Eskisehir Osmangazi University, Electrical and Electronics Eng. Department

Power System Analysis I   Midterm I   20.10.2011

Instructor: Ass. Prof. Dr. Bunyamin Tamyurek   SOLUTIONS

No notes are allowed in the exam. Exam duration is 70 minutes.

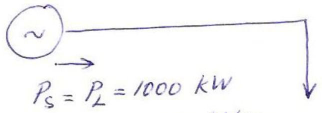
P1 (50): An industrial plant consisting primarily of induction motor loads absorbs 1000 kW at 0.7 power factor lagging.

a) First, a shunt capacitor is connected to the system to improve the power factor. Compute the required kVA rating of this shunt capacitor to raise the source power factor to 0.9 lagging.
b) Draw the power triangle for this case.
c) Later, a synchronous motor rated 1000 hp with 90% efficiency operating at rated load and 0.96 power factor leading is added to the plant. Compute the resulting power factor at the source after the synchronous motor is added. Assume that the source voltage is constant and the shunt capacitor is still connected to the system. (1 hp = 0.746 kW)
d) Draw the power triangle for the second case.

P2 (50): A balanced three-phase, 60 Hz, positive sequence Y-connected synchronous generator has an internal impedance of 0.25+j0.5 Ω/phase. The voltage at the terminals of the generator is given as $\bar{V}_{ca} = 381\angle 160°$. The generator feeds two balanced three-phase loads that are connected in parallel through a distribution line having an impedance of 0.3+j2.0 Ω/phase. One of the loads is Y-connected with an impedance of 30+j20 Ω/phase. The other load is Δ-connected with an impedance of 75-j15 Ω/phase.

a) Calculate the line currents at the generator terminals.
b) Calculate the real and reactive power delivered by the generator.
c) Calculate the line-to-line voltages at the load terminals.
d) Calculate the current per phase in each load.
e) Calculate the total real and reactive powers absorbed by each load and the line.
f) Check that the total complex power delivered by the generator equals to the total complex power absorbed by the line and loads.
g) Calculate the efficiency of the generator

Solution to Problem 1:



$\overrightarrow{P_S} = P_L = 1000$ kW $P_L = 1000$ kW   0.7 lagging power factor

$\overrightarrow{Q_S} = 1020.2$ kVar $Q_L = 1020.2$ kVar

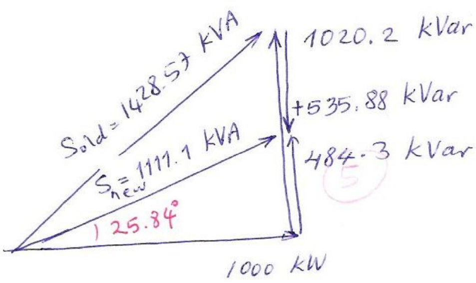
a) if a shunt capacitor is connected to the system,

$P_S = P_L = 1000$ kW

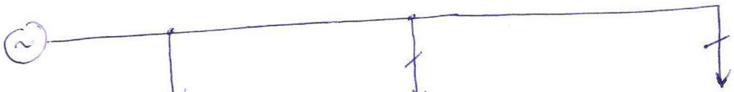
$Q_{snew} = 1000 \tan[\cos^{-1}(0.9)] = 484.3$ kVar

$Q_C = Q_{sold} - Q_{snew} = 1020.2 - 484.3 = 535.88$ kVar

$S_{new} = 1111.1$ kVA



b)



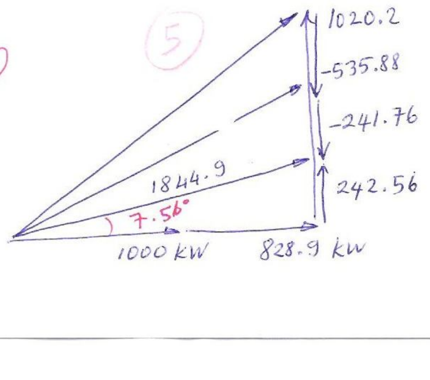
$Q_{motor} = 241.76$ kVar

$P_S = 1000 + 828.9 = 1828.9$ kW

$Q_S = 1020.2 - 535.88 - 241.76 = 242.56$ kVar

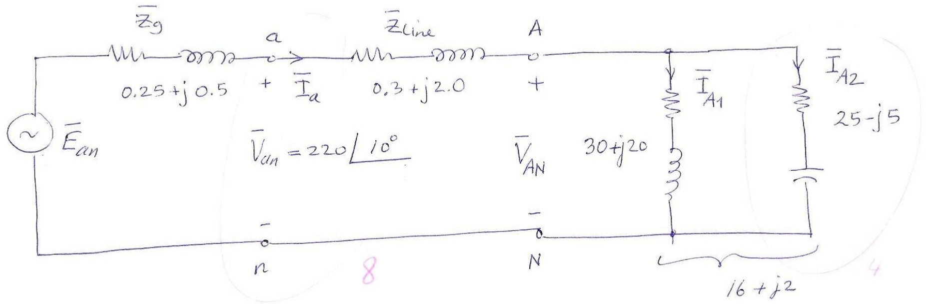
$S_S = 1844.9$ kVA

$$\text{power factor} = \frac{1828.9}{1844.9} = 0.9913$$



2)

Solution to Problem 2



$\bar{V}_{ca} = 381\angle 160°$

$\bar{V}_{ab} = 381\angle 40°$

$\bar{V}_{an} = 220\angle 10°$

a) $\bar{I}_a = \dfrac{220\angle 10°}{(16.3 + j4)} = \dfrac{220\angle 10°}{16.784\angle 13.79°} = 13.1\angle -3.8°$ (8)

$\bar{I}_b = 13.1\angle -123.8°$ A

$\bar{I}_c = 13.1\angle 116.2°$ A (2)

b) $\bar{V}_{an} = 220\angle 10°$ V

$\bar{I}_a = 13.1\angle -3.8°$ A

$P_{3\phi} = 3\,(220)\,(13.1)\cos(10 + 3.8) = 8396.4$ W

$Q_{3\phi} = 3\,(220)\,(13.1)\sin(13.8) = 2062.4$ Var

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c) $\bar{V}_{AN} = \bar{V}_{an} - \bar{I}_a \cdot \bar{Z}_{line}$

$\bar{V}_{AN} = 220\angle 10^\circ - (13.1\angle -3.8^\circ)(0.3 + j2)$

$\bar{V}_{AN} = 211.36\angle 3.342^\circ$ V

$\bar{V}_{AB} = 366.1\angle 33.342^\circ$ V 2

$\bar{V}_{BC} = 366.1\angle -86.66^\circ$ V 1

$\bar{V}_{CA} = 366.1\angle 153.342^\circ$ V 1

d) $\bar{I}_{A1} = \dfrac{\bar{V}_{AN}}{\bar{Z}_Y} = \dfrac{211.36\angle 3.342^\circ}{30+j20} = 5.862\angle -30.35^\circ$ A 2

$\bar{I}_{A2} = \dfrac{211.36\angle 3.342^\circ}{25-j5} = 8.29\angle 14.65^\circ$ A 2

$\bar{I}_{AB} = 4.786\angle 44.65^\circ$ A 1

e) $P_1 = 3(211.36)(5.862)\cos(3.342 + 30.35) = 3092.64$ W 1

$P_2 = 3(366.1)(4.786)\cos(33.342 - 44.65) = 5154.42$ W 1

$Q_1 = 2061.8$ Var 1 $\quad Q_{line} = 1029.66$ Var 1

$Q_2 = -1032$ Var 1 $\quad P_{line} = 154.45$ W 1

f) $P_{generator} = 8396.4 = 3092.64 + 5154.42 + 154.45$

$\stackrel{\checkmark}{=} 8401$ 1

$Q_{generator} = 2062.4 = 2061.8 - 1032 + 1029.66$

$\stackrel{\checkmark}{=} 2059.5$ 1

g)

$P_{output-generator} = 8396.4 \ W$

$P_{Loss-generator} = 3 \times (13.1)^2 (0.25) = 128.7 \ W$

$$\eta = \frac{8396.4}{8525.1} = 0.985$$

$\eta = 98.5\%$ 3

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