Universidad de las Fuerzas Armadas "ESPE"

Fundamentos de Circuitos Eléctricos

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NRC: 4867

SECCIÓN 21–1 Introducción a máquinas trifásicas

1. La salida de un generador de ca tiene un valor máximo de 250 V. ¿A qué ángulo el valor instantáneo es igual a 75 V?

Formula a usar valor instantáneo:

$$V_\alpha = V_{max} * sen(\alpha)$$

V_α= 75 v

V_{max}= 250 v

$$arcsen\left(\frac{V_\alpha}{V_{max}}\right) = \alpha$$

$$arcsen\left(\frac{75}{250}\right) = \alpha$$

$$\alpha = 17{,}45°$$

2. Cierto generador trifásico de dos polos tiene una velocidad de rotación de 60 rpm. ¿Cuál es la frecuencia de cada voltaje producido por este generador? ¿Cuál es el ángulo de fase entre cada voltaje?

$$w = 60\,rpm \rightarrow 6{,}283\ \frac{rad}{s}$$

Formulas a utilizar:

Frecuencia :

$$f = \frac{w}{2\pi}$$

$$f = \frac{6{,}283}{2\pi} = 0{,}99\ Hz$$

$$T = \frac{1}{F} = 1.01\ s$$

Angulo de fase

Por ser sistema trifásico siempre es 120°

SECCIÓN 21–2 Generadores en aplicaciones de potencia

3. Un generador monofásico alimenta una carga compuesta por un resistor de 200 ohmios y un capacitor con reactancia de 175 ohmios. El generador produce un voltaje de 100 V. Determine la magnitud de la corriente de carga.

$$Xc = 175\Omega$$

$$R = 200\ \Omega$$

$$I_{RL} = \frac{V}{R} = \frac{100 < 0°}{200 < 0°} = 0{,}5 < 0°$$

$$I_{RL} = \frac{V}{Xc} = \frac{100 < 0°}{175 < 90°} = 0{,}57 < -90°$$

$$I = 376\ mA$$

4. Determine la fase de la corriente de carga con respecto al voltaje del generador del problema 3.

$$I = 376\,mA$$

$$V = 100\,V$$

$$Fase: 90°$$

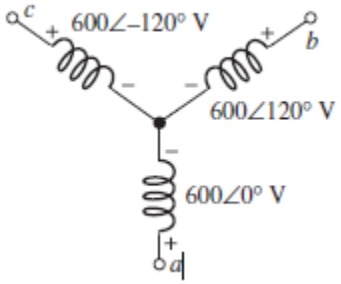
5. Una carga trifásica desbalanceada en un sistema de cuatro hilos tiene corrientes de 2 ∠ 20° A, 3 ∠140°, y 1.5 ∠ -100° A. Determine la corriente en la línea neutra.

$$L_{Rl1} + L_{Rl2} + L_{Rl3} = I_{RN}$$

$$I_{RN} = 2 < 20 + 3 < 140 + 1{,}5 < -100 = 1{,}323 < 120{,}89\,A$$

SECCIÓN 21–3 Tipos de generadores trifásicos

6. Determine los voltajes de línea en la figura 21-35.



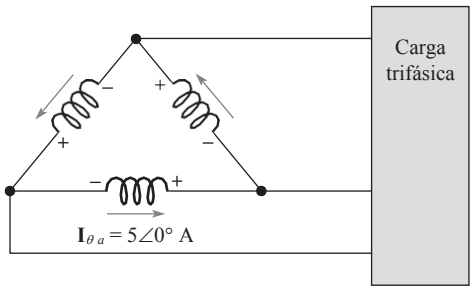
$$V_L = \sqrt{3}(V_\theta < 30° + \theta)$$

$$V_{Lc} = \sqrt{3}(600 < -90°) = \ \ 1039{,}2 < -90$$

$$V_{La} = \sqrt{3}(600 < 30°) = \ \ 1039{,}2 < 30$$

$$V_{Lb} = \sqrt{3}(600 < 120°) = \ \ 1039{,}2 < 150$$

7. Determine las corrientes de línea en la figura 21-36.



$Ia = 5 < 0\ A$

$Ib = 5 < 120\ A$

$Ic = 5 < -120\ A$

$Il1 = \sqrt{3} * Ia < -30 - 0 = 8.66 < -30$

$Il2 = \sqrt{3} * Ib < 90 - 0 = 8.66 < 90$

$Il3 = \sqrt{3} * Ic < -150 - 0 = 8.66 < -150$

8. Desarrolle un diagrama fasorial de corriente completo para la figura 21-36.

$Ia = 5 < 0\ A$

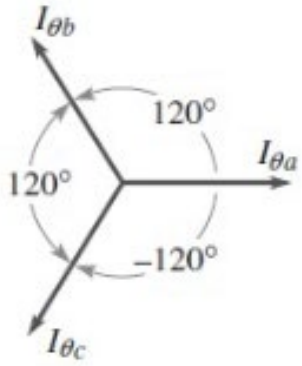
$Ib = 5 < 120\ A$

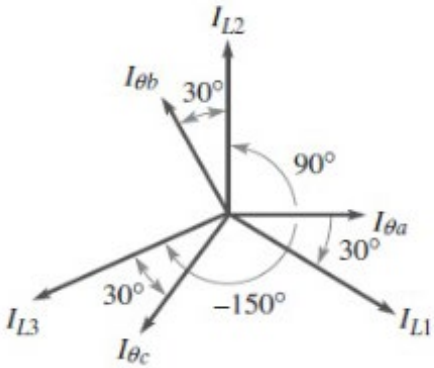
$Ic = 5 < -120\ A$

$Il1 = \sqrt{3} * Ia < -30 - 0 = 8.66 < -30$

$Il2 = \sqrt{3} * Ib < 90 - 0 = 8.66 < 90$

$Il3 = \sqrt{3} * Ic < -150 - 0 = 8.66 < -150$

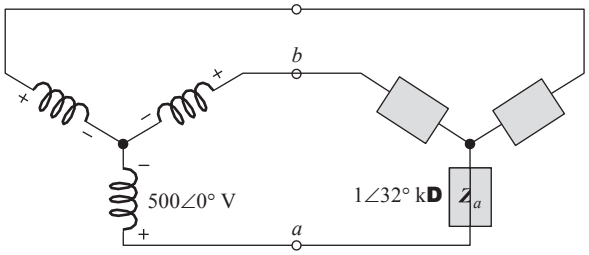




9. Determine las siguientes cantidades para el sistema Y-Y de la figura 21-37:

(a) Los voltajes de línea (b) Las corrientes de fase (c) Las corrientes de línea

(d) Las corrientes de carga (e) Los voltajes de carga



a)

$$Za = Zb = Zc = 1 < 32k\Omega$$

$$Vza = Vl1 = 500\sqrt{3} < 150\,V = 866.025 < 150\,V$$

$$Vzb = Vl2 = 500\sqrt{3} < 30\,V = 866.025 < 30\,V$$

$$Vzc = Vl3 = 500\sqrt{3} < -90\,V = 866.025 < -90\,V$$

d)

$$Iza = \frac{Va}{Za} = \frac{500 < 0\,V}{1 < 32k\Omega} = 500 < -32\,(ma)$$

$$Izb = \frac{Vb}{Zb} = \frac{500 < 120\,V}{1 < 32k\Omega} = 500 < 88\,(ma)$$

$$Izc = \frac{Vc}{Zc} = \frac{500 < -120\,V}{1 < 32k\Omega} = 500 < -152\,(ma)$$

b)

$$Ia = 0.5 < -32\,A$$

$$Ib = 0.5 < 88\,A$$

$$Ic = 0.5 < -152\,A$$

c)

$$Il1 = 0.5 < -32\ A$$

$$Il2 = 0.5 < 88\ A$$

$$Il3 = 0.5 < -152\ A$$

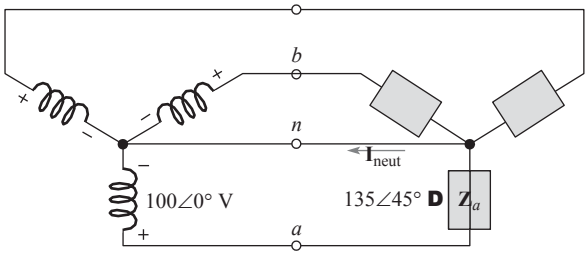
e)

$$Vza = 500 < 0\ V$$

$$Vzb = 500 < 120\ V$$

$$Vzc = 500 < -120\ V$$

10. Repita el problema 9 para el sistema de la figura 21-38, y también determine la corriente neutra.



a)

$$Za = 135 < 45\ \Omega$$

$$Zb = 200 < 20\ \Omega$$

$$Zc = 100 < 60\ \Omega$$

$$Vza = Vl1 = 100\sqrt{3} < 150\ V = 173.20 < 150\ V$$

$$Vzb = Vl2 = 100\sqrt{3} < 30\ V = 173.20 < 30\ V$$

$$Vzc = Vl3 = 100\sqrt{3} < -90\ V = 173.20 < -90\ V$$

d)

$$Iza = \frac{Va}{Za} = \frac{100 < 0\ V}{135 < 45\ \Omega} = 0.740 < -45\ (A)$$

$$Izb = \frac{Vb}{Zb} = \frac{100 < -120\,V}{100 < 60\Omega} = 1 < 180\ (A)$$

$$Izc = \frac{Vc}{Zc} = \frac{100 < 120\,V}{200 < 20\Omega} = 0.5 < -140\ (A)$$

b)

$$Ia = 0.740 < -45\ (A)$$

$$Ib = 1 < 180\ (A)$$

$$Ic = 0.5 < -140\ (A)$$

c)

$$Il1 = 0.740 < -45\ (A)$$

$$Il2 = 1 < 180\ (A)$$

$$Il3 = 0.5 < -140\ (A)$$

e)

$$Vza = 100 < 0\,V$$

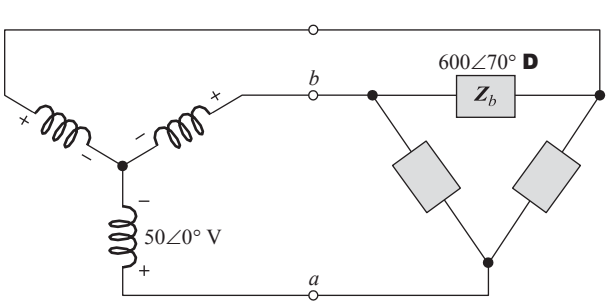
$$Vzb = 100 < 120\,V$$

$$Vzc = 100 < -120\,V$$

f)

$$In = Iza + Izb + Izc = 0.740 < -45\ (A) + 1 < 180\ (A) + 0.5 < -140\ (A) = 1.205 - < 135.50\ (A)$$

11. Repita el problema 9 para el sistema de la figura 21-39.



a)

$$Za = Zb = Zc = 600 < 70\ \Omega$$

$$Vza = Vl1 = 50\sqrt{3} < 150\ V = 88.6025 < 150\ V$$

$$Vzb = Vl2 = 50\sqrt{3} < 30\ V = 88.6025 < 30\ V$$

$$Vzc = Vl3 = 50\sqrt{3} < -90\ V = 88.6025 < -90\ V$$

d)

$$Iza = \frac{Va}{Za} = \frac{50 < 0\ V}{600 < 70\ \Omega} = 0.0833 < -70\ (A)$$

$$Izb = \frac{Vb}{Zb} = \frac{50 < -120\ V}{600 < 70\ \Omega} = 0.0833 < 170\ (A)$$

$$Izc = \frac{Vc}{Zc} = \frac{50 < 120\ V}{600 < 70\ \Omega} = 0.0833 < 50\ (A)$$

b)

$$Ia = 0.0833 < -70\ (A)$$

$$Ib = 0.0833 < 170\ (A)$$

$$Ic = 0.0833 < 50\ (A)$$

c)

$$Il1 = 0.0833 < -70\ (A)$$

$$Il2 = 0.0833 < 170\ (A)$$

$$Il3 = 0.0833 < 50\ (A)$$

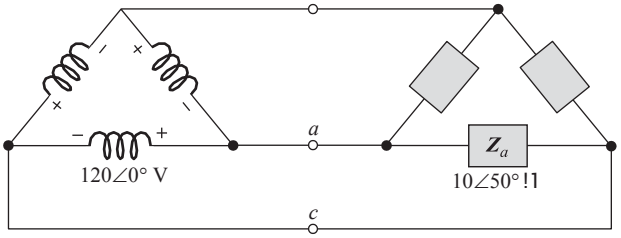
e)

$$Vza = 50 < 0\ V$$

$$Vzb = 50 < 120\ V$$

$$Vzc = 50 < -120\ V$$

12. Repita el problema 9 para el sistema de la figura 21-40.



a)

$$Za = Zb = Zc = 10 < 50\ \Omega$$

$$Vza = Vl1 = 120\sqrt{3} < 150\ V = 207.84 < 150\ V$$

$$Vzb = Vl2 = 120\sqrt{3} < 30\ V = 207.84 < 30\ V$$

$$Vzc = Vl3 = 120\sqrt{3} < -90\ V = 207.84 < -90\ V$$

d)

$$Iza = \frac{Va}{Za} = \frac{120 < 0\ V}{10 < 50\ \Omega} = 12 < -50\ (A)$$

$$Izb = \frac{Vb}{Zb} = \frac{120 < -120\ V}{10 < 50\ \Omega} = 12 < -170\ (A)$$

$$Izc = \frac{Vc}{Zc} = \frac{120 < 120\ V}{10 < 50\ \Omega} = 12 < 70\ (A)$$

b)

$$Ia = 12 < -50\ (A)$$

$$Ib = 12 < -170\ (A)$$

$$Ic = 12 < 70\ (A)$$

c)

$$Il1 = 12 < -50\ (A)$$

$$Il2 = 12 < -170\ (A)$$

$$Il3 = 12 < 70\ (A)$$

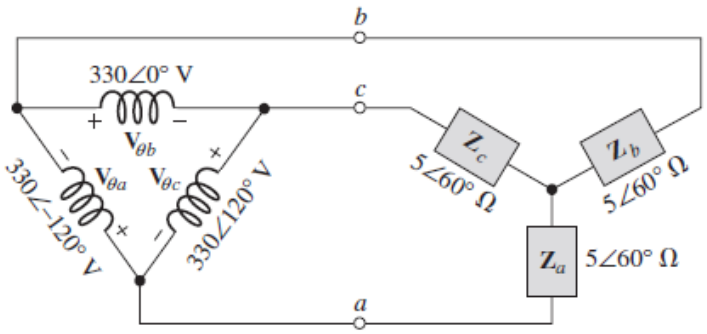
e)

$$Vza = 120 < 0\ V$$

$$Vzb = 120 < 120\ V$$

$$Vzc = 120 < -120\ V$$

13. Determine los voltajes de línea y las corrientes de carga para el sistema de la figura 21-41.



▲ **FIGURA 21–41**

$$V_\Theta = V_L$$

$$V_{L(ab)} = V_{\theta a}$$

$$V_{L(ab)} = 330 < -120° \, V$$

$$V_{L(ac)} = V_{\theta c}$$

$$V_{L(ac)} = 330 < 120° \, V$$

$$V_{L(bc)} = V_{\theta b}$$

$$V_{L(bc)} = 330 < 0° \, V$$

$$V_{Za} = \frac{V_{\theta a}}{\sqrt{3}}$$

$$V_{Za} = \frac{330 < (-120 + 30)° \, V}{\sqrt{3}}$$

$$V_{Za} = 190.52 < -90° \, V$$

$$V_{Zb} = \frac{V_{\theta b}}{\sqrt{3}}$$

$$V_{Zb} = \frac{330 < (0 + 30)° \, V}{\sqrt{3}}$$

$$V_{Zb} = 190.52 < 30° \, V$$

$$V_{Zc} = \frac{V_{\theta c}}{\sqrt{3}}$$

$$V_{Zc} = \frac{330 < (120 + 30)° \, V}{\sqrt{3}}$$

$$V_{Zc} = 190.52 < 150° \, V$$

$$I_{Za} = \frac{V_{Za}}{Z_a}$$

$$I_{Za} = \frac{190.52 < -90° \, V}{5 < 60° \, \Omega}$$

$$I_{Za} = 38.10 < -150° \, A$$

$$I_{Zb} = \frac{V_{Zb}}{Z_b}$$

$$I_{Zb} = \frac{190.52 < 30° \, V}{5 < 60° \, \Omega}$$

$$I_{Zb} = 38.10 < -30° \, A$$

$$I_{Zc} = \frac{V_{Zc}}{Z_c}$$

$$I_{Zc} = \frac{190.52 < 150° \, V}{5 < 60° \, \Omega}$$

$$I_{Zc} = 38.10 < 90° \, A$$

Potencia Trifásica

14. La potencia en cada fase de un sistema trifásico balanceado es de 1200 W. ¿Cuál es la potencia total?

$$P_T = P_1 + P_2 + P_3$$

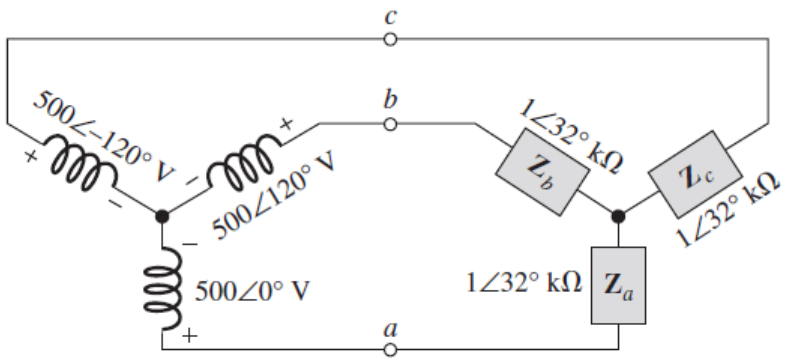
$$P_1 = P_2 = P_3$$

$$P_T = 3P$$

$$P_T = 3(1200)$$

$$P_T = 3600 \, W$$

15. Determine la potencia suministrada a la carga en las figuras 21-37 a 21-41.



▲ FIGURA 21–37

$$I_\Theta = \frac{V_\Theta}{Z}$$

$$I_\Theta = \frac{500 \, V}{1 \, k\Omega}$$

$$I_\Theta = 500\ mA$$

$$I_\Theta = I_L = I_Z$$

$$I_Z = 500\ mA$$

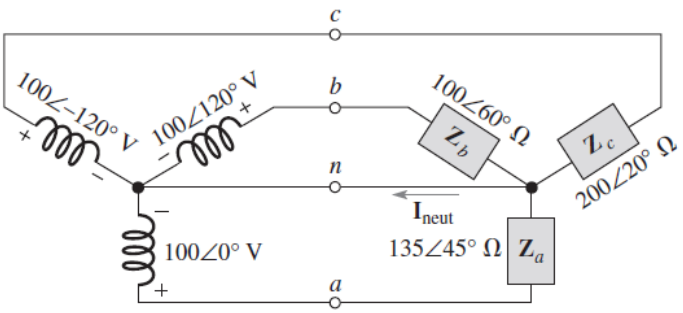
$$V_Z = V_\Theta$$

$$V_Z = 500\ V$$

$$P_L = 3V_Z I_Z cos\Theta$$

$$P_L = 3(500\ V)(500\ mA)\cos\ (32°)$$

$$P_L = 636\ W$$



▲ FIGURA 21–38

$$I_{\Theta a} = \frac{V_{\Theta a}}{Z_a}$$

$$I_{\Theta a} = \frac{100 < 0°\ V}{135 < 45°\ \Omega}$$

$$I_{\Theta a} = 0.74 < -45°\ A$$

$$I_{\Theta b} = \frac{V_{\Theta b}}{Z_b}$$

$$I_{\Theta a} = \frac{100 < 120°\ V}{100 < 60°\ \Omega}$$

$$I_{\Theta a} = 1 < 60°\ A$$

$$I_{\Theta c} = \frac{V_{\Theta c}}{Z_c}$$

$$I_{\Theta a} = \frac{100 < -120°\ V}{200 < 20°\ \Omega}$$

$$I_{\Theta a} = 0.5 < -140°\ A$$

$$I_\Theta = I_L = I_Z$$

$$I_{Za} = I_{\Theta a}$$

$$I_{Za} = 0.74 < -45°\ A$$

$$I_{Zb} = I_{\Theta b}$$

$$I_{Za} = 1 < 60° \, A$$

$$I_{Zc} = I_{\Theta c}$$

$$I_{Zc} = 0.5 < -140° \, A$$

$$V_{Za} = V_{\Theta a}$$

$$V_{Za} = 100 < 0° \, V$$

$$V_{Zb} = V_{\Theta b}$$

$$V_{Zb} = 100 < 120° \, V$$

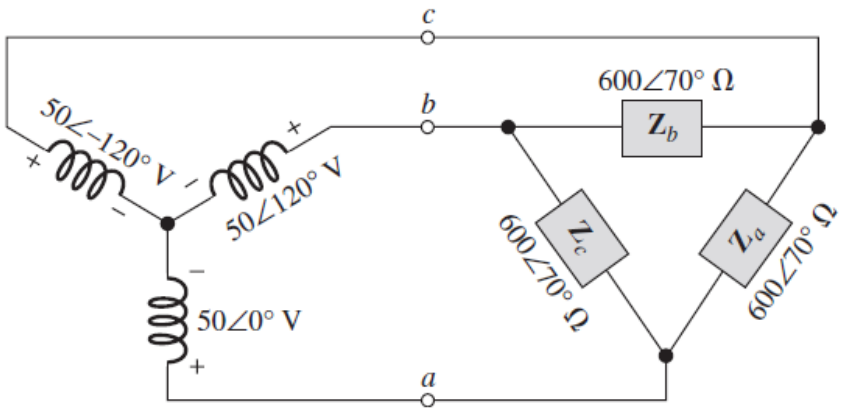
$$V_{Zc} = V_{\Theta c}$$

$$V_{Za} = 100 < -120° \, V$$

$$P_L = V_{Za} I_{Za} cos\Theta_a + V_{Zb} I_{Zb} cos\Theta_b + V_{Zc} I_{Zc} cos\Theta_c$$

$$P_L = (100 \, V)(0.74 \, A)\cos(45°) + (100 \, V)(1 \, A)\cos(60°) + (100 \, V)(0.5 \, A)\cos(20°)$$

$$P_L = 149 \, W$$



▲ FIGURA 21–39

$$V_L = \sqrt{3} V_\Theta$$

$$V_L = \sqrt{3}(50 \, V)$$

$$V_L = 86.6 \, V$$

$$V_Z = V_L$$

$$V_Z = 86.6 \, V$$

$$I_Z = \frac{V_Z}{Z}$$

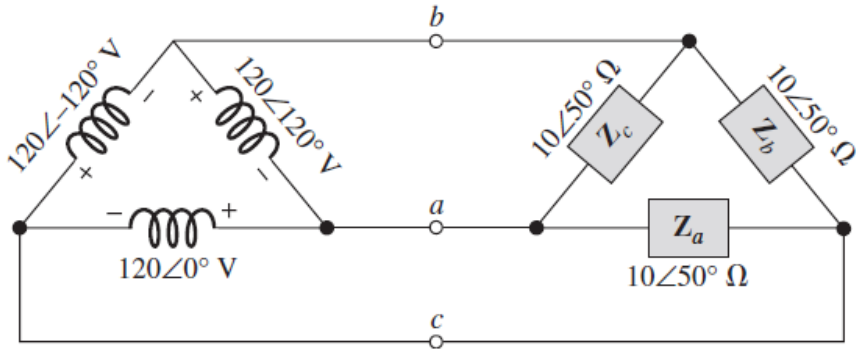
$$I_Z = \frac{86.6 \, V}{600 \, \Omega}$$

$$I_Z = 144 \, mA$$

$$P_L = 3V_Z I_Z cos\Theta$$

$$P_L = 3(86.6\ V)(144\ mA)\cos\ (70°)$$

$$P_L = 12.8\ W$$



▲ FIGURA 21–40

$$V_Z = V_\Theta$$

$$V_Z = 120\ V$$

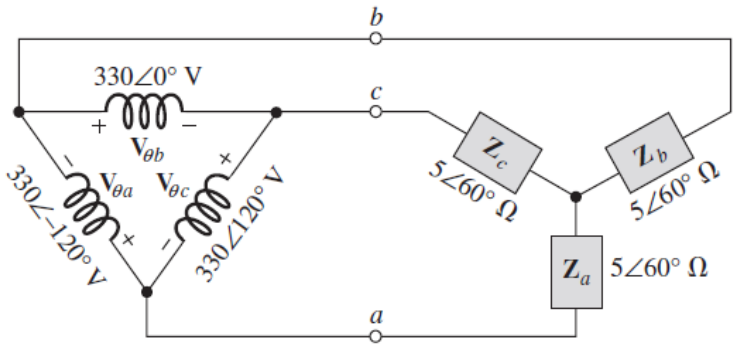
$$I_Z = \frac{V_Z}{Z}$$

$$I_Z = 12\ A$$

$$P_L = 3V_Z I_Z cos\Theta$$

$$P_L = 3(120\ V)(12\ A)\cos\ (50°)$$

$$P_L = 2.77\ kW$$



▲ FIGURA 21–41

$$V_\Theta = \sqrt{3}V_Z$$

$$V_Z = \frac{V_\Theta}{\sqrt{3}}$$

$$V_Z = \frac{330\ V}{\sqrt{3}}$$

$$V_Z = 190.52\ V$$

$$I_Z = \frac{V_Z}{Z}$$

$$I_Z = \frac{190.52\ V}{5\ \Omega}$$

$$I_Z = 38.10\ A$$

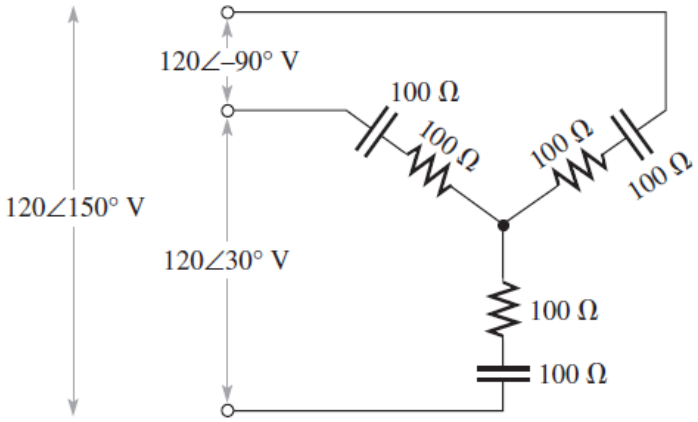
$$P_L = 3V_Z I_Z cos\Theta$$

$$P_L = 3(190.2\ V)(38.10\ A)\cos\ (60°)$$

$$P_L = 10.9\ kW$$

16. Determine la potencia total suministrada a la carga en la figura 21-42.

▶ **FIGURA 21–42**



$$Z = 100 - j100\ \Omega$$

$$Z = 141.42 < -45°\ \Omega$$

$$Z = Z_a = Z_b = Z_c$$

$$V_{Za} = \frac{V_{L(ac)}}{\sqrt{3}}$$

$$V_{Za} = \frac{120 < (30 - 30)°\ V}{\sqrt{3}}$$

$$V_{Za} = 69.29 < 0°\ V$$

$$V_{Zb} = \frac{V_{L(ab)}}{\sqrt{3}}$$

$$V_{Zb} = \frac{120 < (150 - 30)°\ V}{\sqrt{3}}$$

$$V_{Zb} = 69.29 < 120°\ V$$

$$V_{Zc} = \frac{V_{L(ac)}}{\sqrt{3}}$$

$$V_{Zc} = \frac{120 < (-90 - 30)° \, V}{\sqrt{3}}$$

$$V_{Zc} = 69.29 < -120° \, V$$

$$I_{Za} = \frac{V_{Za}}{Z_a}$$

$$I_{Za} = \frac{69.29 < 0° \, V}{141.42 < 45° \, \Omega}$$

$$I_{Za} = 0.489 < 45° \, A$$

$$I_{Zb} = \frac{V_{Zb}}{Z_b}$$

$$I_{Zb} = \frac{69.29 < 120° \, V}{141.42 < -45° \, \Omega}$$

$$I_{Zb} = 0.489 < 165° \, A$$

$$I_{Zc} = \frac{V_{Zc}}{Z_c}$$

$$I_{Zc} = \frac{69.29 < -120° \, V}{141.42 < -45° \, \Omega}$$

$$I_{Zc} = 0.489 < -75° \, A$$

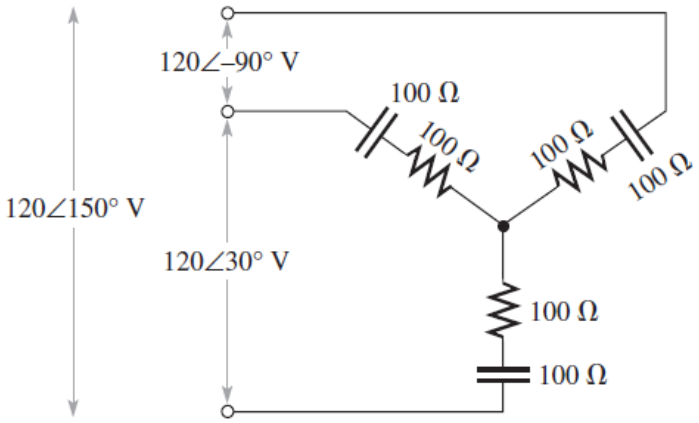
$$P_{L(tot)} = 3V_Z I_Z cos\Theta$$

$$P_{L(tot)} = 3(69.29 \, V)(0.489 \, A)\cos(-45°)$$

$$P_{L(tot)} = 72 \, W$$

* **17.** Utilice el método de tres wattímetros para medir el sistema de la figura 21-42. ¿Cuánta potencia indica cada wattímetro?

▶ FIGURA 21–42



$$Z = 100 - j100\ \Omega$$

$$Z = 141.42 < -45°\ \Omega$$

$$Z = Z_a = Z_b = Z_c$$

$$V_{Za} = \frac{V_{L(ac)}}{\sqrt{3}}$$

$$V_{Za} = \frac{120\ V}{\sqrt{3}}$$

$$V_{Za} = 69.29\ V$$

$$I_{Za} = \frac{V_{Za}}{V_a}$$

$$I_{Za} = \frac{69.29\ V}{141.42\ \Omega}$$

$$I_{Za} = 0.489\ A$$

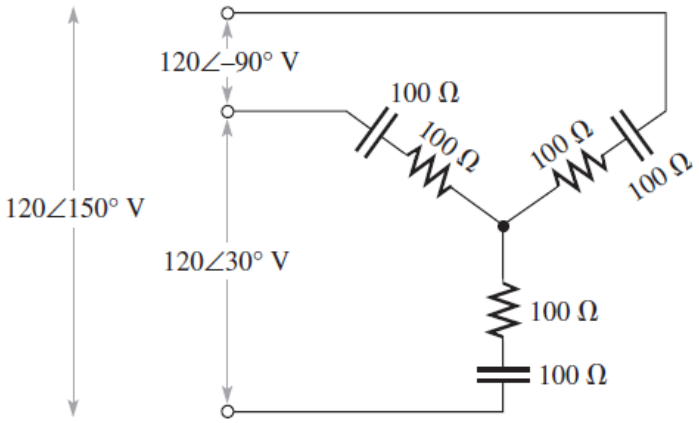
$$P = V_{Za} I_{Za} cos\Theta$$

$$P = (69.29\ V)(0.49\ A)\cos(-45°)$$

$$P = 24.2\ W$$

* **18.** Repita el problema 17 empleando el método de dos wattímetros.

▶ FIGURA 21–42



$$Z = 100 - j100\ \Omega$$

$$Z = 141.42 < -45°\ \Omega$$

$$Z = Z_a = Z_b = Z_c$$

$$V_Z = \frac{V_L}{\sqrt{3}}$$

$$V_Z = \frac{120\ V}{\sqrt{3}}$$

$$V_Z = 69.3\ V$$

$$I_Z = \frac{V_Z}{Z}$$

$$I_Z = \frac{69.3\ V}{141.42\ \Omega}$$

$$I_Z = 0.49\ A$$

$$P_1 = \sqrt{3} V_Z I_Z \cos\ (30° + \theta)$$

$$P_1 = \sqrt{3}(69.3\ V)(0.49\ A)\cos\ (30° - 45°)$$

$$P_1 = 57.96\ W$$

$$P_2 = \sqrt{3} V_Z I_Z \cos\ (30° - \theta)$$

$$P_1 = \sqrt{3}(69.3\ V)(0.49\ A)\cos\ (30° + 45°)$$

$$P_1 = 15.54\ W$$

$$P = P_1 + P_2$$

$$P = (57.96 + 15.54)W$$

$$P = 73.5\ W$$