Power System Analysis I **Midterm II** **Fall** **09.12.2011**

SOLUTIONS

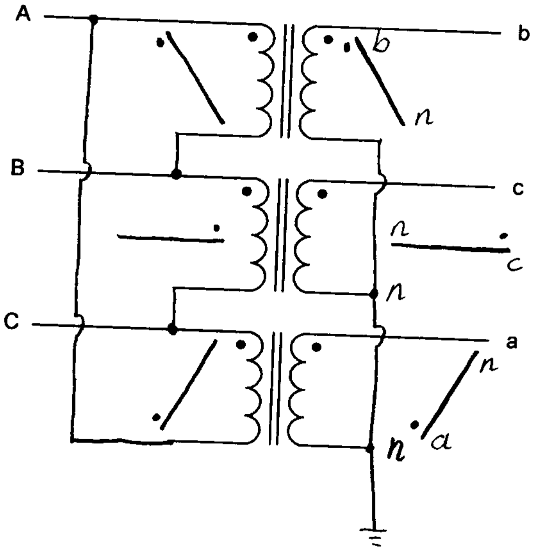
P1 (30): The following schematic shows three identical single-phase two-winding transformers. Using these single-phase transformers, we want to construct a three-phase transformer bank. Assume positive-sequence balanced three-phase system.

(5) **a)** Connect the high-voltage side as delta (Δ) and the low-voltage side as solidly grounded wye (Y).

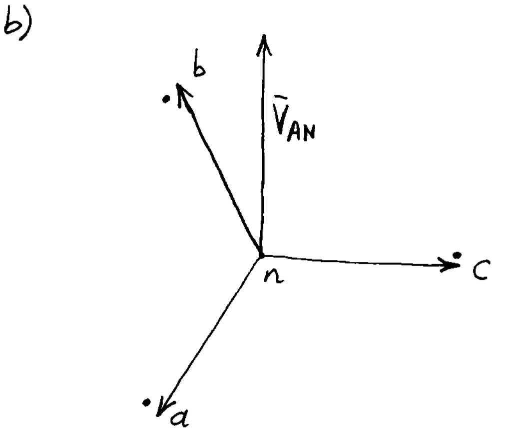
(15) **b)** Assume that the phasor voltages shown below are applied to the high-voltage side windings, draw the phasor voltage diagram for the low-voltage side and find the phase shift between $\bar{V}_{AN}$ and $\bar{V}_{an}$.

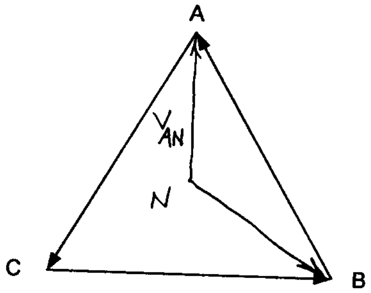
(10) **c)** For the same given input voltages, modify the low-voltage terminal connections and labeling so that $\bar{V}_{an}$ lags $\bar{V}_{AN}$ by 90°.

a)



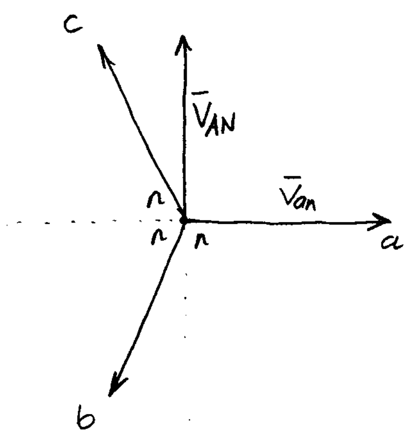
b)

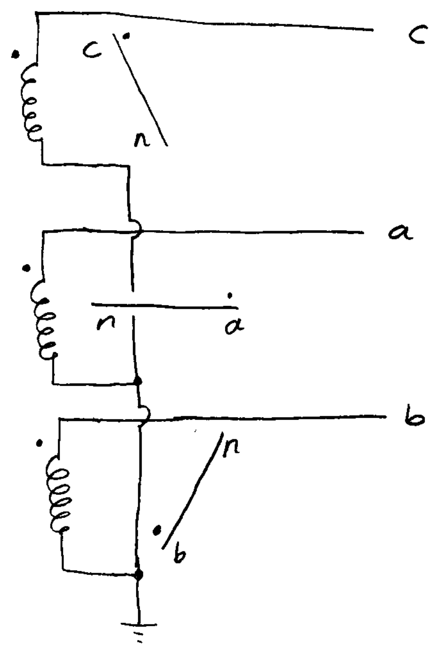




$\bar{V}_{AN}$ lags $\bar{V}_{an}$ by 150°.

c)

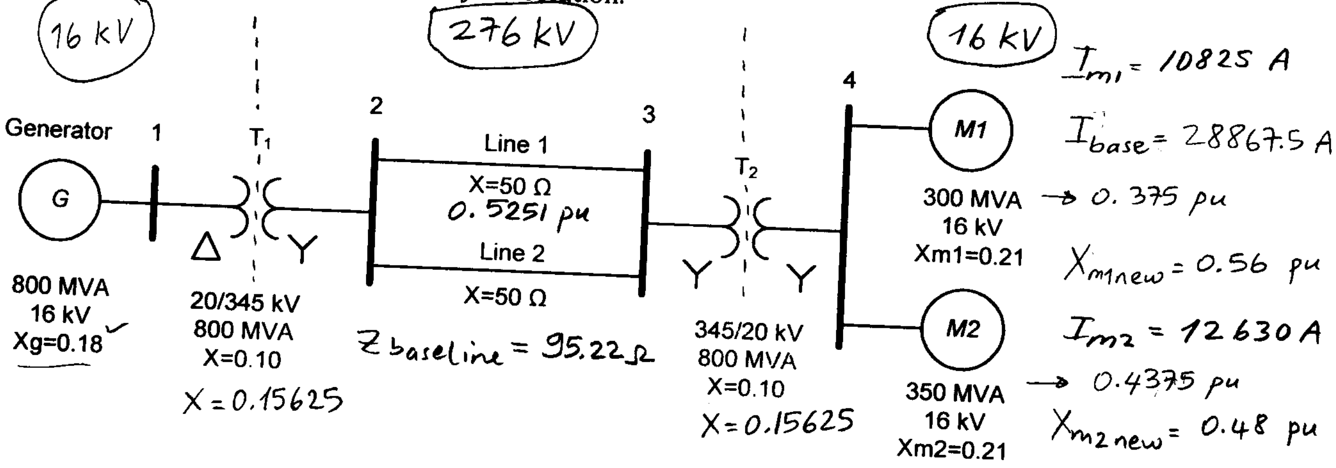




P2 (35): The figure below shows the one-line diagram of a three-phase power system.

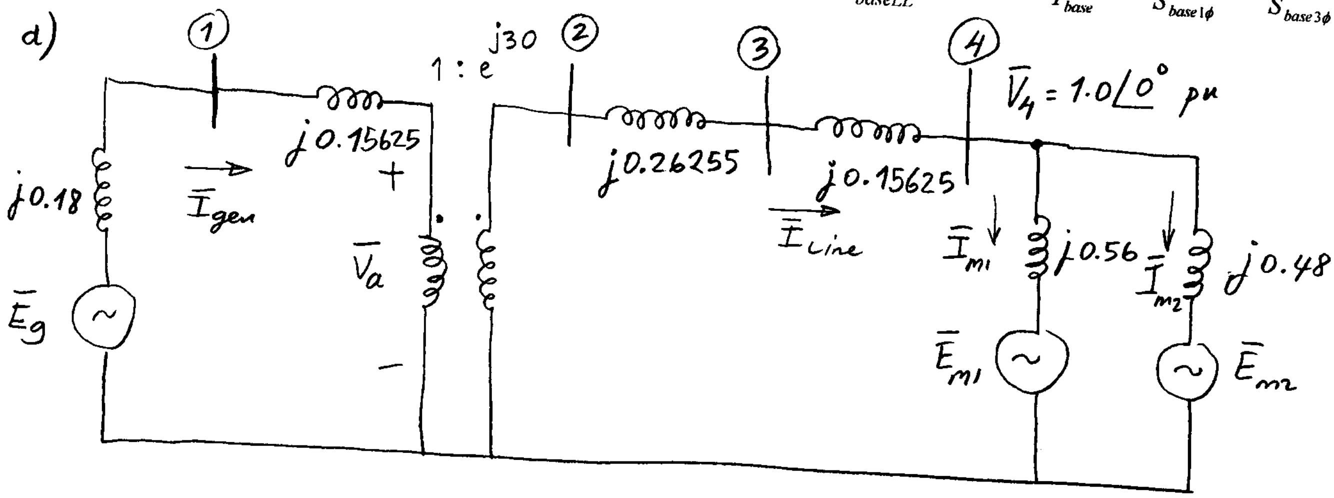
20 **a)** Draw the per-unit impedance diagram of the system including the transformer phase shifts. Use the ratings of the generator as the base values.

15 **b)** The motors are drawing their rated powers from the system at the unity power factor with the bus 4 voltage is at 16 kV. Determine the voltage at bus 1 and the current supplied by the generator. Include the phase shifts of the transformers in your solution.



$$Z_{new} = Z_{old}\left(\frac{V_{baseold}}{V_{basenew}}\right)^2\left(\frac{S_{basenew}}{S_{baseold}}\right) \qquad I_{base} = \frac{S_{base1\phi}}{V_{baseLN}} = \frac{S_{base3\phi}}{\sqrt{3}V_{baseLL}} \qquad Z_{base} = \frac{V_{baseLN}}{I_{base}} = \frac{V^2_{baseLN}}{S_{base1\phi}} = \frac{V^2_{baseLL}}{S_{base3\phi}}$$

d)



b)

$$\left.\begin{array}{l}\bar{I}_{m1} = 0.375 \text{ pu} \\ \bar{I}_{m2} = 0.4375 \text{ pu}\end{array}\right\} \quad \bar{I}_{line} = 0.8125 \text{ pu}$$

first find the voltage at bus 2

$$\bar{V}_2 = 1.0 + (0.8125)(0.4188\angle 90^\circ) = 1.0563\angle 18.792^\circ$$

5

$$\bar{V}_a = \bar{V}_2\angle -30^\circ = 1.0563\angle -11.208^\circ$$

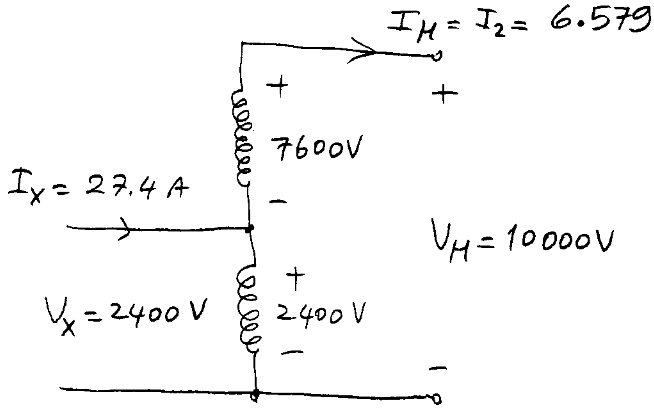
Also $\bar{I}_{gen} = \bar{I}_{line}\angle -30^\circ = 0.8125\angle -30^\circ$ pu

$$\bar{V}_1 = 1.0563\angle -11.208^\circ + (0.8125\angle -30^\circ)(0.15625\angle 90^\circ) = 1.104\angle -4.96^\circ$$

$\bar{I}_{gen} = 0.8125\angle -30^\circ$ pu 5

$\bar{V}_1 = 1.104\angle -4.96^\circ$ 5

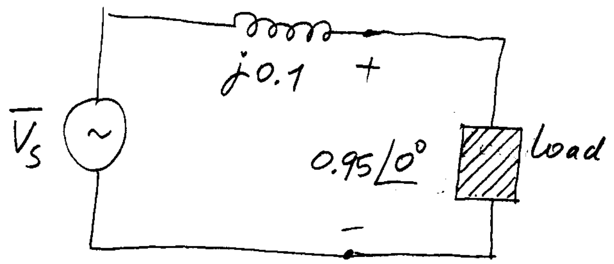
P3 (15): A single-phase 50 kVA and 2400/7600 V two-winding transformer is to be connected as a step-up autotransformer. **a)** Determine the voltage and power rating as an autotransformer, and **b)** Draw the circuit schematic of the autotransformer.



$S_H = 10000 \times 6.579$
$= 65790$ VA

$$\boxed{\begin{array}{c} 2400/10000\text{ V} \\ 65790\text{ VA} \end{array}}$$

P4 (10): A step-down three-phase transformer connected between an ideal voltage source and a three-phase load supplies 1.2 pu reactive power to the load at 0.95 pu voltage and 0.8 lagging power factor. Find the source voltage in pu. The transformer windings are Y / Y connected and it has 0.10 pu leakage reactance.



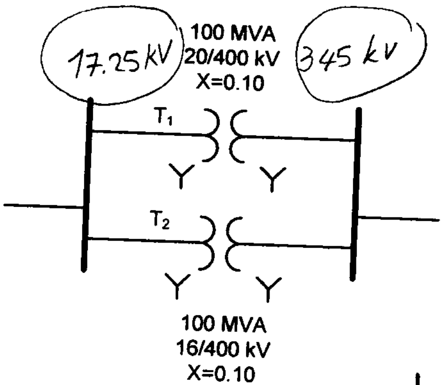
$$\bar{I}_{Load} = \frac{1.2}{0.95\,(0.6)} \angle -\cos^{-1}(0.8)$$

$$\bar{I}_{Load} = 2.1053 \angle -36.87^\circ \text{ pu}$$

$$\bar{V}_S = 0.95 + (2.1053\angle -36.87^\circ)(0.1\angle 90^\circ)$$

$$\bar{V}_S = 1.0894 \angle 8.89^\circ \text{ pu}$$

P5 (10): Draw the per-unit reactance diagram of the parallel connected transformers given below. Assume 100 MVA and 345 kV base at the high voltage side.



For T_1 $\quad a_t = b = 20$

For T_2 $\quad a_t = \frac{400}{16} = 25$

assume $b = 20$

so $\quad c = \frac{a_t}{b} = \frac{25}{20} = 1.25$