ECE370 POWER & ENERGY SYSTEMS
Homework Set 1 - Solutions

1.1 Given the complex numbers $\boldsymbol{A_1} = 8 + j6$ and $\boldsymbol{A_2} = 10\underline{/53.1^0}$ calculate the following, giving the answers in both rectangular and polar form.

a) $\boldsymbol{A_1} + \boldsymbol{A_2}$
b) $\boldsymbol{A_1}\,\boldsymbol{A_2}$
c) $\boldsymbol{A_1} / (\boldsymbol{A_2})^*$
d) $(\boldsymbol{A_2})^2$
e) $[100 + (\boldsymbol{A_2})^2]/(\boldsymbol{A_1})^*$

a) $\boldsymbol{A_1} + \boldsymbol{A_2} = (8 + j6) + (6 + j8) = 14 + j14 = 14\sqrt{2}\angle 45$

b) $\boldsymbol{A_1}\,\boldsymbol{A_2} = 10\angle 36.9 \times 10\angle 53.1 = 100\angle 90 = j100$

c) $\boldsymbol{A_1} / (\boldsymbol{A_2})^* = 1\angle 90 = j$

d) $(\boldsymbol{A_2})^2 = 100\angle 106.2 = -28 + j96$

e) $[100 + (\boldsymbol{A_2})^2]/(\boldsymbol{A_1})^* = [100 + 100\angle 106.2]/10\angle -36.9 = 12\angle 90 = j12$

1.2

a) A 12-pole generator is to be connected to a 50 Hz power grid. Compute the speed of its turbine.
b) An 8-pole generator is to be connected to a 60 Hz power grid. Compute the speed of its turbine.

From the notes: $f = \frac{p}{120} n_s$ Hz, or: $n_s = \frac{120f}{p}$

a) $n_s = \frac{120 \; x \; 50}{12} = 500 \; rpm$

b) $n_s = \frac{120 \; x \; 60}{8} = 900 \; rpm$

1.3 An industrial plant consists of several induction motors. The plant's power factor is 0.6 lagging (rf = 0.8) and it absorbs 400 kVAR from the substation bus.

a) Compute the required kVAR rating of the capacitor connected across the load to raise the pf to 0.9 lagging.

b) A 200 hp, 90% efficiency synchronous motor with a pf of 0.8 lead is connected to the same bus after the pf has been corrected. Calculate the resulting pf. (1 hp = 746 W).

a) $P_L = Q_L \frac{pf}{rf} = 400 \frac{0.6}{0.8} = 300\ kW$

$P_L = 300\ kW$, $PF = 0.6$ lagging, $\theta = \cos^{-1} 0.6 = 53.1°$

$Q_L = P_L \tan\theta = 300 \tan 53.1° = 400\ KVAR$

$Q_{new} = P_L \tan\theta_{new} = 300 \tan(\cos^{-1} 0.9) = 145.3\ KVAR$

$Q_{cap} = Q_{new} - Q_L = 145.3 - 400 = -254.7\ KVAR$

b)

$P_M' = 200\ hp$, $\eta = 90\%$, $PF = 0.8$ leading, $\theta_M = \cos^{-1} 0.8 = 36.9°$

$P_M = \frac{200 \times 0.746}{0.90} = 165.8\ KW$

$Q_M = P_M \tan\theta_M = 165.8 \tan 36.9° = -124.35\ KVAR$

$P_T = P_L + P_M = 300 + 165.8 = 465.8\ KW$

$Q_T = Q_L + Q_{cap} + Q_M = 400 - 254.7 - 124.35 = 20.95$ kVAR

$\theta_T = \tan^{-1} \frac{Q_T}{P_T} = \tan^{-1} \frac{20.95}{465.8} = 2.6^0$ $\quad \therefore \quad pf_T = \cos(2.6) =$ **0.999 lag**

1.4 Concept Quiz

1.1. What is the function of a power plant turbine?
To convert thermal energy (or hydro kinetic energy) into rotating mechanical energy to drive a generator.

1.2. What is the function of a power plant generator?
To convert the rotating mechanical energy into electrical energy.

1.3. What is the function of the hydro dam?
To increase the potential energy of the water behind the dam.

1.4. Why are transformers used with transmission lines?
To reduce losses by reducing current (also reduces the wire size)

1.5. A 2-pole generator is to be connected to a 60 Hz power grid. Compute the speed of its turbine.
3600 rpm.

1.6. A 2-pole generator is to be connected to a 50 Hz grid. Compute the speed of its turbine.
3000 rpm.

1.7. Why are insulators used on power line towers?
To prevent the conductors from touching the tower.

1.8. Why are tower insulators built as disk shapes?
To increase the flashover distance between conductor & tower.

1.9. Why is the frequency of the airplane power system 400 Hz?
To reduce the size of magnetic components.

1.10. Why are there different voltage and frequency standards worldwide?
Different safety concerns, also competition inhibited collaboration.

1.11. Why are the transmission line towers higher than the distribution line towers?
Higher voltages.

1.12. What are the various forces that an insulator must withstand?
Wind storms, freezing rain, earth movement.