Power System Analysis I

Midterm I

SOLUTIONS

P1 (10): Consider a single-phase load with an applied voltage of $v(t) = 400\sin(\omega t + 40°)$ Volts and a load current of $i(t) = 50\sin(\omega t + 20°)$ Amperes.

a) Find the real and reactive power absorbed by the load.

b) Find the power factor and specify whether it is lagging or leading.

$\bar{V} = \frac{400}{\sqrt{2}} \angle 40°$

$\bar{I} = \frac{50}{\sqrt{2}} \angle 20°$

(a) $\bar{S} = \bar{V}\bar{I}^* = \frac{400}{\sqrt{2}} \cdot \frac{50}{\sqrt{2}} \angle 40-20° = 10000 \angle 20°$

Real power $P = 9396.93$ W (3)

Reactive power $Q = 3420.20$ W (2)

(b) $pf = \cos(20) = 0.94$ (3)

$\delta - \beta = 40 - 20 = 20 > 0$

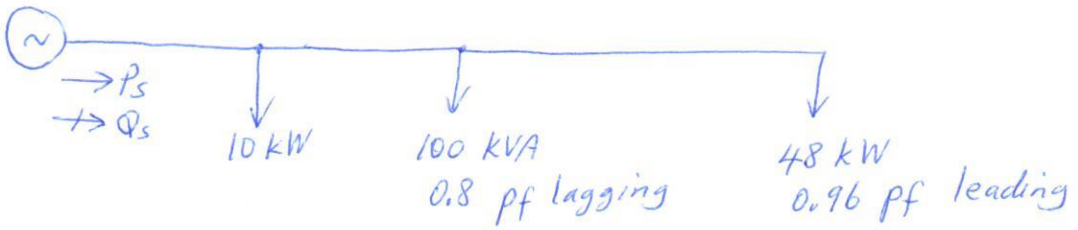
power factor is lagging (2)

P2 (40): A source delivers power to an industrial load consists of the following three loads connected in parallel: (1) a heater load drawing 10 kW, (2) an induction motor drawing 100 kVA at 0.8 power factor lagging, and (3) a synchronous motor drawing 48 kW at 0.96 power factor leading.

a) Determine the real, reactive, and apparent power delivered by the source. Also, draw the source power triangle.

b) Find the minimum value of capacitance of the shunt capacitor bank in μF that is needed to satisfy the reactive power regulation requirements set forth in Turkey. Assume that the source voltage and frequency are constant and equal to 220 V and 50 Hz, respectively.

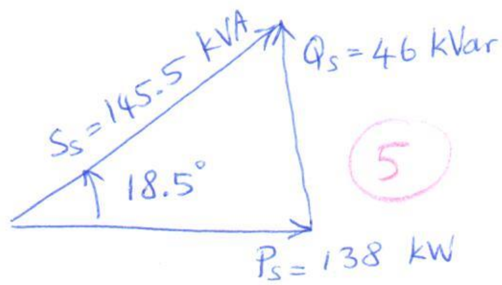
c) Draw the power triangle after the power factor correction and determine the new source power factor.



(a) $P_s = 10 + 100(0.8) + 48 = 138$ kW (5)

$Q_s = 60 - 14 = 46$ kVar (5)

$S_s = 145.5$ kVA (5)



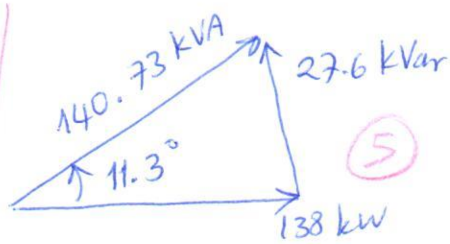
(5)

(b) $Q_{s\,max} = 0.2 \times 138 = 27.6$ kVar

$Q_{C\,min} = 46 - 27.6 = 18.4$ kVar

$C_{min} = \frac{18400}{(2\pi 50)(220)^2} = 1.21$ mF $= 1210$ μF (15)

c)



(5)

$pf = 0.98$

P3 (40): Two three-phase generators supply a three-phase load through separate three-phase lines. The load absorbs 50 kW at 0.8 power factor lagging. The line impedance is $(1.5 + j2)\ \Omega$ per phase between generator G1 and the load, and $(1 + j1.2)\ \Omega$ per phase between generator G2 and the load. If generator G2 supplies 20 kW at 0.8 power factor lagging, with a terminal voltage of 500 V line-to-line, determine

a) The voltage at the load terminals

b) The voltage at the terminals of generator G1,

c) And the real and reactive power supplied by generator G1.

Assume balanced operation.

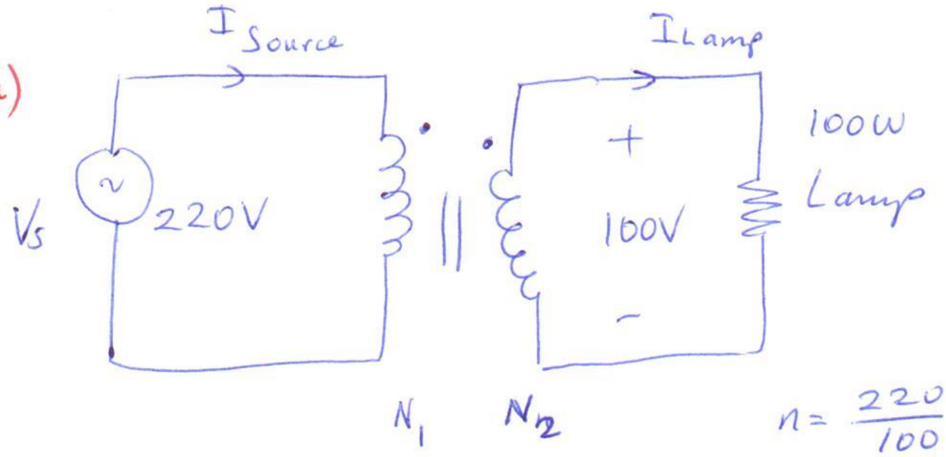
The solution is at the next page.

P4 (10): A 100 V 100 W lamp is going to be operated on 220 V 50 Hz AC supply. Normally this operation is not possible. Nevertheless, it can be possible after addition of a component to the circuit. There are two possible ways to make the lamp operable on 220 V supply.

a) Suggest one of the ways.

b) Based on your solution method. Find the current supplied by the source.

a)

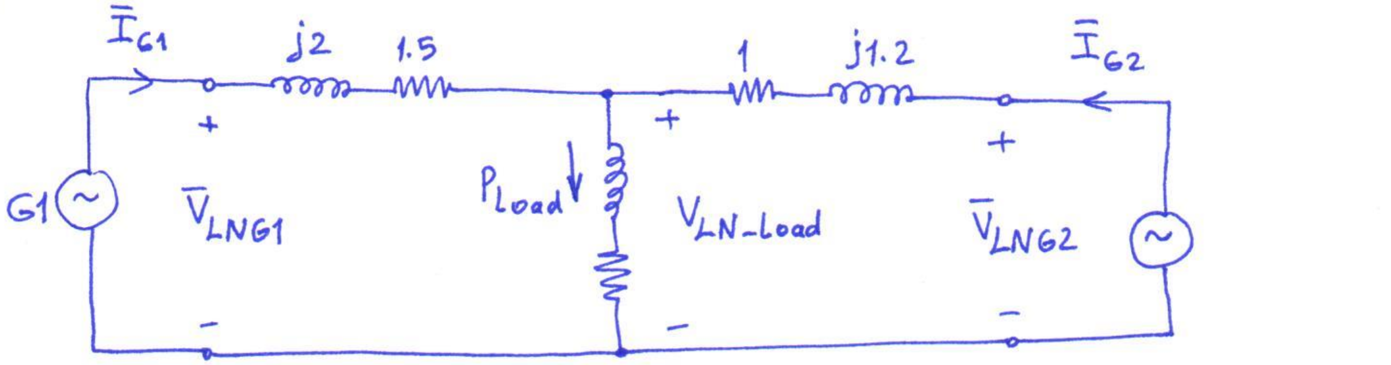


$n = \frac{220}{100} = 2.2$

We can use a transformer to prodive the proper interface. Transformer turns ratio is selected as 2.2 so that the voltage across the lamp is 100 V.

b) $I_{Lamp} = \frac{100}{100} = 1\ A$

$I_{source} = \frac{1}{2.2} = 0.4545\ A$



$P_{Load} = 50$ kW
0.8 lagging

$P_{G2} = 20$ kW
0.8 pf lagging

a) $\bar{I}_{G2} = \dfrac{20000}{\sqrt{3}(500)(0.8)} \angle -36.87^\circ = \boxed{28.87 \angle -36.87^\circ \text{ A}}$ (5)

$\bar{V}_{LN-Load} = \dfrac{500}{\sqrt{3}} \angle 0^\circ - (28.87 \angle -36.87^\circ)(1 + j1.2)$

$= 288.7 - 43.88 - j10.4 = 244.82 - j10.4$

$\boxed{\bar{V}_{LN-load} = 245 \angle -2.43^\circ}$ (5)

b) $\bar{I}_{Load} = \dfrac{50000}{3(245)(0.8)} \angle -2.43^\circ - 36.87^\circ = \boxed{85 \angle -39.3^\circ \text{ A}}$ (5)

$\bar{I}_{G1} = \bar{I}_{Load} - \bar{I}_{G2} = 85 \angle -39.3 - 28.87 \angle -36.87^\circ$

$\boxed{\bar{I}_{G1} = 56.17 \angle -40.55^\circ \text{ A}}$ (5)

$\bar{V}_{G1-LN} = 245 \angle -2.43^\circ + (56.17 \angle -40.55)(1.5 + j2)$

$\boxed{= 382.4 \angle 3.03^\circ \text{ V}}$ (10)

c) $P_{G1} = 3(382.4)(56.17)\cos(3.03 + 40.55^\circ)$

$\boxed{= 46679.9 \text{ Watt}}$ (7)

$Q_{G1} = 3(382.4)(56.17)\sin(43.58)$

$\boxed{= 44421.6 \text{ Var}}$ (3)