Homework Set #19

DUE Monday, April 30, 2012

1. Problem 11.10 (9.10 in abridged version) *(V_{AN} = 262.79∠-2.17 °V)*

[a] $\mathbf{I}_{aA} = \frac{277\angle 0^\circ}{80 + j60} = 2.77\angle -36.87^\circ$ A (rms)

$\mathbf{I}_{bB} = \frac{277\angle -120^\circ}{80 + j60} = 2.77\angle -156.87^\circ$ A (rms)

$\mathbf{I}_{cC} = \frac{277\angle 120^\circ}{80 + j60} = 2.77\angle 83.13^\circ$ A (rms)

$\mathbf{I}_o = \mathbf{I}_{aA} + \mathbf{I}_{bB} + \mathbf{I}_{cC} = 0$

[b] $\mathbf{V}_{AN} = (78 + j54)\mathbf{I}_{aA} = 262.79\angle -2.17^\circ$ V (rms)

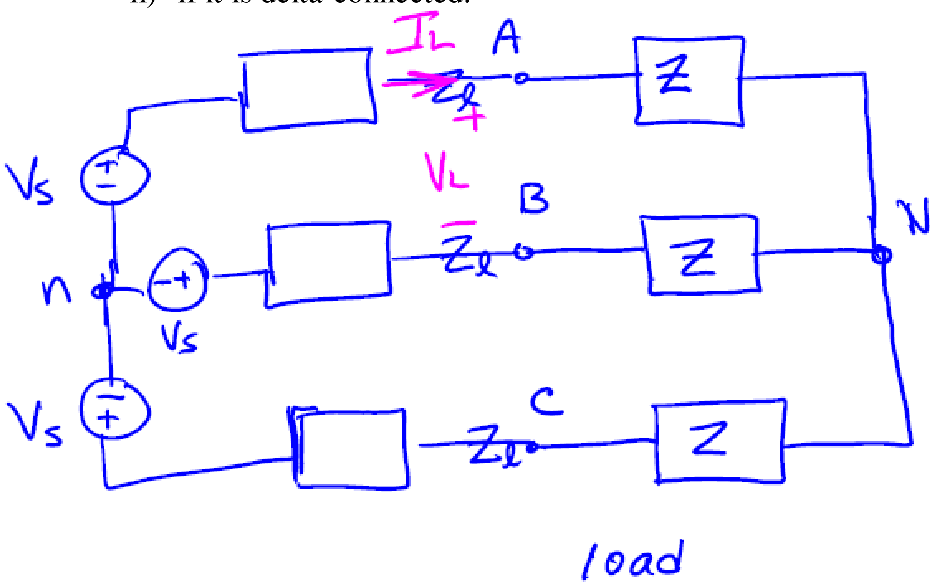
[c] $\mathbf{V}_{AB} = \mathbf{V}_{AN} - \mathbf{V}_{BN}$

$\mathbf{V}_{BN} = (77 + j56)\mathbf{I}_{bB} = 263.73\angle -120.84^\circ$ V (rms)

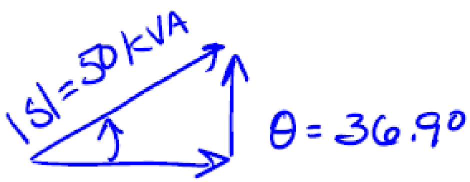
$\mathbf{V}_{AB} = 262.79\angle -2.17^\circ - 263.73\angle -120.84^\circ = 452.89\angle 28.55^\circ$ V (rms)

[d] Unbalanced — see conditions for a balanced circuit on p. 504 of the text!

2. A three-phase, 50 kVA, 600V, 60Hz generator operates at rated terminal voltage and supplies a ***line current*** of 48 A at a 0.8 lagging power factor to a balanced three-phase load.
   a. Determine the real, reactive, and apparent power taken by the load.
   b. Determine the impedance (Ω/ph) of the load:
      i) if it is wye-connected,
      ii) if it is delta-connected.



Generator power



$P = |S| \cos\theta$

$P = (50\,k)(0.8) = 40\,kW$

$Q = \sqrt{50^2 - 40^2} = 30\,kVAR$

$|S| = 50\,kVA$

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

For wye-connection:

$V_L = 600\angle 0^\circ \quad V \quad \Rightarrow V_{AN} = \frac{600}{\sqrt{3}}\angle 0^\circ \ V$

$I_L = 48\angle -36.9^\circ \ A \quad \Rightarrow I_A = 48\angle -36.9^\circ \ A$

$$Z = \frac{V_{AN}}{I_A} = \frac{600/\sqrt{3}}{48\angle -36.9^\circ}$$

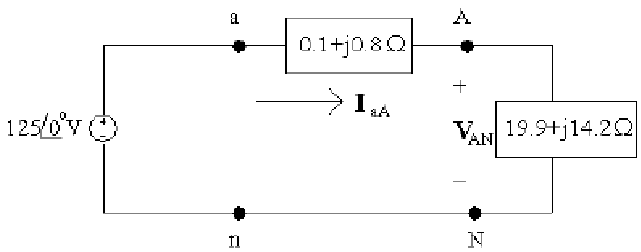
$$\boxed{Z = 7.217\angle 36.9^\circ \ \Omega/ph}$$

For delta-connection: $Z_\Delta = 3 \times Z_Y$

$$\boxed{Z_\Delta = 21.65\underline{/36.9} \ \ \Omega/ph}$$

3. Problem 11.11 (9.11 in abridged version).

Make a sketch of the a-phase:



[a] Find the a-phase line current from the a-phase circuit:

$$\mathbf{I}_{aA} = \frac{125\underline{/0^\circ}}{0.1 + j0.8 + 19.9 + j14.2} = \frac{125\underline{/0^\circ}}{20 + j15}$$

$$= 4 - j3 = 5\underline{/-36.87^\circ}\text{ A (rms)}$$

Find the other line currents using the acb phase sequence:

$$\mathbf{I}_{bB} = 5\underline{/-36.87^\circ + 120^\circ} = 5\underline{/83.13^\circ}\text{ A (rms)}$$

$$\mathbf{I}_{cC} = 5\underline{/-36.87^\circ - 120^\circ} = 5\underline{/-156.87^\circ}\text{ A (rms)}$$

[b] The phase voltage at the source is $\mathbf{V}_{an} = 125\underline{/0^\circ}$ V. Use Fig. 11.9(b) to find the line voltage, $\mathbf{V}_{an}$, from the phase voltage:

$$\mathbf{V}_{ab} = \mathbf{V}_{an}(\sqrt{3}\underline{/-30^\circ}) = 216.51\underline{/-30^\circ}\text{ V (rms)}$$

Find the other line voltages using the acb phase sequence:

$$\mathbf{V}_{bc} = 216.51\underline{/-30^\circ + 120^\circ} = 216.51\underline{/90^\circ}\text{ V (rms)}$$

$$\mathbf{V}_{ca} = 216.51\underline{/-30^\circ - 120^\circ} = 216.51\underline{/-150^\circ}\text{ V (rms)}$$

[c] The phase voltage at the load in the a-phase is $\mathbf{V}_{AN}$. Calculate its value using $\mathbf{I}_{aA}$ and the load impedance:

$$\mathbf{V}_{AN} = \mathbf{I}_{aA}Z_L = (4 - j3)(19.9 + j14.2) = 122.2 - j2.9 = 122.23\underline{/-1.36^\circ}\text{ V (rms)}$$

Find the phase voltage at the load for the b- and c-phases using the acb sequence:

$$\mathbf{V}_{BN} = 122.23\underline{/-1.36^\circ + 120^\circ} = 122.23\underline{/118.64^\circ}\text{ V (rms)}$$

$$\mathbf{V}_{CN} = 122.23\underline{/-1.36^\circ - 120^\circ} = 122.23\underline{/-121.36^\circ}\text{ V (rms)}$$

[d] The line voltage at the load in the a-phase is $\mathbf{V}_{AB}$. Find this line voltage from the phase voltage at the load in the a-phase, $\mathbf{V}_{AN}$, using Fig, 11.9(b):

$$\mathbf{V}_{AB} = \mathbf{V}_{AN}(\sqrt{3}\underline{/-30^\circ}) = 211.72\underline{/-31.36^\circ}\text{ V (rms)}$$

Find the line voltage at the load for the b- and c-phases using the acb sequence:

$$\mathbf{V}_{BC} = 211.72\underline{/-31.36^\circ + 120^\circ} = 211.72\underline{/88.64^\circ}\text{ V (rms)}$$

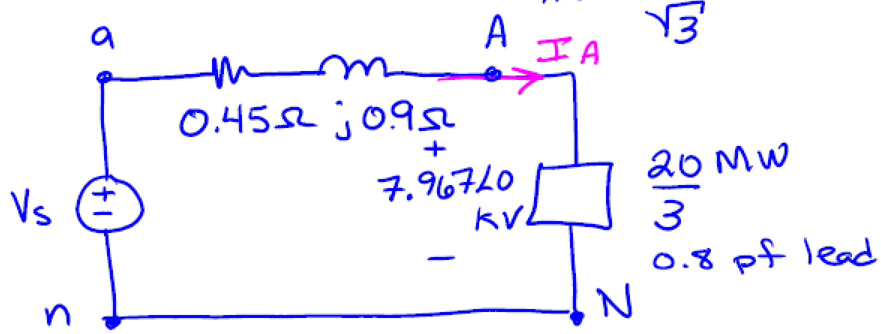
$$\mathbf{V}_{CA} = 211.72\underline{/-31.36^\circ - 120^\circ} = 211.72\underline{/-151.36^\circ}\text{ V (rms)}$$

4. A 3ϕ load, supplied with 13.8kV at the load end, absorbs 20MW at 0.8 pf leading. The feeder impedance is 0.45 + j0.9 Ω/ϕ (Ohms per phase).
   a. Draw the single-phase equivalent circuit.
   b. Find the line current.
   c. What is the percent voltage regulation (%VR)?
   d. Is the value obtained in part (c) usually acceptable for general industrial power systems?
   e. What is the percent efficiency of transmission (%η)?

a) Single phase ckt

$V_L = 13.8$

$V_{AN} = \frac{13.8}{\sqrt{3}} \angle 0°$



b) $S = VI^*$ $\quad P = VI\cos\theta$

$$I = \frac{P}{V\cos\theta} = \frac{P}{V\,pf} = \frac{\frac{20}{3}(10^6)}{(0.8)(7.967\angle 0°)(10^3)}$$

$$\boxed{I = 1046 \angle 36.9° \text{ A}}$$

c) $V_s = I(0.45 + j0.9) + 7.967\angle 0°$

$V_s = 7848 \angle 7.6 V$

$$V_R = \frac{V_s - V_{Load}}{V_{load}} = \frac{7848 - 7967}{7967}$$

$$\boxed{V_R = -1.5\%}$$

acceptible if magnitude of VR < 5%

neg VR if pf is leading

e) $S_s = V_s I^*$

$S_s = 8.21 \angle 29.3^\circ = 7.159 - j4.015$ MVA/ph

$P_s = 7.159$ mW/ph

$P_{Load} = 6.667$ mW/ph

$$\eta = \frac{6.667}{7.159} \times 100\%$$

$$\boxed{\eta = 93.12\%}$$