ECE370 POWER & ENERGY SYSTEMS
Homework Set 2 – Solutions

2.1 A ***single-phase*** source has a terminal voltage $\boldsymbol{V} = 720\underline{/-40^0}$ V. It supplies a current of $\boldsymbol{I} = 30\underline{/-10^0}$ A to an electrical load.

a) Is the load lagging or leading?

b) Find the complex power supplied by the source.

c) Determine the real power and state whether the source is delivering or absorbing.

d) Determine the reactive power and state whether the source is delivering to the load or absorbing from the load.

e) Determine the impedance of the load and state whether it is inductive or capacitive.

a) $\boldsymbol{V} = 720\underline{/-40^0}$ and $\boldsymbol{I} = 30\underline{/-10^0}$ $\therefore$ $\theta = -40 + 10 = -30^0$

i.e. current is 30^0 ***ahead*** of the voltage $\therefore$ the load is ***leading***

b) $\boldsymbol{S} = 720\underline{/-40} \times 30\underline{/+10} = 21.6\underline{/-30} = 18.7 - j10.8$ kVA

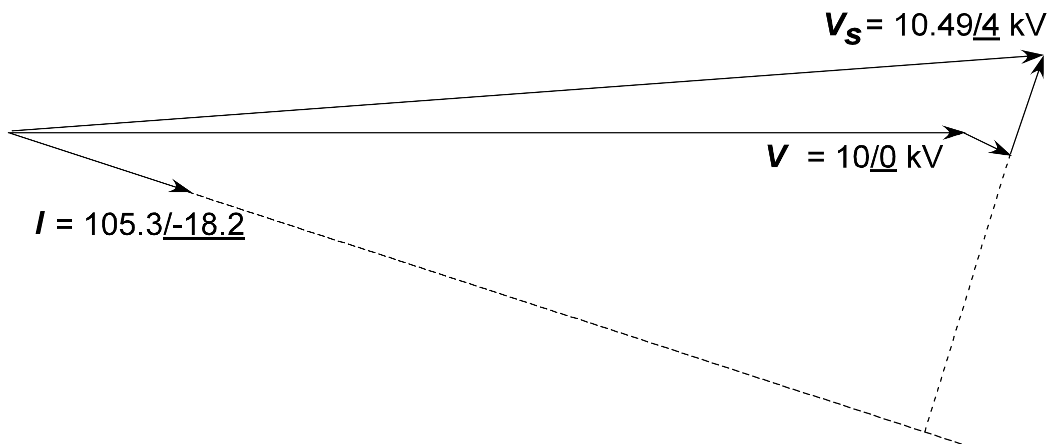
c) P = 18.7 kW (delivered to load because it is positive)

d) Q = 10.8 kVAR (absorbed from load because it is negative)

e) $\boldsymbol{Z} = \frac{V}{I} = \frac{720\angle -40}{30\angle -10} = 24\angle -30\ \Omega = 20.79 - j12\ \Omega$, this is ***capacitive***

2.2 A three-phase distribution feeder whose impedance is 2 + j8 Ω supplies a load of 1000 kW/ph at 0.95 ***lag***, 10kV (phase), 60 Hz.

a) Determine the supply voltage and current and show that the phasor diagram is:

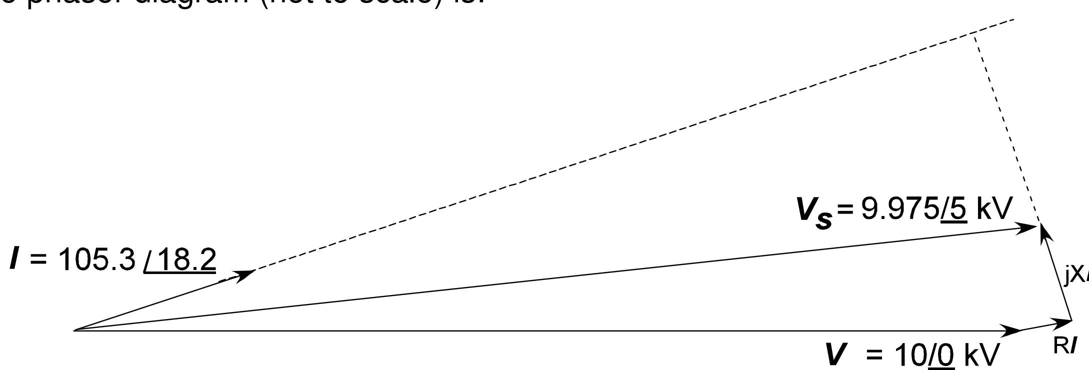


b) Re-draw the phasor diagram (not necessarily to scale, but use a straight-edge) if the pf is 0.95 ***lead*** and the current magnitude stays constant at the value in part (a). Be sure to mark the values of all the parameters that are indicated above.

$\boldsymbol{I} = 105.3\angle +18.2$ A because the current is now leading.

and: $\boldsymbol{V_s} = (2 + j8) \times 105.3\angle{+18.2} + 10 \times 10^3\angle 0 = \boxed{9975\angle 5 \text{ V}}$

The phasor diagram (not to scale) is:



2.3 A 3ϕ, 800 kVA, 2.4 kV, 60 Hz generator operates at rated terminal voltage and supplies rated current at a 0.8 ***leading*** power factor to a balanced 3ϕ load.

a) Determine the real, reactive, and apparent power.

b) Determine the impedance per phase of the load if it is wye-connected.

c) Determine the impedance per phase of the load if it is delta-connected.

a) S = 800 kVA (given) $\quad \boldsymbol{S} = 800\underline{/-\cos^{-1}0.8} = 800\underline{/-36.9^0}$ kVA = 266⅔∠-36.9 kVA/ph

P = 800cos(-36.9) = 640 kW

Q = 800sin(-36.9) = -480 kVAR

b) $\boldsymbol{V_\phi} = \dfrac{2.4\ x\,10^3\angle 0}{\sqrt{3}} = 1386\angle 0\ V \quad \boldsymbol{I_\phi} = \dfrac{S_\phi\,*}{V_\phi} = \dfrac{266.7\ x\,10^3\angle 36.9}{1386\angle 0} = 192.5\underline{/36.9}$ A

$\boldsymbol{Z_Y} = \dfrac{V_\phi}{I_\phi}$ so $|Z_Y| = \dfrac{1386}{192.5}$ = 7.2 Ω/ph and $\boxed{\boldsymbol{Z_Y} = 7.2\underline{/-36.9} = 5.76 - j4.32\ \Omega/\text{ph}}$

c) $\boldsymbol{Z_\Delta} = 3\boldsymbol{Z_Y} \quad \therefore \quad \boxed{\boldsymbol{Z_\Delta} = 21.6\underline{/-36.9} = 17.28 - j12.96\ \Omega/\text{ph}}$

2.4 A 3ϕ load consists of a 150 hp motor operating at a power factor of 0.85 lagging with 93¼% efficiency. It is fed from a 440 V, 60 Hz supply. In parallel with this load is a 3ϕ capacitor bank that draws 50 kVAR. Find:

(a) Current in the load, the current in the capacitor bank, and total line current.

(b) Resultant power factor.

(1 hp = 746 W)

a) $P_{mech} = 150 \times 746 = 111.9$ kW so $P_{elec} = \dfrac{P_{mech}}{\eta} = \dfrac{111.9}{0.9325} = 120$ kW

$P_L = 120$ kW, $V_L = 440$ V, $PF_L = 0.85$ lagging

$Q_c = 50$ kVAR

$$\mathbf{I}_L = \frac{120{,}000 \angle -\cos^{-1} 0.85}{\sqrt{3}\,(440)(0.85)} = 185.2 \angle -31.8^\circ \text{ A}$$

$$\mathbf{I}_c = \frac{50{,}000}{\sqrt{3}\,(440)} \angle 90^\circ = 65.6 \angle 90^\circ \text{ A}$$

$$\mathbf{I}_T = \mathbf{I}_L + \mathbf{I}_c = 185.2 \angle -31.8^\circ + 65.6 \angle 90^\circ = 160.6 \angle -11.49^\circ$$

b) $PF = \cos(11.49^\circ) = 0.98$ lagging

2.5 A three-phase motor load draws 30.4 kVAR with a pf of 0.65 lag, 230 V, 60 Hz. A capacitor bank is placed across the terminals to make the combined power factor 0.95 lagging.

(a) Determine the required kVAR rating of the capacitor bank.

(b) Determine the line current before and after the capacitors are added.

pf = 0.65 lag $\therefore$ rf = 0.7599 and $S_M = \frac{Q}{rf} = \frac{30.4}{0.7599} = 40\ kVA$

$S_M = 40\ kVA,\quad V_M = 230\ V,\quad PF_M = 0.65$ lagging

$P_M = 40(0.65) = 26\ kW$

$\theta_M = \cos^{-1} 0.65 = 49.46°$

$Q_M = P_M \tan\theta_M = 26 \tan 49.46° = 30.4\ kVAR$

$PF_{new} = 0.95$

$\theta_{new} = \cos^{-1} 0.95 = 18.19°$

$Q_{new} = P_M \tan\theta_{new} = 8.54\ kVAR = Q_M + Q_C$

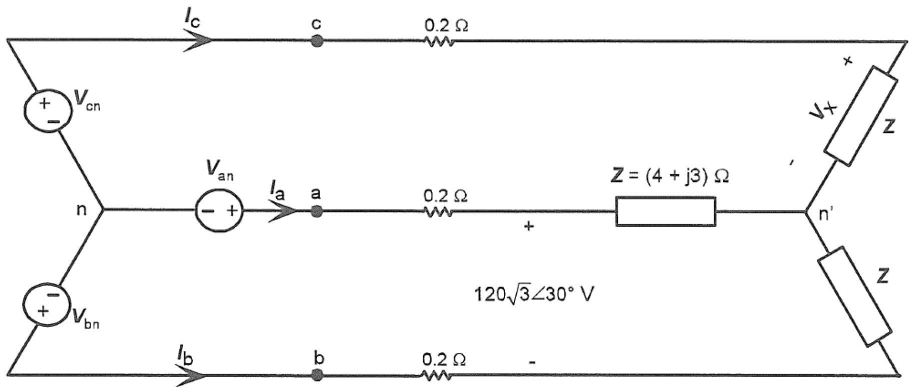
$\therefore\ Q_C = Q_{new} - Q_M = 8.54 - 30.4 = -21.86\ kVAR$

$I_{before} = \frac{40{,}000}{\sqrt{3}(230)} \angle -\cos^{-1} 0.65 = 100 \angle -49.46°$

$I_{after} = \frac{26{,}000}{\sqrt{3}(230)(0.95)} \angle -\cos^{-1} 0.95 = 68.7 \angle -18.19°$

2.6 Complete the Concept Quiz at the end of Chapter 2 in the course notes. Assume the systems are balanced and have positive sequence.

The diagram below is used for the next five questions.



1) T/F The magnitude of I_a is $24\sqrt{3}$ A F (= 24A)

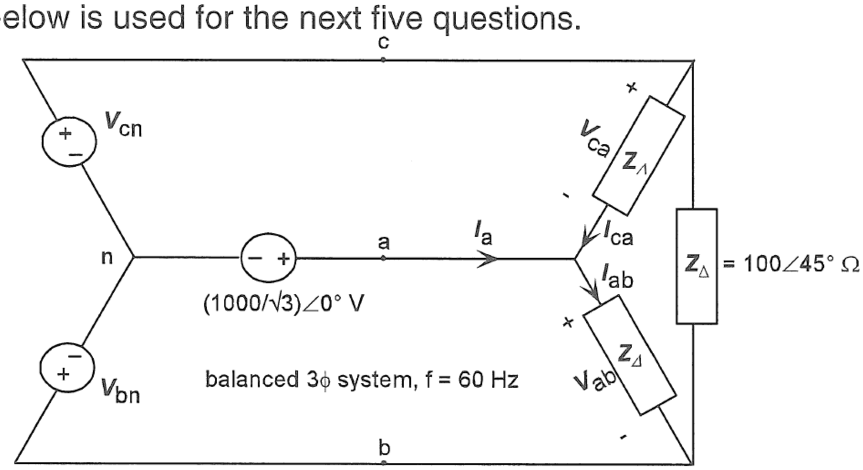
2) T/F The power delivered to the load is 2304 W. F (= 3× 2304 W)

3) T/F $\%\eta = \left(\frac{4000}{42}\right)\%$ T

4) T/F $V_x = 120\angle 120°$ V T

5) T/F The power factor of the load is 0.8 leading. F (= 0.8 lag)

The diagram below is used for the next five questions.



6) T/F The instantaneous power delivered to the 3ϕ load is independent of time. T

7) T/F $V_{bn} = (1000/\sqrt{3})\angle -120°$ V and $V_{ab} = 1000\angle 30°$ V T

8) T/F $I_{ab} = 10\angle -45°$ A F (= 10∠-15)

9) T/F $v_{ca}(t) = 1000\sqrt{2}\cos(2\pi 60t + 150°)$ V T

10) T/F $P_{3\varphi} = 10\cos 45°$ KW F (= $\sqrt{3}$ 10 cos 45° kW)