The Ohio State University
Department of Electrical Engineering

EE 341

Energy Conversion
Midterm

Print Your Name

_______________Solution_______________

The Last Four Digits of Your SSN:

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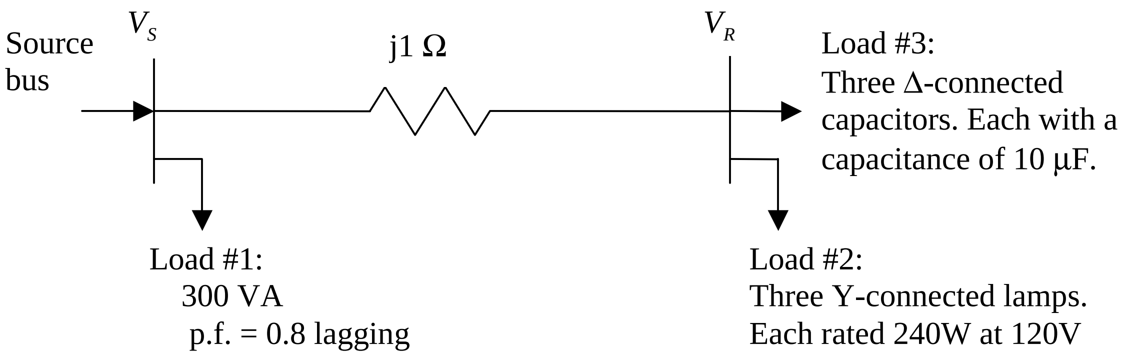
“No aid is given, received or observed”

Signature : _________________________________

Problem No.1: (30 points)

Consider a three-phase feeder shown below:



The Source bus voltage V_S is maintained at 240 V (line-to-line), 60 Hz. Compute the complex power supplied by the source and the power factor of the source.

Solution:

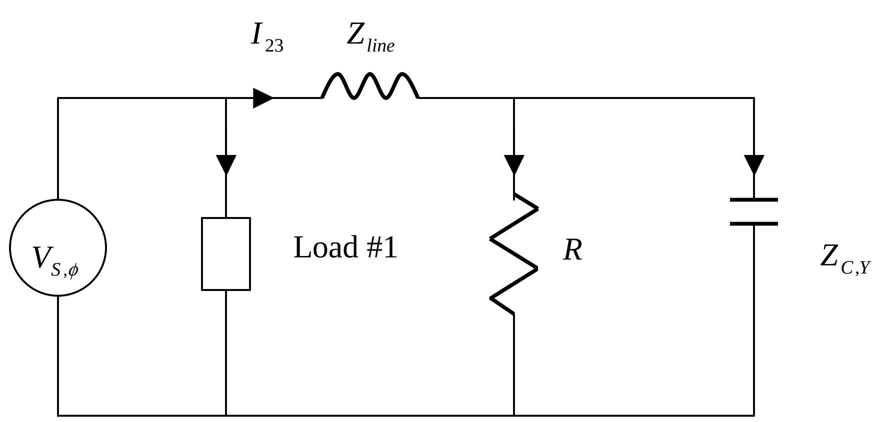
load 1: $S_1 = 300\angle\cos^{-1}(0.8) = 300\angle 36.87^o VA$

load 2: $R = \dfrac{V_{lamp}^2}{P_{lamp}} = \dfrac{120^2}{240} = 60\Omega$

load 3: $Z_{C,\Delta} = -j\dfrac{1}{\omega C} = -j\dfrac{1}{2\pi \times 60 \times 10e-6} = -j265.3\Omega$

$Z_{C,Y} = Z_{C,\Delta}/3 = -j88.4\Omega$

The single-phase equivalent circuit is shown as below:



$$V_{S,\phi} = \frac{240}{\sqrt{3}} = 138.56\angle 0^o V$$

The equivalent impedance of the line and load #2, #3 is

$$Z_{eq} = Z_{line} + R // Z_{C,Y} = j1 + \frac{(60)(-j88.4)}{60 - j88.4} = 41.08 - j26.88 = 49.09\angle -33.19^{o}\,\Omega$$

So the current I_{23} is

$$I_{23} = \frac{V_{S,\phi}}{Z_{eq}} = \frac{138.56\angle 0^{0}}{49.09\angle -33.19^{0}} = 2.82\angle 33.19^{0}\,A$$

The power delivered by the source is

$$S_{S,3\phi} = 3V_{S,\phi}I_{23}^{*} + S_{1} = 3\times 138.56\angle 0^{0} \times 2.82\angle 33.19^{0} + 300\angle 36.87^{0} = 1221.8 - j462.3VA$$
$$= 1306.4\angle -20.73^{0}VA$$

And power factor is $PF = \cos(-20.73^{0}) = 0.935$ leading.

Problem No.2: (40 points)

A 10 kVA, 20,000/480-V single-phase transformer is tested on HV side with the following data:

Short-circuit test: $V_{SC} = 1130V$ $I_{SC} = 1.00A$ $P_{SC} = 260W$

a) Determine the equivalent circuit of the transformer referred to secondary side.
b) If the transformer is supplying a rated load with 0.8 PF lagging under rated voltage. Find the voltage regulation of this transformer.

Solution:

a) From primary side (HV):

$$|Z_{EQ}| = V_{SC}/I_{SC} = 1130/1.00 = 1130\Omega$$

$$\cos\theta = \frac{P_{SC}}{V_{SC} I_{SC}} = \frac{260}{1130 \times 1.00} = 0.2301 \Rightarrow \theta = 76.7^o$$

so $Z_{EQ} = 1130\angle 76.7^o = 260 + j1100\Omega$

converting to secondary side:

$$a = 20000/480 = 41.67$$

$$Z'_{EQ} = Z_{EQ}/a^2 = 0.15 + j0.63\Omega$$

b) $S = 10\angle\cos^{-1}(0.8) = 10\angle 36.87^o\ kVA$

$$V_S = 480\angle 0V$$

$$I_S = \left(\frac{S}{V_S}\right)^* = \left(\frac{10000\angle 36.87^o}{480\angle 0^o}\right)^* = 20.83\angle -36.87^o\ A$$

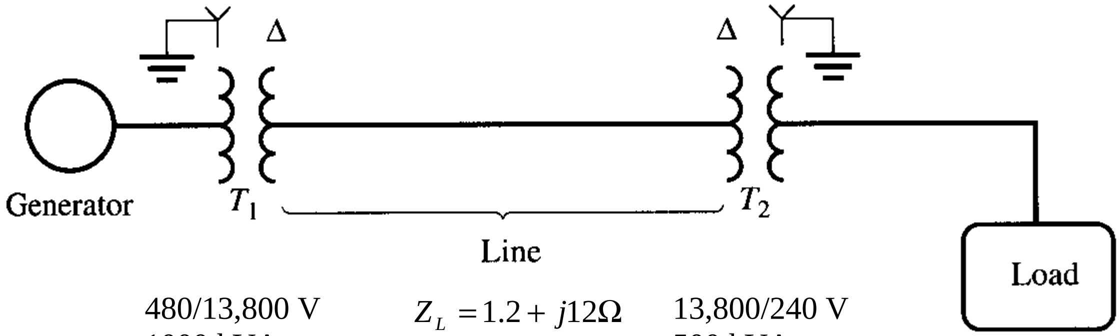
$$V'_P = V_S + I_S Z'_{EQ} = 480\angle 0^o + 20.83\angle -36.87^o \times (0.15 + j0.63) = 490.5\angle 1.01^o V$$

the voltage regulation is:

$$VR = \frac{|V'_P| - |V_S|}{|V_S|} \times 100\% = \frac{490.5 - 480}{480} \times 100\% = 2.19\%$$

Problem No.3: (30 points)

Consider a three-phase power system as shown below:



480/13,800 V	$Z_L = 1.2 + j12\Omega$	13,800/240 V	
1000 kVA		500 kVA	
R=0.02 pu		R=0.03 pu	400 kVA
X=0.05 pu		X=0.08 pu	0.8 PF lagging

If the power base is chosen to be 1000 kVA, and the voltage base at the generator side to be 480 V. **Answer the following questions (please circle the right answers): You must show your steps. No credit will be given without your steps.**

a) What is the voltage base at load side?

(i) 480 V (ii) 13,800 V (iii) 240 V (iv) 120 V

$$V_{b3} = 480 \times (13800/480) \times (240/13800) = 240V$$

b) What is the power base at load side?

(i) 1000 kVA (ii) 500 kVA (iii) 400 kVA (iv) 320 kW

Power bases should be all the same for the whole system.

c) What is the per-unit value of line impedance at selected bases?

(i) 5.21+j52.1 (ii) 0.0063+j0.063 (iii) 0.0021+j0.021 (iv) 20.83+j208.3

$$Z_{b2} = (13800)^2 / 1000000 = 190.4\Omega, \; Z_{L,pu} = (1.2 + j12)/190.4 = 0.0063 + j0.063$$

d) What is the per-unit impedance of transformer T1 at selected bases?

(i) 0.01+j0.025 (ii) 0.02+j0.05 (iii) 0.04+j0.1 (iv) 0.08+j0.2

Bases are same as ratings. No need to transform.

e) What is the per-unit impedance of transformer T2 at selected bases?

(i) 0.015+j0.04 (ii) 0.03+j0.08 (iii) 0.06+j0.16 (iv) 0.12+j0.32

$$Z_{T2,new} = (0.03 + j0.08) \times (13800/13800)^2 \times (1000/500) = 0.06 + j0.16$$

f) What is the per-unit value of the load power?

(i) 0.32+j0.24 (ii) 0.32-j0.24 (iii) 0.64+j0.48 (iv) 0.64-j0.48

$$S_{load,pu} = (400/1000)\angle\cos^{-1}(0.8) = 0.32 + j0.24$$