Review Last Class

For Parallel [*RL* parallel, *RC* parallel, *RLC* parallel] Circuit

Admittance calculation, Admittance Diagram, Impedance calculation,

Supply voltage or current Calculation

Current passing through the Different elements Calculation

Instantaneous equation of voltage and different branches current

Phasor or Vector Diagram

Power Factor, Reactive Factor,

Power or Active Power, Reactive Power, Apparent Power

Instantaneous Power equation

Power Triangle

Current Divider Rule (CDR)

Kirchhoff's Current Law (KCL)

Chapter 16

Series-Parallel Circuits

*10. For the network in Fig. 16.48:

a. Find the total impedance $\mathbf{Z}_T$ and the admittance $\mathbf{Y}_T$.
b. Find the source current $\mathbf{I}_s$ in phasor form.
c. Find the currents $\mathbf{I}_1$ and $\mathbf{I}_2$ in phasor form.
d. Find the voltages $\mathbf{V}_1$ and $\mathbf{V}_{ab}$ in phasor form.
e. Find the average power delivered to the network.
f. Find the power factor of the network, and indicate whether it is leading or lagging.

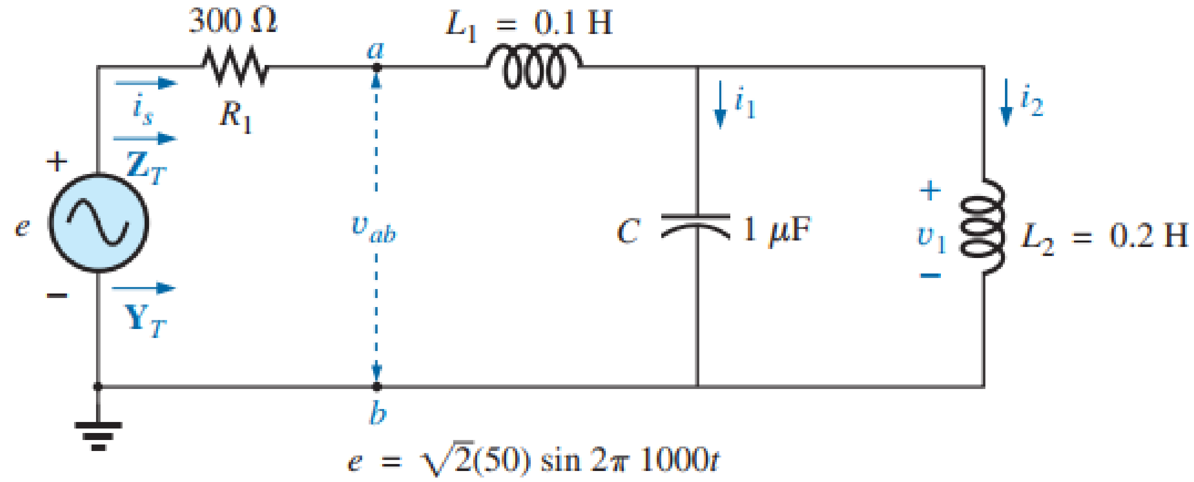


FIG. 16.48 *Problem 10.*

Solution: Here, $E = 50$ V, $f = 1000$ Hz and $\omega = 2\pi \times 1000 = 6280$ rad/s $\quad \boldsymbol{E} = 50\text{V}\angle 0°$

$$X_{L1} = \omega L_1 = (6280 \text{ rad/s})(0.1 \text{ H}) = 628\ \Omega$$

$$X_C = \frac{1}{\omega C} = \frac{1}{(6280 \text{ rad/s})(1 \times 10^{-6} \text{ F})} = 159.24\ \Omega$$

$$X_{L2} = \omega L_2 = (6280 \text{ rad/s})(0.2 \text{ H}) = 1256\ \Omega$$

Let, $\boldsymbol{Z}_1 = 300\ \Omega = 300\Omega\angle 0°$

$$\boldsymbol{Z}_2 = j628\ \Omega = 628\Omega\angle 90°$$

$$\boldsymbol{Z}_3 = -j159.24\ \Omega = 159.24\Omega\angle -90°$$

$$\boldsymbol{Z}_4 = j1256\ \Omega = 1256\Omega\angle 90°$$

Fig. 16.48(a) shows the redrawing circuit of Fig. 16.48.

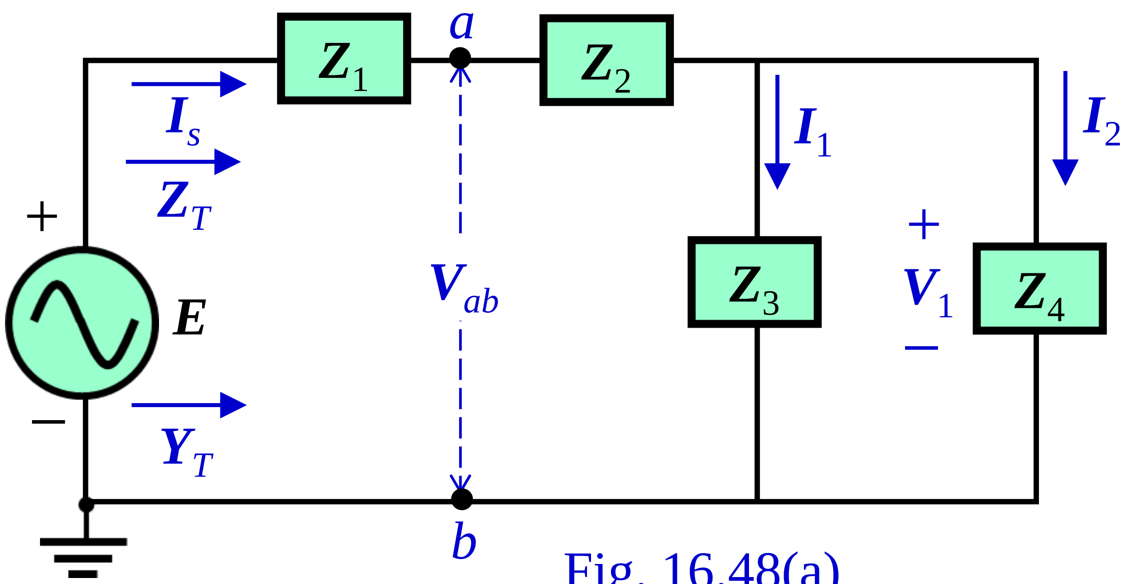


Fig. 16.48(a)

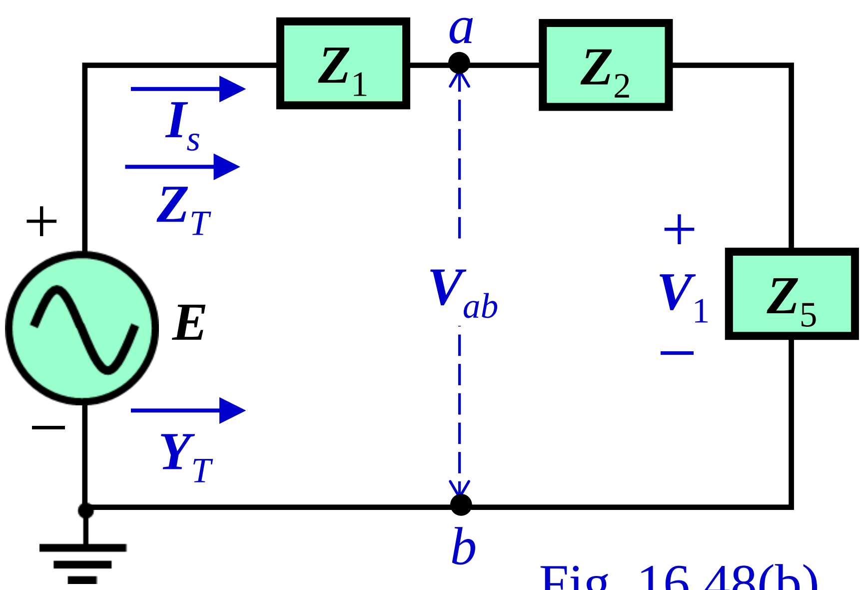


Fig. 16.48(b)

$$Z_5 = \frac{Z_3 Z_4}{Z_3 + Z_4} = \frac{(-j159.24\ \Omega)(j1256\ \Omega)}{(-j159.24\ \Omega) + (j1256\ \Omega)}$$

$$= -j182.36\ \Omega = 182.36\Omega\angle -90°$$

Fig. 16.48(b) shows the redrawing circuit of Fig. 16.48(a).

$$Z_6 = Z_2 + Z_5 = j445.64\ \Omega = 445.64\Omega\angle 90°$$

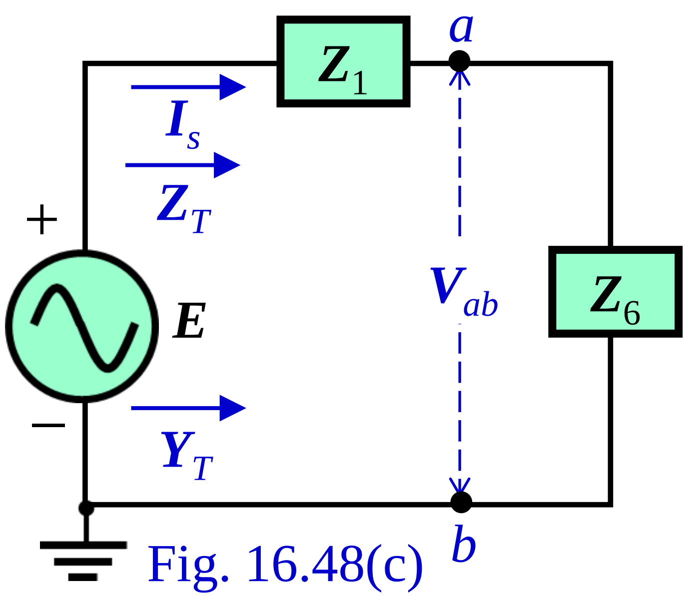


Fig. 16.48(c)

Fig. 16.48(c) shows the redrawing circuit of Fig. 16.48(b).

$$Z_T = Z_1 + Z_6 = 300 + j445.64\ \Omega = 537.21\Omega\angle 56.05°$$

Fig. 16.48(d) shows the redrawing circuit of Fig. 16.48(c).

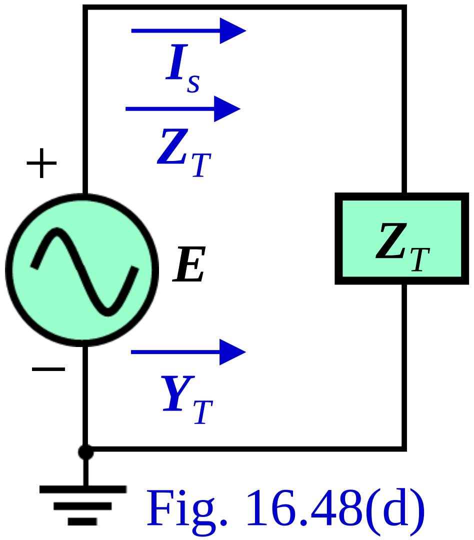


Fig. 16.48(d)

$$Y_T = \frac{1}{Z_T} = \frac{1}{537.21\Omega\angle 56.0°}$$
$$= \mathbf{1.861mS\angle -56.05°}$$

(***b***) $I_s = \frac{E}{Z_T} = \frac{50\text{V}\angle 0°}{537.21\Omega\angle 56.05°} = \mathbf{93.07mA\angle -56.05°}$

(***c***) Referring to Fig. 16.48(a) and Fig. 16.48(b), we have:

$$I_1 = \frac{Z_5}{Z_3} I_s = \mathbf{106.58mA\angle -56.05°}$$

$$I_2 = \frac{Z_5}{Z_4} I_s = \mathbf{13.52mA\angle 123.96°}$$

(***d***) Referring to Fig. 16.48(b) and Fig. 16.48(c), we have:

$$V_{ab} = Z_6 I_s = \mathbf{41.48V\angle 33.95°}$$

$$V_1 = Z_5 I_s = \mathbf{16.98V\angle 213.95°}$$

(***e***) Average power:

$$P = EI_s \cos\theta_T$$
$$= 50 \times (93.07\text{mA})\cos(56.05°) = \mathbf{2.6\ W}$$

(***f***) Power Factor:

$$F_p = \cos\theta_T = \mathbf{0.558\ Lagging}$$

Practice Book Remaining Examples

And

All Problems of Chapter 16

EXAMPLE 16.7 For the network in Fig. 16.14:

a. Compute $\mathbf{I}$.
b. Find $\mathbf{I}_1$, $\mathbf{I}_2$, and $\mathbf{I}_3$.
c. Verify Kirchhoff's current law by showing that

$$\mathbf{I} = \mathbf{I}_1 + \mathbf{I}_2 + \mathbf{I}_3$$

d. Find the total impedance of the circuit.

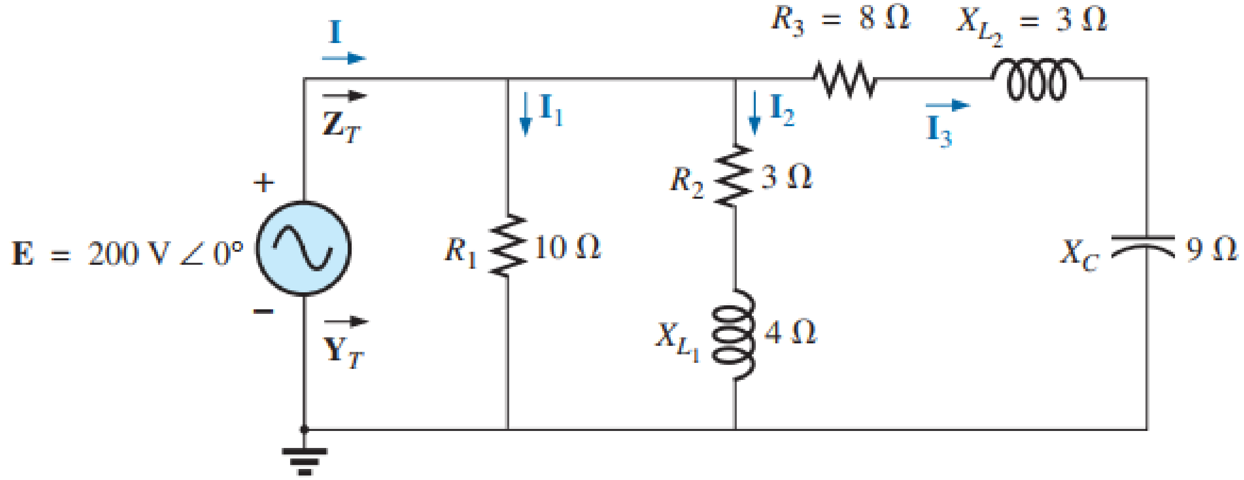


FIG. 16.14
Example 16.7.

Solutions:

a. $\mathbf{Z}_1 = R_1 = 10\ \Omega\angle 0°$

$\mathbf{Z}_2 = R_2 + j\,X_{L_1} = 3\ \Omega + j\,4\ \Omega$

$\mathbf{Z}_3 = R_3 + j\,X_{L_2} - j\,X_C = 8\ \Omega + j\,3\ \Omega - j\,9\ \Omega = 8\ \Omega - j\,6\ \Omega$

Redrawing the circuit as in Fig. 16.15 reveals a strictly parallel network where

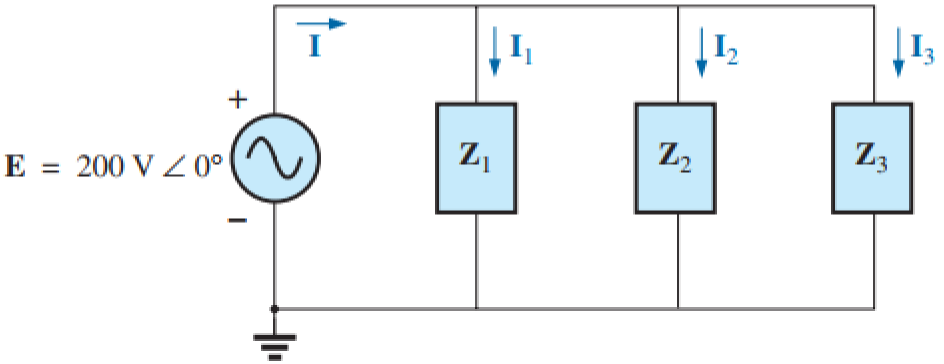


FIG. 16.15 *Network in Fig. 16.14 following the assignment of the subscripted impedances.*

The total admittance is

$$\mathbf{Y}_T = \mathbf{Y}_1 + \mathbf{Y}_2 + \mathbf{Y}_3$$
$$= \frac{1}{\mathbf{Z}_1} + \frac{1}{\mathbf{Z}_2} + \frac{1}{\mathbf{Z}_3} = \frac{1}{10\ \Omega} + \frac{1}{3\ \Omega + j\,4\ \Omega} + \frac{1}{8\ \Omega - j\,6\ \Omega}$$
$$= 0.1\text{ S} + \frac{1}{5\ \Omega\angle 53.13°} + \frac{1}{10\ \Omega\angle -36.87°}$$
$$= 0.3\text{ S} - j\,0.1\text{ S} = 0.316\text{ S}\angle -18.435°$$

The current **I**:

$$\mathbf{I} = \mathbf{E}\mathbf{Y}_T = (200\text{ V}\angle 0^\circ)(0.326\text{ S}\angle -18.435^\circ)$$
$$= \mathbf{63.2\text{ A}\angle -18.44^\circ}$$

(*b*) Find the currents I_1, I_2 and I_3.

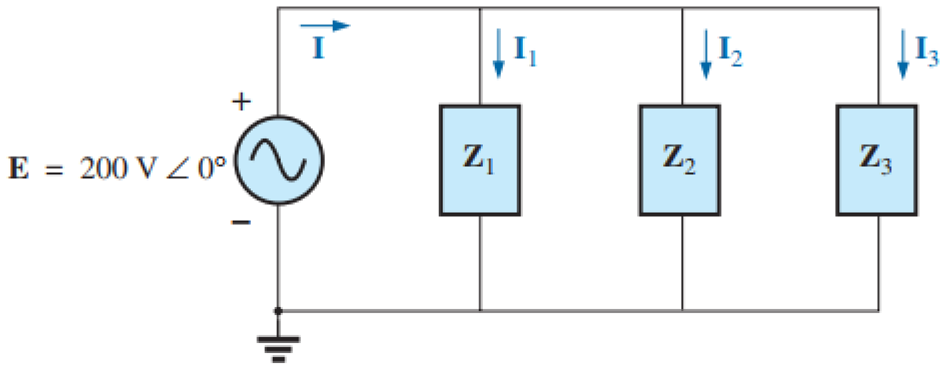


FIG. 16.15 *Network in Fig. 16.14 following the assignment of the subscripted impedances.*

b. Since the voltage is the same across parallel branches,

$$\mathbf{I}_1 = \frac{\mathbf{E}}{\mathbf{Z}_1} = \frac{200\text{ V}\angle 0^\circ}{10\ \Omega\angle 0^\circ} = \mathbf{20\text{ A}\angle 0^\circ}$$

$$\mathbf{I}_2 = \frac{\mathbf{E}}{\mathbf{Z}_2} = \frac{200\text{ V}\angle 0^\circ}{5\ \Omega\angle 53.13^\circ} = \mathbf{40\text{ A}\angle -53.13^\circ}$$

$$\mathbf{I}_3 = \frac{\mathbf{E}}{\mathbf{Z}_3} = \frac{200\text{ V}\angle 0^\circ}{10\ \Omega\angle -36.87^\circ} = \mathbf{20\text{ A}\angle +36.87^\circ}$$

(*c*) Verify KCL:

c. $$\mathbf{I} = \mathbf{I}_1 + \mathbf{I}_2 + \mathbf{I}_3$$
$$60 - j\,20 = 20\angle 0^\circ + 40\angle -53.13^\circ + 20\angle +36.87^\circ$$
$$= (20 + j\,0) + (24 - j\,32) + (16 + j\,12)$$
$$60 - j\,20 = 60 - j\,20 \qquad \text{(checks)}$$

(*d*) Find the total impedance of the circuit.

d. $$\mathbf{Z}_T = \frac{1}{\mathbf{Y}_T} = \frac{1}{0.316\text{ S}\angle -18.435^\circ}$$
$$= \mathbf{3.17\ \Omega\angle 18.44^\circ}$$

EXAMPLE 16.8 For the network in Fig. 16.18:

a. Calculate the total impedance $\mathbf{Z}_T$.
b. Compute $\mathbf{I}$.
c. Find the total power factor.
d. Calculate $\mathbf{I}_1$ and $\mathbf{I}_2$.
e. Find the average power delivered to the circuit.

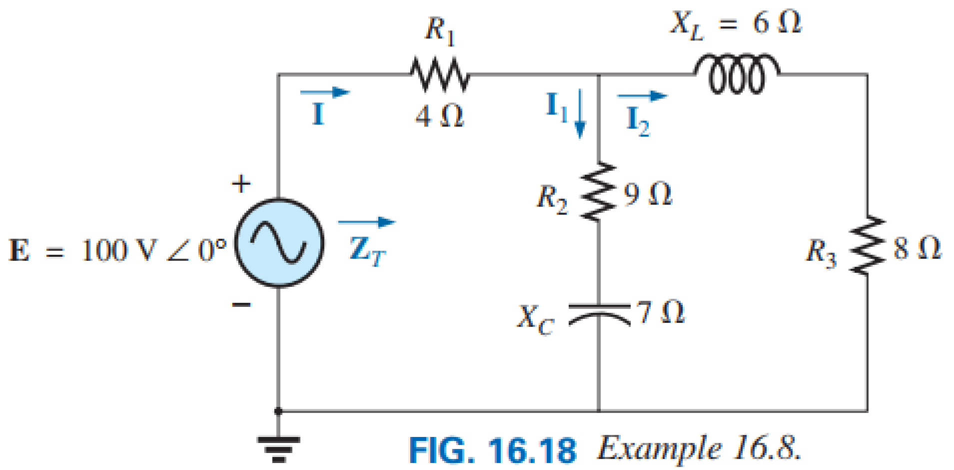


FIG. 16.18 *Example 16.8.*

Solutions:

a. $\mathbf{Z}_1 = R_1 = 4\ \Omega \angle 0°$

$\mathbf{Z}_2 = R_2 - j X_C = 9\ \Omega - j\,7\ \Omega = 11.40\ \Omega \angle -37.87°$

$\mathbf{Z}_3 = R_3 + j X_L = 8\ \Omega + j\,6\ \Omega = 10\ \Omega \angle +36.87°$

Redrawing the circuit as in Fig. 16.19, we have

$$\mathbf{Z}_T = \mathbf{Z}_1 + \mathbf{Z}_{T_1} = \mathbf{Z}_1 + \frac{\mathbf{Z}_2\mathbf{Z}_3}{\mathbf{Z}_2 + \mathbf{Z}_3}$$

$$= 4\ \Omega + \frac{(11.4\ \Omega \angle -37.87°)(10\ \Omega \angle 36.87°)}{(9\ \Omega - j\,7\ \Omega) + (8\ \Omega + j\,6\ \Omega)}$$

$$= 4\ \Omega + 6.68\ \Omega + j\,0.28\ \Omega = 10.68\ \Omega + j\,0.28\ \Omega$$

$$\mathbf{Z}_T = \mathbf{10.68\ \Omega \angle 1.5°}$$

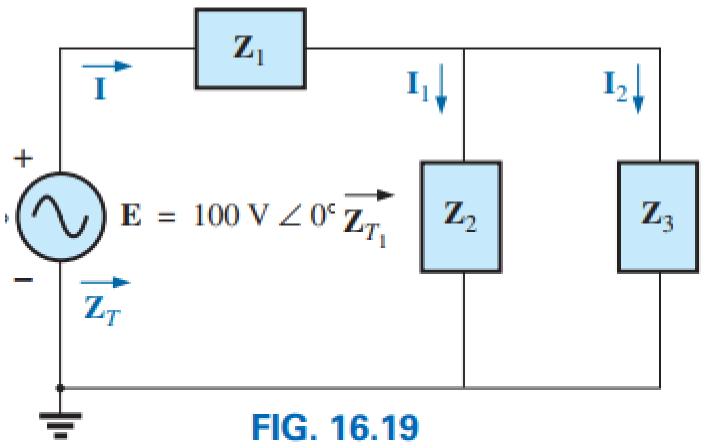


FIG. 16.19

b. $\mathbf{I} = \dfrac{\mathbf{E}}{\mathbf{Z}_T} = \dfrac{100\text{ V }\angle 0°}{10.684\ \Omega\ \angle 1.5°} = \mathbf{9.36\ A\ \angle -1.5°}$

c. $F_p = \cos\theta_T = \dfrac{R}{Z_T} = \dfrac{10.68\ \Omega}{10.684\ \Omega} \cong \mathbf{1}$

d. Current divider rule:

$$\mathbf{I}_2 = \frac{\mathbf{Z}_2\mathbf{I}}{\mathbf{Z}_2 + \mathbf{Z}_3} = \frac{(11.40\ \Omega\ \angle -37.87°)(9.36\text{ A }\angle -1.5°)}{(9\ \Omega - j\,7\ \Omega) + (8\ \Omega + j\,6\ \Omega)}$$

$$= \frac{106.7\text{ A }\angle -39.37°}{17 - j\,1} = \frac{106.7\text{ A }\angle -39.37°}{17.03\ \angle -3.37°}$$

$$\mathbf{I}_2 = \mathbf{6.27\ A\ \angle -36°}$$

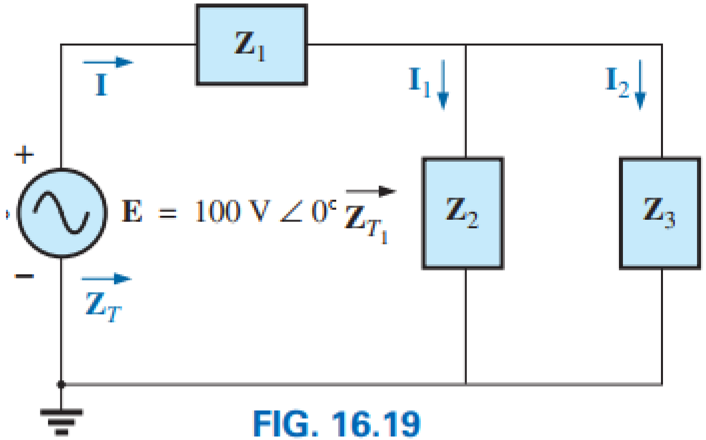


FIG. 16.19

Applying Kirchhoff's current law (rather than another application of the current divider rule) yields

$$\mathbf{I}_1 = \mathbf{I} - \mathbf{I}_2$$

or

$$\mathbf{I} = \mathbf{I}_1 - \mathbf{I}_2$$
$$= (9.36\text{ A }\angle -1.5°) - (6.27\text{ A }\angle -36°)$$
$$= (9.36\text{ A} - j\,0.25\text{ A}) - (5.07\text{ A} - j\,3.69\text{ A})$$
$$\mathbf{I}_1 = 4.29\text{ A} + j\,3.44\text{ A} = \mathbf{5.5\ A\ \angle 38.72°}$$

e. $P_T = EI\cos\theta_T$

$$= (100\text{ V})(9.36\text{ A})\cos 1.5°$$
$$= (936)(0.99966)$$
$$P_T = \mathbf{935.68\ W}$$

Power Factor Correction (PFC)

Or

Power Factor Improvement

We know that, $S = \sqrt{P^2 + Q^2} = EI$ $\qquad pf = \frac{P}{S} = \frac{P}{\sqrt{P^2 + Q^2}}$

It is observed from above equations that, low power factor of load means high apparent power. High apparent power means high current flows through the transmission line since the supply voltage E is constant. The effects of high current flow through the transmission line are as follows:

(**1**) Increased power losses (by a squared factor since $P_{xline}=I^2R_{xline}$) in the transmission lines due to the resistance of the lines

(**2**) Required larger conductors, increasing the amount of copper needed for the system

(**3**) Voltage drop in Transmission line is increased as well as load terminal voltage is decreased

(**4**) Increased power bill

The required reactive power of load can be supplied by connecting capacitors (reactive elements) at the terminal of load. As a results high reactive power supplied by the source is not required as well as supply apparent power and current will be reduced.

The process of introducing reactive elements (capacitors) to bring the power factor closer to unity is called **power-factor correction.**

Example 19.7 A 5 hp motor with a 0.6 lagging power factor and an efficiency of 92% is connected to a 208 V, 60 Hz supply.

a. Establish the power triangle for the load.

b. Determine the power-factor capacitor that must be placed in parallel with the load to raise the power factor to unity.

c. Determine the change in supply current from the uncompensated to the compensated system.

Solutions:

a. Since 1 hp = 746 W,

$$P_o = 5 \text{ hp} = 5(746 \text{ W}) = 3730 \text{ W}$$

and $$P_i \text{ (drawn from the line)} = \frac{P_o}{\eta} = \frac{3730 \text{ W}}{0.92} = 4054.35 \text{ W}$$

Also, $$F_p = \cos\theta = 0.6$$

and $$\theta = \cos^{-1} 0.6 = 53.13°$$

Applying $$\tan\theta = \frac{Q_L}{P_i}$$

we obtain $$Q_L = P_i \tan\theta = (4054.35 \text{ W}) \tan 53.13° = 5405.8 \text{ VAR } (L)$$

and

$$S = \sqrt{P_i^2 + Q_L^2} = \sqrt{(4054.35 \text{ W})^2 + (5405.8 \text{ VAR})^2} = 6757.25 \text{ VA}$$

The power triangle appears in Fig. 19.30.

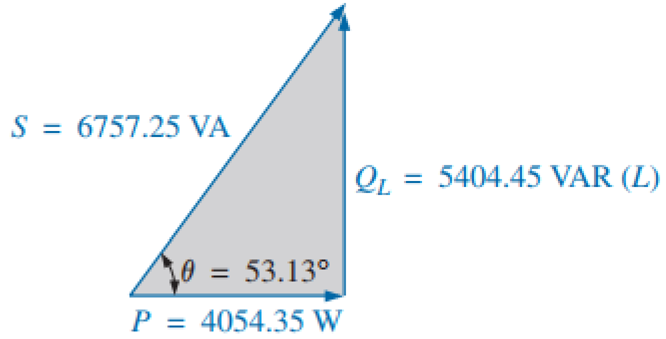


FIG. 19.30
Initial power triangle for the load in Example 19.7.

b. A net unity power-factor level is established by introducing a capacitive reactive power level of 5405.8 VAR to balance Q_L. Since

$$Q_C = \frac{V^2}{X_C}$$

then $$X_C = \frac{V^2}{Q_C} = \frac{(208\text{ V})^2}{5405.8\text{ VAR }(C)} = 8\ \Omega$$

and $$C = \frac{1}{2\pi f X_C} = \frac{1}{(2\pi)(60\text{ Hz})(8\ \Omega)} = \mathbf{331.6\ \mu F}$$

Practice Book Problems
[Ch. 15] 16, 17 and 18

c. **At 0.6F_p,**

$$S = VI = 6757.25\text{ VA}$$

and $$I = \frac{S}{V} = \frac{6757.25\text{ VA}}{208\text{ V}} = \mathbf{32.49\ A}$$

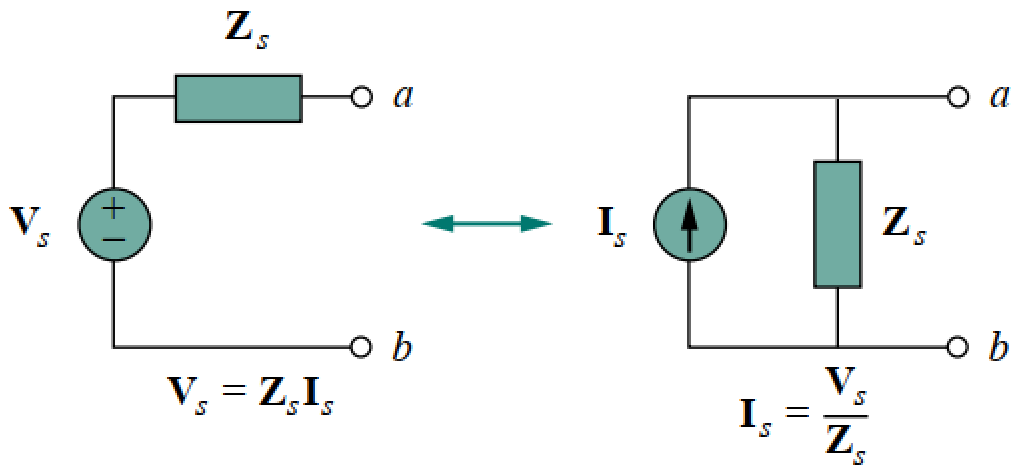
At unity F_p,

$$S = VI = 4054.35\text{ VA}$$

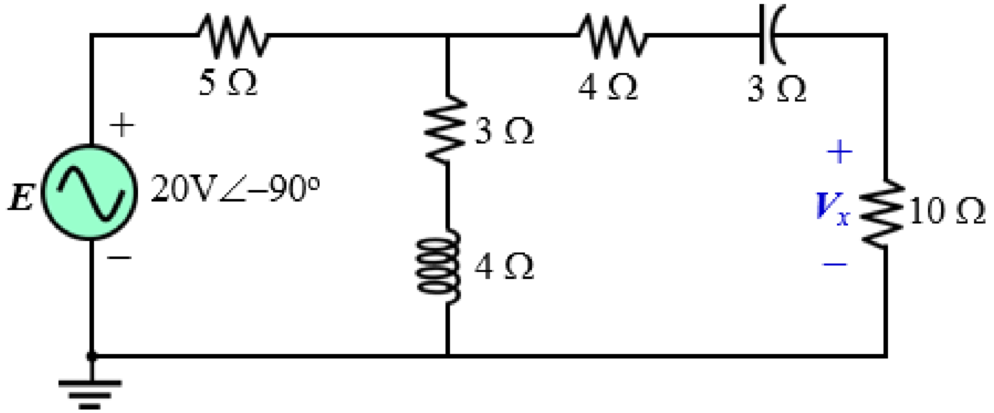
and $$I = \frac{S}{V} = \frac{4054.35\text{ VA}}{208\text{ V}} = \mathbf{19.49\ A}$$

producing a 40% reduction in supply current.

Source Transformation



EXAMPLE 16.3: Calculate V_x in the circuit of following figure using the method of source transformation.

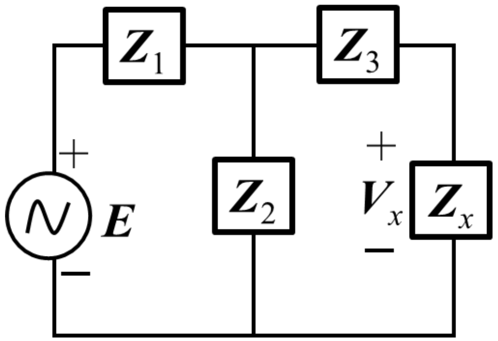


Solution: Let,

$$\boldsymbol{E} = 20\text{V}\angle 0^\circ \qquad \boldsymbol{Z}_1 = 5\ \Omega \qquad \boldsymbol{Z}_2 = 3 + j4\ \Omega$$

$$\boldsymbol{Z}_3 = 4 - j3\Omega \qquad \boldsymbol{Z}_x = 10\ \Omega$$

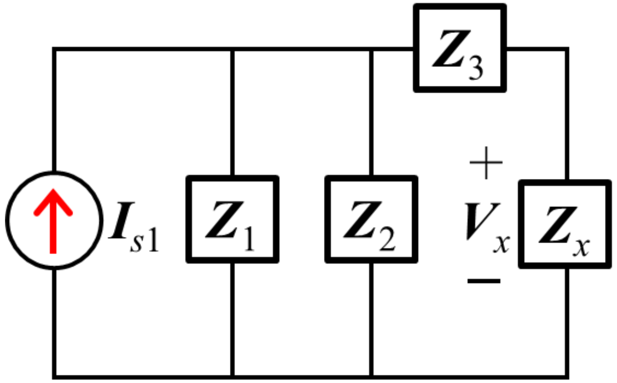
Redrawing circuit is shown in **Fig. (a)**. Now, the series combination of voltage source and $\boldsymbol{Z}_1$ resistance convert to parallel circuit as follows:



(*a*)

$$\boldsymbol{I}_{s1} = \frac{\boldsymbol{E}}{\boldsymbol{Z}_1} = -j4\ \text{A}$$

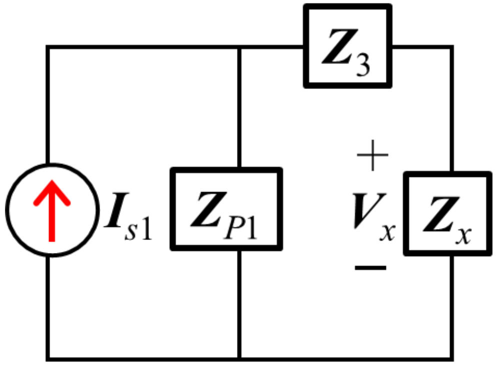
Redrawing circuit is shown in **Fig. (b)**.



(*b*)

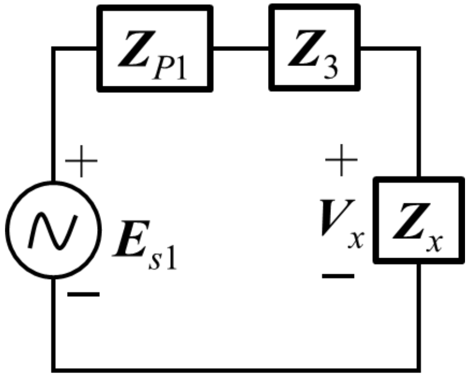
$$Z_{P1} = \frac{Z_1 Z_2}{Z_1 + Z_2} = 2.5 + j1.25\ \Omega$$

Redrawing circuit is shown in **Fig. (c)**.



(*c*)

Converting the current source to a voltage source yields the circuit in **Fig. (*d*)**, where,



(*d*)

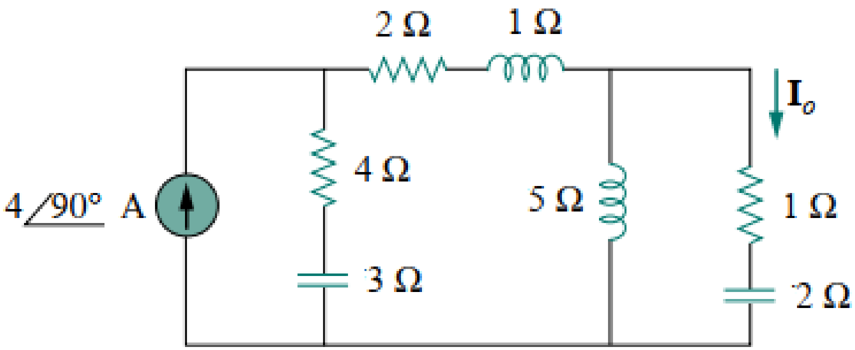
$$E_{s1} = I_{s1} Z_{P1} = 5 - j10\ \text{V}$$

Now, by using VDR, we have:

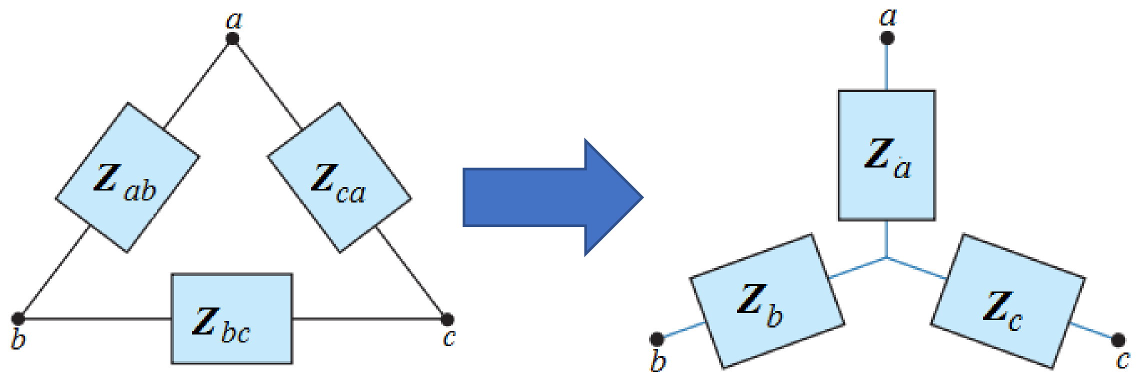
$$V_x = \frac{Z_x}{Z_{P1} + Z_3 + Z_x} E_{s1} = 5.519\angle -28°\ \text{V}$$

Practice Problem

Calculate I_o in the circuit of following figure using the method of source transformation.



Δ (Π) to Y (T) Conversion

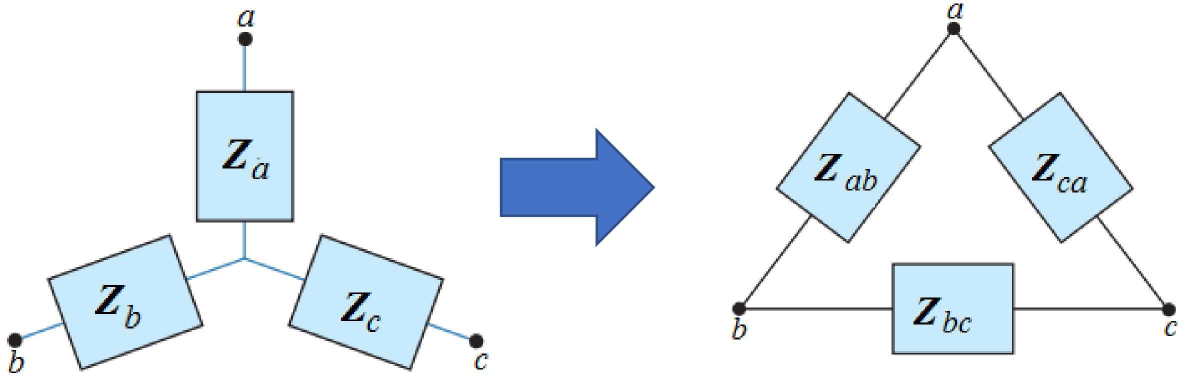


Z_{ab}, Z_{bc} and Z_{ca} are know.

Let, $Z_{abc} = Z_{ab} + Z_{bc} + Z_{ca}$

$$Z_a = \frac{Z_{ab}Z_{ca}}{Z_d} \qquad Z_b = \frac{Z_{bc}Z_{ab}}{Z_d} \qquad Z_c = \frac{Z_{ca}Z_{bc}}{Z_d}$$

Y (T) to Δ (Π) Conversion



Z_a, Z_b and Z_c are know.

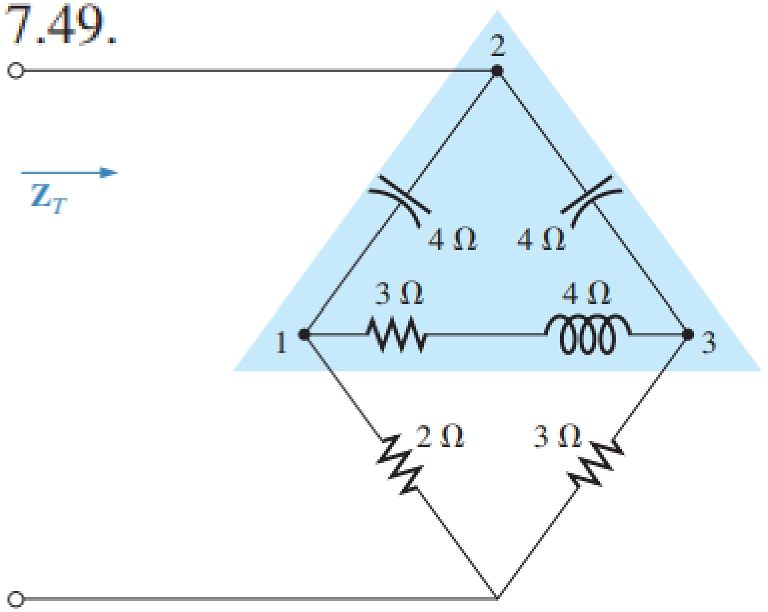
Let, $Z_{abc} = Z_a Z_b + Z_b Z_c + Z_c Z_a$

$$Z_{ab} = \frac{Z_{abc}}{Z_c} \qquad Z_{bc} = \frac{Z_{abc}}{Z_a} \qquad Z_{ca} = \frac{Z_{abc}}{Z_b}$$

If $Z_{ab} = Z_{bc} = Z_{ca} = Z_\Delta$ then $Z_a = Z_b = Z_c = Z_Y$

$Z_\Delta = 3Z_Y$ and $Z_Y = \dfrac{Z_\Delta}{3}$

EXAMPLE 17.20 Find the total impedance $\mathbf{Z}_T$ of the network in Fig.17.49.



Solution: $\mathbf{Z}_{12} = -j4\ \Omega;\quad \mathbf{Z}_{23} = -j4\ \Omega;\quad \mathbf{Z}_{31} = 3 + j4\ \Omega$

$\mathbf{Z}_4 = 2\ \Omega;\quad \mathbf{Z}_5 = 2\ \Omega$

$$\mathbf{Z}_d = \mathbf{Z}_{12} + \mathbf{Z}_{23} + \mathbf{Z}_{31} = 3 - j4\ \Omega = 5\Omega\angle -53.13°$$

$$\mathbf{Z}_1 = \frac{\mathbf{Z}_{12}\mathbf{Z}_{31}}{\mathbf{Z}_d} = \frac{(-j4)(3+j4)}{3-j4} = 3.84 + j1.11\,\Omega$$

$$\mathbf{Z}_2 = \frac{\mathbf{Z}_{23}\mathbf{Z}_{12}}{\mathbf{Z}_d} = \frac{(-j4)(-j4)}{3-j4} = -1.2 - j2.56\,\Omega$$

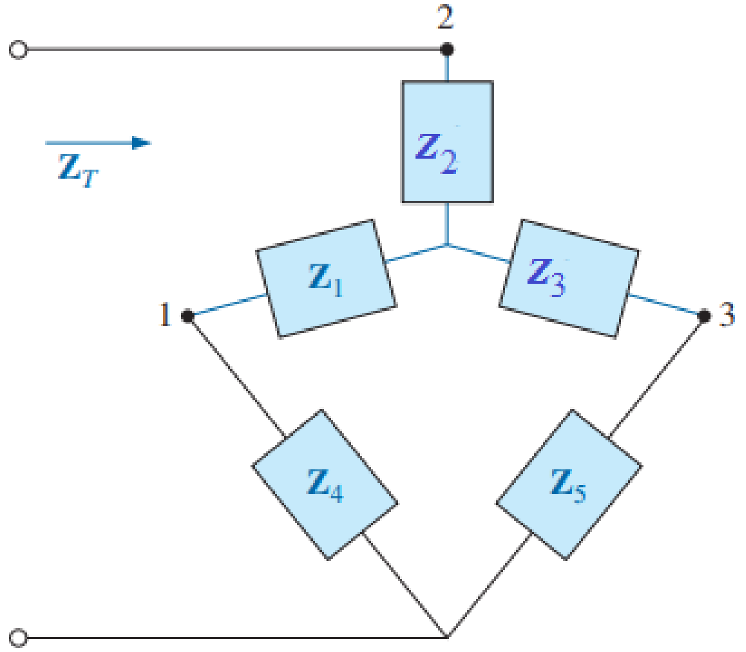
$$\mathbf{Z}_3 = \frac{\mathbf{Z}_{31}\mathbf{Z}_{23}}{\mathbf{Z}_d} = \frac{(3+j4)(-j4)}{3-j4} = 3.84 + j1.11\,\Omega$$

$$\mathbf{Z}_{s1} = \mathbf{Z}_1 + \mathbf{Z}_4 = 5.84 + j1.11\,\Omega$$

$$\mathbf{Z}_{s2} = \mathbf{Z}_3 + \mathbf{Z}_5 = 6.84 + j1.11\,\Omega$$

$$\mathbf{Z}_p = \frac{\mathbf{Z}_{s1}\mathbf{Z}_{s2}}{\mathbf{Z}_{s1} + \mathbf{Z}_{s2}} = 3.15 + j0.56\ \Omega$$

$$\mathbf{Z}_T = \mathbf{Z}_2 + \mathbf{Z}_p$$
$$= 1.23 - j2.0\ \Omega$$
$$= 2.35\Omega\angle -58.41°$$



EXAMPLE 17.21 Using both the Δ-Y and Y-Δ transformations, find the total impedance $\mathbf{Z}_T$ for the network in Fig. 17.51.

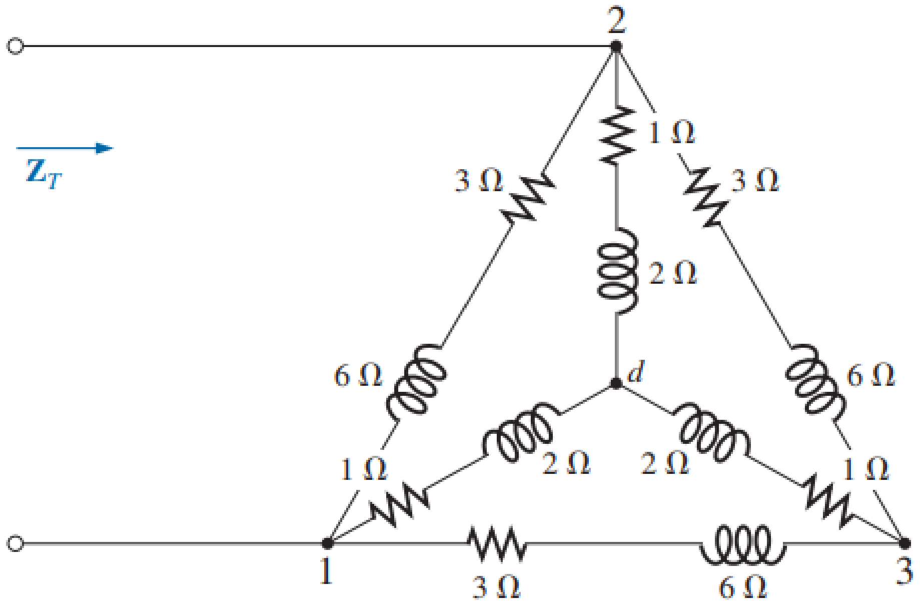
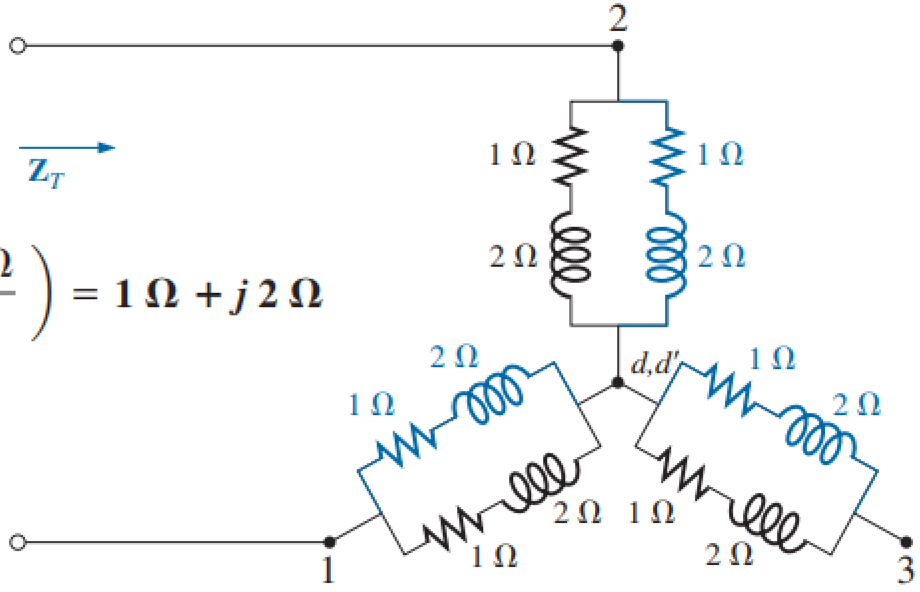


FIG. 17.51 *Example 17.21.*

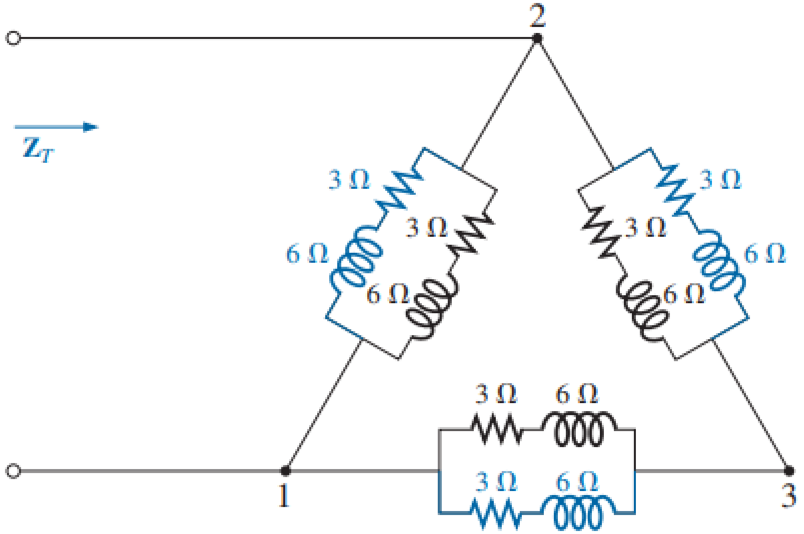


$$\mathbf{Z}_T = 2\left(\frac{1\ \Omega + j\,2\ \Omega}{2}\right) = \mathbf{1\ \Omega + \mathit{j}\,2\ \Omega}$$

$$\mathbf{Z}' = \frac{3\ \Omega + j\,6\ \Omega}{2} = 1.5\ \Omega + j\,3\ \Omega$$

$$\mathbf{Z}_T = \frac{\mathbf{Z}'\,(2\mathbf{Z}')}{\mathbf{Z}' + 2\mathbf{Z}'} = \frac{2(\mathbf{Z}')^2}{3\mathbf{Z}'} = \frac{2\mathbf{Z}'}{3}$$

$$= \frac{2(1.5\ \Omega + j\,3\ \Omega)}{3} = \mathbf{1\ \Omega + \mathit{j}\,2\ \Omega}$$



Chapter 18

Networks Theorem (AC)

Superposition Theorem

Statement: The current through, or voltage across, an element in a linear bilateral network is equal to the algebraic sum of the currents or voltages produced independently by each source.

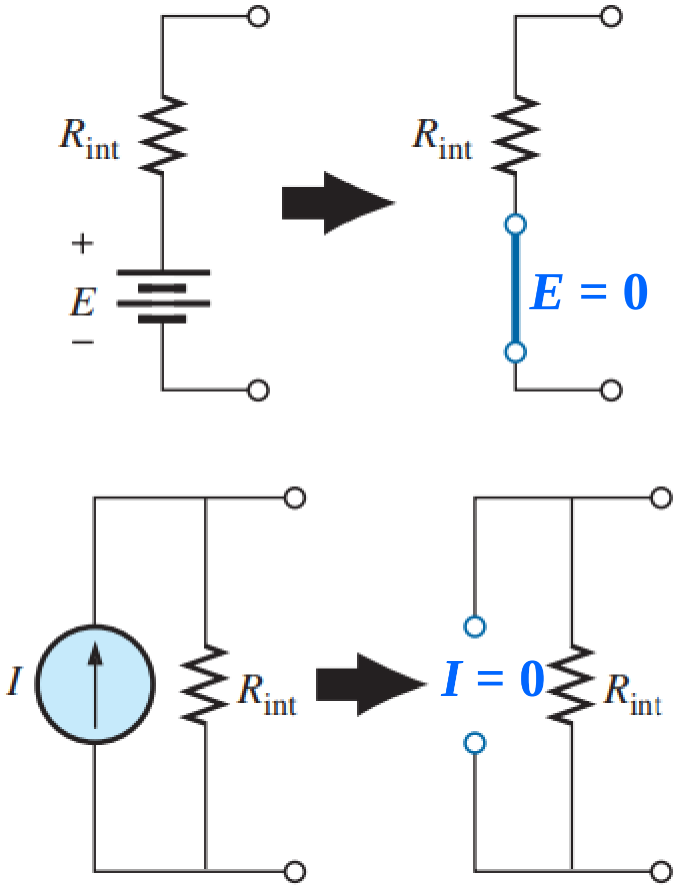
Steps to Apply Superposition Theorem

Step 1: Select a single source acting alone. Short the other voltage sources to make voltage is zero and open the current sources to make current is zero, if internal impedances are not known. If known, replace them by their internal impedances.

Step 2: Find the current through or the voltage across the required element, due to the source under consideration, using a suitable simplification technique.

Step 3: Repeat the above two steps for all the sources.

Step 4: Add all the individual effects produced by individual sources, to obtained the total current in or voltage across the element.



EXAMPLE 18.2: Using superposition, find the current ***I*** in Fig. 18.6.

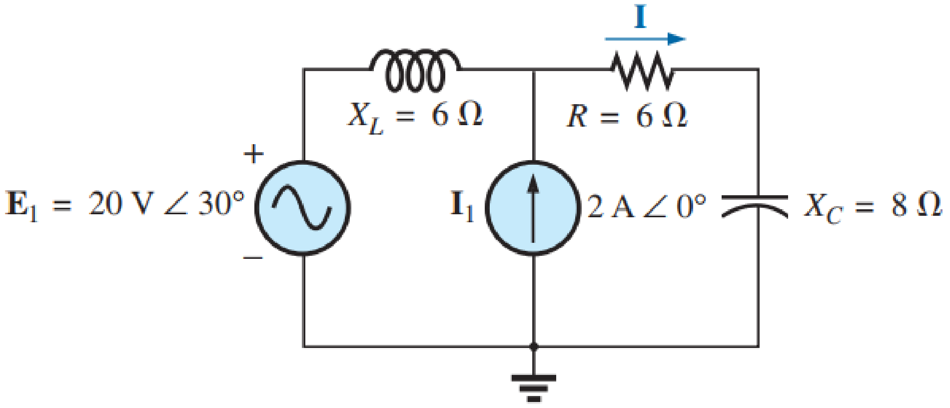


FIG. 18.6 *Example 18.2.*

Solution: For the redrawn circuit (Fig. 18.7),

$$\boldsymbol{Z}_1 = j6\ \Omega; \qquad \boldsymbol{Z}_2 = 6\ - j8\ \Omega$$

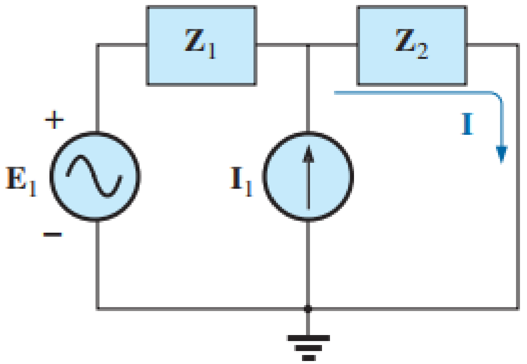


FIG. 18.7
Assigning the subscripted impedances to the network in Fig. 18.6.

Consider the effects of the current source (Fig. 18.8).

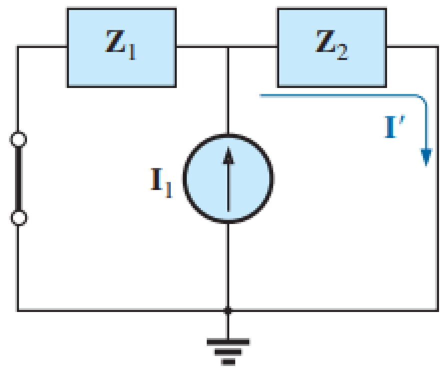


FIG. 18.8

Applying the current divider rule, we have

$$\mathbf{I}' = \frac{\mathbf{Z}_1\mathbf{I}_1}{\mathbf{Z}_1 + \mathbf{Z}_2} = \frac{(j\,6\ \Omega)(2\ \text{A})}{j\,6\ \Omega + 6\ \Omega - j\,8\ \Omega} = \frac{j\,12\ \text{A}}{6 - j\,2}$$

$$= \frac{12\ \text{A}\ \angle 90^\circ}{6.32\ \angle -18.43^\circ}$$

$$\mathbf{I}' = 1.9\ \text{A}\ \angle 108.43^\circ$$

Consider the effects of the voltage source (Fig. 18.9).

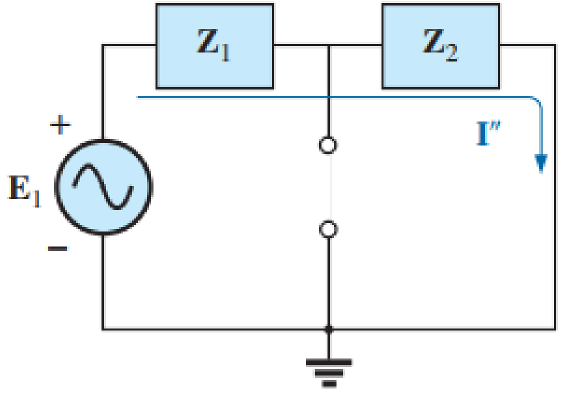


FIG. 18.9

Applying the Ohm's law give us:

$$I'' = \frac{E_1}{Z_T} = \frac{E_1}{Z_1 + Z_2} = \frac{20\text{ V} \angle 30^\circ}{6.32\ \Omega \angle -18.43^\circ}$$
$$= 3.16\text{ A} \angle 48.43^\circ$$

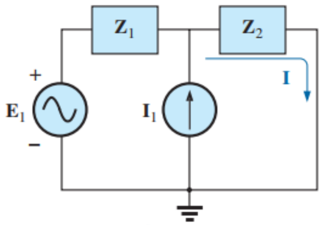


FIG. 18.7
Assigning the subscripted impedances to the network in Fig. 18.6.

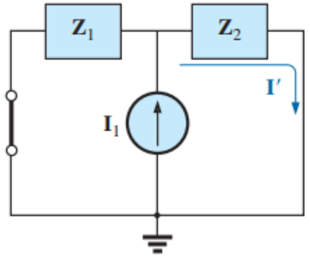


FIG. 18.8

The total current through the 6 Ω resistor (Fig. 18.10) is

$$\begin{aligned} I &= I' + I'' \\ &= 1.9\text{ A} \angle 108.43^\circ + 3.16\text{ A} \angle 48.43^\circ \\ &= (-0.60\text{ A} + j\,1.80\text{ A}) + (2.10\text{ A} + j\,2.36\text{ A}) \\ &= 1.50\text{ A} + j\,4.16\text{ A} \\ I &= \mathbf{4.42\ A \angle 70.2^\circ} \end{aligned}$$