Solution 11.46

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

$\mathbf{S} = [\underbrace{95.26}_{P} - j\underbrace{55}_{Q}]\,VA$

Apparent power = **110 VA** = $|\bar{S}|$

Real power = **95.26 W** = P

Reactive power = **55 VAR** = $-Q$

pf is **leading** because current leads voltage

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

$\mathbf{S} = [\underbrace{1497.2}_{=P} + j\underbrace{401.2}_{=Q}]\,VA$

Apparent power = **1550 VA** = $|\bar{S}|$

Real power = **1497.2 W** = P

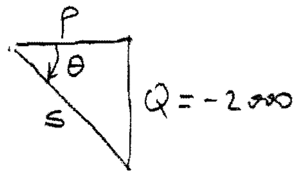
Reactive power = **401.2 VAR** = $+Q$

pf is **lagging** because current lags voltage

Solution 11.48

(a) $\mathbf{S} = P - jQ = \mathbf{[269 - \mathit{j}150]\ \mathit{VA}}$

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



$S \cdot \sin\theta = Q$
$S \cdot \cos\theta = P$

$$Q = S\sin\theta \longrightarrow S = \frac{Q}{\sin\theta} = \frac{2000}{\sin(25.84°)} = 4{,}588.31$$

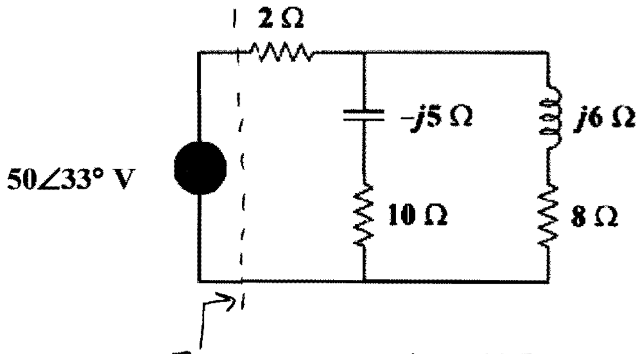
$$P = S\cos\theta = 4129.48$$

$\mathbf{S} = \mathbf{[4.129 - \mathit{j}2]\ \mathit{kVA}}$

Solution 11.51

For the entire circuit in Fig. 11.70, calculate:

(a) the power factor
(b) the average power delivered by the source
(c) the reactive power
(d) the apparent power
(e) the complex power



Z_T

Figure 11.70
For Prob. 11.51.

Solution

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

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

$\mathbf{Z}_T = 8.152 + j0.768 = 8.188\angle 5.382°$　　$pf = \theta_v - \theta_i = \angle Z_T$

pf = cos(5.382°) = **0.9956 (lagging)**

(b) $\mathbf{S} = \frac{1}{2}\mathbf{V}\mathbf{I}^* = \frac{|\mathbf{V}|^2}{2(\mathbf{Z}_T)^*} = \frac{(50)^2}{2(8.188\angle\textbf{-5.382°})}$　　$I^* = \frac{V^*}{Z_T^*}$

$\mathbf{S} = \cancel{305.325}\ 152.66\angle 5.382°$ VA $= \underbrace{151.99}_{P} + j14.32$ VA

$P = S\cos\theta = \cancel{\textbf{304}}\ 151.99\ \textbf{W}$

(c) $Q = S\sin\theta = \cancel{\textbf{28.64}}\ 14.32\ \textbf{VAR}$

(d) $S = |\mathbf{S}| = \cancel{\textbf{305.3}}\ 152.66\ \textbf{VA}$

(e) ~~S = 305.325∠5.382° = (304+j28.64) VA~~
See (b)

Solution 11.39

RMS

An ac motor with impedance $\mathbf{Z_L} = (2 + j1.2)\ \Omega$ is supplied by a 220-V, 60-Hz source. (a) Find pf, P, and Q. (b) Determine the capacitor required to be connected in parallel with the motor so that the power factor is corrected to unity.

Solution

(a) $\mathbf{Z_L} = 2 + j1.2 = 2.3324\angle 30.964°$

pf = cos(30.964) = **0.8575** $= \measuredangle Z_L$ (lagging)

$\mathbf{S} = V^2/(\mathbf{Z_L})^* = 48{,}400/(2.3324\angle{-30.964°}) = 20{,}751\angle 30.964°$ V in Rms.
$= \underbrace{17.794\text{ kW}}_{P} + j\,\underbrace{10.676\text{ kVAR}}_{Q}.$

P = **17.794 kW**

Q = **10.676 kVAR (lagging)**

reduce all reactive power

(b) $X_C = V^2/Q_C = 48{,}400/10{,}676 = 4.5335 = 1/(377C)$ or
$C =$ **585.1 μF.**

$$C = \frac{Q_c}{\omega V_{rms}^2} = \frac{Q}{2\pi f (220)^2}$$

{It is important to note that this capacitor will see a peak voltage of 220$\sqrt{2}$ = 311.08V, this means that the specifications on the capacitor must be at least this or greater!}

Solution 11.69

Refer to the circuit shown in Fig. 11.88.

(a) What is the power factor?
(b) What is the average power dissipated?
(c) What is the value of the capacitance that will give a unity power factor when connected to the load?

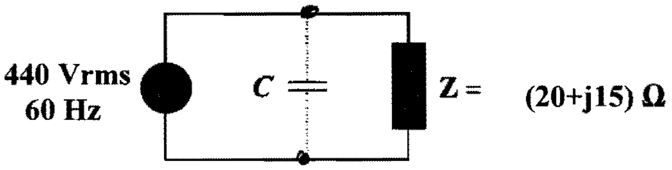


Figure 11.88
For Prob. 11.69.

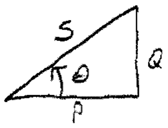
Solution

(a) Given that $\mathbf{Z} = 20 + j15$ $= 25\angle 36.87^\circ$ $\theta = \angle \mathbf{Z}$

$$\tan\theta = \frac{15}{20} \longrightarrow \theta = 36.87^\circ$$

$$\text{pf} = \cos\theta = \mathbf{0.8}$$

(b) $$\mathbf{S} = \frac{|\mathbf{V}_{rms}|^2}{\mathbf{Z}^*} = \frac{(440)^2}{25\angle -36.87^\circ} = \underbrace{6{,}195.2}_{P} + j\underbrace{4{,}646.4}_{Q} \text{ VA}$$



The average power absorbed $= \text{P} = \text{Re}(\mathbf{S}) = \mathbf{6.195\ kW}$

(c) For unity power factor, $\theta_1 = 0^\circ$, which implies that the reactive power due to the capacitor is $Q_C = 4.6464$ kVAR

reduce all reactive power

$$C = \frac{Q_C}{\omega V_{rms}^2} = \frac{Q}{2\pi f\,(440)^2}$$

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

$$C = \frac{Q_c}{\omega V^2} = \frac{(4{,}646.4)}{(2\pi)(60)(440)^2} = \mathbf{63.66\ \mu F}$$

Solution 11.73

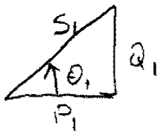
(a) $\mathbf{S} = 10 - j15 + j22 = 10 + j7$ kVA

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

(b) $\mathbf{S} = \mathbf{V}\mathbf{I}^* \longrightarrow \mathbf{I}^* = \dfrac{\mathbf{S}}{\mathbf{V}} = \dfrac{10{,}000 + j7{,}000}{240} = 41.667 + j\,29.167$ Arms

$\mathbf{I} = 41.667 - j29.167 = \mathbf{50.86\angle{-35^\circ}}$ **Arms**

(c) $\theta_1 = \tan^{-1}\left(\dfrac{7}{10}\right) = 35^\circ$, $\quad \theta_2 = \underbrace{\cos^{-1}(0.96)}_{\text{requested}} = 16.26^\circ$

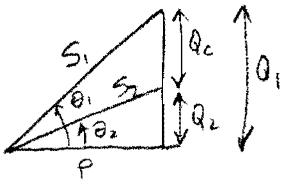


$Q_c = P_1[\tan\theta_1 - \tan\theta_2] = 10[\tan(35^\circ) - \tan(16.26^\circ)]$

$Q_c = \mathbf{4.083\ kVAR}$

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

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



$Q_2 = Q_1 - Q_c = 7 - 4.083 = 2.917$ kVAR

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

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

$$\mathbf{I}_2^* = \frac{\mathbf{S}_2}{\mathbf{V}} = \frac{10{,}000 + j2917}{240} = 41.667 + j12.154 \text{ Arms}$$

$\mathbf{I}_2 = 41.667 - j12.154 = \mathbf{43.4\angle{-16.26^\circ}}$ **Arms**

Note $|I_2| < |I_1|$ $= 50.87$ Arms, which is an important aspect of power factor correction

Solution 11.91

The nameplate of an electric motor has the following information:

Line voltage: 220 V rms
Line current: 15 A rms
Line frequency: 60 Hz
Power: 2700 W

Determine the power factor (lagging) of the motor. Find the value of the capacitance *C* that must be connected across the motor to raise the pf to unity.

Solution

I = V/Z which leads to Z = [220/15]∠θ = 14.6667∠θ, S = (220)(15)∠θ = 3.3∠θ kVA, where $\cos^{-1}(2700/3300) = \cos^{-1}(0.818182) = 35.097°$, and ~~$X_L$ = 3300sin(35.097°) = 1897.38 = X_C. This leads to C = 1/[377(1897.38)] = 1.398 µF~~.

pf = **0.8182** (lagging)

~~**C = 1.398 µF**~~

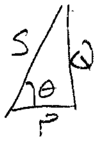
0.8182 (lagging), ~~**1.398 µF**~~

$$|Z| = \frac{|V|}{|I|} = \frac{220 V_{rms}}{15 A_{rms}} = 14.667\,\Omega$$

$$\measuredangle Z = \theta_v - \theta_i = \cos^{-1}(pf)$$

$$S = V_{rms} \cdot I_{rms} = 220 \cdot 15 = 3300 \text{ VA}$$

$$\& \; P = 2700 \text{ W} \quad \text{(given).}$$



$$\therefore \; P = S\cos\theta \Rightarrow \cos\theta = \frac{P}{S} = \frac{2700}{3300}$$

$$\therefore \; \underline{\underline{pf = \cos\theta = 0.8182}} \; ; \; \theta = 35.10°$$

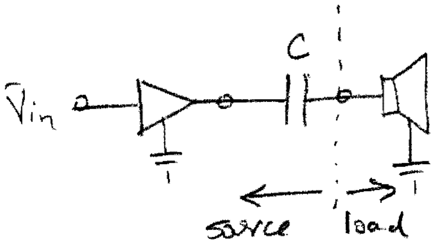
(lagging)

$$C = \frac{Q_c}{\omega V_{rms}^2} = \frac{Q}{\omega V_{rms}^2} \leftarrow \text{reduce all reactive power}$$

$$Q = S\sin\theta = 3300 \cdot \sin(\theta)$$
$$= 1{,}897.52 \text{ VAR}$$

$$\therefore \; \underline{\underline{C}} = \frac{1897.52}{2\pi \cdot 60 \cdot (220)^2} = \underline{\underline{103.99\,\mu F}}$$

Solution 11.95



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

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

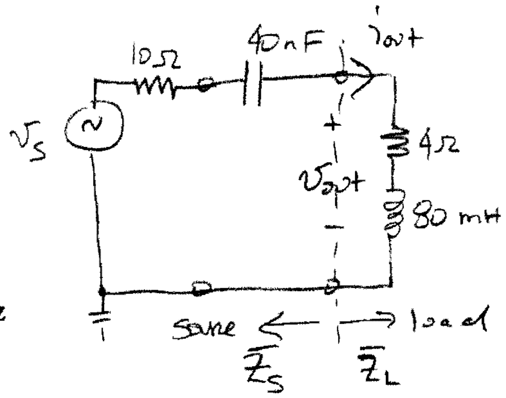
For maximum ~~load~~ power transfer to the load.

$\mathbf{Z}_L = \mathbf{Z}_s^* \longrightarrow R_s = R_L, \quad X_c = X_L$ Can't happen!

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

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

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



(b) $P = \left(\frac{V_s}{(10+4)}\right)^2 4 = \left(\frac{4.6}{14}\right)^2 4 = \mathbf{431.8\ mW}$ (since V_s is in rms)

$$I_{out} = \frac{V_s}{Z_L + Z_s} = \frac{4.6V\cdot\sqrt{2}}{R_L + jX_L + R_s + jX_s} \underset{X_L = X_C}{\overset{\uparrow}{=}} \frac{4.6\cdot\sqrt{2}}{R_L + R_S}$$

$$= \frac{4.6\sqrt{2}}{4+10} = 0.4647\,A \angle 0^\circ \text{ at } f = 2.814\text{ kHz}.$$

$$\therefore\ \underline{\underline{P}} = \frac{1}{2}|I_{out}|^2 \cdot R_L = \frac{1}{2}(0.4647)^2\, 4 = \underline{\underline{431.8\,mW}}$$

Solution 12.1

For the abc sequence,

$\bar{V}_{ab} = \sqrt{3}\, V_p \angle 30^\circ$ & $V_{an} = V_p \angle 0^\circ$

$\therefore \bar{V}_{an} = \frac{V_{ab}}{\sqrt{3}} \angle -30^\circ = \frac{400}{\sqrt{3}} \angle -30^\circ$

(a) If $\mathbf{V}_{ab} = 400$, then

$$\mathbf{V}_{an} = \frac{400}{\sqrt{3}} \angle -30^\circ = \mathbf{231\angle -30^\circ\ V}$$

$$\mathbf{V}_{bn} = \mathbf{231\angle -150^\circ\ V}$$

$$\mathbf{V}_{cn} = \mathbf{231\angle -270^\circ\ V}$$

-120°

-120°

(b) For the acb sequence,

$$\mathbf{V}_{ab} = \mathbf{V}_{an} - \mathbf{V}_{bn} = V_p\angle 0^\circ - V_p\angle 120^\circ$$

$$\mathbf{V}_{ab} = V_p\left(1 + \frac{1}{2} - j\frac{\sqrt{3}}{2}\right) = V_p\sqrt{3}\angle -30^\circ$$

i.e. in the acb sequence, $\mathbf{V}_{ab}$ lags $\mathbf{V}_{an}$ by 30°.

Hence, if $\mathbf{V}_{ab} = 400$, then

$$\mathbf{V}_{an} = \frac{400}{\sqrt{3}} \angle 30^\circ = \mathbf{231\angle 30^\circ\ V}$$

$$\mathbf{V}_{bn} = \mathbf{231\angle 150^\circ\ V}$$

$$\mathbf{V}_{cn} = \mathbf{231\angle -90^\circ\ V}$$

Solution 12.3

Given a balanced Y-connected three-phase generator with a line-to-line voltage of $\mathbf{V}_{ab} = 100\angle 45°$ V and $\mathbf{V}_{bc} = 100\angle 165°$ V, determine the phase sequence and the value of $\mathbf{V}_{ca}$.

Solution

Since $\mathbf{V}_{bc}$ leads $\mathbf{V}_{ab}$ by 120° we have a **acb** sequence and $\mathbf{V}_{ca} = \mathbf{100\angle{-75°}}$ **V**.