Name:______________________________ ID:____________

ENEL 487 Final Examination

Wednesday, April 29, 2015

Time: 12:00 – 3:00 pm

Location: Auxiliary 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 7 problems and 16 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 100.
- 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	Total
Mark	/15	/15	/15	/15	/15	/15	/10	/100

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 student I.D. card on their desk for the duration of the examination. Students writing mid-term tests may also be asked to provide proof of identification. Students without an I.D. card but who are able to 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 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 an invigilator has collected their papers.
3) All enquiries and requests must be addressed to supervisors only.
4) No electronic devices of any kind may be used during the test.
5) **Candidates are strictly cautioned against:** (a) speaking to other candidates or communicating with them under any circumstances whatsoever; (b) bringing into the examination room any textbook, notebook or memoranda not authorized by the examiner; (c) making use of calculators and/or portable computing machines not authorized by the instructor; (d) leaving examination papers exposed to view; (e) attempting to read other students' examination papers.

   The penalty for violation of these rules is suspension or expulsion or such other penalty as may be determined.
6) Candidates are requested to write only in spaces provided. If you write any rough work on the question paper, cross it out with a large "X" and write "Rough Work" beside it. Rough work will not be marked. You may use the back of the pages for rough work.
7) If you remove the staple from this paper, write your name at the top of every page.
8) Candidates are cautioned against writing in their exam papers any matter extraneous to the actual answering of the question set.
9) A candidate must report to a supervisor before leaving the examination room.
10) Exam papers must be handed to the supervisor-in-charge promptly when the signal is given. Failure to comply with this regulation will be cause for rejection of an exam paper.
11) If during the course of an examination a student becomes ill or receives word of a domestic affliction, the student should 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 examination is supported by a completed Physician/Counsellor Statement form. Students can consult professionals at University Health Services or University Counselling Services during normal working hours or consult their physician/counsellor in the community. **Should a student write an examination, hand in the paper for marking, and later report extenuating circumstances to support a request for cancellation of the paper and for another examination, such request will be denied.**
12) Smoking during examinations is strictly prohibited.

Problem 1:

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

1) For a purely capacitive element under sinusoidal steady-state excitation, the voltage and current phasors are:

a) in phase

b) perpendicular to each other with **V** leading **I**

c) perpendicular to each other with **I** leading **V**

d) None of the above

2) The average power in a single-phase ac circuit with a purely inductive load, for sinusoidal steady-state excitation is:

a) $(I_{rms})^2 X_L$

b) $(V_{max})^2/X_L$

c) Zero

d) None of the above

3) The admittance of a -j 1/2 Ω impedance is:

a) -j2 S

b) j2 S

c) -j4 S

d) None of the above

4) For a balanced Δ load supplied by a balanced source, the line currents into the load are $\sqrt{3}$ times the load currents and lag by 30 degrees.

a) True

b) False

5) Transmission line conductance is usually neglected in power system studies.

a) True

b) False

6) Bundling reduces the series reactance of the line?

a) Yes

b) No

7) In the Newton Raphson method, the Jacobian Matrix J(x) consists of

a) Partial derivatives

b) Inverses

c) P_{branch} and Q_{branch} expressions

d) None of the above

8) Which of the following variables is known for a load bus?

a) Real Power consumed by the load

b) Voltage angle

c) Jacobian matrix

d) Voltage magnitude

9) The Ybus of a 14 bus systems is a __________ matrix

a) 14×1

b) (14 – 1)×14

c) 14×14

d) Not enough information given

10) The bus selected as the slack bus must have a source of both real and reactive power.

a) True

b) False

11) Per Unit quantity has the same unit/dimension as that of the actual quantity.

a) True

b) False

12) The Alberta market has a demand of 5000MW at the moment. The offers received from the generators are as follows: generator A offers 1000MW at $15, generator B offers 1000MW at $25, generator C offers 4000MW at $0, generator D offers 2000MW at $20, and generator E offers 2000MW at $10. What is the market clearing price?

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

a) $20

b) $0

c) $15

d) None of the above

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

a) Forced air

b) Forced oil

c) Natural air flow

d) None of the above (i.e. They are all acceptable)

14) Select the material with the best conductivity.

a) Gold

b) Aluminum

c) Copper

d) Silver

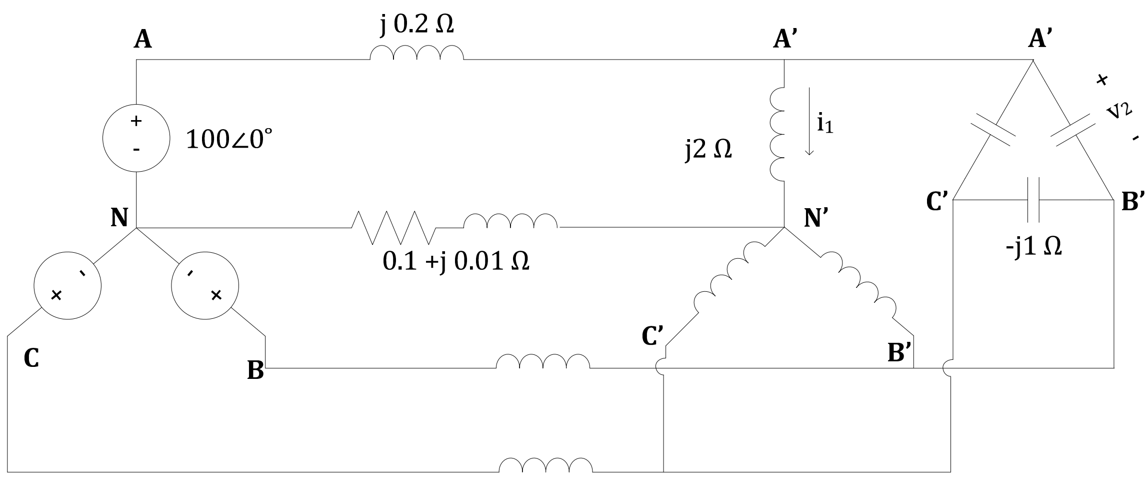
15) In design of ACSR conductors, more aluminum results in lower resistance while more steel results in higher strength.

a) True

b) False

Problem 2:

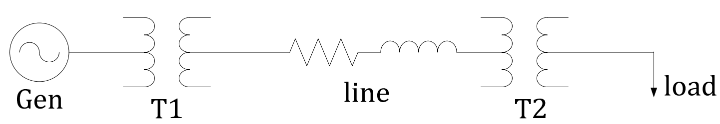
Consider the balanced three-phase system shown below. Determine v_2 (t) and i_1 (t). [15 marks]



Problem 3:

The three phase system shown below has the following ratings:

Generator:	60 MVA,	13.8kV (line-to-line),	$X_{gen} = 0.2$ pu
T1:	50 MVA,	13.2 kV/132 kV,	$X_{T1} = 0.091$ pu
T2:	50 MVA,	138 kV/13.8 kV,	$X_{T2} = 0.083$ pu
Line:	15.87 + j79.35 Ω per phase		
Load:	Z Ω per phase (i.e. unknown impedance)		



Select a power base of 60 MVA for the system and a base voltage of 13.8kV for the generator zone. Under these base values, the system was analyzed. It was calculated that the load is drawing a current of $0.7\angle{-40^\circ}$ pu, and its terminal voltage is $1\angle 0^\circ$ pu.

a) Draw the impedance diagram of the system in per unit. The load impedance can be labeled as Z_{pu}. You will need numerical values for all other impedances. [8 marks]

b) Find the load's active and reactive power in per unit. Hint: You can use $\mathbf{S}_{pu} = \mathbf{V}_{pu}\mathbf{I}_{pu}{}^*$ [3 marks]

c) Find the actual quantity of the load's three phase active and reactive power in MW and MVAr. [1 marks]

d) What is the line current at the load terminals in Amps? [1 mark]

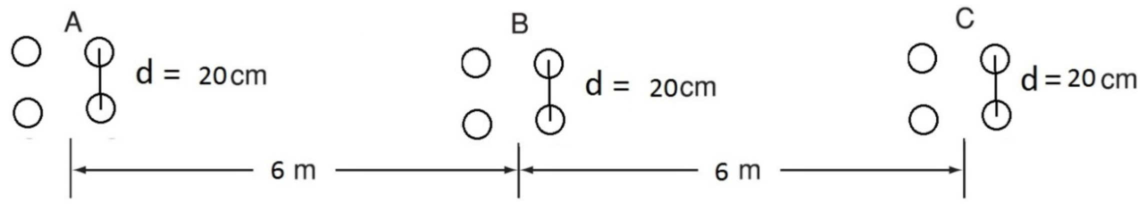
e) Find the total active power losses in the line in per unit and MW. [2 marks]

Problem 4:

A 60-Hz, 200-km, three-phase overhead transmission line, constructed of ACSR conductors, has a series impedance of (0.2+ j0.8) Ω/km per phase and admittance of $j10\times10^{-6}$ S/km per phase. Using the nominal π circuit, compute ABCD parameters and the voltage and current at the sending end if the load at the receiving end draws 200 MVA at 0.9 lagging and at a line-to-line voltage of 230 kV. [15 marks]

Problem 5:

Figure below shows the conductor configuration of a completely transposed, three-phase overhead transmission line with bundled phase conductors. All conductors have a radius of 0.7 cm.



a) Determine the inductance per phase in mH/km. [4 marks]

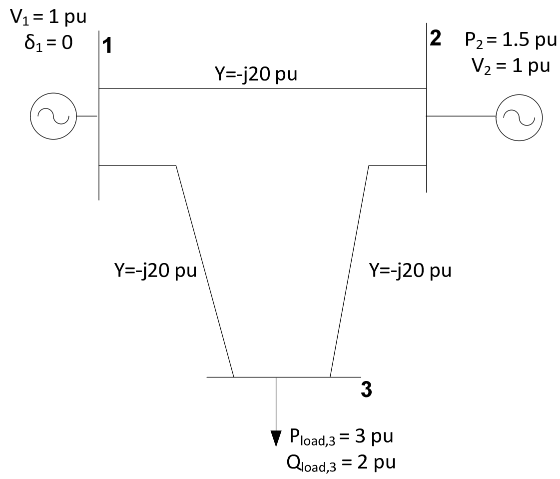
b) Determine the inductive line reactance per phase in Ω/km at 60 Hz. Also, calculate the reactive power absorbed by the inductance if a 100 km transmission line with this configuration is operating at 1000A. [4 marks]

c) Determine the line-to-neutral capacitance in nF/km per phase. [3 marks]

d) Determine the capacitive reactance in Ω/km per phase. Also, calculate the reactive power supplied by the reactance if a 100 km transmission line with this configuration is operating at 200kV. [4 marks]

Problem 6:

Considering the system below:



a) Complete the following table. Do not include P_{load} and Q_{load} in this table. [3 marks]

Bus number	Bus type	Known variables	Unknown variables
1			
2			
3			

b) Create the Y_{bus} matrix for this system [2 marks]

c) Write and simplify the active power flow equations for buses 1 and 2, and reactive power flow equation for bus 1. Plug in all the known variables, expand the equations, keep the angles in degrees, and simplify as much as possible. [6 Marks]

d) Write the expression for the element in row 3, column 3 of J_{11} and row 1, column 1 of J_{12} [4 marks]

Problem 7:

The following table shows the branch data of a 4 bus system:

Line number	Bus to bus	Branch resistance, R (p.u)	Branch Reactance, X (p.u)
1	1-2	0.564	0.981
2	2-3	0.873	0.765
3	2-4	1.092	0.45
4	3-4	0.5	1
5	4-1	0.199	0.203

a) Calculate the elements in $Y_{bus}[1,1]$ and $Y_{bus}[1,4]$? [4 marks]

b) A capacitor bank of $j0.2\Omega$ is connected to bus 1. Will the Y_{bus} matrix change? If yes, calculate the modified elements in the Y_{bus}. If not, explain why. Also, state one reason for adding a capacitor bank to a bus in the power system. [6 marks]

Constants/Conventions

ε	$8.85\text{x}10^{-12}$
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}	$\sqrt{r \cdot d}$ $\sqrt[3]{r \cdot d^2}$ $1.091\sqrt[4]{r \cdot d^3}$

General

Single Phase $\overline{\text{S}}$:	$\overline{S} = \overline{V} \cdot \overline{I}^*$
Q for L and C:	$Q_L = \frac{V^2}{X_L} \qquad Q_C = -\frac{V^2}{X_C}$
Y Connection:	$\overline{V_l} = \sqrt{3}\angle 30^{\text{o}} \cdot \overline{V_\phi}$
Δ Connection:	$\overline{I_l} = \sqrt{3}\angle{-30^{\text{o}}} \cdot \overline{I_\phi}$
3 Phase Power:	$\overline{S_{3\phi}} = 3 \cdot \overline{V_\phi} \cdot \overline{I_\phi^*}$ $S = \sqrt{3} \cdot V_l \cdot I_l$ $P = S \cdot pf \qquad S^2 = P^2 + Q^2$

Per Unit

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

Transmission Lines

Line Inductance:	$L = 2\text{x}10^{-7} \cdot \ln\frac{D}{D_s}$
or	$L = 2\text{x}10^{-7} \cdot \ln\frac{D_{eq}}{D_S}$
or	$L = 2\text{x}10^{-7} \cdot \ln\frac{D_{eq}}{D_{SL}}$
Line Capacitance:	$C_{an} = \frac{2\pi\varepsilon}{\ln\frac{D}{r}}$
or	$C_{an} = \frac{2\pi\varepsilon}{\ln\frac{D_{eq}}{r}}$
or	$C_{an} = \frac{2\pi\varepsilon}{\ln\frac{D_{eq}}{D_{SC}}}$
Line Equations:	$\gamma = \sqrt{z \cdot y}$ $Z_c = \sqrt{\frac{z}{y}}$

$$I(x) = I_R \cosh(\gamma x) + \frac{V_R}{Z_c} \cdot \sinh(\gamma x)$$

$$V(x) = V_R \cosh(\gamma x) + I_R Z_c \sinh(\gamma x)$$

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

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

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