qquad \mathbf{I} = 4\angle -50°$

$$\mathbf{S} = \frac{1}{2}\mathbf{V}\,\mathbf{I}^* = 224\angle 60° = \underline{\mathbf{112 + j194\ VA}}$$

Average power = $\underline{\mathbf{112\ W}}$

Reactive power = $\underline{\mathbf{194\ VAR}}$

(b) $\mathbf{V} = 160\angle 0°, \qquad \mathbf{I} = 25\angle 45°$

$$\mathbf{S} = \frac{1}{2}\mathbf{V}\,\mathbf{I}^* = 200\angle -45° = \underline{\mathbf{141.42 - j141.42\ VA}}$$

Average power = $\underline{\mathbf{141.42\ W}}$

Reactive power = $\underline{\mathbf{-141.42\ VAR}}$

(c) $$\mathbf{S} = \frac{|\mathbf{V}|^2}{\mathbf{Z}^*} = \frac{(80)^2}{50\angle -30°} = 128\angle 30° = \underline{\mathbf{90.51 + j64\ VA}}$$

Average power = $\underline{\mathbf{90.51\ W}}$

Reactive power = $\underline{\mathbf{64\ VAR}}$

(d) $$\mathbf{S} = |\mathbf{I}|^2\,\mathbf{Z} = (100)(100\angle 45°) = \underline{\mathbf{7.071 + j7.071\ kVA}}$$

Average power = $\underline{\mathbf{7.071\ kW}}$

Reactive power = $\underline{\mathbf{7.071\ kVAR}}$

Chapter 11, Solution 48.

(a) $\mathbf{S} = \text{P} - \text{jQ} = \underline{\mathbf{269 - j150\ VA}}$

(b) $\text{pf} = \cos\theta = 0.9 \longrightarrow \theta = 25.84°$

$$\text{Q} = \text{S}\sin\theta \longrightarrow \text{S} = \frac{\text{Q}}{\sin\theta} = \frac{2000}{\sin(25.84°)} = 4588.31$$

$\text{P} = \text{S}\cos\theta = 4129.48$

$\mathbf{S} = \underline{\mathbf{4129 - j2000\ VA}}$

(c) $$\text{Q} = \text{S}\sin\theta \longrightarrow \sin\theta = \frac{\text{Q}}{\text{S}} = \frac{450}{600} = 0.75$$

$\theta = 48.59$, $\text{pf} = 0.6614$

$\text{P} = \text{S}\cos\theta = (600)(0.6614) = 396.86$

$\mathbf{S} = \underline{\mathbf{396.9 + j450\ VA}}$

(d) $$\text{S} = \frac{|\mathbf{V}|^2}{|\mathbf{Z}|} = \frac{(220)^2}{40} = 1210$$

$$\text{P} = \text{S}\cos\theta \longrightarrow \cos\theta = \frac{\text{P}}{\text{S}} = \frac{1000}{1210} = 0.8264$$

$\theta = 34.26°$

$\text{Q} = \text{S}\sin\theta = 681.25$

$\mathbf{S} = \underline{\mathbf{1000 + j681.2\ VA}}$

Chapter 11, Solution 49.

(a) $$\mathbf{S} = 4 + \text{j}\frac{4}{0.86}\sin(\cos^{-1}(0.86))\ \text{kVA}$$

$\mathbf{S} = \underline{\mathbf{4 + j2.373\ kVA}}$

(b) $\quad \text{pf} = \dfrac{P}{S} = \dfrac{1.6}{2} 0.8 = \cos\theta \longrightarrow \sin\theta = 0.6$

$$\mathbf{S} = 1.6 - j2\sin\theta = \underline{\mathbf{1.6 - j1.2\ kVA}}$$

(c) $\quad \mathbf{S} = \mathbf{V}_{rms}\,\mathbf{I}^*_{rms} = (208\angle 20°)(6.5\angle 50°)\ \text{VA}$

$$\mathbf{S} = 1.352\angle 70° = \underline{\mathbf{0.4624 + j1.2705\ kVA}}$$

(d) $\quad \mathbf{S} = \dfrac{|\mathbf{V}|^2}{\mathbf{Z}^*} = \dfrac{(120)^2}{40 - j60} = \dfrac{14400}{72.11\angle\text{-}56.31°}$

$$\mathbf{S} = 199.7\angle 56.31° = \underline{\mathbf{110.77 + j166.16\ VA}}$$

Chapter 11, Solution 50.

(a) $\quad \mathbf{S} = P - jQ = 1000 - j\dfrac{1000}{0.8}\sin(\cos^{-1}(0.8))$

$$\mathbf{S} = 1000 - j750$$

But, $\quad \mathbf{S} = \dfrac{|\mathbf{V}_{rms}|^2}{\mathbf{Z}^*}$

$$\mathbf{Z}^* = \frac{|\mathbf{V}_{rms}|^2}{\mathbf{S}} = \frac{(220)^2}{1000 - j750} = 30.98 + j23.23$$

$$\mathbf{Z} = \underline{\mathbf{30.98 - j23.23\ \Omega}}$$

(b) $\quad \mathbf{S} = |\mathbf{I}_{rms}|^2\,\mathbf{Z}$

$$\mathbf{Z} = \frac{\mathbf{S}}{|\mathbf{I}_{rms}|^2} = \frac{1500 + j2000}{(12)^2} = \underline{\mathbf{10.42 + j13.89\ \Omega}}$$

(c) $\quad \mathbf{Z}^* = \dfrac{|\mathbf{V}_{rms}|^2}{\mathbf{S}} = \dfrac{|\mathbf{V}|^2}{2\mathbf{S}} = \dfrac{(120)^2}{(2)(4500\angle 60°)} = 1.6\angle\text{-}60°$

$$\mathbf{Z} = 1.6\angle 60° = \underline{\mathbf{0.8 + j1.386\ \Omega}}$$

Chapter 11, Solution 51.

(a) $\mathbf{Z}_T = 2 + (10 - j5) \,||\, (8 + j6)$

$$\mathbf{Z}_T = 2 + \frac{(10 - j5)(8 + j6)}{18 + j} = 2 + \frac{110 + j20}{18 + j}$$

$\mathbf{Z}_T = 8.152 + j0.768 = 8.188\angle 5.382°$

pf $= \cos(5.382°) = \underline{\mathbf{0.9956 \quad (lagging)}}$

(b) $$\mathbf{S} = \frac{1}{2}\mathbf{V}\mathbf{I}^* = \frac{|\mathbf{V}|^2}{2\mathbf{Z}^*} = \frac{(16)^2}{(2)(8.188\angle -5.382°)}$$

$\mathbf{S} = 15.63\angle 5.382°$

$P = S\cos\theta = \underline{\mathbf{15.56\ W}}$

(c) $Q = S\sin\theta = \underline{\mathbf{1.466\ VAR}}$

(d) $S = |\mathbf{S}| = \underline{\mathbf{15.63\ VA}}$

(e) $\mathbf{S} = 15.63\angle 5.382° = \underline{\mathbf{15.56 + j1.466\ VA}}$

Chapter 11, Solution 52.

$$S_A = 2000 + j\frac{2000}{0.8}0.6 = 2000 + j1500$$
$$S_B = 3000x0.4 - j3000x0.9165 = 1200 - j2749$$
$$S_C = 1000 + j500$$
$$S = S_A + S_B + S_C = 4200 - j749$$

(a) $$\text{pf} = \frac{4200}{\sqrt{4200^2 + 749^2}} = \underline{0.9845 \text{ leading.}}$$

(b) $$S = V_{rms}I^*_{rms} \longrightarrow I^*_{rms} = \frac{4200 - j749}{120\angle 45°} = 35.55\angle -55.11°$$

$I_{rms} = \underline{\mathbf{35.55\angle -55.11°\ A}}$.

Chapter 11, Solution 53.

$$S = S_A + S_B + S_C = 4000(0.8–j0.6) + 2400(0.6+j0.8) + 1000 + j500$$

$$= 5640 + j20 = 5640\angle 0.2^\circ$$

(a)

$$I^*_{rms} = \frac{S_B}{V_{rms}} + \frac{S_A + S_C}{V_{rms}} = \frac{S}{V_{rms}} = \frac{5640\angle 0.2^\circ}{\frac{120\angle 30^\circ}{\sqrt{2}}} = 66.46\angle -29.8^\circ$$

$$I = \sqrt{2}x66.46\angle 29.88^\circ = \underline{93.97\angle 29.8^\circ\,\text{A}}$$

(b) pf = cos(0.2˚) **≈ <u>1.0 lagging</u>**.

Chapter 11, Solution 54.

(a) $$\mathbf{S} = \text{P} - \text{jQ} = 1000 - \text{j}\frac{1000}{0.8}\sin(\cos^{-1}(0.8))$$

$$\mathbf{S} = 1000 - \text{j}750$$

But, $$\mathbf{S} = \frac{|\mathbf{V}_{rms}|^2}{\mathbf{Z}^*}$$

$$\mathbf{Z}^* = \frac{|\mathbf{V}_{rms}|^2}{\mathbf{S}} = \frac{(220)^2}{1000 - \text{j}750} = 30.98 + \text{j}23.23$$

$$\mathbf{Z} = \underline{\mathbf{30.98 - j23.23\,\Omega}}$$

(b) $$\mathbf{S} = |\mathbf{I}_{rms}|^2\mathbf{Z}$$

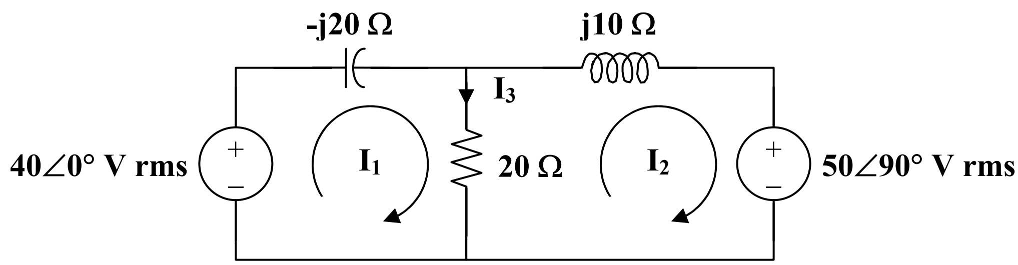
$$\mathbf{Z} = \frac{\mathbf{S}}{|\mathbf{I}_{rms}|^2} = \frac{1500 + \text{j}2000}{(12)^2} = \underline{\mathbf{10.42 + j13.89\,\Omega}}$$

(c) $$\mathbf{Z}^* = \frac{|\mathbf{V}_{rms}|^2}{\mathbf{S}} = \frac{|\mathbf{V}|^2}{2\mathbf{S}} = \frac{(120)^2}{(2)(4500\angle 60^\circ)} = 1.6\angle -60^\circ$$

$$\mathbf{Z} = 1.6\angle 60^\circ = \underline{\mathbf{0.8 + j1.386\,\Omega}}$$

Chapter 11, Solution 55.

We apply mesh analysis to the following circuit.



For mesh 1, $40 = (20 - j20)I_1 - 20I_2$

$$2 = (1 - j)I_1 - I_2 \qquad (1)$$

For mesh 2, $-j50 = (20 + j10)I_2 - 20I_1$

$$-j5 = -2I_1 + (2 + j)I_2 \qquad (2)$$

Putting (1) and (2) in matrix form,

$$\begin{bmatrix} 2 \\ -j5 \end{bmatrix} = \begin{bmatrix} 1-j & -1 \\ -2 & 2+j \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \end{bmatrix}$$

$$\Delta = 1 - j, \qquad \Delta_1 = 4 - j3, \qquad \Delta_2 = -1 - j5$$

$$I_1 = \frac{\Delta_1}{\Delta} = \frac{4 - j3}{1 - j} = \frac{1}{2}(7 - j) = 3.535\angle 8.13°$$

$$I_2 = \frac{\Delta_2}{\Delta} = \frac{-1 - j5}{1 - j} = 2 - j3 = 3.605\angle -56.31°$$

$$I_3 = I_1 - I_2 = (3.5 + j0.5) - (2 - j3) = 1.5 + j3.5 = 3.808\angle 66.8°$$

For the 40-V source,

$$\mathbf{S} = -\mathbf{V}\mathbf{I}_1^* = -(40)\left(\frac{1}{2}\cdot(7 - j)\right) = \underline{\mathbf{-140 + j20\ VA}}$$

For the capacitor,

$$\mathbf{S} = |\mathbf{I}_1|^2\mathbf{Z}_c = \underline{\mathbf{-j250\ VA}}$$

For the resistor,

$$\mathbf{S} = |\mathbf{I}_3|^2 R = \underline{\mathbf{290\ VA}}$$

For the inductor,

$$\mathbf{S} = |\mathbf{I}_2|^2\mathbf{Z}_L = \underline{\mathbf{j130\ VA}}$$

For the j50-V source,

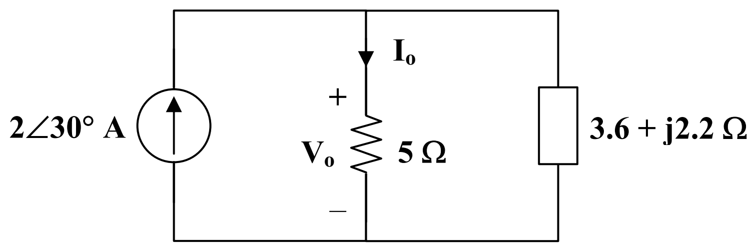
$$\mathbf{S} = \mathbf{V}\mathbf{I}_2^* = (j50)(2 + j3) = \underline{\mathbf{-150 + j100\ VA}}$$

Chapter 11, Solution 56.

$$- j2 \parallel 6 = \frac{(6)(-j2)}{6 - j2} = 0.6 - j1.8$$

$$3 + j4 + (-j2) \parallel 6 = 3.6 + j2.2$$

The circuit is reduced to that shown below.



$$\mathbf{I}_o = \frac{3.6 + j2.2}{8.6 + j2.2}(2\angle 30°) = 0.95\angle 47.08°$$

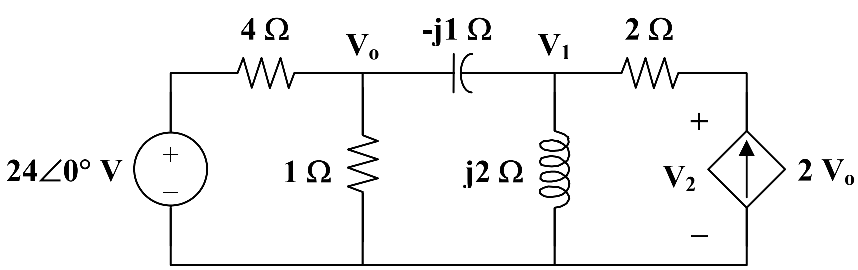
$$\mathbf{V}_o = 5\mathbf{I}_o = 4.75\angle 47.08°$$

$$\mathbf{S} = \frac{1}{2}\mathbf{V}_o\mathbf{I}_s^* = \frac{1}{2}\cdot(4.75\angle 47.08°)(2\angle -30°)$$

$$\mathbf{S} = 4.75\angle 17.08° = \underline{\mathbf{4.543 + j1.396\ VA}}$$

Chapter 11, Solution 57.

Consider the circuit as shown below.



At node o,

$$\frac{24 - \mathbf{V}_o}{4} = \frac{\mathbf{V}_o}{1} + \frac{\mathbf{V}_o - \mathbf{V}_1}{-j}$$

$$24 = (5 + j4)\,\mathbf{V}_o - j4\,\mathbf{V}_1 \qquad (1)$$

At node 1, $$\frac{\mathbf{V}_o - \mathbf{V}_1}{-j} + 2\,\mathbf{V}_o = \frac{\mathbf{V}_1}{j2}$$

$$\mathbf{V}_1 = (2 - j4)\,\mathbf{V}_o \qquad (2)$$

Substituting (2) into (1),

$$24 = (5 + j4 - j8 - 16)\,\mathbf{V}_o$$

$$\mathbf{V}_o = \frac{-24}{11 + j4}, \qquad \mathbf{V}_1 = \frac{(-24)(2 - j4)}{11 + j4}$$

The voltage across the dependent source is

$$\mathbf{V}_2 = \mathbf{V}_1 + (2)(2\,\mathbf{V}_o) = \mathbf{V}_1 + 4\,\mathbf{V}_o$$

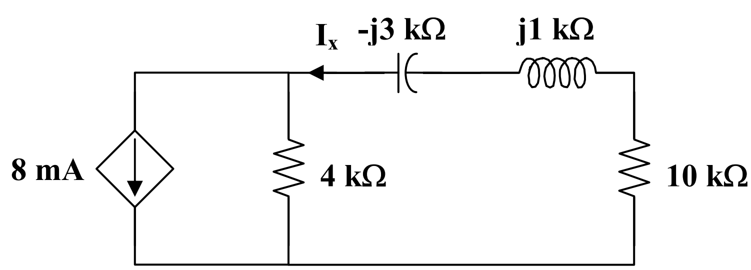
$$\mathbf{V}_2 = \frac{-24}{11 + j4} \cdot (2 - j4 + 4) = \frac{(-24)(6 - j4)}{11 + j4}$$

$$\mathbf{S} = \frac{1}{2}\mathbf{V}_2\,\mathbf{I}^* = \frac{1}{2}\mathbf{V}_2\,(2\,\mathbf{V}_o^*)$$

$$\mathbf{S} = \frac{(-24)(6 - j4)}{11 + j4} \cdot \frac{-24}{11 - j4} = \left(\frac{576}{137}\right)(6 - j4)$$

$$\mathbf{S} = \underline{\mathbf{25.23 - j16.82\ VA}}$$

Chapter 11, Solution 58.



From the left portion of the circuit,

$$\mathbf{I}_o = \frac{0.2}{500} = 0.4\ \text{mA}$$

$$20\,\mathbf{I}_o = 8\ \text{mA}$$

From the right portion of the circuit,

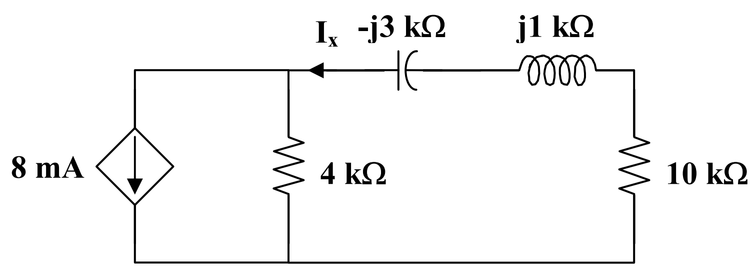
$$\mathbf{I}_x = \frac{4}{4 + 10 + j - j3}(8 \text{ mA}) = \frac{16}{7 - j} \text{ mA}$$

$$\mathbf{S} = \left| \mathbf{I}_x \right|^2 R = \frac{(16 \times 10^{-3})^2}{50} \cdot (10 \times 10^3)$$

$$\mathbf{S} = \underline{\mathbf{51.2\ mVA}}$$

Chapter 11, Solution 59.

Consider the circuit below.



$$4 + \frac{240 - \mathbf{V}_o}{50} = \frac{\mathbf{V}_o}{-j20} + \frac{\mathbf{V}_o}{40 + j30}$$

$$88 = (0.36 + j0.38)\,\mathbf{V}_o$$

$$\mathbf{V}_o = \frac{88}{0.36 + j0.38} = 168.13\angle -46.55°$$

$$\mathbf{I}_1 = \frac{\mathbf{V}_o}{-j20} = 8.41\angle 43.45°$$

$$\mathbf{I}_2 = \frac{\mathbf{V}_o}{40 + j30} = 3.363\angle -83.42°$$

Reactive power in the inductor is

$$\mathbf{S} = \frac{1}{2}\left| \mathbf{I}_2 \right|^2 \mathbf{Z}_L = \frac{1}{2} \cdot (3.363)^2 (j30) = \underline{\mathbf{j169.65\ VAR}}$$

Reactive power in the capacitor is

$$\mathbf{S} = \frac{1}{2}\left| \mathbf{I}_1 \right|^2 \mathbf{Z}_c = \frac{1}{2} \cdot (8.41)^2 (-j20) = \underline{\mathbf{-\ j707.3\ VAR}}$$

Chapter 11, Solution 60.

$$S_1 = 20 + j\frac{20}{0.8}\sin(\cos^{-1}(0.8)) = 20 + j15$$

$$S_2 = 16 + j\frac{16}{0.9}\sin(\cos^{-1}(0.9)) = 16 + j7.749$$

$$S = S_1 + S_2 = 36 + j22.749 = 42.585\angle 32.29°$$

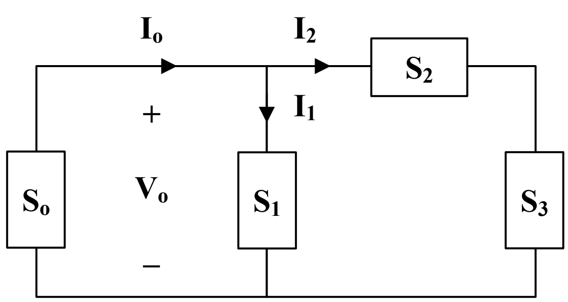
But $\quad S = V_o\, I^* = 6\, V_o$

$$V_o = \frac{S}{6} = \underline{\mathbf{7.098\angle 32.29°}}$$

$$pf = \cos(32.29°) = \underline{\mathbf{0.8454 \quad (lagging)}}$$

Chapter 11, Solution 61.

Consider the network shown below.



$$\mathbf{S}_2 = 1.2 - j0.8 \text{ kVA}$$

$$\mathbf{S}_3 = 4 + j\frac{4}{0.9}\sin(\cos^{-1}(0.9)) = 4 + j1.937 \text{ kVA}$$

Let $\quad \mathbf{S}_4 = \mathbf{S}_2 + \mathbf{S}_3 = 5.2 + j1.137 \text{ kVA}$

But $\quad \mathbf{S}_4 = \frac{1}{2}\mathbf{V}_o\,\mathbf{I}_2^*$

$$\mathbf{I}_2^* = \frac{2\mathbf{S}_4}{\mathbf{V}_o} = \frac{(2)(5.2 + j1.137)\times 10^3}{100\angle 90°} = 22.74 - j104$$

$$\mathbf{I}_2 = 22.74 + j104$$

Similarly, $\mathbf{S}_1 = 2 - j\frac{2}{0.707}\sin(\cos^{-1}(0.707)) = 2 - j2 \text{ kVA}$

But $\mathbf{S}_1 = \frac{1}{2}\mathbf{V}_o\,\mathbf{I}_1^*$

$$\mathbf{I}_1^* = \frac{2\mathbf{S}_1}{\mathrm{V}_o} = \frac{(4 - j4)\times 10^3}{j100} = -40 - j40$$

$$\mathbf{I}_1 = -40 + j40$$

$$\mathbf{I}_o = \mathbf{I}_1 + \mathbf{I}_2 = -17.26 + j144 = 145\angle 96.83°$$

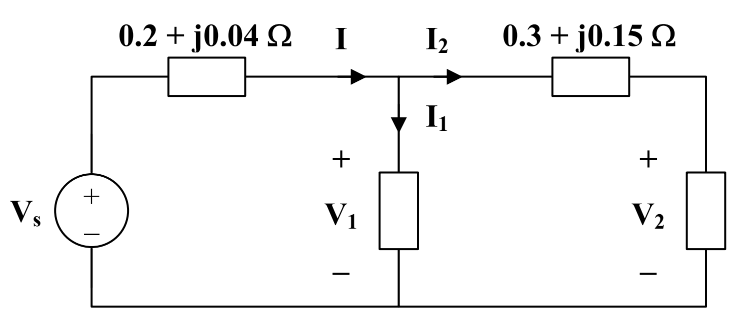
$$\mathbf{S}_o = \frac{1}{2}\mathrm{V}_o\mathrm{I}_o^*$$

$$\mathbf{S}_o = \frac{1}{2}\cdot(100\angle 90°)(145\angle -96.83°) \text{ VA}$$

$$\mathbf{S}_o = \underline{\mathbf{7.2 - j0.862\ kVA}}$$

Chapter 11, Solution 62.

Consider the circuit below



$$\mathbf{S}_2 = 15 - j\frac{15}{0.8}\sin(\cos^{-1}(0.8)) = 15 - j11.25$$

But $\quad \mathbf{S}_2 = \mathbf{V}_2\,\mathbf{I}_2^*$

$$\mathbf{I}_2^* = \frac{\mathbf{S}_2}{\mathbf{V}_2} = \frac{15 - j11.25}{120}$$

$$\mathbf{I}_2 = 0.125 + j0.09375$$
$$\mathbf{V}_1 = \mathbf{V}_2 + \mathbf{I}_2\,(0.3 + j0.15)$$
$$\mathbf{V}_1 = 120 + (0.125 + j0.09375)(0.3 + j0.15)$$
$$\mathbf{V}_1 = 120.02 + j0.0469$$

$$\mathbf{S}_1 = 10 + j\frac{10}{0.9}\sin(\cos^{-1}(0.9)) = 10 + j4.843$$

But $\quad \mathbf{S}_1 = \mathbf{V}_1\,\mathbf{I}_1^*$

$$\mathbf{I}_1^* = \frac{\mathbf{S}_1}{\mathbf{V}_1} = \frac{11.111\angle 25.84^\circ}{120.02\angle 0.02^\circ}$$

$$\mathbf{I}_1 = 0.093\angle -25.82^\circ = 0.0837 - j0.0405$$
$$\mathbf{I} = \mathbf{I}_1 + \mathbf{I}_2 = 0.2087 + j0.053$$
$$\mathbf{V}_s = \mathbf{V}_1 + \mathbf{I}\,(0.2 + j0.04)$$
$$\mathbf{V}_s = (120.02 + j0.0469) + (0.2087 + j0.053)(0.2 + j0.04)$$
$$\mathbf{V}_s = 120.06 + j0.0658$$
$$\mathbf{V}_s = \underline{\mathbf{120.06\angle 0.03^\circ\ V}}$$

Chapter 11, Solution 63.

Let $\quad \mathbf{S} = \mathbf{S}_1 + \mathbf{S}_2 + \mathbf{S}_3$.

$$\mathbf{S}_1 = 12 - j\frac{12}{0.866}\sin(\cos^{-1}(0.866)) = 12 - j6.929$$

$$\mathbf{S}_2 = 16 + j\frac{16}{0.85}\sin(\cos^{-1}(0.85)) = 16 + j9.916$$

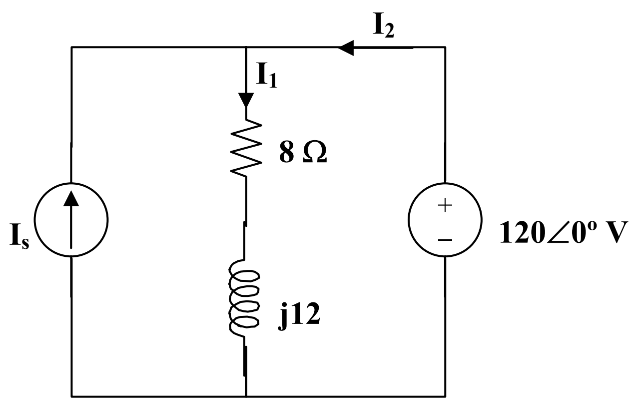
$$\mathbf{S}_3 = \frac{(20)(0.6)}{\sin(\cos^{-1}(0.6)} + j20 = 15 + j20$$

$$\mathbf{S} = 43 + j22.987 = \frac{1}{2}\mathbf{V}\,\mathbf{I}_o^*$$

$$\mathbf{I}_o^* = \frac{2\mathbf{S}}{\mathbf{V}} = \frac{44 + j22.98}{110}$$

$$\mathbf{I}_o = \underline{\mathbf{0.4513\angle - 27.58^\circ\ A}}$$

Chapter 11, Solution 64.



$$I_s + I_2 = I_1 \text{ or } I_s = I_1 - I_2$$

$$I_1 = \frac{120}{8 + j12} = 4.615 - j6.923$$

But, $$S = VI_2^* \longrightarrow I_2^* = \frac{S}{V} = \frac{2500 - j400}{120} = 20.83 - j3.333$$

$$\text{or } I_2 = 20.83 + j3.333$$

$$I_s = I_1 - I_2 = -16.22 - j10.256 = \underline{\mathbf{19.19\angle -147.69^\circ\ A}}.$$

Chapter 11, Solution 65.

$$C = 1\text{ nF} \longrightarrow \frac{1}{j\omega C} = \frac{-j}{10^4 \times 10^{-9}} = -j100\text{ k}\Omega$$

At the noninverting terminal,

$$\frac{4\angle 0° - \mathbf{V}_o}{100} = \frac{\mathbf{V}_o}{-j100} \longrightarrow \mathbf{V}_o = \frac{4}{1+j}$$

$$\mathbf{V}_o = \frac{4}{\sqrt{2}}\angle -45°$$

$$v_o(t) = \frac{4}{\sqrt{2}}\cos(10^4 t - 45°)$$

$$P = \frac{V_{rms}^2}{R} = \left(\frac{4}{\sqrt{2}} \cdot \frac{1}{\sqrt{2}}\right)^2 \left(\frac{1}{50 \times 10^3}\right)\text{ W}$$

$$P = \underline{\mathbf{80\ \mu W}}$$

Chapter 11, Solution 66.

As an inverter,

$$\mathbf{V}_o = \frac{-\mathbf{Z}_f}{\mathbf{Z}_i}\mathbf{V}_s = \frac{-(2+j4)}{4+j3} \cdot (4\angle 45°)$$

$$\mathbf{I}_o = \frac{\mathbf{V}_o}{6-j2}\text{ mA} = \frac{-(2+j4)(4\angle 45°)}{(6-j2)(4+j3)}\text{ mA}$$

The power absorbed by the 6-kΩ resistor is

$$P = \frac{1}{2}\left|\mathbf{I}_o\right|^2 R = \frac{1}{2} \cdot \left(\frac{\sqrt{20} \times 4}{\sqrt{40} \times 5}\right)^2 \times 10^{-6} \times 6 \times 10^3$$

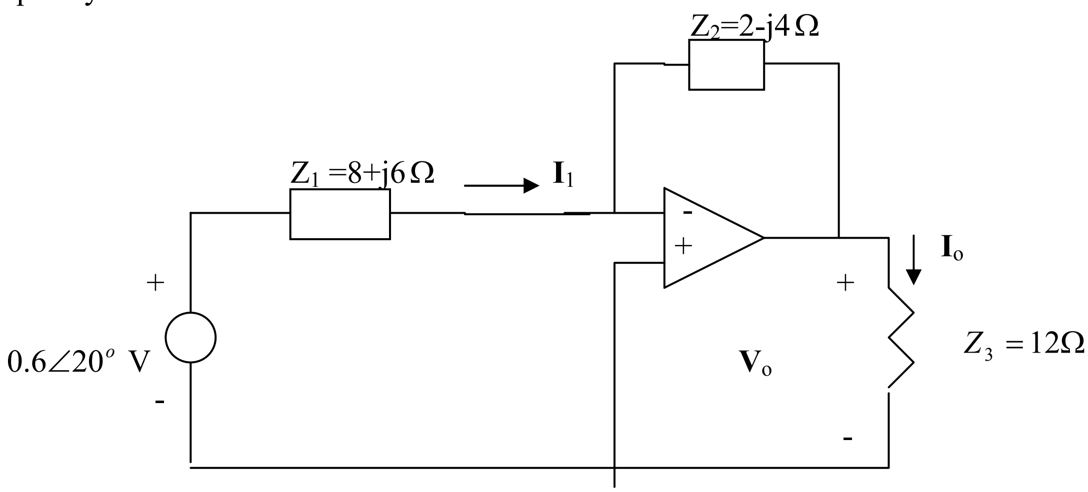
$$P = \underline{\mathbf{0.96\ mW}}$$

Chapter 11, Solution 67.

$$\omega = 2, \quad 3\text{H} \longrightarrow j\omega L = j6, \quad 0.1\text{F} \longrightarrow \frac{1}{j\omega C} = \frac{1}{j2x0.1} = -j5$$

$$10//(-j5) = \frac{-j50}{10-j5} = 2-j4$$

The frequency-domain version of the circuit is shown below.



(a) $$I_1 = \frac{0.6\angle 20^o - 0}{8+j6} = \frac{0.5638 + j0.2052}{8+j6} = 0.06\angle -16.87^o$$

$$S = \frac{1}{2} V_s I^*{}_1 = (0.3\angle 20^o)(0.06\angle +16.87^o) = \underline{14.4 + j10.8\,\text{mVA}} = \underline{18\angle 36.86^o \text{ mVA}}$$

(b) $$V_o = -\frac{Z_2}{Z_1} V_s, \qquad I_o = \frac{V_o}{Z_3} = -\frac{(2-j4)}{12(8+j6)}(0.6\angle 20^o) = 0.0224\angle 99.7^o$$

$$P = \frac{1}{2} | I_o |^2 R = 0.5(0.0224)^2 (12) = \underline{2.904\,\text{mW}}$$

Chapter 11, Solution 68.

Let $\mathbf{S} = \mathbf{S}_R + \mathbf{S}_L + \mathbf{S}_c$

where $\mathbf{S}_R = P_R + jQ_R = \frac{1}{2} I_o^2 R + j0$

$$\mathbf{S}_L = P_L + jQ_L = 0 + j\frac{1}{2} I_o^2 \omega L$$

$$\mathbf{S}_c = P_c + jQ_c = 0 - j\frac{1}{2} I_o^2 \cdot \frac{1}{\omega C}$$

Hence, $$\underline{\mathbf{S} = \frac{1}{2}\mathbf{I}_o^2\left[\mathbf{R} + \mathbf{j}\left(\omega\mathbf{L} - \frac{1}{\omega\mathbf{C}}\right)\right]}$$

Chapter 11, Solution 69.

(a) Given that $\mathbf{Z} = 10 + j12$

$$\tan\theta = \frac{12}{10} \longrightarrow \theta = 50.19°$$

$$\text{pf} = \cos\theta = \underline{\mathbf{0.6402}}$$

(b) $$\mathbf{S} = \frac{|\mathbf{V}|^2}{2\mathbf{Z}^*} = \frac{(120)^2}{(2)(10 - j12)} = 295.12 + j354.09$$

The average power absorbed $= P = \text{Re}(\mathbf{S}) = \underline{\mathbf{295.1\ W}}$

(c) For unity power factor, $\theta_1 = 0°$, which implies that the reactive power due to the capacitor is $Q_c = 354.09$

But $$Q_c = \frac{V^2}{2X_c} = \frac{1}{2}\omega C V^2$$

$$C = \frac{2Q_c}{\omega V^2} = \frac{(2)(354.09)}{(2\pi)(60)(120)^2} = \underline{\mathbf{130.4\ \mu F}}$$

Chapter 11, Solution 70.

$$\text{pf} = \cos\theta = 0.8 \longrightarrow \sin\theta = 0.6$$
$$Q = S\sin\theta = (880)(0.6) = 528$$

If the power factor is to be unity, the reactive power due to the capacitor is
$$Q_c = Q = 528 \text{ VAR}$$

But $$Q = \frac{V_{rms}^2}{X_c} = \frac{1}{2}\omega C V^2 \longrightarrow C = \frac{2Q_c}{\omega V^2}$$

$$C = \frac{(2)(528)}{(2\pi)(50)(220)^2} = \underline{\mathbf{69.45\ \mu F}}$$

Chapter 11, Solution 71.

$$P_1 = Q_1 = 150x0.7071 = 106.065, \quad Q_2 = 50, \quad S_2 = \frac{Q_2}{0.6}, \quad P_2 = 0.8S = 0.8\frac{50}{0.6} = 66.67$$

$$\overline{S}_1 = 106.065 + j106.065, \quad \overline{S}_2 = 66.67 - j50$$

$$\overline{S} = \overline{S}_1 + \overline{S}_2 = 172.735 + j56.06 = 181.6\angle 17.98^o, \quad pf = \cos 17.98^o = 0.9512$$

$$Q_c = P(\tan\theta_1 - \tan\theta_2) = 172.735(\tan 17.98^o - 0) = 56.058$$

$$C = \frac{Q_c}{\omega V^2{}_{rms}} = \frac{56.058}{2\pi x 60 x 120^2} = \underline{10.33\ \mu\text{F}}$$

Chapter 11, Solution 72.

(a) $$\theta_1 = \cos^{-1}(0.76) = 40.54°$$
$$\theta_2 = \cos^{-1}(0.9) = 25.84°$$

$$Q_c = P(\tan\theta_1 - \tan\theta_2)$$
$$Q_c = (40)[\tan(40.54°) - \tan(25.84°)] \text{ kVAR}$$
$$Q_c = 14.84 \text{ kVAR}$$

$$C = \frac{Q_c}{\omega V_{rms}^2} = \frac{14840}{(2\pi)(60)(120)^2} = \underline{\mathbf{2.734\ mF}}$$

(b) $\theta_1 = 40.54°$, $\theta_2 = 0°$

$$Q_c = (40)[\tan(40.54°) - 0]\text{ kVAR} = 34.21\text{ kVAR}$$

$$C = \frac{Q_c}{\omega V_{rms}^2} \frac{34210}{(2\pi)(60)(120)^2} = \underline{\mathbf{6.3\ mF}}$$

Chapter 11, Solution 73.

(a) $\mathbf{S} = 10 - j15 + j22 = 10 + j7\text{ kVA}$

$S = \left|\mathbf{S}\right| = \sqrt{10^2 + 7^2} = \underline{\mathbf{12.21\ kVA}}$

(b) $\mathbf{S} = \mathbf{V}\mathbf{I}^* \longrightarrow \mathbf{I}^* = \dfrac{\mathbf{S}}{\mathbf{V}} = \dfrac{10{,}000 + j7{,}000}{240}$

$\mathbf{I} = 41.667 - j29.167 = \underline{\mathbf{50.86\angle\text{-}35°\ A}}$

(c) $\theta_1 = \tan^{-1}\left(\dfrac{7}{10}\right) = 35°$, $\theta_2 = \cos^{-1}(0.96) = 16.26°$

$Q_c = P_1[\tan\theta_1 - \tan\theta_2] = 10[\tan(35°) - \tan(16.26°)]$

$Q_c = \underline{\mathbf{4.083\ kVAR}}$

$$C = \frac{Q_c}{\omega V_{rms}^2} = \frac{4083}{(2\pi)(60)(240)^2} = \underline{\mathbf{188.03\ \mu F}}$$

(d) $\mathbf{S}_2 = P_2 + jQ_2$, $P_2 = P_1 = 10\text{ kW}$

$Q_2 = Q_1 - Q_c = 7 - 4.083 = 2.917\text{ kVAR}$

$\mathbf{S}_2 = 10 + j2.917\text{ kVA}$

But $\mathbf{S}_2 = \mathbf{V}\mathbf{I}_2^*$

$$\mathbf{I}_2^* = \frac{\mathbf{S}_2}{\mathbf{V}} = \frac{10{,}000 + j2917}{240}$$

$\mathbf{I}_2 = 41.667 - j12.154 = \underline{\mathbf{43.4\angle\text{-}16.26°\ A}}$

Chapter 11, Solution 74.

(a) $\theta_1 = \cos^{-1}(0.8) = 36.87°$

$$S_1 = \frac{P_1}{\cos\theta_1} = \frac{24}{0.8} = 30 \text{ kVA}$$

$Q_1 = S_1 \sin\theta_1 = (30)(0.6) = 18 \text{ kVAR}$
$\mathbf{S}_1 = 24 + j18 \text{ kVA}$

$\theta_2 = \cos^{-1}(0.95) = 18.19°$

$$S_2 = \frac{P_2}{\cos\theta_2} = \frac{40}{0.95} = 42.105 \text{ kVA}$$

$Q_2 = S_2 \sin\theta_2 = 13.144 \text{ kVAR}$
$\mathbf{S}_2 = 40 + j13.144 \text{ kVA}$

$\mathbf{S} = \mathbf{S}_1 + \mathbf{S}_2 = 64 + j31.144 \text{ kVA}$

$$\theta = \tan^{-1}\left(\frac{31.144}{64}\right) = 25.95°$$

$\text{pf} = \cos\theta = \underline{\mathbf{0.8992}}$

(b) $\theta_2 = 25.95°, \qquad \theta_1 = 0°$

$Q_c = P[\tan\theta_2 - \tan\theta_1] = 64[\tan(25.95°) - 0] = 31.144 \text{ kVAR}$

$$C = \frac{Q_c}{\omega V_{rms}^2} = \frac{31{,}144}{(2\pi)(60)(120)^2} = \underline{\mathbf{5.74\ mF}}$$

Chapter 11, Solution 75.

(a) $$\mathbf{S}_1 = \frac{|\mathbf{V}|^2}{\mathbf{Z}_1^*} = \frac{(240)^2}{80 + j50} = \frac{5760}{8 + j5} = 517.75 - j323.59 \text{ VA}$$

$$\mathbf{S}_2 = \frac{(240)^2}{120 - j70} = \frac{5760}{12 - j7} = 358.13 + j208.91 \text{ VA}$$

$$\mathbf{S}_3 = \frac{(240)^2}{60} = 960 \text{ VA}$$

$$\mathbf{S} = \mathbf{S}_1 + \mathbf{S}_2 + \mathbf{S}_3 = \underline{\mathbf{1835.88 - j114.68\ VA}}$$

(b) $$\theta = \tan^{-1}\left(\frac{114.68}{1835.88}\right) = 3.574°$$

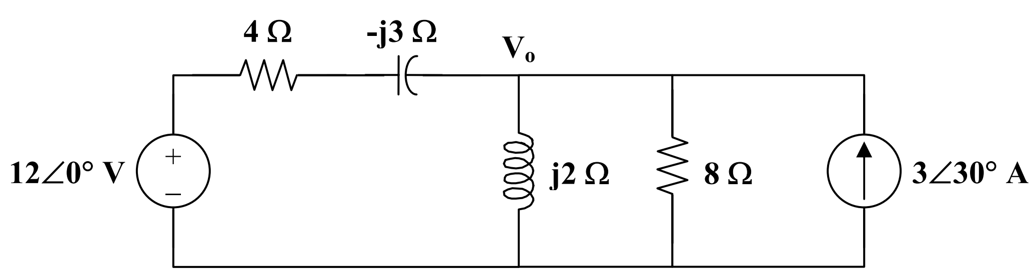
$$\text{pf} = \cos\theta = \underline{\mathbf{0.998}}$$

(c) $$Q_c = P[\tan\theta_2 - \tan\theta_1] = 18.35.88[\tan(3.574°) - 0]$$
$$Q_c = 114.68 \text{ VAR}$$

$$C = \frac{Q_c}{\omega V_{rms}^2} = \frac{114.68}{(2\pi)(50)(240)^2} = \underline{\mathbf{6.336\ \mu F}}$$

Chapter 11, Solution 76.

The wattmeter reads the real power supplied by the current source. Consider the circuit below.



$$3\angle 30° + \frac{12 - \mathbf{V}_o}{4 - j3} = \frac{\mathbf{V}_o}{j2} + \frac{\mathbf{V}_o}{8}$$

$$\mathbf{V}_o = \frac{36.14 + j23.52}{2.28 - j3.04} = 0.7547 + j11.322 = 11.347\angle 86.19°$$

$$\mathbf{S} = \frac{1}{2}\mathbf{V}_o\,\mathbf{I}_o^* = \frac{1}{2}\cdot(11.347\angle 86.19°)(3\angle\text{-}30°)$$

$$\mathbf{S} = 17.021\angle 56.19°$$

$$\text{P} = \text{Re}(\mathbf{S}) = \underline{\mathbf{9.471\ W}}$$

Chapter 11, Solution 77.

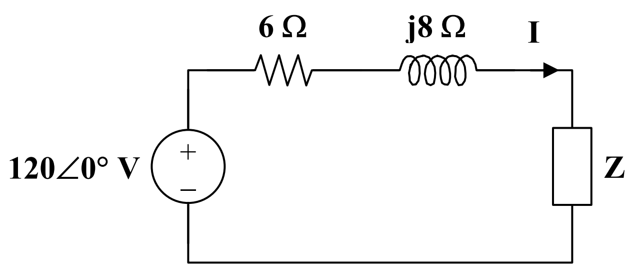
The wattmeter measures the power absorbed by the parallel combination of 0.1 F and 150 Ω.

$$120\cos(2t) \longrightarrow 120\angle 0°, \qquad \omega = 2$$

$$4\text{ H} \longrightarrow j\omega L = j8$$

$$0.1\text{ F} \longrightarrow \frac{1}{j\omega C} = \text{-}j5$$

Consider the following circuit.



$$\mathbf{Z} = 15 \,||\, (\text{-}j5) = \frac{(15)(\text{-}j5)}{15 - j5} = 1.5 - j4.5$$

$$\mathbf{I} = \frac{120}{(6 + j8) + (1.5 - j4.5)} = 14.5\angle\text{-}25.02°$$

$$\mathbf{S} = \frac{1}{2}\mathbf{V}\mathbf{I}^* = \frac{1}{2}|\mathbf{I}|^2\,\mathbf{Z} = \frac{1}{2}\cdot(14.5)^2(1.5 - j4.5)$$

$$\mathbf{S} = 157.69 - j473.06\text{ VA}$$

The wattmeter reads

$$\text{P} = \text{Re}(\mathbf{S}) = \underline{\mathbf{157.69\ W}}$$

Chapter 11, Solution 78.

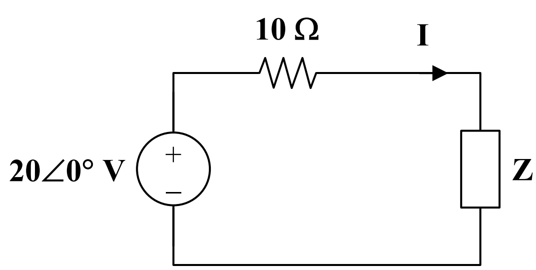
The wattmeter reads the power absorbed by the element to its right side.

$$2\cos(4t) \longrightarrow 2\angle 0°, \qquad \omega = 4$$

$$1\text{ H} \longrightarrow j\omega L = j4$$

$$\frac{1}{12}\text{ F} \longrightarrow \frac{1}{j\omega C} = \text{-}j3$$

Consider the following circuit.



$$\mathbf{Z} = 5 + j4 + 4 \,||\, \text{-}j3 = 5 + j4 + \frac{(4)(\text{-}j3)}{4 - j3}$$

$$\mathbf{Z} = 6.44 + j2.08$$

$$\mathbf{I} = \frac{20}{16.44 + j2.08} = 1.207\angle\text{-}7.21°$$

$$\mathbf{S} = \frac{1}{2}\left|\mathbf{I}\right|^2 \mathbf{Z} = \frac{1}{2}\cdot(1.207)^2(6.44 + j2.08)$$

$$P = \text{Re}(\mathbf{S}) = \underline{\mathbf{4.691\ W}}$$

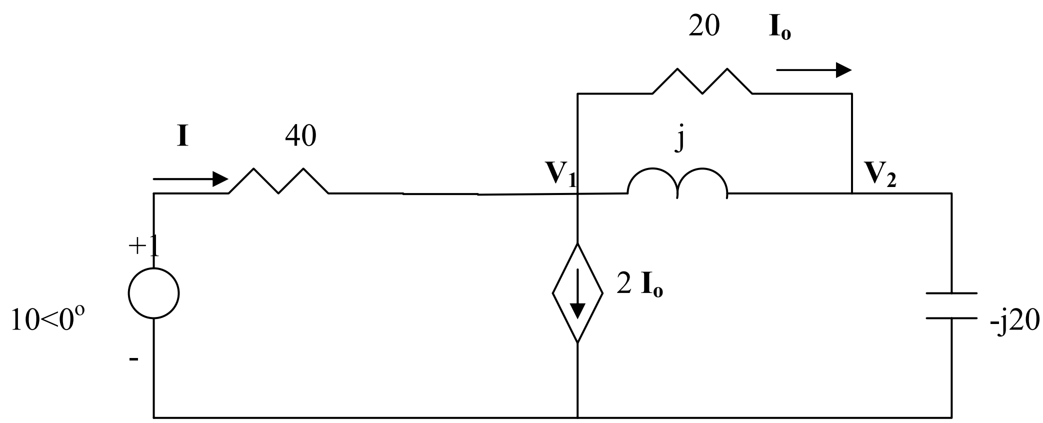
Chapter 11, Solution 79.

The wattmeter reads the power supplied by the source and partly absorbed by the 40-Ω resistor.

$\omega = 100,$

$$10\,\text{mH} \longrightarrow j100x10x10^{-3} = j, \qquad 500\mu\text{F} \longrightarrow \frac{1}{j\omega C} = \frac{1}{j100x500x10^{-6}} = -j20$$

The frequency-domain circuit is shown below.



At node 1,

$$\frac{10 - V_1}{40} = 2I_o + \frac{V_1 - V_2}{j} + \frac{V_1 - V_2}{20} = \frac{3(V_1 - V_2)}{20} + \frac{V_1 - V_2}{j} \longrightarrow \qquad (1)$$

$$10 = (7 - j40)V_1 + (-6 + j40)V_2$$

At node 2,

$$\frac{V_1 - V_2}{j} + \frac{V_1 - V_2}{20} = \frac{V_2}{-j20} \longrightarrow 0 = (20 + j)V_1 - (19 + j)V_2 \qquad (2)$$

Solving (1) and (2) yields $\mathbf{V_1} = 1.5568 - j4.1405$

$$I = \frac{10 - V_1}{40} = 0.8443 + j0.4141, \qquad S = \frac{1}{2}VI^{\bullet} = 4.2216 - j2.0703$$

P = Re(S) = **4.222 W**.

Chapter 11, Solution 80.

(a) $\mathbf{I} = \dfrac{\mathbf{V}}{\mathbf{Z}} = \dfrac{110}{6.4} = \underline{\mathbf{17.19\ A}}$

(b) $\mathbf{S} = \dfrac{\mathbf{V}^2}{\mathbf{Z}} = \dfrac{(110)^2}{6.4} = 1890.625$

$\cos\theta = \text{pf} = 0.825 \longrightarrow \theta = 34.41°$

$P = S\cos\theta = 1559.76 \cong \underline{\mathbf{1.6\ kW}}$

Chapter 11, Solution 81.

$\text{kWh consumed} = 4017 - 3246 = 771\ \text{kWh}$

The electricity bill is calculated as follows :

(a) Fixed charge = \$12
(b) First 100 kWh at \$0.16 per kWh = \$16
(c) Next 200 kWh at \$0.10 per kWh = \$20
(d) The remaining energy (771 – 300) = 471 kWh
at \$0.06 per kWh = \$28.26.

Adding (a) to (d) gives **<u>\$76.26</u>**

Chapter 11, Solution 82.

(a) $P_1 = 5{,}000, \quad Q_1 = 0$

$P_2 = 30{,}000x0.82 = 24{,}600, \quad Q_2 = 30{,}000\sin(\cos^{-1}0.82) = 17{,}171$

$\overline{S} = \overline{S}_1 + \overline{S}_2 = (P_1 + P_2) + j(Q_1 + Q_2) = 29{,}600 + j17{,}171$

$S = |\overline{S}| = \underline{34.22\ \text{kVA}}$

(b) $Q = \underline{\mathbf{17.171\ kVAR}}$

(c) $pf = \dfrac{P}{S} = \dfrac{29{,}600}{34{,}220} = 0.865$

$Q_c = P(\tan\theta_1 - \tan\theta_2)$

$= 29{,}600\left[\tan(\cos^{-1}0.865) - \tan(\cos^{-1}0.9)\right] = \underline{2833\ \text{VAR}}$

(d) $C = \dfrac{Q_c}{\omega V^2_{rms}} = \dfrac{2833}{2\pi x60x240^2} = \underline{130.46\mu\,\text{F}}$

Chapter 11, Solution 83.

(a) $\overline{S} = \frac{1}{2}VI^* = \frac{1}{2}(210\angle 60^o)(8\angle -25^o) = 840\angle 35^o$

$P = S\cos\theta = 840\cos 35^o = \underline{688.1\text{ W}}$

(b) S = **<u>840 VA</u>**

(c) $Q = S\sin\theta = 840\sin 35^o = \underline{481.8\text{ VAR}}$

(d) $pf = P/S = \cos 35^o = \underline{0.8191\ \text{(lagging)}}$

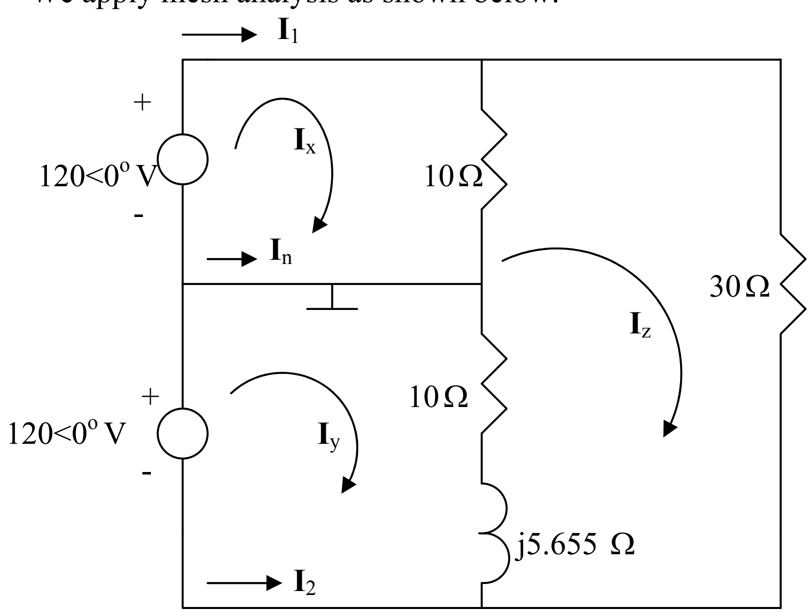
Chapter 11, Solution 84.

(a) Maximum demand charge $= 2{,}400 \times 30 = \$72{,}000$
Energy cost $= \$0.04 \times 1{,}200 \times 10^3 = \$48{,}000$
Total charge = **<u>$120,000</u>**

(b) To obtain $120,000 from 1,200 MWh will require a flat rate of
$\frac{\$120{,}000}{1{,}200 \times 10^3}$ per kWh = **<u>$0.10 per kWh</u>**

Chapter 11, Solution 85.

(a) 15 mH $\longrightarrow$ $j2\pi x60x15x10^{-3} = j5.655$
We apply mesh analysis as shown below.



For mesh x,

$$120 = 10\,\mathbf{I}_x - 10\,\mathbf{I}_z \qquad (1)$$

For mesh y,

$$120 = (10+j5.655)\,\mathbf{I}_y - (10+j5.655)\,\mathbf{I}_z \qquad (2)$$

For mesh z,

$$0 = -10\,\mathbf{I}_x - (10+j5.655)\,\mathbf{I}_y + (50+j5.655)\,\mathbf{I}_z \qquad (3)$$

Solving (1) to (3) gives

$$\mathbf{I}_x = 20,\ \mathbf{I}_y = 17.09-j5.142,\ \mathbf{I}_z = 8$$

Thus,

$$\mathbf{I}_1 = \mathbf{I}_x = \underline{20\text{ A}}$$

$$\mathbf{I}_2 = -\mathbf{I}_y = -17.09+j5.142 = \underline{17.85\angle 163.26^o\ \text{ A}}$$

$$\mathbf{I}_n = \mathbf{I}_y - \mathbf{I}_x = -2.091 - j5.142 = \underline{5.907\angle -119.5^o\ \text{ A}}$$

(b) $$\overline{S_1} = \frac{1}{2}(120)I^{\bullet}{}_x = 60x20 = 1200, \qquad \overline{S_2} = \frac{1}{2}(120)I^{\bullet}{}_y = 1025.5 - j308.5$$

$$\overline{S} = \overline{S_1} + \overline{S_2} = \underline{2225.5 - j308.5\text{ VA}}$$

(c) pf = P/S = 2225.5/2246.8 = $\underline{0.9905}$

Chapter 11, Solution 86.

For maximum power transfer

$$\mathbf{Z}_L = \mathbf{Z}_{Th}^* \longrightarrow \mathbf{Z}_i = \mathbf{Z}_{Th} = \mathbf{Z}_L^*$$

$$\mathbf{Z}_L = R + j\omega L = 75 + j(2\pi)(4.12\times10^6)(4\times10^{-6})$$

$$\mathbf{Z}_L = 75 + j103.55\,\Omega$$

$$\mathbf{Z}_i = \underline{\mathbf{75 - j103.55\,\Omega}}$$

Chapter 11, Solution 87.

$$\mathbf{Z} = R \pm jX$$

$$\mathbf{V}_R = \mathbf{I}R \longrightarrow R = \frac{\mathbf{V}_R}{\mathbf{I}} = \frac{80}{50\times10^{-3}} = 1.6\text{ k}\Omega$$

$$\left|\mathbf{Z}\right|^2 = R^2 + X^2 \longrightarrow X^2 = \left|\mathbf{Z}\right|^2 - R^2 = (3)^2 - (1.6)^2$$

$$X = 2.5377\text{ k}\Omega$$

$$\theta = \tan^{-1}\left(\frac{X}{R}\right) = \tan^{-1}\left(\frac{2.5377}{1.6}\right) = 57.77°$$

$$\text{pf} = \cos\theta = \underline{\mathbf{0.5333}}$$

Chapter 11, Solution 88.

(a) $\mathbf{S} = (110)(2\angle 55°) = 220\angle 55°$

$P = S\cos\theta = 220\cos(55°) = \underline{\mathbf{126.2\ W}}$

(b) $S = \left|\mathbf{S}\right| = \underline{\mathbf{220\ VA}}$

Chapter 11, Solution 89.

(a) Apparent power $= S = \underline{\mathbf{12\ kVA}}$

$P = S\cos\theta = (12)(0.78) = 9.36\ \text{kW}$
$Q = S\sin\theta = 12\sin(\cos^{-1}(0.78)) = 7.51\ \text{kVAR}$

$\mathbf{S} = P + jQ = \underline{\mathbf{9.36 + j7.51\ kVA}}$

(b) $$\mathbf{S} = \frac{\left|\mathbf{V}\right|^2}{\mathbf{Z}^*} \longrightarrow \mathbf{Z}^* = \frac{\left|\mathbf{V}\right|^2}{\mathbf{S}} = \frac{(210)^2}{(9.36 + j7.51)\times 10^3}$$

$\mathbf{Z} = \underline{\mathbf{34.398 + j27.6\ \Omega}}$

Chapter 11, Solution 90

Original load :

$P_1 = 2000\ \text{kW}, \qquad \cos\theta_1 = 0.85 \longrightarrow \theta_1 = 31.79°$

$$S_1 = \frac{P_1}{\cos\theta_1} = 2352.94\ \text{kVA}$$

$Q_1 = S_1\sin\theta_1 = 1239.5\ \text{kVAR}$

Additional load :

$P_2 = 300\ \text{kW}, \qquad \cos\theta_2 = 0.8 \longrightarrow \theta_2 = 36.87°$

$$S_2 = \frac{P_2}{\cos\theta_2} = 375\ \text{kVA}$$

$Q_2 = S_2\sin\theta_2 = 225\ \text{kVAR}$

Total load :

$$\mathbf{S} = \mathbf{S}_1 + \mathbf{S}_2 = (P_1 + P_2) + j(Q_1 + Q_2) = P + jQ$$
$$P = 2000 + 300 = 2300 \text{ kW}$$
$$Q = 1239.5 + 225 = 1464.5 \text{ kVAR}$$

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

$$\cos\theta = \frac{P}{S_1} = \frac{2300}{2352.94} = 0.9775$$

or $\qquad \theta = 12.177°$

The maximum load kVAR for this condition is

$$Q_m = S_1 \sin\theta = 2352.94 \sin(12.177°)$$
$$Q_m = 496.313 \text{ kVAR}$$

The capacitor must supply the difference between the total load kVAR (i.e. Q) and the permissible generator kVAR (i.e. Q_m). Thus,

$$Q_c = Q - Q_m = \underline{\mathbf{968.2\ kVAR}}$$

Chapter 11, Solution 91

$$P = S\cos\theta$$

$$\text{pf} = \cos\theta = \frac{P}{S} = \frac{2700}{(220)(15)} = \underline{0.8182}$$

$$Q = S\sin\theta = 220(15)\sin(35.09°) = 1897.3$$

When the power is raised to unity pf, $\theta_1 = 0°$ and $Q_c = Q = 1897.3$

$$C = \frac{Q_c}{\omega V_{rms}^2} = \frac{1897.3}{(2\pi)(60)(220)^2} = \underline{\mathbf{104\ \mu F}}$$

Chapter 11, Solution 92

(a) Apparent power drawn by the motor is

$$S_m = \frac{P}{\cos\theta} = \frac{60}{0.75} = 80 \text{ kVA}$$

$$Q_m = \sqrt{S^2 - P^2} = \sqrt{(80)^2 - (60)^2} = 52.915 \text{ kVAR}$$

Total real power

$$P = P_m + P_c + P_L = 60 + 0 + 20 = 80 \text{ kW}$$

Total reactive power

$$Q = Q_m + Q_c + Q_L = 52.915 - 20 + 0 = \underline{\mathbf{32.91\ kVAR}}$$

Total apparent power

$$S = \sqrt{P^2 + Q^2} = \underline{\mathbf{86.51\ kVA}}$$

(b) $$\text{pf} = \frac{P}{S} = \frac{80}{86.51} = \underline{\mathbf{0.9248}}$$

(c) $$I = \frac{S}{V} = \frac{86510}{550} = \underline{\mathbf{157.3\ A}}$$

Chapter 11, Solution 93

(a) $$P_1 = (5)(0.7457) = 3.7285 \text{ kW}$$

$$S_1 = \frac{P_1}{\text{pf}} = \frac{3.7285}{0.8} = 4.661 \text{ kVA}$$

$$Q_1 = S_1 \sin(\cos^{-1}(0.8)) = 2.796 \text{ kVAR}$$
$$\mathbf{S}_1 = 3.7285 + j2.796 \text{ kVA}$$

$$P_2 = 1.2 \text{ kW}, \qquad Q_2 = 0 \text{ VAR}$$
$$\mathbf{S}_2 = 1.2 + j0 \text{ kVA}$$

$$P_3 = (10)(120) = 1.2 \text{ kW}, \qquad Q_3 = 0 \text{ VAR}$$
$$\mathbf{S}_3 = 1.2 + j0 \text{ kVA}$$

$Q_4 = 1.6$ kVAR , $\cos\theta_4 = 0.6 \longrightarrow \sin\theta_4 = 0.8$

$$S_4 = \frac{Q_4}{\sin\theta_4} = 2 \text{ kVA}$$

$P_4 = S_4 \cos\theta_4 = (2)(0.6) = 1.2$ kW
$\mathbf{S}_4 = 1.2 - j1.6$ kVA

$\mathbf{S} = \mathbf{S}_1 + \mathbf{S}_2 + \mathbf{S}_3 + \mathbf{S}_4$
$\mathbf{S} = 7.3285 + j1.196$ kVA

Total real power = $\underline{\mathbf{7.3285\ kW}}$
Total reactive power = $\underline{\mathbf{1.196\ kVAR}}$

(b) $$\theta = \tan^{-1}\left(\frac{1.196}{7.3285}\right) = 9.27°$$

pf = $\cos\theta = \underline{\mathbf{0.987}}$

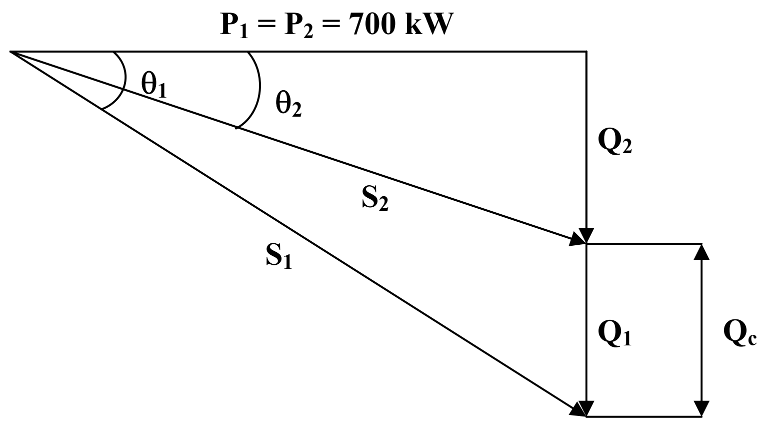
Chapter 11, Solution 94

$\cos\theta_1 = 0.7 \longrightarrow \theta_1 = 45.57°$
$S_1 = 1$ MVA $= 1000$ kVA
$P_1 = S_1 \cos\theta_1 = 700$ kW
$Q_1 = S_1 \sin\theta_1 = 714.14$ kVAR

For improved pf,
$\cos\theta_2 = 0.95 \longrightarrow \theta_2 = 18.19°$
$P_2 = P_1 = 700$ kW

$$S_2 = \frac{P_2}{\cos\theta_2} = \frac{700}{0.95} = 736.84 \text{ kVA}$$

$Q_2 = S_2 \sin\theta_2 = 230.08$ kVAR



(a) Reactive power across the capacitor

$$Q_c = Q_1 - Q_2 = 714.14 - 230.08 = 484.06 \text{ kVAR}$$

Cost of installing capacitors $= \$30 \times 484.06 = \underline{\mathbf{\$14,521.80}}$

(b) Substation capacity released $= S_1 - S_2$

$$= 1000 - 736.84 = 263.16 \text{ kVA}$$

Saving in cost of substation and distribution facilities

$$= \$120 \times 263.16 = \underline{\mathbf{\$31,579.20}}$$

(c) **<u>Yes</u>**, because (a) is greater than (b). Additional system capacity obtained by using capacitors costs only 46% as much as new substation and distribution facilities.

Chapter 11, Solution 95

(a) Source impedance $\mathbf{Z}_s = R_s - jX_c$

Load impedance $\mathbf{Z}_L = R_L + jX_2$

For maximum load transfer

$$\mathbf{Z}_L = \mathbf{Z}_s^* \longrightarrow R_s = R_L, \quad X_c = X_L$$

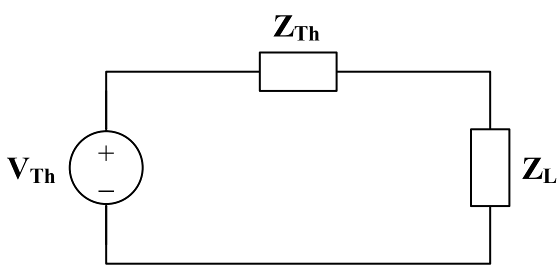
$$X_c = X_L \longrightarrow \frac{1}{\omega C} = \omega L$$

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

$$f = \frac{1}{2\pi\sqrt{LC}} = \frac{1}{2\pi\sqrt{(80\times10^{-3})(40\times10^{-9})}} = \underline{\mathbf{2.814\ kHz}}$$

(b) $$P = \frac{V_s^2}{4R_L} = \frac{(4.6)^2}{(4)(10)} = \underline{\mathbf{529\ mW}} \qquad \text{(since } V_s \text{ is in rms)}$$

Chapter 11, Solution 96



(a) $$V_{Th} = 146\ \text{V}, \quad 300\ \text{Hz}$$
$$Z_{Th} = 40 + j8\ \Omega$$

$$Z_L = Z_{Th}^* = \underline{\mathbf{40 - j8\ \Omega}}$$

(b) $$P = \frac{\left|V_{Th}\right|^2}{8R_{Th}} = \frac{(146)^2}{(8)(40)} = \underline{\mathbf{66.61\ W}}$$

Chapter 11, Solution 97

$$Z_T = (2)(0.1 + j) + (100 + j20) = 100.2 + j22\ \Omega$$

$$I = \frac{V_s}{Z_T} = \frac{240}{100.2 + j22}$$

$$P = \left|I\right|^2 R_L = 100\left|I\right|^2 = \frac{(100)(240)^2}{(100.2)^2 + (22)^2} = \underline{\mathbf{547.3\ W}}$$