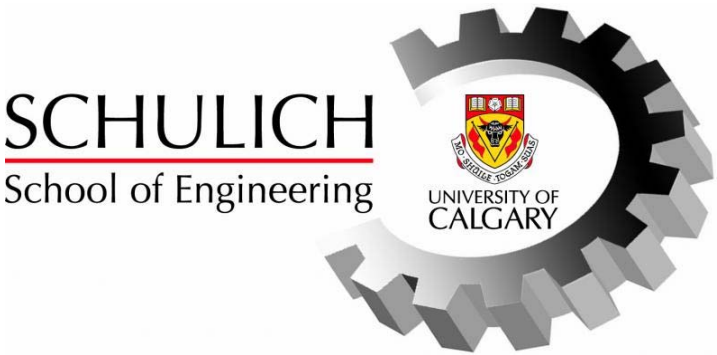


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Name: _____ ID: _____



ENEL 487 Final Examination

Wednesday, April 20, 2016

Time: 8:00 – 11:00 am

Location: Red Gym

Instructor: Pouyan (Yani) Jazayeri

- Please note that the official University of Calgary examination regulations are printed on page 2 of this paper.
- Exam consists of 8 problems and 15 pages.
- Write answers in the space provided below each question.
- Show your work neatly in the work area. Otherwise, marks for partially correct answers cannot be given.
- Total marks for the exam is 90.
- Closed book exam. You may not refer to books or notes during the test.
- No wireless devices or earphones allowed during exam.
- Only scientific calculators without formulae storage and text display are allowed.

Question	1	2	3	4	5	6	7	8	Total
Mark	/15	/10	/10	/10	/10	/10	/10	/15	/90

EXAMINATION RULES AND REGULATIONS

STUDENT IDENTIFICATION

Each candidate must sign the Seating List confirming presence at the examination. All candidates for final examinations are required to place their University of Calgary I.D. cards on their desks for the duration of the examination. (Students writing mid-term tests can also be asked to provide identity proof.) Students without an I.D. card who can produce an acceptable alternative I.D., e.g., one with a printed name and photograph, are allowed to write the examination.

A student without acceptable I.D. will be required to complete an Identification Form. The form indicates that there is no guarantee that the examination paper will be graded if any discrepancies in identification are discovered after verification with the student's file. A Student who refuses to produce identification or who refuses to complete and sign the Identification Form is not permitted to write the examination.

EXAMINATION RULES

- 1) Students late in arriving will not normally be admitted after one-half hour of the examination time has passed.
- 2) No candidate will be permitted to leave the examination room until one-half hour has elapsed after the opening of the examination, nor during the last 15 minutes of the examination. All candidates remaining during the last 15 minutes of the examination period must remain at their desks until their papers have been collected by an invigilator.
- 3) All inquiries and requests must be addressed to supervisors only.
- 4) The following is strictly prohibited:
 - speaking to other candidates or communicating with them under any circumstances whatsoever;
 - bringing into the examination room any textbook, notebook or memoranda not authorized by the examiner;
 - making use of calculators, cameras, cell-phones, computers, head-sets, pagers, PDA'S or any device not authorized by the examiner;
 - leaving answer papers exposed to view;
 - attempting to read other student's examination papers.

The penalty for violation of these rules is suspension or expulsion or such other penalty as may be determined.

- 5) Candidates are requested to write on both sides of the page, unless the examiner has asked that the left hand page be reserved for rough drafts and calculations.
- 6) Discarded matter is to be struck out and not removed by mutilation of the examination answer book.
- 7) Candidates are cautioned against writing in their answer book any matter extraneous to the actual answering of the question set.
- 8) The candidate is to write his/her name on each answer book as directed and is to number each book.
- 9) During the examination a candidate must report to a supervisor before leaving the examination room.
- 10) Candidates must stop writing when the signal is given. Answer books must be handed to the supervisor-in-charge promptly. Failure to comply with this regulation will be cause for rejection of an answer paper.
- 11) If during the course of an examination a student becomes ill or receives word of a domestic affliction, the student must report at once to the supervisor, hand in the unfinished paper and request that it be cancelled.

If physical and/or emotional ill health is the cause, the student must report at once to a physician/counsellor so that subsequent application for a deferred Final examination is supported by a completed Physician/Counsellor Statement form.

Students can consult professionals at SU Wellness Center during normal working hours or consult their physician/counsellor in the community.

Once an examination has been handed in for marking a student cannot request that the examination be cancelled for whatever reason. Such a request will be denied. Retroactive withdrawals will also not be considered.

Problem 1:

Answer the following questions on the scantron sheet provided to you. Correct answers are rewarded 1 point.

- 1) We can only apply per phase analysis to systems where:
 - a) All loads and sources are Y connected
 - b) All loads and sources are delta connected
 - c) There are no restrictions to using per phase analysis with regards to connection types.
 - d) All lines are Y connected
 - e) A and D

- 2) Which statement about phase and line voltages (V) and currents (I) in Wye and Delta connections is correct?
 - a) Phase I = line I in Wye, and phase V = line-line V in Delta
 - b) Phase I = line I in Delta, and phase V = line-line V in Wye
 - c) Phase I = line I and phase V = line-line V in Wye
 - d) Phase I = line I and phase V = line-line V in Delta
 - e) None of the above

- 3) Transformer open circuit (OC) and short circuit (SC) tests allow us to calculate certain equivalent circuit values. Which parameters are calculated from the OC test and which are from the SC test?
 - a) The OC test gives the resistances and the SC test gives the reactances
 - b) The OC test gives the series (leakage) impedance and the SC test gives the shunt admittance
 - c) The OC test gives the shunt admittance and the SC test gives the series (leakage) impedance
 - d) The OC test gives the voltages and the SC test gives currents
 - e) None of the above

- 4) In a long line Pi model, we use series impedance Z' and shunt admittance $Y'/2$. In the short line model, we use:
 - a) Series impedance Z' and shunt admittance $Y'/2$
 - b) Series impedance Z' and shunt admittance $Y/2$
 - c) Series impedance Z and shunt admittance $Y/2$
 - d) Series impedance Z and shunt admittance 0
 - e) Series impedance 0 and shunt admittance 0

- 5) In the power flow at the slack (swing) bus,
 - a) P and V are fixed
 - b) P and Q are fixed
 - c) P and δ are fixed
 - d) V and Q are fixed
 - e) None of the above

- 6) If the diameter of a transmission line conductor is increased, then:
- a) Both the inductance and the capacitance increase
 - b) The inductance increases and the capacitance decreases
 - c) The inductance decreases and the capacitance increases
 - d) Both the inductance and the capacitance decrease
 - e) The inductance decreases and the capacitance remains unchanged
- 7) Supplying reactive power locally (at the load side) leads to increased line current, thus increased line losses.
- a) True
 - b) False
- 8) The total real power losses of an ideal transformer are always zero.
- a) True
 - b) False
- 9) Bundled conductors can be used to decrease transmission line capacity (ampacity)
- a) True
 - b) False
- 10) In a large power system, majority of busses are:
- a) Slack busses
 - b) Generator busses
 - c) Load busses
 - d) None of the above
- 11) Power flow studies involve solving simultaneous_____
- a) Linear algebraic equations
 - b) Non-linear algebraic equations
 - c) Linear differential equations
 - d) Non-linear differential equations
 - e) None of the above.
- 12) Which of the following is not true for the bus admittance matrix (Y_{bus}) in a large power system:
- a) It is symmetric
 - b) It is a square matrix
 - c) It is a fully populated matrix
 - d) None of the diagonal elements can be zero.
 - e) None of the above. (All the statements are true.)

13) Which of the following is not a common heat dissipation technique for transformers?

- a) Forced air
- b) Forced oil
- c) Natural air flow
- d) Natural oil flow
- e) None of the above (i.e. They are all acceptable)

14) Aluminum has surpassed copper as the material for transmission lines because:

- a) Aluminum has better conductivity
- b) Aluminum is cheaper
- c) Aluminum is stronger
- d) "This probably has something to do with China!" - Donald Trump
- e) Both A and b

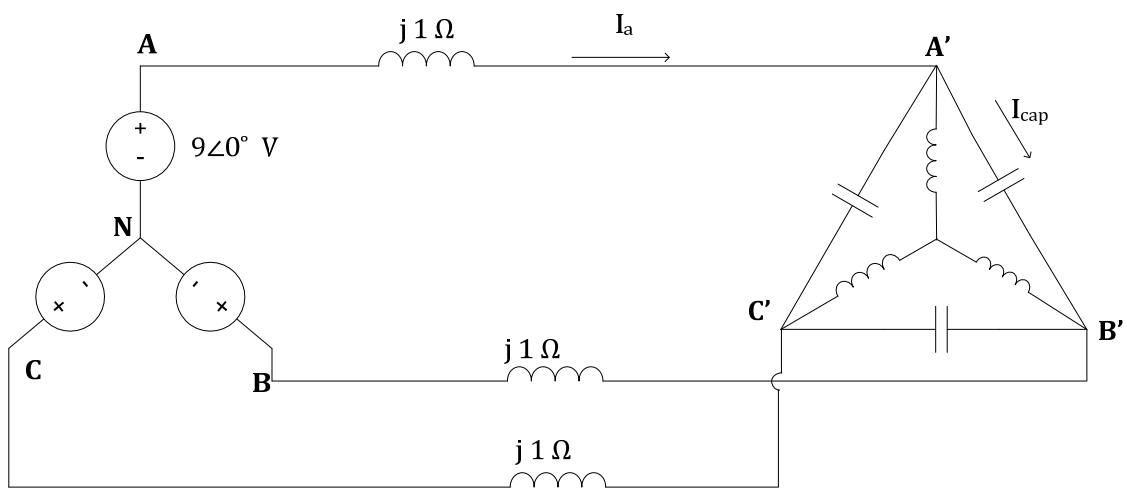
15) The Alberta market has a demand of 4500MW at the moment. The offers received from the generators are as follows: generator A offers 1000MW at \$15/MWh, generator B offers 1000MW at \$25/MWh, generator C offers 2000MW at \$0/MWh, generator D offers 2000MW at \$20/MWh, and generator E offers 1000MW at \$10/MWh. Which of the following statements is true?

- a) Generator D receives \$20/MWh and is dispatched at 2000MW
- b) Generator D receives less than \$20/MWh and is dispatched at less than 2000MW
- c) Generator D receives \$20/MWh and is dispatched at less than 2000MW
- d) Generator C receives their bid of \$0/MWh and is dispatched at 2000MW
- e) None of the above

You can ignore this question as the electricity market in Alberta has changed

Problem 2:

Consider the balanced three-phase system shown below. Each inductor has an impedance of $Z_L = j10\Omega$ and each capacitor $Z_C = -j15\Omega$. Determine I_a , I_{cap} , and total three phase complex power supplied by the source. Hint: The inductor and capacitor are simply three phase loads connected in parallel. [10 marks]



Problem 3:

Two balanced three phase loads are connected in parallel. Load 1 draws 10 kW at 0.8 pf lagging. Load 2 draws 20 kVA at 0.6 pf leading. The loads are supplied by a balanced 3 phase 480 V source.

a) Draw the power triangle for the combined load. [5 marks]

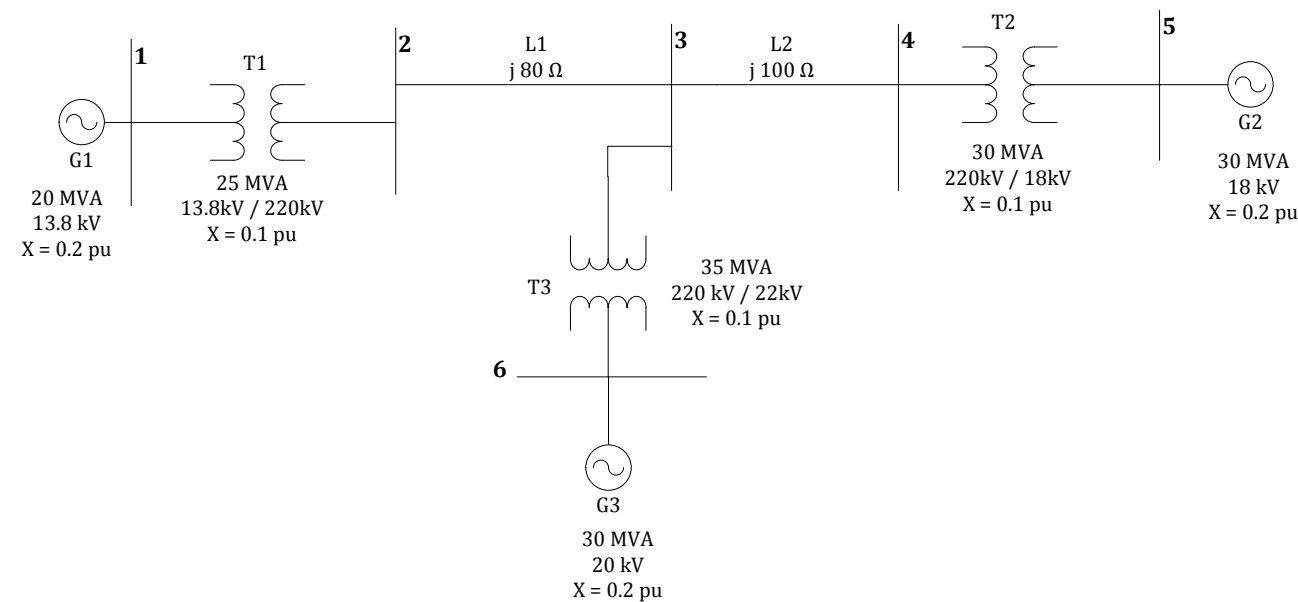
b) Determine the power factor of the combined load. [1 mark]

c) Determine the magnitude of the line current from the source. [1 mark]

- d)** Y-connected inductors are now installed in parallel with the load. What value of inductive reactance is needed in each leg of the Y connection to bring the source power factor to unity? [3 marks]

Problem 4:

The single line diagram of a three phase system is shown below.



Draw the impedance diagram for this system with all reactances marked in pu. Label the points corresponding to the busses in your impedance diagram. (i.e. there should be a point labelled 1 corresponding to bus 1, and so on). Use a power base of 50 MVA and a voltage base of 13.8kV in the generator G1 zone. [10 marks]

Problem 5:

The following parameters have been calculated for a 500kV line: $z = 0.02 + j0.5 \Omega/\text{km}$, $y = j7 \times 10^{-6} \text{ S/km}$. With the receiving end voltage at 500kV, the receiving end power is $100 + j500 \text{ MVA}$.

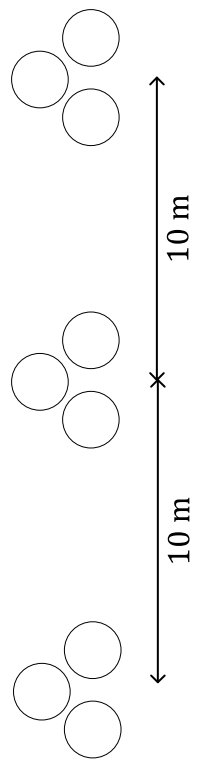
a) Write the expression for $V(x)$. [7 marks]

b) We have decided to represent this line with a short line model. Draw this model and label all the applicable impedances and admittances. Also, write a new expression for $V(x)$ based on this model. (i.e. An expression that provides the voltage at any point x as measured from the receiving end.) [3 marks]

Problem 6:

A bundled, three phase, completely transposed, 60 Hz, 500kV line is composed of three ACSR Curlew 1033.5 kcmil conductor per phase with flat vertical spacing of 10 meters as shown below. The conductors have a diameter of 3.284 cm and GMR of 0.0133m. The spacing between the conductors in each bundle is 50 cm.

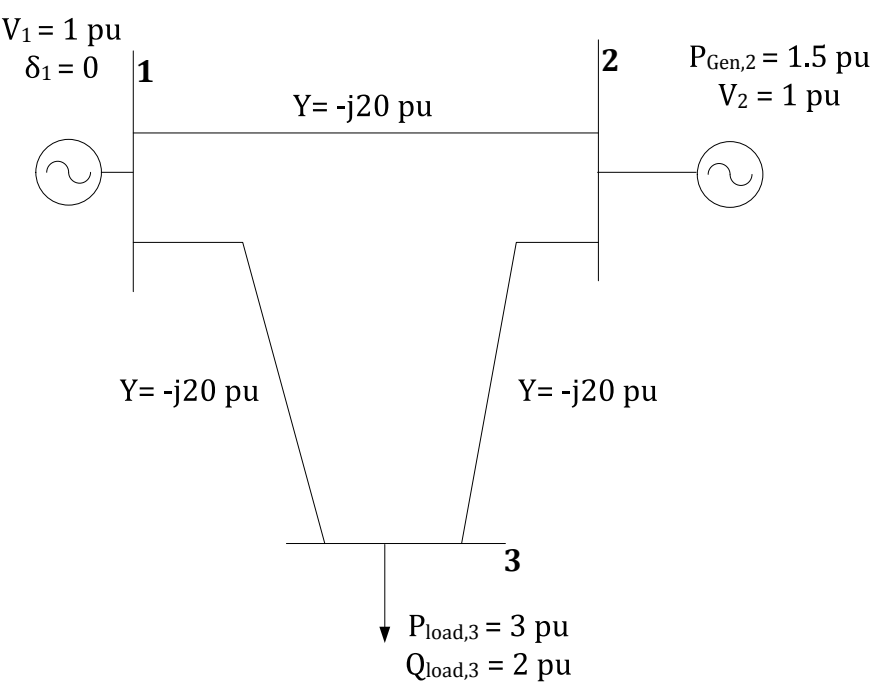
a) Determine the inductive line reactance per phase in Ω/km . [5 marks]



b) The capacitance-to-neutral in F/m and admittance-to-neutral in S/km. [5 marks]

Problem 7:

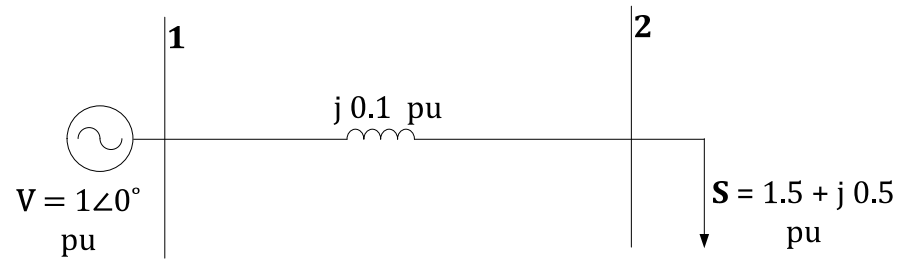
Considering the system below:



Write the expression (and if possible, find the values) for the element in row 1, column 2 of J_{21} and row 2, column 2 of J_{22} [10 marks]

Problem 8:

Consider the two bus system shown below:



- a)** Create the Y_{bus} for this system. [2 marks]
- b)** Create the X vector for this system. [2 marks]
- c)** Write the real and reactive power flow equations for bus 2. Plug in all the know values and simplify as much as possible. [4 marks]

- d)** The 2 equations from part c) can form a system of non-linear equations with $[\delta_2 \ V_2]^T$ as the unknowns. Perform one iteration of the Newton-Raphson method in solving this system of equations (i.e. what is $X^{(1)}$?) Use an initial guess of $1\angle 30^\circ$ for the voltage. [7 marks]

Constants/Conventions

$$\begin{array}{l|l} \epsilon & 8.85 \times 10^{-12} \\ r' & 0.7788 \cdot r \\ D_{SL} & \sqrt{D_S \cdot d} \\ & \sqrt[3]{D_S \cdot d^2} \\ & 1.091 \sqrt[4]{D_S \cdot d^3} \\ D_{SC} & \sqrt{r \cdot d} \\ & \sqrt[3]{r \cdot d^2} \\ & 1.091 \sqrt[4]{r \cdot d^3} \end{array}$$

General

$$\begin{array}{l|l} \text{Single Phase } \bar{S}: & \bar{S} = \bar{V} \cdot \bar{I}^* \\ \text{Q for L and C:} & Q_L = \frac{V^2}{X_L} \quad Q_C = \frac{V^2}{X_C} \\ \text{Y Connection:} & \bar{V}_{ll} = \sqrt{3} \angle 30^\circ \cdot \bar{V}_\phi \\ \Delta \text{ Connection:} & \bar{I}_l = \sqrt{3} \angle -30^\circ \cdot \bar{I}_\phi \\ \text{3 Phase Power:} & \bar{S}_{3\phi} = 3 \cdot \bar{V}_\phi \cdot \bar{I}_\phi^* \\ & S = \sqrt{3} \cdot V_{ll} \cdot I_l \\ & P = S \cdot pf \quad S^2 = P^2 + Q^2 \end{array}$$

Per Unit

$$\begin{array}{l|l} \text{Single Phase:} & S_{\text{base},1\phi} = P_{\text{base},1\phi} = Q_{\text{base},1\phi} \\ & I_{\text{base}} = \frac{S_{\text{base},1\phi}}{V_{\text{base,L-N}}} \\ & Z_{\text{base}} = R_{\text{base}} = X_{\text{base}} \\ & Z_{\text{base}} = \frac{V_{\text{base,L-N}}}{I_{\text{base}}} = \frac{V_{\text{base,L-N}}^2}{S_{\text{base},1\phi}} \\ \text{Three Phase:} & S_{\text{base},3\phi} = 3 \cdot S_{\text{base},1\phi} \\ & V_{\text{base,L-L}} = \sqrt{3} V_{\text{base,L-N}} \\ & I_{\text{base}} = \frac{S_{\text{base},3\phi}}{\sqrt{3} V_{\text{base,L-L}}} \\ & Z_{\text{base}} = \frac{V_{\text{base,L-L}}^2}{S_{\text{base},3\phi}} \\ \text{Change of Base:} & Z_{\text{pu,new}} = Z_{\text{pu,old}} \left(\frac{V_{\text{base,old}}}{V_{\text{base,new}}} \right)^2 \frac{S_{\text{base,new}}}{S_{\text{base,old}}} \end{array}$$

Transmission Lines

$$\begin{array}{l|l} \text{Line Inductance:} & L = 2 \times 10^{-7} \cdot \ln \frac{D}{D_s} \\ & L = 2 \times 10^{-7} \cdot \ln \frac{D_{eq}}{D_s} \\ & L = 2 \times 10^{-7} \cdot \ln \frac{D_{eq}}{D_{SC}} \\ \text{Line Capacitance:} & C_{an} = \frac{2\pi\epsilon}{\ln \frac{D}{r}} \\ & C_{an} = \frac{2\pi\epsilon}{\ln \frac{D_{eq}}{r}} \\ & C_{an} = \frac{2\pi\epsilon}{\ln \frac{D_{eq}}{D_{SC}}} \\ \text{Line Equations:} & \gamma = \sqrt{z \cdot y} \\ & Z_c = \sqrt{\frac{z}{y}} \\ & I(x) = I_R \cosh(\gamma x) + \frac{V_R}{Z_c} \sinh(\gamma x) \\ & V(x) = V_R \cosh(\gamma x) + I_R Z_c \sinh(\gamma x) \\ \text{Nominal } \pi \text{ Model:} & A = D = 1 + \frac{YZ}{2} \\ & B = Z \\ & C = Y(1 + \frac{YZ}{4}) \\ \text{Eq } \pi \text{ Model:} & Z' = Z \frac{\sinh(\gamma l)}{(\gamma l)} \\ & \frac{Y'}{2} = \frac{Y}{2} \frac{\tanh(\frac{\gamma l}{2})}{(\frac{\gamma l}{2})} \end{array}$$

$$\text{For: } x = a + jb,$$

$$\cosh(x) = \cosh(a) \cos(b) + j \sinh(a) \sin(b)$$

$$\sinh(x) = \sinh(a) \cos(b) + j \cosh(a) \sin(b)$$

Power Flow

$$f_i = P_{\text{gen},i} - P_{\text{load},i} - \sum_{k=1}^N V_i V_k G[i,k] \cos(\delta_i - \delta_k) - \sum_{k=1}^N V_i V_k B[i,k] \sin(\delta_i - \delta_k)$$

$$f_{N+i} = Q_{\text{gen},i} - Q_{\text{load},i} - \sum_{k=1}^N V_i V_k G[i,k] \sin(\delta_i - \delta_k) + \sum_{k=1}^N V_i V_k B[i,k] \cos(\delta_i - \delta_k)$$