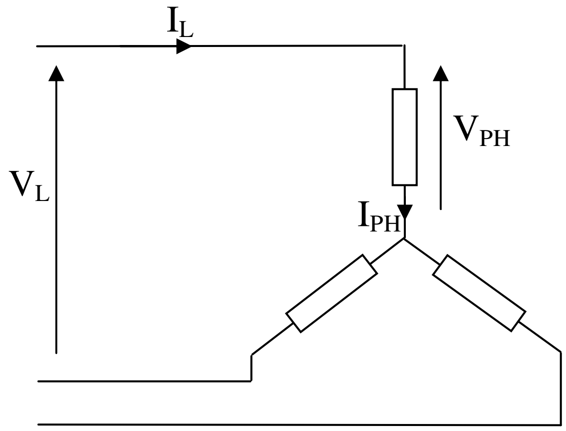
Tutorial Sheet – No 7 Answers

1



V_L = 440V$_{rms}$
I_{PH} = 30∠–30°A$_{rms}$

For star connection:

$$I_L = I_{PH} = 30\angle -30^\circ \text{ A}_{rms}$$

$$V_{PH} = \frac{V_L}{\sqrt{3}} = \frac{440}{\sqrt{3}} = \mathbf{254V_{rms}}$$

And the total power is given by:

$$P_{TOT} = \sqrt{3}V_L I_L \cos\phi = \sqrt{3} \times 440 \times 30 \times \cos 30^\circ = \mathbf{19.8kW}$$

2 Given:

V_L = 415V$_{rms}$
I_L = 20∠–30°A$_{rms}$

For star connection:

$$I_{PH} = I_L = 20\angle -30^\circ \text{ A}_{rms}$$

$$V_{PH} = \frac{V_L}{\sqrt{3}} = \frac{415}{\sqrt{3}} = \mathbf{239.9V_{rms}}$$

The total power dissipated in the system is given by:

$$P = \sqrt{3} \times V_L \times I_L \times \cos\phi = \sqrt{3} \times 415 \times 20 \times \cos 30^\circ = \mathbf{12.45kW}$$

3 When the load is delta connected the voltage across each leg will increase by a factor of √3 and therefore the current in each leg will increase by √3. Now for a delta connected load the line voltage is equal to the phase voltage, but the line current is √3 times the phase (leg) current. Therefore:

$$V_{LineNew} = V_{PhaseNew} = \mathbf{415V_{rms}}$$

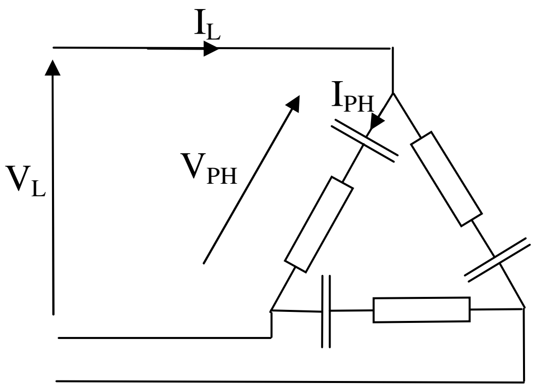
and:

$$I_{LineNew} = \sqrt{3} \times I_{PhaseNew} = \sqrt{3} \times \sqrt{3} \times I_{PhaseOld} = \mathbf{60A_{rms}}$$

The total power dissipated in the delta system is given by:

$$P = \sqrt{3} \times V_L \times I_L \times \cos\phi = \sqrt{3} \times 415 \times 60 \times \cos 30^\circ = \mathbf{37.35kW}$$

4



Calculate the phase impedance:

$$Z_{PH} = R + \frac{1}{j2\pi fC} = R - \frac{j}{2\pi fC} = 50 - \frac{j}{2\pi \times 50 \times 50 \times 10^{-6}} = 50 - j63.67 = 80.95\angle -51.85^\circ \ \Omega$$

For a delta system:

$$I_L = \sqrt{3} I_{PH}$$
$$V_L = V_{PH}$$

so:

$$I_{PH} = \frac{V_{PH}}{Z_{PH}} = \frac{440\angle 0^\circ}{80.95\angle -51.85^\circ} = \mathbf{5.43\angle 51.85^\circ A_{rms}}$$

Therefore:

$$|I_L| = \sqrt{3}|I_{PH}| = \sqrt{3} \times 5.43 \ \text{A}_{rms} = \mathbf{9.41 A_{rms}}$$

The total power dissipated in the delta system is given by:

$$P = \sqrt{3} \times V_L \times I_L \times \cos\phi = \sqrt{3} \times 440 \times 9.41 \times \cos 51.85^\circ = \mathbf{4.43kW}$$

and the total VA of the system is given by:

$$VA = \sqrt{3} \times V_L \times I_L = \sqrt{3} \times 440 \times 9.41 = \mathbf{7.17kVA}$$

5 Since the motor is delivering 1.49MW of mechanical power and has an efficiency of 93% then the electrical input power to the motor is:

$$P_{IN} = \frac{1.49}{0.93} = 1.6\text{MW}$$

since:

$$P = \sqrt{3} \times V_L \times I_L \times \cos\phi$$

and:

$$VA = \sqrt{3} \times V_L \times I_L$$

then the input VA to the motor is:

$$VA = \frac{P}{\cos\phi} = \frac{1.6}{0.85} = 1.882\text{MVA}$$

so the line current is:

$$I_L = \frac{VA}{\sqrt{3}V_L} = \frac{1.882 \times 10^6}{\sqrt{3} \times 2200} = 494\text{A}_{rms}$$

Since the generator is star connected then:

$$I_{PH\_GEN} = I_L = \mathbf{494 A_{rms}}$$

and the motor is delta connected so:

$$I_{PH\_MOTOR} = \frac{I_L}{\sqrt{3}} = \frac{494}{\sqrt{3}} = \mathbf{285 A_{rms}}$$

6 First express the phase impedance of the motor in polar form:

$$Z_{PH} = R + jX_L = 8 + j6 = 10\angle 36.87^\circ \ \Omega$$

Now since the motor is star connected:

$$V_{PH} = \frac{V_L}{\sqrt{3}} = \frac{415}{\sqrt{3}} = 240 \text{ V}_{rms}$$

and:

$$I_L = I_{PH} = \frac{V_{PH}}{Z_{PH}} = \frac{240\angle 0^\circ}{10\angle 36.87^\circ} = \mathbf{24\angle -36.87^\circ = 19.2 - j14.4\ A_{rms}}$$

since the motor is an inductive impedance the power factor will be lagging and equal to:

$$pf = \cos\phi = \cos 36.87^\circ = \mathbf{0.8\ lagging}$$

The electrical power input to the motor is given by:

$$P = \sqrt{3}\times V_L \times I_L \times \cos\phi = \sqrt{3}\times 415\times 24\times 0.8 = 13.8\text{kW}$$

but since the motor is 90% efficient the mechanical output power will be:

$$P_{OUT} = P_{IN}\times\frac{\eta}{100} = 13.8\times\frac{90}{100} = \mathbf{12.42kW}$$

Calculate the current drawn by the power factor correction capacitors per phase:

$$Z_{CPH} = \frac{1}{j2\pi fC} = -\frac{j}{2\pi\times 50\times 200\times 10^{-6}} = -15.9\angle -90^\circ\ \Omega$$

and:

$$I_{CPH} = \frac{V_{PH}}{Z_{CPH}} = \frac{240\angle 0^\circ}{15.9\angle -90^\circ} = 15.07\angle 90^\circ = j15.07\ \text{A}_{rms}$$

So the total current drawn from the supply will be the sum of the motor and capacitor currents:

$$I_{TOT} = I_{PH} + I_{CPH} = 19.2 - j14.4 + j15.07 = 19.2 + j0.67 = \mathbf{19.2\angle 2^\circ\ A_{rms}}$$

7 Express the phase impedance in polar for:

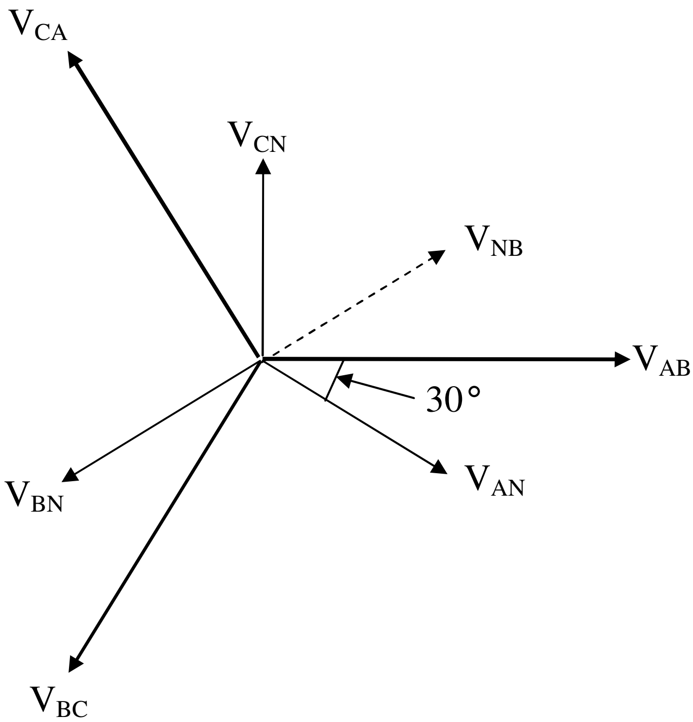
$$Z_{PH} = 7.07 + j7.07 = 10\angle 45^\circ\ \Omega$$

and since the system is star connected then:

$$|V_{PH}| = \frac{|V_L|}{\sqrt{3}} = \frac{220}{\sqrt{3}} = 127\ V_{rms}$$

Taking the line voltage between A and B, VAB, as reference and drawing the phasor diagram noting that (vector addition):

$$\overline{V}_{AB} = \overline{V}_{AN} + \overline{V}_{NB} = \overline{V}_{AN} - \overline{V}_{BN}$$



From the diagram it can be seen that the phase voltages lag behind the line voltages by 30° therefore:

V_{AN} = **127∠–30° V$_{rms}$**
V_{BN} = **127∠–150° V$_{rms}$**
V_{CN} = **127∠–270° V$_{rms}$**

and the phase currents can be found as:

$$I_{A\_PH} = \frac{V_{AN}}{Z_{PH}} = \frac{127\angle -30^\circ}{10\angle 45^\circ} = \mathbf{12.7\angle -75^\circ\ A_{rms}}$$

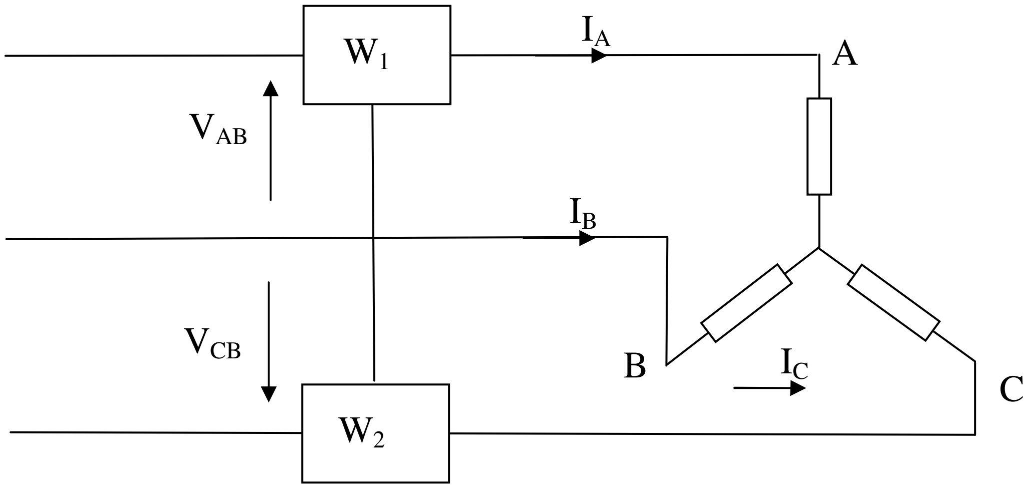
$$I_{B\_PH} = \frac{V_{BN}}{Z_{PH}} = \frac{127\angle -150^\circ}{10\angle 45^\circ} = \mathbf{12.7\angle -195^\circ\ A_{rms}}$$

$$I_{C\_PH} = \frac{V_{CN}}{Z_{PH}} = \frac{127\angle -270^\circ}{10\angle 45^\circ} = \mathbf{12.7\angle -315^\circ\ A_{rms}}$$

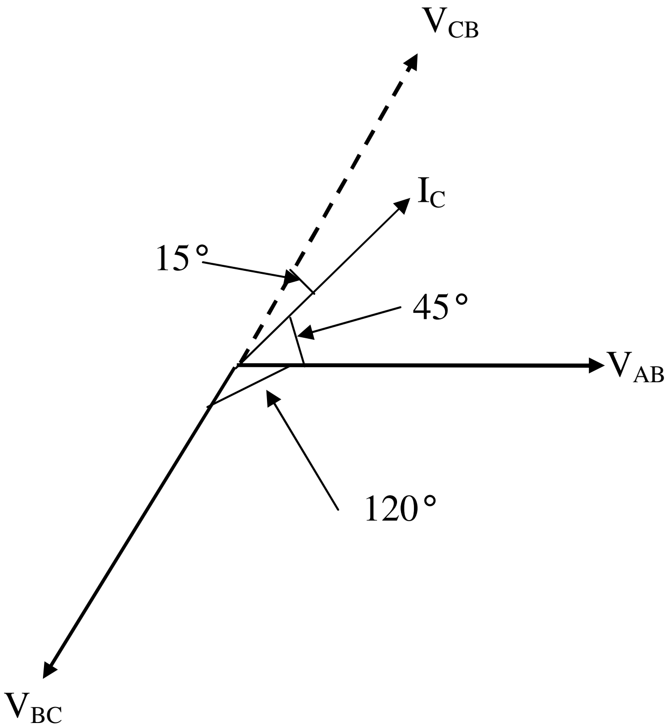
The power measured by the first wattmeter is given by the product of the line voltage and the corresponding line current multiplied by the cosine of the angle between them:

$$W_1 = V_{AB} I_{A\_PH} \cos\phi_1 = 220 \times 12.7 \times \cos 75^\circ = \mathbf{723W}$$

The correct method of measuring power in a 3 phase system is to connect the current coil in the other phase (C) and the voltage coil between this phase and the phase with no current coil in it (B) as shown in the diagram.



Note the sense of the voltage coil for the second wattmeter (V_{CB} not V_{BC}).



Draw the phasor diagram to determine the angle between VCB and IC then the power measured by the second wattmeter is:

$$W_2 = V_{CB} I_{C\_PH} \cos\phi_2 = 220 \times 12.7 \times \cos 15^\circ = \mathbf{2698W}$$

Check:

$$P_{TOT} = W_1 + W_2 = 723 + 2698 = 3421\text{W}$$

and:

$$P_{TOT} = \sqrt{3} V_L I_L \cos\phi = \sqrt{3} \times 220 \times 12.7 \times \cos 45^\circ = 3421\text{W}$$