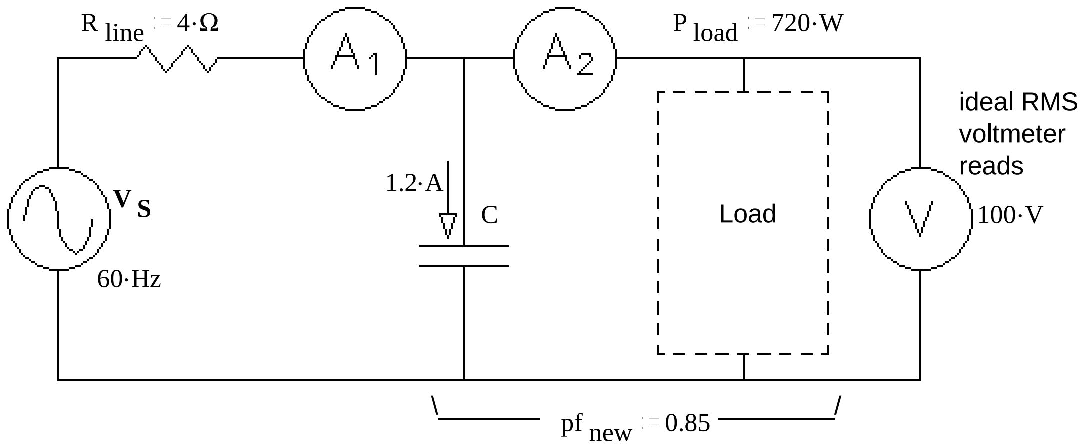
ECE3600 Final given: Fall 22 Fin F22

1. (36 pts) A capacitor (C, shown below) is used to partially correct the power factor of a load to 0.85. A_1 and A_2 are ideal ammeters. V is an ideal voltmeter. The load uses 720W. Find the following:

a) The RMS readings of the two ideal ammeters.

I_{A1} = ?

I_{A2} = ?



b) The load can be modeled as 2 parts in series. Draw the model and find the values of the parts.

More on next page ===>

c) The magnitude of the source voltage. V_S = ?

d) The efficiency. η = ?

e) Add an additional component to the drawing above in order to completely correct the power factor.
Find the value of the component.

Add the component to the drawing!

f) Without making any additional calculations, would the efficiency be better or worse with the added component of part e)? circle one

i) better (higher η) ii) worse (lower η) iii) could be either iv) no difference

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2. (26 pts) A one-line drawing of a 3-phase system is shown. Some 3-phase Ps and Qs are also shown. The 3-phase transformer is made of 3 individual single-phase transformers, each with a 5:1 turns ratio. Consider them to be ideal. They are hooked up Y - Y step-down so that the voltages on the left are 5x the voltages on the right. Remember that bus and line voltages are the same. a) Find the complex power consumed by load 1.

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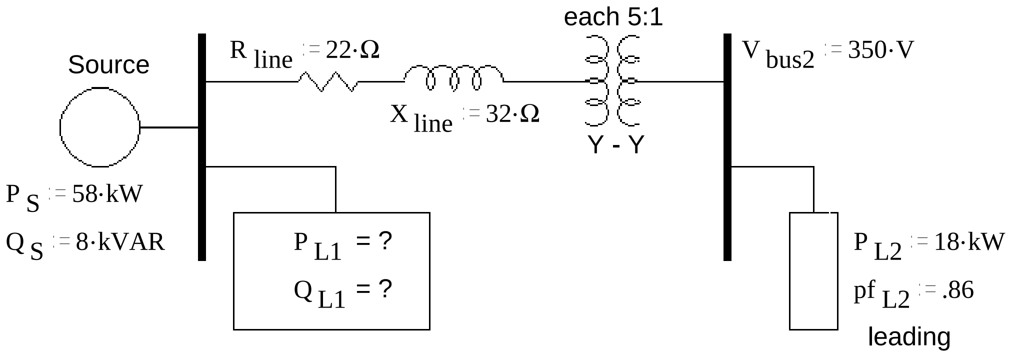
Hints: Work from load 2 back and if you don't use Ps and Qs to solve this problem it will be VERY HARD!



b) What is the efficiency of this system? $\eta = ?$

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3. (24 pts) Consider the small power system shown below. values shown are per-unit.

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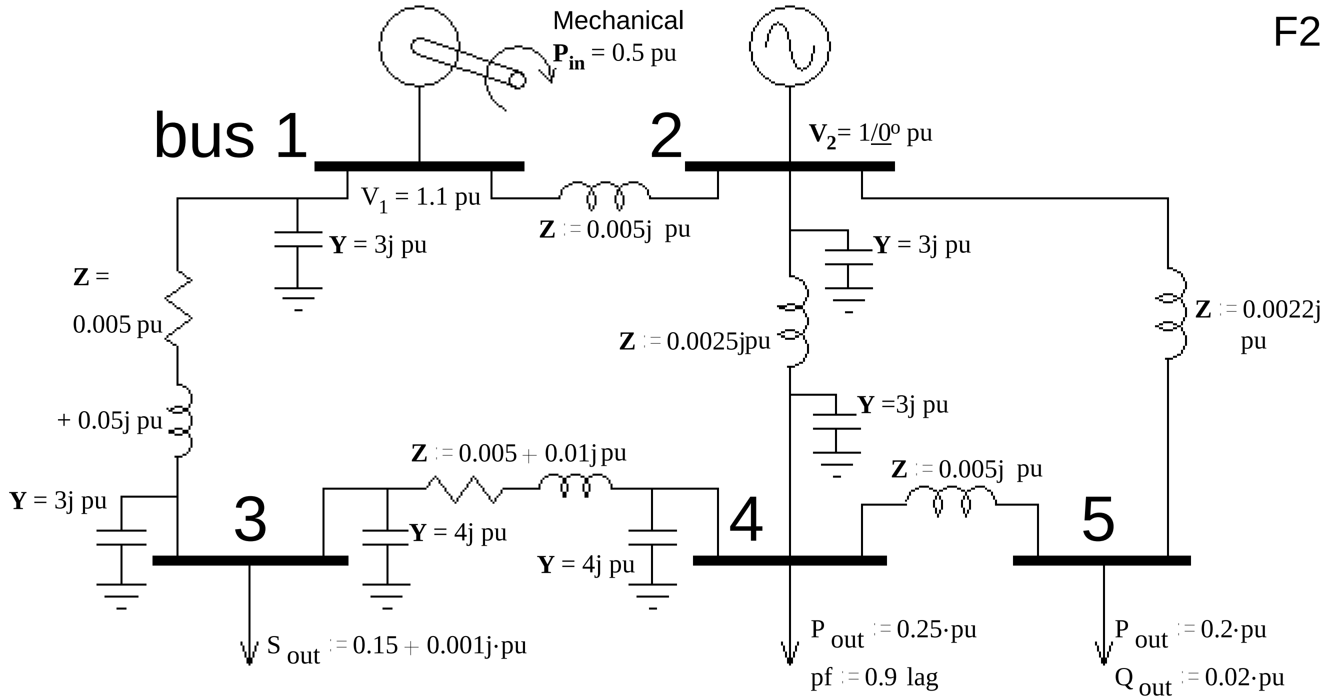

a) Identify each bus as "slack", "load", or "generator".

bus 1. ______________ 2. ______________ 3. ______________ 4. ______________ 5. ______________

b) Show $\mathbf{V_1}$, $\mathbf{V_3}$, $\mathbf{V_4}$ and $\mathbf{V_5}$ on the drawing (as letters, not values).

c) Show $\mathbf{I_1}$, $\mathbf{I_2}$, $\mathbf{I_3}$, $\mathbf{I_4}$ and $\mathbf{I_5}$ on the drawing and draw arrows to indicate the direction of each.

d) What is the 5x5 matrix shown below called? ____

$$\begin{bmatrix} \mathbf{I_1} \\ \mathbf{I_2} \\ \mathbf{I_3} \\ \mathbf{I_4} \\ \mathbf{I_5} \end{bmatrix} = \begin{bmatrix} \_\_ & \_\_ & \_\_ & \_\_ & \_\_ \\ \_\_ & \_\_ & \_\_ & \_\_ & \_\_ \\ \_\_ & \_\_ & \_\_ & \_\_ & \_\_ \\ \_\_ & \_\_ & \mathbf{A} & \mathbf{B} & \_\_ \\ \_\_ & \_\_ & \_\_ & \_\_ & \_\_ \end{bmatrix} \cdot \begin{bmatrix} \mathbf{V_1} \\ \mathbf{V_2} \\ \mathbf{V_3} \\ \mathbf{V_4} \\ \mathbf{V_5} \end{bmatrix}$$

e) A number of the elements of the matrix are zero (0). Fill in all the zero elements.

f) Find elements **A** and **B** in the matrix.

4. (36 pts) A 345 kV transmission line has the following length and line parameters. $S := \text{siemens}$

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$len := 120 \cdot km$ $r := 0.12 \cdot \frac{\Omega}{km}$ $x := 0.6 \cdot \frac{\Omega}{km}$ $g := 0 \cdot \frac{S}{km}$ $y := j \cdot 8 \cdot 10^{-6} \cdot \frac{S}{km}$

a) Choose the most appropriate model for this transmission line and draw it, including the impedance and/or admittance value(s).

A 3ϕ load is connected at the receiving end of the transmission line. The load consumes 180MW of real power and has a power factor of 0.9, **leading**. Add it to the drawing above. The line voltage at the **load** is 342.5 kV. Assume the phase angle of the load voltage on your drawing, $\mathbf{V_R}$, is $\angle 0°$.

b) Find the line current, $\mathbf{I_{Line}}$ (not $\mathbf{I_S}$) in a complex-number form. $\mathbf{I_{Line}} = ?$

More on next page ===>

c) Same load and conditions as part b). Find the source phase voltage, $\mathbf{V_S}$, magnitude and phase. $\mathbf{V_S}$ = ?

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d) What is the line voltage at the source (magnitude)?

e) What is the "power angle" (δ)?

f) Do you see something weird about $|\mathbf{V_R}|$ and $|\mathbf{V_S}|$? If yes, what is it and what is the cause?

g) Find the impedance of one phase of the load, assuming Y-connected.

h) Find the impedance of one phase of the load, assuming Δ-connected.

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5. (34 pts) A permanent-magnet DC motor is coupled to a mechanical load. If it is hooked to a 8-V source, it draws 2.2A and spins at 20rad/sec. If it is hooked to a 20-V source, it draws 4.0A and spins at 80rad/sec.

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a) Find R_A and $K\phi$. Hint: Solve 2 equations for 2 unknowns.
Keep at least 4 significant digits for all your numbers. The results are very sensitive to roundoff errors.

$V_{T1} := 8 \cdot V$ $\quad I_{A1} := 2.2 \cdot A$ $\quad \omega_1 := 20 \cdot \frac{rad}{sec}$ $\qquad V_{T2} := 20 \cdot V$ $\quad I_{A2} := 4.0 \cdot A$ $\quad \omega_2 := 80 \cdot \frac{rad}{sec}$

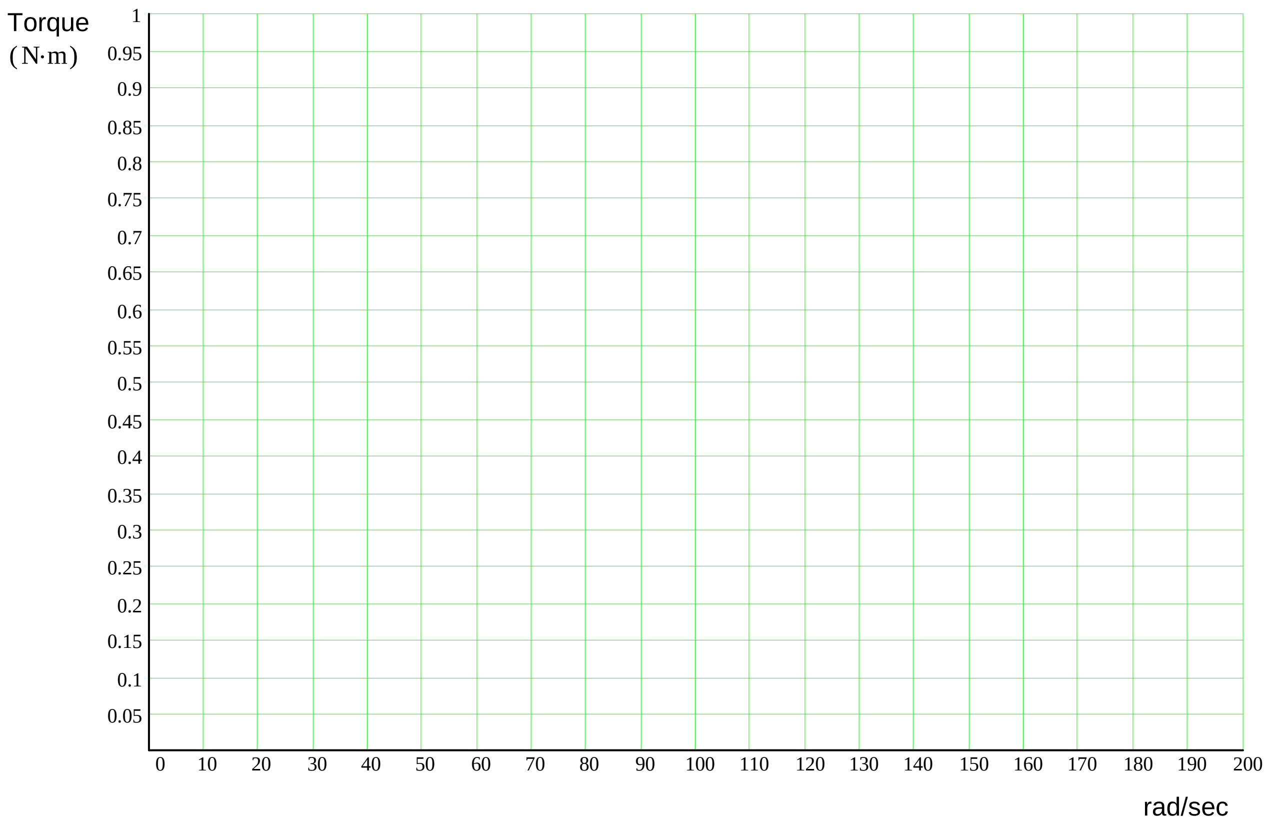
b) If we assume that the mechanical load torque combined with the internal frictional torque of the motor is some constant torque plus some torque that is proportional to speed, the we could express the induced torque like this:

$\tau_{ind} = B \cdot \omega + D$ $\qquad$ B and D are constants and $\quad \tau_{ind} = K\phi \cdot I_A$

Find the constants B and D from the information given.

More room on next page ===>

c) On the graph below, plot the two torque-speed "curves" of the motor. One for each V_T given. Note: ~~The expression for the slope given on your Exam 3 information sheet is incorrect~~. The two end-point expressions are correct.
Put an "X" or "+" at the two points of operation given in the original problem statement.



PLOT 3 LINES

d) Find the correct expression for the slope of the torque-speed curve for this type of motor. Also, confirm that the two end-point expressions given on your Exam 3 information sheet are correct.
That is, confirm that when the speed is 0, the torque is $V_T K\phi / R_A$ and when torque is 0, the speed is $V_T / K\phi$.
Show your work from basic equations!

DERIVE 3 EXPRESSIONS

Turn Over, last problem on the back ---->

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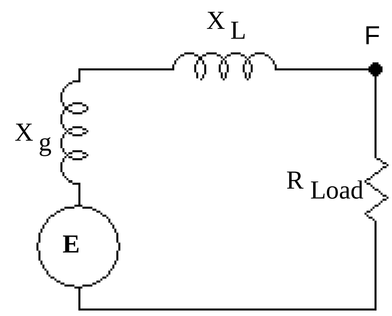
6. (24 pts) One phase of a balanced 3-phase system is shown here.

   A fault occurs point F. It is a dead short from line A to ground.

   a) Draw the circuit you would have to analyze to find the fault current. Identify the parts and Include the component voltages and currents at the fault.

   b) Set up a mathematical expression (or expressions) to find the fault current. If you use thevenin values, make sure you show how to get them from items in the drawing. (Don't forget j & that the fault current is NOT $\mathbf{I}_{A1}$)



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Total ________ / 180

Answers

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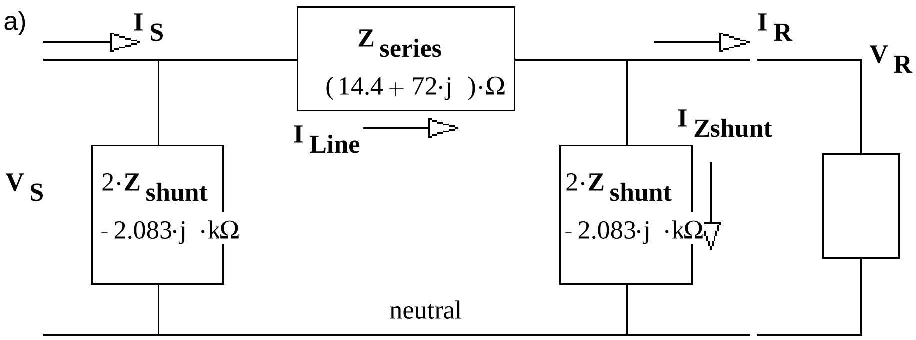
1. a) $8.47 \cdot A$ $9.16 \cdot A$ b) $8.58 \cdot \Omega$ $17.9 \cdot mH$ c) $130.0 \cdot V$ d) $71.5 \cdot \%$ e) $118.4 \cdot \mu F$ f) i)

2. a) $36.85 + 14.1 \cdot j$ kVA b) $94.6 \cdot \%$

3. a) gen slack load load load
b) at each bus
c) at each bus, flowing into grid
d) Admittance
e) $\begin{bmatrix} \_\_ & \_\_ & \_\_ & 0 & 0 \\ \_\_ & \_\_ & 0 & \_\_ & \_\_ \\ \_\_ & 0 & \_\_ & \_\_ & 0 \\ 0 & \_\_ & \mathbf{A} & \mathbf{B} & \_\_ \\ 0 & \_\_ & 0 & \_\_ & \_\_ \end{bmatrix}$
f) $-40 + 80 \cdot j$ pu $-86.6 \cdot pu$

4. a)



$P_{load3\phi} := 180 \cdot MW$
$pf := .9$ **leading**

b) $388 \cdot A$ $38.6 \cdot deg$ c) $186.4 \cdot kV$ $7.81 \cdot deg$ d) $322.9 \cdot kV$ e) $7.81 \cdot deg$

f) YES, $|V_R|$ is bigger than $|V_S|$ This can happen when the load power factor is leading.

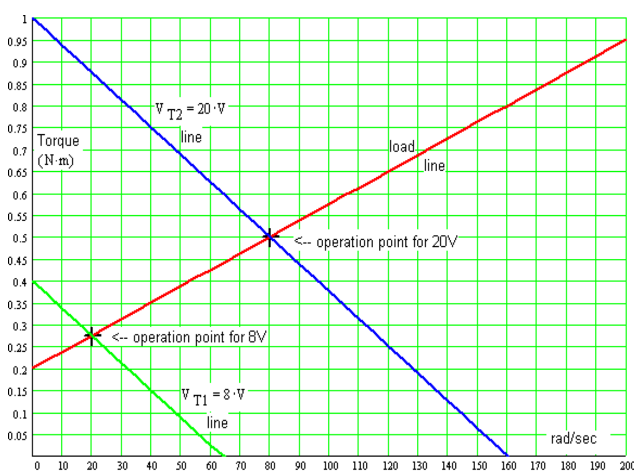
g) $586.5 \cdot \Omega$ $-25.84 \cdot deg$ h) $1759.6 \cdot \Omega$ $-25.84 \cdot deg$ $I_A = \frac{\tau}{K\phi}$

5. a) $2.5 \cdot \Omega$ $0.125 \cdot V \cdot sec$ b) $3.75 \cdot 10^{-3} \cdot N \cdot m \cdot sec$ $0.2 \cdot N \cdot m$ d) $V_T = I_A \cdot R_A + E_A$

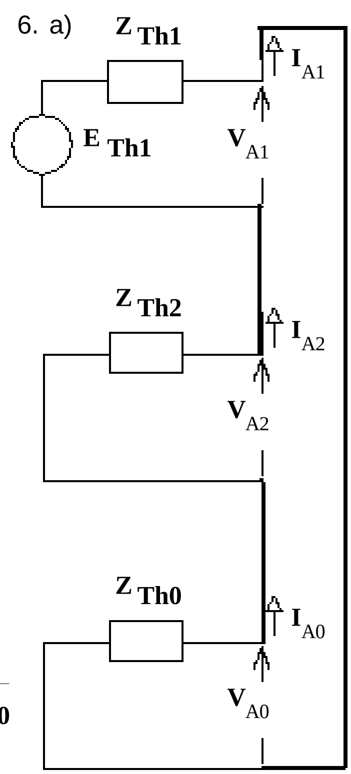
So: $V_T = \frac{\tau}{K\phi} \cdot R_A + K\phi \cdot \omega$ If $\omega = 0$, then $V_T = \frac{\tau}{K\phi} \cdot R_A$ $\tau = \frac{V_T \cdot K\phi}{R_A}$ $E_A = K\phi \cdot \omega$

If $\tau = 0$, then $V_T = K\phi \cdot \omega$ $\omega = \frac{V_T}{K\phi}$ Slope = $\frac{rise}{run} = -\frac{\left(\frac{V_T \cdot K\phi}{R_A}\right)}{\left(\frac{V_T}{K\phi}\right)} = -\frac{(K\phi)^2}{R_A}$

c)



6. a)



$I_{fault} = 3 \cdot I_{A1} = 3 \cdot \frac{E_{Th1}}{Z_{Th1} + Z_{Th2} + Z_{Th0}}$

b)

$Z_{Th1} = \frac{1}{\frac{1}{(X''_{g1} + X_{L1}) \cdot j} + \frac{1}{R_{Load1}}}$

$E_{Th1} = E'' \cdot \frac{R_{Load1}}{(X''_{g1} + X_{L1}) \cdot j + R_{Load1}}$

$Z_{Th2} = \frac{1}{\frac{1}{(X_{g2} + X_{L2}) \cdot j} + \frac{1}{R_{Load2}}}$

$Z_{Th0} = \frac{1}{\frac{1}{(X_{g0} + X_{L0}) \cdot j} + \frac{1}{R_{Loa02}}}$