P 10.1 **[a]** $P = \frac{1}{2}(250)(4)\cos(45 + 30) = 500\cos 75^\circ = 129.41\ \text{W} \quad \text{(abs)}$

$Q = 500\sin 75^\circ = 482.96\ \text{VAR} \quad \text{(abs)}$

[b] $P = \frac{1}{2}(18)(5)\cos(30 + 75) = 45\cos(105^\circ) = -11.65\ \text{W} \quad \text{(del)}$

$Q = 45\sin(105^\circ) = 43.47\ \text{VAR} \quad \text{(abs)}$

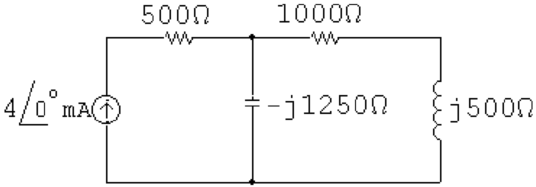
[c] $P = \frac{1}{2}(150)(2)\cos(-65 - 50) = 150\cos(-115^\circ) = -63.39\ \text{W} \quad \text{(del)}$

$Q = 150\sin(-115^\circ) = -135.95\ \text{VAR} \quad \text{(del)}$

[d] $P = \frac{1}{2}(80)(10)\cos(120 - 170) = 400\cos(-50^\circ) = 257.12\ \text{W} \quad \text{(abs)}$

$Q = 400\sin(-50^\circ) = -306.42\ \text{VAR} \quad \text{(del)}$

P 10.5 $\mathbf{I}_g = 4\underline{/0^\circ}$ mA; $\qquad \dfrac{1}{j\omega C} = -j1250\,\Omega; \qquad j\omega L = j500\,\Omega$

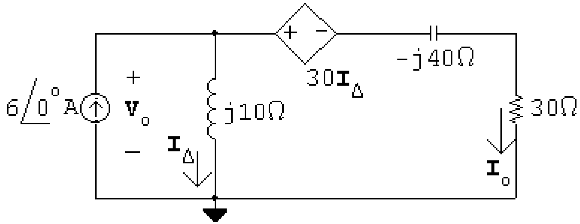


$$Z_{\rm eq} = 500 + [-j1250 \| (1000 + j500)] = 1500 - j500\,\Omega$$

$$P_g = -\frac{1}{2}|I|^2 \mathrm{Re}\{Z_{\rm eq}\} = -\frac{1}{2}(0.004)^2(1500) = -12\,\mathrm{mW}$$

The source delivers 12 mW of power to the circuit.

P 10.6 $j\omega L = j20{,}000(0.5 \times 10^{-3}) = j10\,\Omega;\qquad \frac{1}{j\omega C} = \frac{10^6}{j20{,}000(1.25)} = -j40\,\Omega$



$$-6 + \frac{\mathbf{V}_o}{j10} + \frac{\mathbf{V}_o - 30(\mathbf{V}_o/j10)}{30 - j40} = 0$$

$$\therefore\quad \mathbf{V}_o\left[\frac{1}{j10} + \frac{1 + j3}{30 - j40}\right] = 6$$

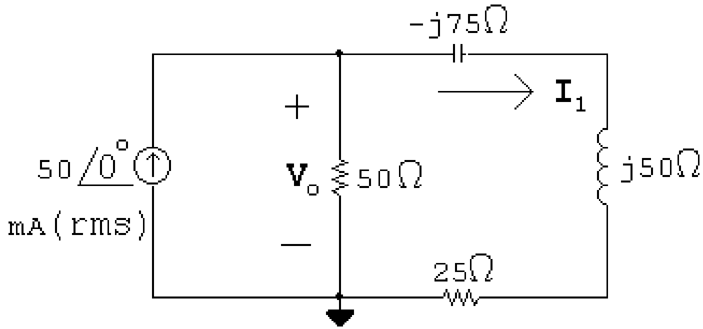
$$\therefore\quad \mathbf{V}_o = 100\underline{/126.87^\circ}\ \text{V}$$

$$\therefore\quad \mathbf{I}_\Delta = \frac{\mathbf{V}_o}{j10} = 10\underline{/36.87^\circ}\ \text{A}$$

$$\mathbf{I}_o = 6\underline{/0^\circ} - \mathbf{I}_\Delta = 6 - 8 - j6 = -2 - j6 = 6.32\underline{/-108.43^\circ}\ \text{A}$$

$$P_{30\Omega} = \frac{1}{2}|\mathbf{I}_o|^2 30 = 600\,\text{W}$$

P 10.17 [a]



$$Z_{\rm eq} = 50\|(25 - j25) = 20 - j10\,\Omega$$

$$\therefore \qquad \mathbf{V}_o = 0.05Z_{\rm eq} = 1 - j0.5\ \text{V(rms)}$$

$$\mathbf{I}_1 = \frac{\mathbf{V}_o}{25 - j25} = 30 + j10\ \text{mA(rms)}$$

$$S_g = -\mathbf{V}_g\mathbf{I}_g^* = -(1 - j0.5)(0.05)$$

$$= -50 + j25\,\text{mVA}$$

[b] Source is delivering 50 mW.

[c] Source is absorbing 25 mVAR.

[d] $Q_{\rm cap} = -|\mathbf{I}_1|^2(75) = -75\ \text{mVAR}$

$$P_{50\Omega} = \frac{|\mathbf{V}_o|^2}{50} = 25\,\text{mW}$$

$$P_{25\Omega} = |\mathbf{I}_1|^2(25) = 25\,\text{mW}$$

$$Q_{\rm ind} = |\mathbf{I}_1|^2(50) = 50\ \text{mVAR}$$

$$P_{\text{middle branch}} = 25\,\text{mW}; \qquad Q_{\text{middle branch}} = 0$$

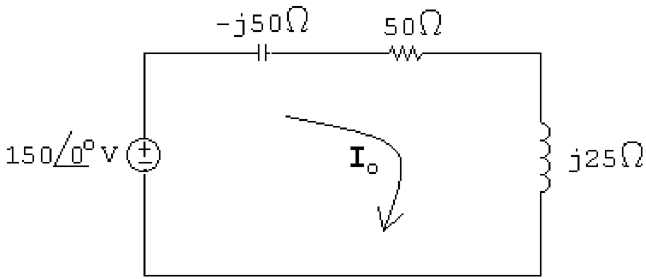
$$P_{\text{right branch}} = 25\,\text{mW}; \qquad Q_{\text{right branch}} = -75 + 50 = -25\ \text{mVAR}$$

[e] $\sum P_{\text{del}} = 50\,\text{mW}$

$$\sum P_{\text{diss}} = 25 + 25 = 50\,\text{mW} = \sum P_{\text{del}}$$

[f] $\sum Q_{\text{abs}} = 25 + 50 = 75\,\text{mVAR} = \sum Q_{\text{dev}}$

P 10.18 $j\omega L = j25\,\Omega; \qquad \dfrac{1}{j\omega C} = -j75\,\Omega$



$$\mathbf{I}_o = \frac{j150}{50 - j25} = 2.4 + j1.2\,\text{A}$$

$$P = \frac{1}{2}|\mathbf{I}_o|^2(50) = \frac{1}{2}(7.2)(50) = 180\,\text{W}$$

$$Q = \frac{1}{2}|\mathbf{I}_o|^2(25) = 90\,\text{VAR}$$

$$S = P + jQ = 180 + j90\,\text{VA}$$

$$|S| = 201.25\,\text{VA}$$

P 10.22 **[a]** $S_1 = 10{,}000 - j4000\,\text{VA}$

$$S_2 = \frac{|\mathbf{V}_\text{L}|^2}{Z_2^*} = \frac{(1000)^2}{60 - j80} = 6 + j8\,\text{kVA}$$

$$S_1 + S_2 = 16 + j4\,\text{kVA}$$

$$1000\mathbf{I}_\text{L}^* = 16{,}000 + j4000; \qquad \therefore \quad \mathbf{I}_\text{L} = 16 - j4\,\text{A(rms)}$$

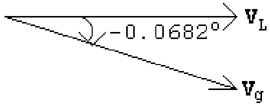
$$\mathbf{V}_g = \mathbf{V}_\text{L} + \mathbf{I}_\text{L}(0.5 + j0.05) = 1000 + (16 - j4)(0.5 + j0.05)$$

$$= 1008.2 - j1.2 = 1008.2\underline{/-0.0682^\circ}\ \text{Vrms}$$

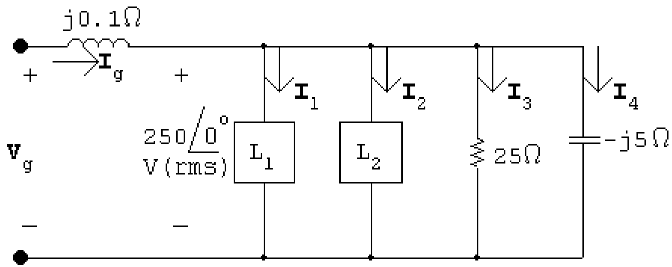
[b] $T = \dfrac{1}{f} = \dfrac{1}{50} = 20\,\text{ms}$

$$\frac{-0.0682^\circ}{360^\circ} = \frac{t}{20\ \text{ms}}; \qquad \therefore \quad t = -3.79\,\mu\text{s}$$

[c] $\mathbf{V}_\text{L}$ leads $\mathbf{V}_g$ by 0.0682° or $3.79\,\mu\text{s}$



P 10.26



$$250\mathbf{I}_1^* = 6000 - j8000$$

$$\mathbf{I}_1^* = 24 - j32; \qquad \therefore \quad \mathbf{I}_1 = 24 + j32\,\text{A(rms)}$$

$$250\mathbf{I}_2^* = 9000 + j3000$$

$$\mathbf{I}_2^* = 36 + j12; \qquad \therefore \quad \mathbf{I}_2 = 36 - j12\,\text{A(rms)}$$

$$\mathbf{I}_3 = \frac{250\underline{/0^\circ}}{25} = 10 + j0\,\text{A}; \qquad \mathbf{I}_4 = \frac{250\underline{/0^\circ}}{-j5} = 0 + j50\,\text{A}$$

$$\mathbf{I}_g = \mathbf{I}_1 + \mathbf{I}_2 + \mathbf{I}_3 + \mathbf{I}_4 = 70 + j70\,\text{A}$$

$$\mathbf{V}_g = 250 + (70 + j70)(j0.1) = 243 + j7 = 243.1\underline{/1.65^\circ}\text{ V (rms)}$$

P 10.31 [a] $\mathbf{I} = \dfrac{270\angle 0^\circ}{36 + j48} = 2.7 - j3.6 = 4.5\angle -53.13^\circ \text{ A(rms)}$

$$P = (4.5)^2(6) = 121.5\,\text{W}$$

[b] $Y_\text{L} = \dfrac{1}{30 + j40} = 12 - j16 \text{ mS}$

$$\therefore \quad X_\text{C} = \frac{1}{-16 \times 10^{-3}} = -62.5\,\Omega$$

[c] $Z_\text{L} = \dfrac{1}{12 \times 10^{-3}} = 83.33\,\Omega$

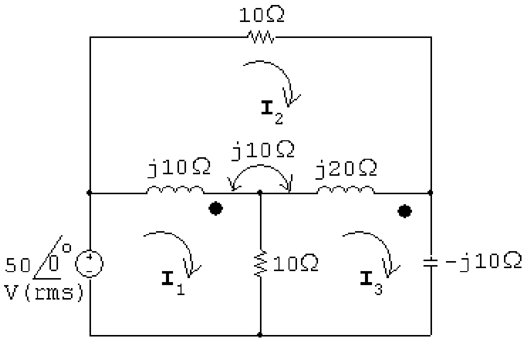
[d] $\mathbf{I} = \dfrac{270\angle 0^\circ}{89.33 + j8} = 3.01\angle -5.12^\circ \text{ A}$

$$P = (3.01)^2(6) = 54.37\,\text{W}$$

[e] $\% = \dfrac{54.37}{121.5}(100) = 44.75\%$

Thus the power loss after the capacitor is added is 44.75% of the power loss before the capacitor is added.

P 10.36 [**a**]



$$50 = j10(\mathbf{I}_1 - \mathbf{I}_2) + j10(\mathbf{I}_3 - \mathbf{I}_2) + 10(\mathbf{I}_1 - \mathbf{I}_3)$$

$$0 = 10\mathbf{I}_2 + j20(\mathbf{I}_2 - \mathbf{I}_3) + j10(\mathbf{I}_2 - \mathbf{I}_1) + j10(\mathbf{I}_2 - \mathbf{I}_1) + j10(\mathbf{I}_2 - \mathbf{I}_3)$$

$$0 = -j10\mathbf{I}_3 + 10(\mathbf{I}_3 - \mathbf{I}_1) + j20(\mathbf{I}_3 - \mathbf{I}_2) + j10(\mathbf{I}_1 - \mathbf{I}_2)$$

Solving,

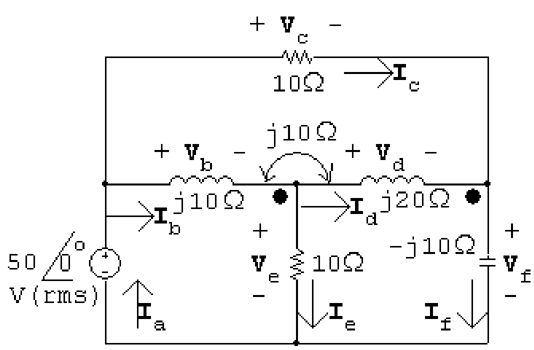
$$\mathbf{I}_1 = 5.5 + j0.5\,\text{A(rms)}; \quad \mathbf{I}_2 = 3 + j2\,\text{A(rms)}; \quad \mathbf{I}_3 = 2 + j2\,\text{A(rms)}$$

$\mathbf{I}_\text{a} = \mathbf{I}_1 = 5.5 + j0.5\,\text{A}$ $\qquad$ $\mathbf{I}_\text{b} = \mathbf{I}_1 - \mathbf{I}_2 = 2.5 - j1.5\,\text{A}$

$\mathbf{I}_\text{c} = \mathbf{I}_2 = 3 + j2\,\text{A}$ $\qquad$ $\mathbf{I}_\text{d} = \mathbf{I}_3 - \mathbf{I}_2 = -1\,\text{A}$

$\mathbf{I}_\text{e} = \mathbf{I}_1 - \mathbf{I}_3 = 3.5 - j1.5\,\text{A}$ $\qquad$ $\mathbf{I}_\text{f} = \mathbf{I}_3 = 2 + j2\,\text{A}$

[b]



$\mathbf{V}_\text{a} = 50\,\text{V}$ $\qquad$ $\mathbf{V}_\text{b} = j10\mathbf{I}_\text{b} + j10\mathbf{I}_\text{d} = 15 + j15\,\text{V}$

$\mathbf{V}_\text{c} = 10\mathbf{I}_\text{c} = 30 + j20\,\text{V}$ $\qquad$ $\mathbf{V}_\text{d} = j20\mathbf{I}_\text{d} + j10\mathbf{I}_\text{b} = 15 + j5\,\text{V}$

$\mathbf{V}_\text{e} = 10\mathbf{I}_\text{e} = 35 - j15\,\text{V}$ $\qquad$ $\mathbf{V}_\text{f} = -j10\mathbf{I}_\text{f} = 20 - j20\,\text{V}$

$$S_\text{a} = -50\mathbf{I}_\text{a}^* = -275 + j25\,\text{VA}$$

$$S_\text{b} = \mathbf{V}_\text{b}\mathbf{I}_\text{b}^* = 15 + j60\,\text{VA}$$

$$S_\text{c} = \mathbf{V}_\text{c}\mathbf{I}_\text{c}^* = 130 + j0\,\text{VA}$$

$$S_\text{d} = \mathbf{V}_\text{d}\mathbf{I}_\text{d}^* = -15 - j5\,\text{VA}$$

$$S_\text{e} = \mathbf{V}_\text{e}\mathbf{I}_\text{e}^* = 145 - j0\,\text{VA}$$

$$S_\text{f} = \mathbf{V}_\text{f}\mathbf{I}_\text{f}^* = 0 - j80\,\text{VA}$$

[c] $\sum P_\text{dev} = 275 + 15 = 290\,\text{W}$

$\sum P_\text{abs} = 15 + 130 + 145 = 290\,\text{W}$

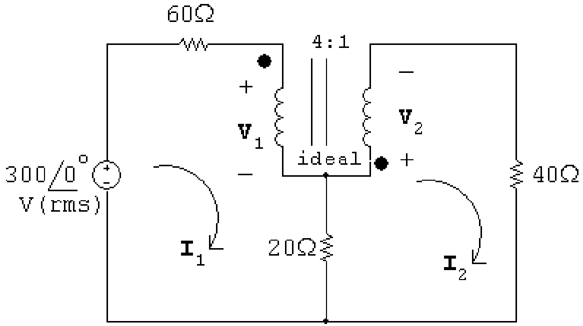
Note that the total power absorbed by the coupled coils is zero: $15 - 15 = 0 = P_\text{b} + P_\text{d}$

[d] $\sum Q_{\text{dev}} = 5 + 80 = 85\,\text{VAR}$

$\sum Q_{\text{abs}} = 25 + 60 = 85\,\text{VAR}$

$\sum Q$ absorbed by the coupled coils is $Q_{\text{b}} + Q_{\text{d}} = 55$

P 10.38 [a]



$$300 = 60\mathbf{I}_1 + \mathbf{V}_1 + 20(\mathbf{I}_1 - \mathbf{I}_2)$$

$$0 = 20(\mathbf{I}_2 - \mathbf{I}_1) + \mathbf{V}_2 + 40\mathbf{I}_2$$

$$\mathbf{V}_2 = \frac{1}{4}\mathbf{V}_1; \qquad \mathbf{I}_2 = -4\mathbf{I}_1$$

Solving,

$$\mathbf{V}_1 = 260\,\text{V (rms)}; \qquad \mathbf{V}_2 = 65\,\text{V (rms)}$$

$$\mathbf{I}_1 = 0.25\,\text{A (rms)}; \qquad \mathbf{I}_2 = -1.0\,\text{A (rms)}$$

$$\mathbf{V}_{5\text{A}} = \mathbf{V}_1 + 20(\mathbf{I}_1 - \mathbf{I}_2) = 285\,\text{V (rms)}$$

$$\therefore \quad P = -(285)(5) = -1425\,\text{W}$$

Thus 1425 W is delivered by the current source to the circuit.

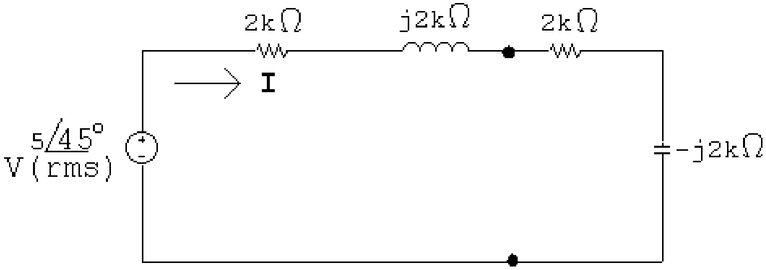
[b] $\mathbf{I}_{20\Omega} = \mathbf{I}_1 - \mathbf{I}_2 = 1.25\,\text{A(rms)}$

$$\therefore \quad P_{20\Omega} = (1.25)^2(20) = 31.25\,\text{W}$$

P 10.41 [a] $Z_{\text{Th}} = j4000 + \dfrac{(4000)(-j4000)}{4000 - j4000} = 2000 + j2000\,\Omega$

$$\therefore \quad Z_{\text{L}} = Z^*_{\text{Th}} = 2000 - j2000\,\Omega$$

[b] $\mathbf{V}_{\text{Th}} = \dfrac{10\underline{/0^\circ}(4000)}{4000 - j4000} = 5 + j5 = 5\sqrt{2}\underline{/45^\circ}\text{ V}$



$$\mathbf{I} = \frac{5\sqrt{2}\underline{/45^\circ}}{4000} = 1.25\sqrt{2}\underline{/45^\circ}\text{ mA}$$

$$|\mathbf{I}_{\text{rms}}| = 1.25\text{ mA}$$

$$P_{\text{load}} = (0.00125)^2(2000) = 3.125\text{ mW}$$

[c] The closest resistor values from Appendix H are $1.8\,\text{k}\Omega$ and $2.2\,\text{k}\Omega$. Find the capacitor value:

$$\frac{1}{8000C} = 2000 \qquad \text{so} \qquad C = 62.5\,\text{nF}$$

The closest capacitor value is 47 nF. Try $R = 1.8\,\text{k}\Omega$:

$$\mathbf{I} = \frac{5\underline{/45^\circ}}{2000 + j2000 + 1800 - j2659.57} = 0.7462 + j1.06\ \text{mA(rms)}$$

$$= 1.3\underline{/54.85^\circ}\ \text{mA(rms)}$$

$$P_{\text{load}} = (0.0013)^2(1800) = 3.03\,\text{mW} \qquad \text{(instead of 3.125 mW)}$$

Try $R = 2.2\,\text{k}\Omega$:

$$\mathbf{I} = \frac{5\underline{/45^\circ}}{2000 + j2000 + 2200 - j2659.57} = 0.6925 + j0.9505\ \text{mA(rms)}$$

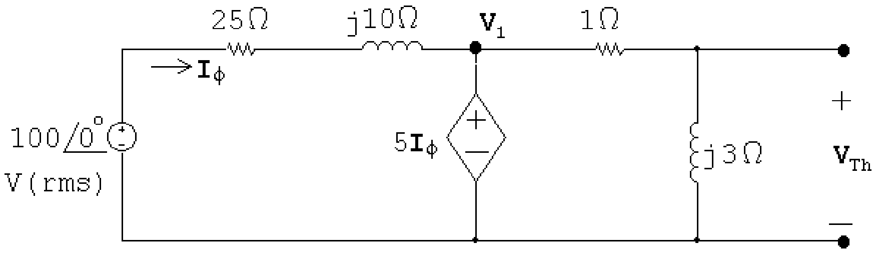
$$= 1.176\underline{/53.92^\circ}\ \text{mA(rms)}$$

$$P_{\text{load}} = (0.001176)^2(2200) = 3.04\,\text{mW} \qquad \text{(instead of 3.125 mW)}$$

Therefore, use the 2.2 kΩ resistor to give a load impedance of

$Z_{\text{L}} = 2200 - j2659.57\,\Omega.$

P 10.44 [a] Open circuit voltage:



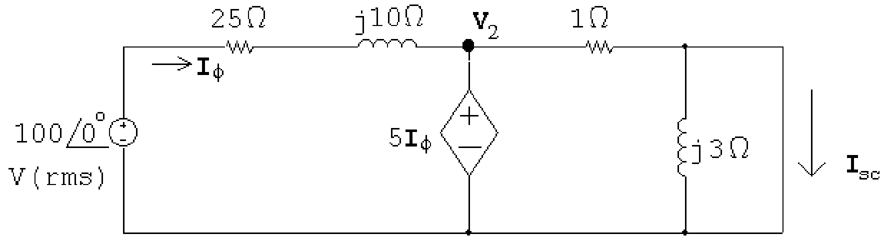
$$\mathbf{V}_1 = 5\mathbf{I}\phi = 5\frac{100 - 5\mathbf{I}_\phi}{25 + j10}$$

$$(25 + j10)\mathbf{I}_\phi = 100 - 5\mathbf{I}\phi$$

$$\mathbf{I}_\phi = \frac{100}{30 + j10} = 3 - j \text{ A}$$

$$\mathbf{V}_{\mathrm{Th}} = \frac{j3}{1+j3}(5\mathbf{I}_\phi) = 15\,\mathrm{V}$$

Short circuit current:



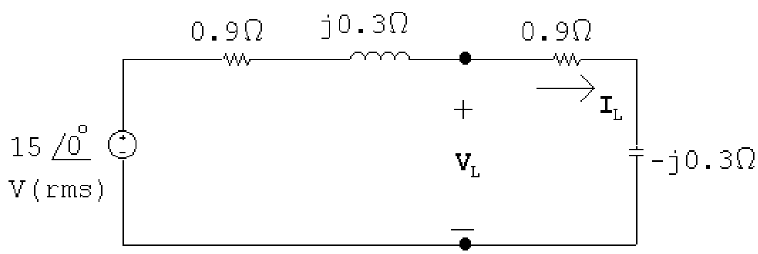
$$\mathbf{V}_2 = 5\mathbf{I}_\phi = \frac{100 - 5\mathbf{I}_\phi}{25 + j10}$$

$$\mathbf{I}_\phi = 3 - j1\,\mathrm{A}$$

$$\mathbf{I}_{\mathrm{sc}} = \frac{5\mathbf{I}_\phi}{1} = 15 - j5\,\mathrm{A}$$

$$Z_{\mathrm{Th}} = \frac{15}{15 - j5} = 0.9 + j0.3\,\Omega$$

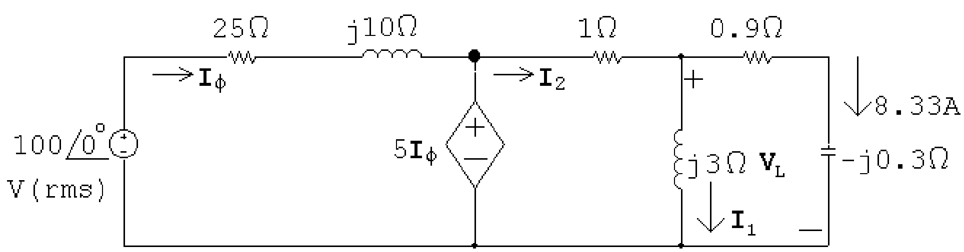
$$Z_L = Z_{\mathrm{Th}}^* = 0.9 - j0.3\,\Omega$$



$$\mathbf{I}_{\mathrm{L}} = \frac{0.3}{1.8} = 8.33\,\mathrm{A(rms)}$$

$$P = |\mathbf{I}_L|^2(0.9) = 62.5\,\mathrm{W}$$

[b] $\mathbf{V}_{\mathrm{L}} = (0.9 - j0.3)(8.33) = 7.5 - j2.5\,\mathrm{V(rms)}$



$$\mathbf{I}_1 = \frac{\mathbf{V}_{\mathrm{L}}}{j3} = -0.833 - j2.5\,\mathrm{A(rms)}$$

$$\mathbf{I}_2 = \mathbf{I}_1 + \mathbf{I}_{\rm L} = 7.5 - j2.5\,\text{A(rms)}$$

$$5\mathbf{I}_\phi = \mathbf{I}_2 + \mathbf{V}_L \quad \therefore \quad \mathbf{I}_\phi = 3 - j1\,\text{A}$$

$$\mathbf{I}_{\rm d.s.} = \mathbf{I}_\phi - \mathbf{I}_2 = -4.5 + j1.5\,\text{A}$$

$$S_g = -100(3 + j1) = -300 - j100\,\text{VA}$$

$$S_{\rm d.s.} = 5(3 - j1)(-4.5 - j1.5) = -75 + j0\,\text{VA}$$

$$P_{\rm dev} = 300 + 75 = 375\,\text{W}$$

$$\%\text{ developed} = \frac{62.5}{375}(100) = 16.67\%$$

Checks:

$$P_{25\Omega} = (10)(25) = 250\,\text{W}$$

$$P_{1\Omega} = (67.5)(1) = 67.5\,\text{W}$$

$$P_{0.9\Omega} = 62.5\,\text{W}$$

$$\sum P_{\rm abs} = 230 + 62.5 + 67.5 = 375 = \sum P_{\rm dev}$$

$$Q_{j10} = (10)(10) = 100\,\text{VAR}$$

$$Q_{j3} = (6.94)(3) = 20.82\,\text{VAR}$$

$$Q_{-j0.3} = (69.4)(-0.3) = -20.82\,\text{VAR}$$

$$Q_{\rm source} = -100\,\text{VAR}$$

$$\sum Q = 100 + 20.82 - 20.82 - 100 = 0$$