10

Sinusoidal Steady State Power Calculations

Assessment Problems

AP 10.1 **[a]** $\mathbf{V} = 100\underline{/-45^\circ}\,\text{V}, \qquad \mathbf{I} = 20\underline{/15^\circ}\,\text{A}$

Therefore

$$P = \frac{1}{2}(100)(20)\cos[-45 - (15)] = 500\,\text{W}, \qquad \text{A} \rightarrow \text{B}$$

$$Q = 1000\sin -60^\circ = -866.03\ \text{VAR}, \qquad \text{B} \rightarrow \text{A}$$

[b] $\mathbf{V} = 100\underline{/-45^\circ}, \qquad \mathbf{I} = 20\underline{/165^\circ}$

$$P = 1000\cos(-210^\circ) = -866.03\,\text{W}, \qquad \text{B} \rightarrow \text{A}$$

$$Q = 1000\sin(-210^\circ) = 500\ \text{VAR}, \qquad \text{A} \rightarrow \text{B}$$

[c] $\mathbf{V} = 100\underline{/-45^\circ}, \qquad \mathbf{I} = 20\underline{/-105^\circ}$

$$P = 1000\cos(60^\circ) = 500\,\text{W}, \qquad \text{A} \rightarrow \text{B}$$

$$Q = 1000\sin(60^\circ) = 866.03\ \text{VAR}, \qquad \text{A} \rightarrow \text{B}$$

[d] $\mathbf{V} = 100\underline{/0^\circ}, \qquad \mathbf{I} = 20\underline{/120^\circ}$

$$P = 1000\cos(-120^\circ) = -500\,\text{W}, \qquad \text{B} \rightarrow \text{A}$$

$$Q = 1000\sin(-120^\circ) = -866.03\ \text{VAR}, \qquad \text{B} \rightarrow \text{A}$$

AP 10.2 pf $= \cos(\theta_v - \theta_i) = \cos[15 - (75)] = \cos(-60^\circ) = 0.5$ leading

rf $= \sin(\theta_v - \theta_i) = \sin(-60^\circ) = -0.866$

AP 10.3 From Ex. 9.4 $I_{\text{eff}} = \dfrac{I_\rho}{\sqrt{3}} = \dfrac{0.18}{\sqrt{3}}\,\text{A}$

$$P = I_{\text{eff}}^2 R = \left(\frac{0.0324}{3}\right)(5000) = 54\,\text{W}$$

AP 10.4 **[a]** $Z = (39 + j26)\|(-j52) = 48 - j20 = 52\underline{/-22.62^\circ}\,\Omega$

Therefore $\mathbf{I}_\ell = \dfrac{250\underline{/0^\circ}}{48 - j20 + 1 + j4} = 4.85\underline{/18.08^\circ}\,\text{A(rms)}$

$\mathbf{V}_\text{L} = Z\mathbf{I}_\ell = (52\underline{/-22.62^\circ})(4.85\underline{/18.08^\circ}) = 252.20\underline{/-4.54^\circ}\,\text{V(rms)}$

$\mathbf{I}_\text{L} = \dfrac{\mathbf{V}_\text{L}}{39 + j26} = 5.38\underline{/-38.23^\circ}\,\text{A(rms)}$

[b] $S_\text{L} = \mathbf{V}_L\mathbf{I}_L^* = (252.20\underline{/-4.54^\circ})(5.38\underline{/+38.23^\circ}) = 1357\underline{/33.69^\circ}$

$= (1129.09 + j752.73)\,\text{VA}$

$P_\text{L} = 1129.09\,\text{W}$; $\qquad Q_\text{L} = 752.73\,\text{VAR}$

[c] $P_\ell = |\mathbf{I}_\ell|^2 1 = (4.85)^2 \cdot 1 = 23.52\,\text{W}$; $\qquad Q_\ell = |\mathbf{I}_\ell|^2 4 = 94.09\,\text{VAR}$

[d] $S_g(\text{delivering}) = 250\mathbf{I}_\ell^* = (1152.62 - j376.36)\,\text{VA}$

Therefore the source is delivering 1152.62 W and absorbing 376.36 magnetizing VAR.

[e] $Q_\text{cap} = \dfrac{|\mathbf{V}_\text{L}|^2}{-52} = \dfrac{(252.20)^2}{-52} = -1223.18\,\text{VAR}$

Therefore the capacitor is delivering 1223.18 magnetizing VAR.

Check: $94.09 + 752.73 + 376.36 = 1223.18\,\text{VAR}$ and

$1129.09 + 23.52 = 1152.62\,\text{W}$

AP 10.5 Series circuit derivation:

$$S = 250\mathbf{I}^* = (40{,}000 - j30{,}000)$$

Therefore $\mathbf{I}^* = 160 - j120 = 200\underline{/-36.87^\circ}\ \text{A(rms)}$

$$\mathbf{I} = 200\underline{/36.87^\circ}\ \text{A(rms)}$$

$$Z = \frac{\mathbf{V}}{\mathbf{I}} = \frac{250}{200\underline{/36.87^\circ}} = 1.25\underline{/-36.87^\circ} = (1 - j0.75)\,\Omega$$

Therefore $R = 1\,\Omega, \qquad X_C = -0.75\,\Omega$

Parallel circuit derivation:

$$P = \frac{(250)^2}{R}; \qquad \text{therefore} \quad R = \frac{(250)^2}{40{,}000} = 1.5625\,\Omega$$

$$Q = \frac{(250)^2}{X_C}; \qquad \text{therefore} \quad X_C = \frac{(250)^2}{-30{,}000} = -2.083\,\Omega$$

AP 10.6 $S_1 = 15{,}000(0.6) + j15{,}000(0.8) = 9000 + j12{,}000\ \text{VA}$

$$S_2 = 6000(0.8) + j6000(0.6) = 4800 - j3600\ \text{VA}$$

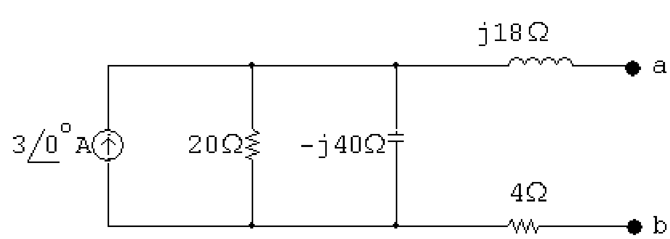
$$S_T = S_1 + S_2 = 13{,}800 + j8400\ \text{VA}$$

$$S_T = 200\mathbf{I}^*; \qquad \text{therefore} \quad \mathbf{I}^* = 69 + j42 \qquad \mathbf{I} = 69 - j42\ \text{A}$$

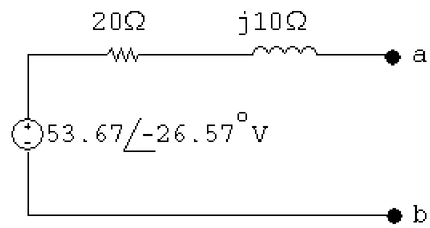
$$\mathbf{V}_s = 200 + j\mathbf{I} = 200 + j69 + 42 = 242 + j69 = 251.64\underline{/15.91^\circ}\ \text{V(rms)}$$

AP 10.7 **[a]** The phasor domain equivalent circuit and the Thévenin equivalent are shown below:

Phasor domain equivalent circuit:



Thévenin equivalent:



$$\mathbf{V}_{\text{Th}} = 3\frac{-j800}{20-j40} = 48 - j24 = 53.67\underline{/-26.57^\circ}\,\text{V}$$

$$Z_{\text{Th}} = 4 + j18 + \frac{-j800}{20-j40} = 20 + j10 = 22.36\underline{/26.57^\circ}\,\Omega$$

For maximum power transfer, $\quad Z_{\text{L}} = (20 - j10)\,\Omega$

[b] $\mathbf{I} = \dfrac{53.67\underline{/-26.57^\circ}}{40} = 1.34\underline{/-26.57^\circ}\,\text{A}$

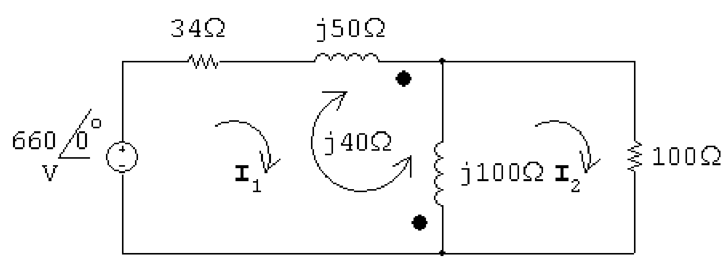
Therefore $\quad P = \left(\dfrac{1.34}{\sqrt{2}}\right)^2 20 = 18\,\text{W}$

[c] $R_{\text{L}} = |Z_{\text{Th}}| = 22.36\,\Omega$

[d] $\mathbf{I} = \dfrac{53.67\underline{/-26.57^\circ}}{42.36 + j10} = 1.23\underline{/-39.85^\circ}\,\text{A}$

Therefore $\quad P = \left(\dfrac{1.23}{\sqrt{2}}\right)^2 (22.36) = 17\,\text{W}$

AP 10.8



Mesh current equations:

$$660 = (34 + j50)\mathbf{I}_1 + j100(\mathbf{I}_1 - \mathbf{I}_2) + j40\mathbf{I}_1 + j40(\mathbf{I}_1 - \mathbf{I}_2)$$

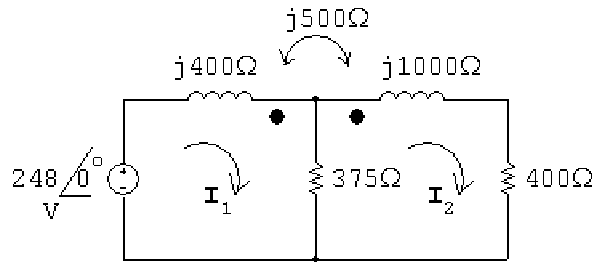
$$0 = j100(\mathbf{I}_2 - \mathbf{I}_1) - j40\mathbf{I}_1 + 100\mathbf{I}_2$$

Solving,

$\mathbf{I}_1 = 3.536\underline{/-45^\circ}\,\text{A},$

$\mathbf{I}_2 = 3.5\underline{/0^\circ}\,\text{A}; \qquad \therefore \quad P = \dfrac{1}{2}(3.5)^2(100) = 612.50\,\text{W}$

AP 10.9 **[a]**



$$248 = j400\mathbf{I}_1 - j500\mathbf{I}_2 + 375(\mathbf{I}_1 - \mathbf{I}_2)$$

$$0 = 375(\mathbf{I}_2 - \mathbf{I}_1) + j1000\mathbf{I}_2 - j500\mathbf{I}_1 + 400\mathbf{I}_2$$

Solving,

$$\mathbf{I}_1 = 0.80 - j0.62\,\text{A}; \qquad \mathbf{I}_2 = 0.4 - j0.3 = 0.5\underline{/-36.87^\circ}\,\text{A}$$

$$\therefore \quad P = \frac{1}{2}(0.25)(400) = 50\,\text{W}$$

[b] $\mathbf{I}_1 - \mathbf{I}_2 = 0.4 - j0.32\,\text{A}$

$$P_{375} = \frac{1}{2}|\mathbf{I}_1 - \mathbf{I}_2|^2(375) = 49.20\,\text{W}$$

[c] $P_g = \dfrac{1}{2}(248)(0.8) = 99.20\,\text{W}$

$$\sum P_{\text{abs}} = 50 + 49.2 = 99.20\,\text{W} \quad \text{(checks)}$$

AP 10.10 **[a]** $V_{\text{Th}} = 210\underline{/0^\circ}\,\text{V}; \qquad \mathbf{V}_2 = \frac{1}{4}\mathbf{V}_1; \qquad \mathbf{I}_1 = \frac{1}{4}\mathbf{I}_2$

Short circuit equations:

$$840 = 80\mathbf{I}_1 - 20\mathbf{I}_2 + \mathbf{V}_1$$

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

$$\therefore \quad \mathbf{I}_2 = 14\,\text{A}; \qquad R_{\text{Th}} = \frac{210}{14} = 15\,\Omega$$

[b] $P_{\max} = \left(\dfrac{210}{30}\right)^2 15 = 735\,\text{W}$

AP 10.11 **[a]** $\mathbf{V}_{\text{Th}} = -4(146\underline{/0^\circ}) = -584\underline{/0^\circ}\,\text{V(rms)} = 584\underline{/180^\circ}\,\text{V(rms)}$

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

Short circuit equations:

$$146\underline{/0^\circ} = 80\mathbf{I}_1 - 20\mathbf{I}_2 + \mathbf{V}_1$$

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

$$\therefore \quad \mathbf{I}_2 = -146/365 = -0.40\,\text{A}; \qquad R_{\text{Th}} = \frac{-584}{-0.4} = 1460\,\Omega$$

[b] $P = \left(\dfrac{-584}{2920}\right)^2 1460 = 58.40\,\text{W}$

Problems

P 10.1 **[a]** $P = \frac{1}{2}(100)(10)\cos(50 - 15) = 500\cos 35^\circ = 409.58\,\text{W} \quad \text{(abs)}$

$Q = 500\sin 35^\circ = 286.79\,\text{VAR} \quad \text{(abs)}$

[b] $P = \frac{1}{2}(40)(20)\cos(-15 - 60) = 400\cos(-75^\circ) = 103.53\,\text{W} \quad \text{(abs)}$

$Q = 400\sin(-75^\circ) = -386.37\,\text{VAR} \quad \text{(del)}$

[c] $P = \frac{1}{2}(400)(10)\cos(30 - 150) = 2000\cos(-120^\circ) = -1000\,\text{W} \quad \text{(del)}$

$Q = 2000\sin(-120^\circ) = -1732.05\,\text{VAR} \quad \text{(del)}$

[d] $P = \frac{1}{2}(200)(5)\cos(160 - 40) = 500\cos(120^\circ) = -250\,\text{W} \quad \text{(del)}$

$Q = 500\sin(120^\circ) = 433.01\,\text{VAR} \quad \text{(abs)}$

P 10.6 **[a]** Area under one cycle of v_g^2:

$$A = (5^2)(2)(30 \times 10^{-6}) + 2^2(2)(37.5 \times 10^{-6})$$
$$= 1800 \times 10^{-6}$$

Mean value of v_g^2:

$$\text{M.V.} = \frac{A}{200 \times 10^{-6}} = \frac{1800 \times 10^{-6}}{200 \times 10^{-6}} = 9$$

$$\therefore \quad V_{\text{rms}} = \sqrt{9} = 3\,\text{V(rms)}$$

[b] $P = \frac{V_{\text{rms}}^2}{R} = \frac{3^2}{2.25} = 4\,\text{W}$

P 10.14 **[a]** $P = \frac{1}{2}\frac{(240)^2}{480} = 60\,\text{W}$

$$-\frac{1}{\omega C} = \frac{-9 \times 10^6}{(5000)(5)} = -360\,\Omega$$

$$Q = \frac{1}{2}\frac{(240)^2}{(-360)} = -80\,\text{VAR}$$

$$p_{\text{max}} = P + \sqrt{P^2 + Q^2} = 60 + \sqrt{(60)^2 + (80)^2} = 160\,\text{W(del)}$$

[b] $p_{\text{min}} = 60 - \sqrt{60^2 + 80^2} = -40\,\text{W(abs)}$

[c] $P = 60\,\text{W}$ from (a)

[d] $Q = -80\,\text{VAR}$ from (a)

[e] generate, because $Q < 0$

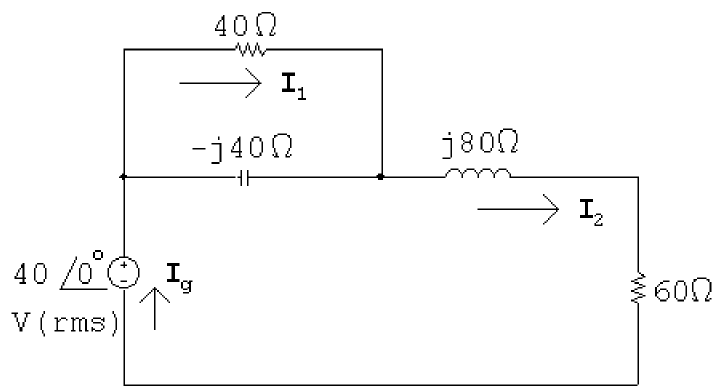
[f] pf $= \cos(\theta_v - \theta_i)$

$$\mathbf{I} = \frac{240}{480} + \frac{240}{-j360} = 0.5 + j0.67 = 0.83\underline{/53.13^\circ}\,\text{A}$$

$\therefore$ pf $= \cos(0 - 53.13^\circ) = 0.6$ leading

[g] rf $= \sin(-53.13^\circ) = -0.8$

P 10.16 **[a]** $\dfrac{1}{j\omega C} = -j40\,\Omega; \qquad j\omega L = j80\,\Omega$



$$Z_{\text{eq}} = 40\| - j40 + j80 + 60 = 80 + j60\,\Omega$$

$$\mathbf{I}_g = \frac{40\underline{/0^\circ}}{80 + j60} = 0.32 - j0.24\,\text{A}$$

$$S_g = -\frac{1}{2}\mathbf{V}_g\mathbf{I}_g^* = -\frac{1}{2}40(0.32 + j0.24) = -6.4 - j4.8\,\text{VA}$$

$P = 6.4\,\text{W(del)}; \qquad Q = 4.8\,\text{VAR(del)}$

$|S| = |S_g| = 8\,\text{VA}$

[b] $\mathbf{I}_1 = \dfrac{-j40}{40 - j40}\mathbf{I}_g = 0.04 - j0.28\,\text{A}$

$$P_{40\Omega} = \frac{1}{2}|\mathbf{I}_1|^2(40) = 1.6\,\text{W}$$

$$P_{60\Omega} = \frac{1}{2}|\mathbf{I}_g|^2(60) = 4.8\,\text{W}$$

$$\sum P_{\text{diss}} = 1.6 + 4.8 = 6.4\,\text{W} = \sum P_{\text{dev}}$$

[c] $\mathbf{I}_{-j40\Omega} = \mathbf{I}_g - \mathbf{I}_1 = 0.28 + j0.04\,\text{A}$

$$Q_{-j40\Omega} = \frac{1}{2}|\mathbf{I}_{-j40\Omega}|^2(-40) = -1.6\,\text{VAR(del)}$$

$$Q_{j80\Omega} = \frac{1}{2}|\mathbf{I}_g|^2(80) = 6.4\,\text{VAR(abs)}$$

$$\sum Q_{\text{abs}} = 6.4 - 1.6 = 4.8\,\text{VAR} = \sum Q_{\text{dev}}$$

P 10.18 **[a]** $S_1 = 16 + j18\,\text{kVA}; \qquad S_2 = 6 - j8\,\text{kVA}; \qquad S_3 = 8 + j0\,\text{kVA}$

$$S_{\text{T}} = S_1 + S_2 + S_3 = 30 + j10\,\text{kVA}$$

$$250\mathbf{I}^* = (30 + j10) \times 10^3; \qquad \therefore \quad \mathbf{I} = 120 - j40\,\text{A}$$

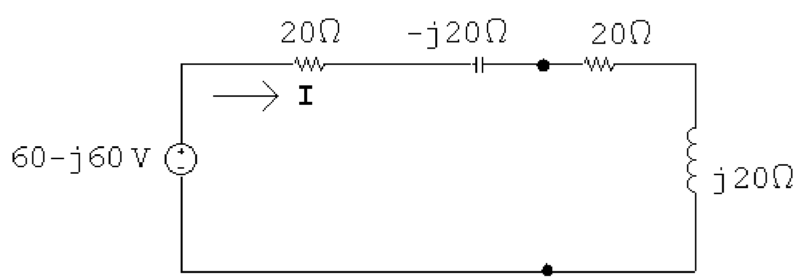
$$Z = \frac{250}{120 - j40} = 1.875 + j0.625\,\Omega = 1.98\underline{/18.43^\circ}\,\Omega$$

[b] pf $= \cos(18.43^\circ) = 0.9487$ lagging

P 10.33 **[a]** $Z_{\text{Th}} = j40\|40 - j40 = 20 - j20$

$$\therefore \quad Z_{\text{L}} = Z_{\text{Th}}^* = 20 + j20\,\Omega$$

[b] $\mathbf{V}_{\text{Th}} = \dfrac{40}{40 + j40}(120) = 60 - j60\,\text{V}$



$$\mathbf{I} = \frac{60 - j60}{40} = 1.5 - j1.5\,\text{A}$$

$$P_{\text{load}} = \frac{1}{2}|\mathbf{I}|^2(20) = 45\,\text{W}$$

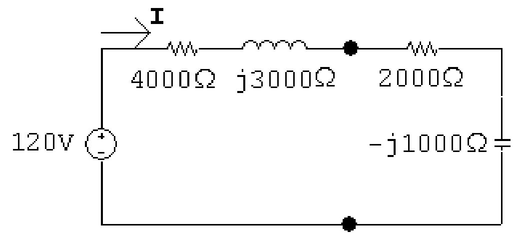
P 10.38 **[a]** First find the Thévenin equivalent:

$$j\omega L = j3000\,\Omega$$

$$Z_{\text{Th}} = 6000\|12{,}000 + j3000 = 4000 + j3000\,\Omega$$

$$\mathbf{V}_{\text{Th}} = \frac{12{,}000}{6000 + 12{,}000}(180) = 120\underline{/0^\circ}\,\text{V}$$

$$\frac{-j}{\omega C} = -j1000\,\Omega$$



$$\mathbf{I} = \frac{120}{6000 + j2000} = 18 - j6\,\text{mA}$$

$$P = \frac{1}{2}|\mathbf{I}|^2(2000) = 360\,\text{mW}$$

[b] Set $C_o = 0.1\,\mu$F so $-j/\omega C = -j2000\,\Omega$ $\quad j3000 - j2000 = j1000\,\Omega$
Set R_o as close as possible to

$$R_o = \sqrt{4000^2 + 1000^2} = 4123.1\,\Omega$$

$$\therefore \quad R_o = 4000\,\Omega$$

[c] $\mathbf{I} = \dfrac{120}{8000 + j1000} = 14.77 - j1.85\text{ mA}$

$$P = \frac{1}{2}|\mathbf{I}|^2(4000) = 443.1\,\text{mW}$$

Yes; $\quad 443.1\,\text{mW} > 360\,\text{mW}$

[d] $\mathbf{I} = \dfrac{120}{8000} = 15\,\text{mA}$

$$P = \frac{1}{2}(0.015)^2(4000) = 450\,\text{mW}$$

[e] $R_o = 4000\,\Omega$; $\quad C_o = 66.67\,\text{nF}$

[f] Yes; $\quad 450\,\text{mW} > 443.1\,\text{mW}$

P 10.39 **[a]** Set $C_o = 0.1\,\mu$F, so $-j/\omega C = -j2000\,\Omega$; also set $R_o = 4123.1\,\Omega$

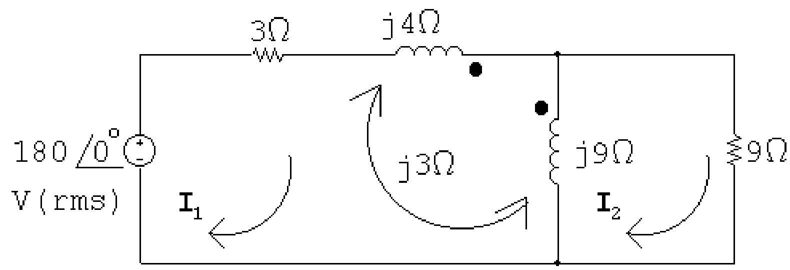
$$\mathbf{I} = \frac{120}{8123.1 + j1000} = 14.55 - j1.79\text{ mA}$$

$$P = \frac{1}{2}|\mathbf{I}|^2(4123.1) = 443.18\,\text{mW}$$

[b] Yes; $\quad 443.18\,\text{mW} > 360\,\text{mW}$

[c] Yes; $\quad 443.18\,\text{mW} < 450\,\text{mW}$

P 10.43 **[a]**



$$180 = 3\mathbf{I}_1 + j4\mathbf{I}_1 + j3(\mathbf{I}_2 - \mathbf{I}_1) + j9(\mathbf{I}_1 - \mathbf{I}_2) - j3\mathbf{I}_1$$

$$0 = 9\mathbf{I}_2 + j9(\mathbf{I}_2 - \mathbf{I}_1) + j3\mathbf{I}_1$$

Solving,

$\mathbf{I}_1 = 18 - j18\,\text{A(rms)}; \qquad \mathbf{I}_2 = 12\underline{/0^\circ}\,\text{A(rms)}$

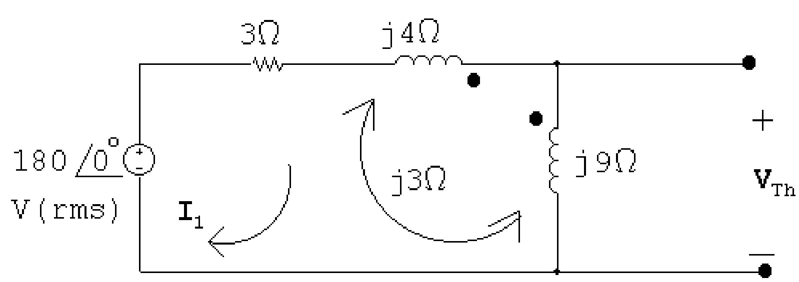
$\therefore \quad \mathbf{V}_o = (12)(9) = 108\underline{/0^\circ}\,\text{V(rms)}$

[b] $P = (12)^2(9) = 1296\,\text{W}$

[c] $S_g = -(180)(18 + j18) = -3240 - j3240\,\text{VA} \quad \therefore \quad P_g = -3240\,\text{W}$

$$\%\text{ delivered } = \frac{1296}{3240}(100) = 40\%$$

P 10.44 **[a]** Open circuit voltage:

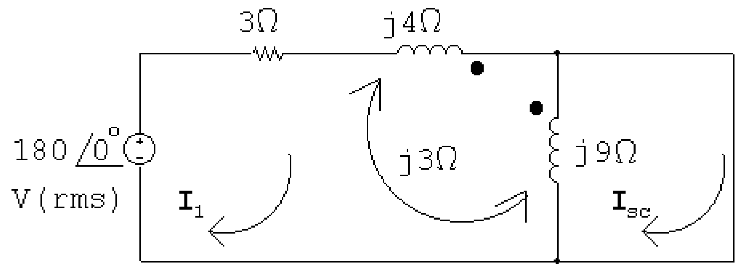


$$180 = 3\mathbf{I}_1 + j4\mathbf{I}_1 - j3\mathbf{I}_1 + j9\mathbf{I}_1 - j3\mathbf{I}_1$$

$$\therefore \quad \mathbf{I}_1 = \frac{180}{3 + j7} = 9.31 - j21.72\,\text{A(rms)}$$

$$\mathbf{V}_{\text{Th}} = j9\mathbf{I}_1 - j3\mathbf{I}_1 = j6\mathbf{I}_1 = 130.34 + j55.86\,\text{V} = 141.81\underline{/23.20^\circ}\,\text{V(rms)}$$

Short circuit current:



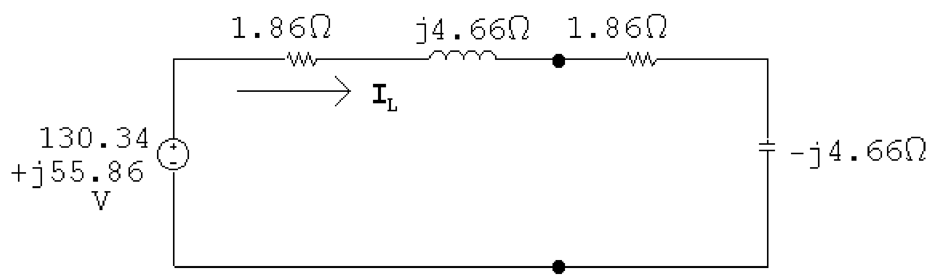
$$180 = 3\mathbf{I}_1 + j4\mathbf{I}_1 + j3(\mathbf{I}_{sc} - \mathbf{I}_1) + j9(\mathbf{I}_1 - \mathbf{I}_{sc}) - j3\mathbf{I}_1$$

$$0 = j9(\mathbf{I}_{sc} - \mathbf{I}_1) + j3\mathbf{I}_1$$

Solving,

$\mathbf{I}_{sc} = 20 - j20\,\text{A} \quad \mathbf{I}_1 = 30 - j20\ \text{A}$

$$Z_{\text{Th}} = \frac{\mathbf{V}_{\text{Th}}}{\mathbf{I}_{sc}} = \frac{130.34 + j55.86}{20 - j20} = 1.86 + j4.66\,\Omega$$



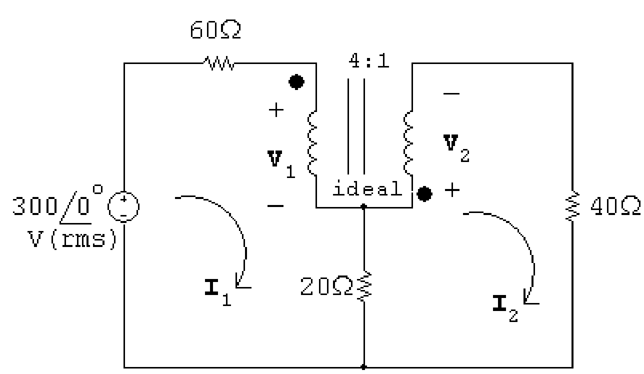
$$\mathbf{I}_{\text{L}} = \frac{130.34 + j55.86}{3.72} = 35 + j15 = 38.08\underline{/23.20^\circ}\ \text{A}$$

$$P_{\text{L}} = (38.12)^2(1.86) = 2700\,\text{W}$$

[b] $\mathbf{I}_1 = \dfrac{Z_o + j9}{j6}\mathbf{I}_2 = \dfrac{1.86 - j4.66 + j9}{j6}(35 + j15) = 30\underline{/0^\circ}\ \text{A(rms)}$

$$P_{\text{dev}} = (180)(30) = 5400\,\text{W}$$

P 10.55 **[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,

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

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

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

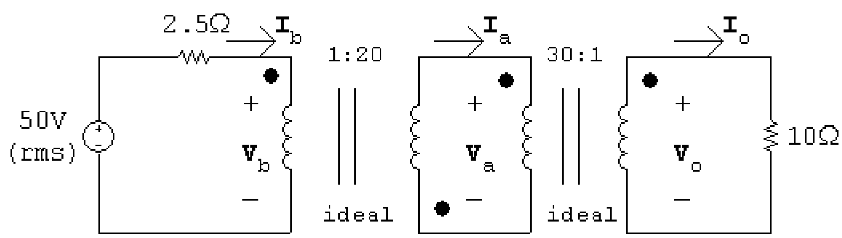
$$\therefore \quad P = -(285)(5) = -1425\,\text{W}$$

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 10.56



$$30\mathbf{V}_o = \mathbf{V}_a; \qquad \frac{\mathbf{I}_o}{30} = \mathbf{I}_a; \qquad \mathbf{V}_o = 10\mathbf{I}_o \qquad \text{therefore} \quad \frac{\mathbf{V}_a}{\mathbf{I}_a} = 9\,\text{k}\Omega$$

$$\frac{\mathbf{V}_b}{1} = \frac{-\mathbf{V}_a}{20}; \qquad \mathbf{I}_b = -20\mathbf{I}_a; \qquad \text{therefore} \quad \frac{\mathbf{V}_b}{\mathbf{I}_b} = \frac{9000}{400} = 22.5\,\Omega$$

Therefore $\mathbf{I}_b = [50/(2.5 + 22.5)] = 2$ A (rms); since the ideal transformers are lossless, $P_{10\Omega} = P_{22.5\Omega}$, and the power delivered to the $22.5\,\Omega$ resistor is $2^2(22.5)$ or 90 W.

P 10.57 **[a]** $\dfrac{\mathbf{V}_b}{\mathbf{I}_b} = \dfrac{a^2 10}{400} = 2.5\,\Omega; \qquad \text{therefore} \quad a^2 = 100, \qquad a = 10$

[b] $\mathbf{I}_b = \dfrac{50}{5} = 10\,\text{A}; \qquad P = (100)(2.5) = 250\,\text{W}$