Charles Darwin University

Final Examination

Family Name	
Given Name/s	
Student Number	
Teaching Period	Semester 1, 2019

ENG474 – Power Systems Analysis	DURATION	
	Reading Time:	10 minutes
	Writing Time:	180 minutes

INSTRUCTIONS TO CANDIDATES

1. This examination is worth 50% of the total assessment for this unit.
2. Read the questions carefully before attempting. Attempt all questions.
3. Questions are not of equal value.
4. In order to explain your work, draw suitable (circuit) diagrams whenever possible.
5. Highlight the final answers.
6. Don't forget the units. Absence of a unit may cost you some credit.

EXAM CONDITIONS

<u>You may begin writing from the commencement of the examination session.</u> The reading time indicated above is provided as a guide only.

This is a CLOSED BOOK examination

Any non-programmable calculator is permitted

No handwritten notes are permitted

No dictionaries are permitted

ADDITIONAL AUTHORISED MATERIALS	EXAMINATION MATERIALS TO BE SUPPLIED
No additional printed material is permitted	1 x 20 Page Book 1 x Scrap Paper

THIS EXAMINATION IS PRINTED DOUBLE-SIDED.

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QUESTION 1 (15 marks)

Answer the following questions as briefly as possible. Long discussion is discouraged. Please use plain English and avoid mathematical expressions whenever possible. **(1 mark each)**

Q1.1 What is the use of ground wires in transmission lines?

Q1.2 How does a Lightning arrester protect a transmission line against a lightning stroke?

Q1.3 Which one is larger, the physical radius or the geometrical mean radius of a stranded conductor?

Q1.4 What is corona? How does corona affect the operation of a transmission line?

Q1.5 What can be done to reduce the ill effects of corona in a transmission line?

Q1.6 What is done to avoid any possible skin effect to a transmission line conductor?

Q1.7 Under which conditions is the Ferranti effect manifested in a transmission line?

Q1.8 Why are some transmission lines transposed?

Q1.9 A 300 km long transmission line having a surge impedance of 400 ohms is cut into two sections, one 100 km long and the other 200 km long. Determine the surge impedances of the two lines.

Q1.10 Calculate the surge impedance loading (SIL) of the 300 km line of the previous question.

Q1.11 If the load demand in a small power system suddenly increases, what effect will it have on the system frequency?

Q1.12 What does a vector group reference of Yd11 mean?

Q1.13 What is an overcurrent relay? What does it exactly do when a fault current flows in the circuit it is supposed to protect?

Q1.14 What is a distance relay? How does it differ from an overcurrent relay?

Q1.15 What is meant by transient stability of power systems?

Go to the next page for Question 2.

QUESTION 2 (5 marks)

Q2.1 What are the advantages of using Newton Raphson method over Gauss-Seidel method for solving simultaneous algebraic equations? **(1 mark)**

Q2.2 Any disadvantages? **(1 mark)**

Q2.3 Figure 2 below shows a single line diagram of a 4-bus power system with 2 generation buses. The numbers (other than the bus numbers 1, 2, 3 and 4) in the figure are the per unit inductive reactances of lines or generators, as the case may be. Line resistances and generator armature resistances are neglected. Determine the admittance matrix for the system. Show all calculations and don't forget the unit(s). **(3 marks)**

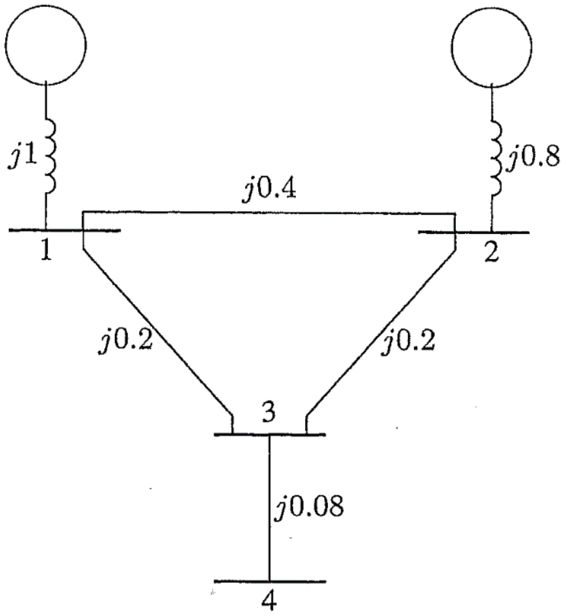

Figure 2. A simple power system for Question 2.
(Ref. H. Saadat, Power System Analysis, McGraw-Hill, 2002)

Go to the next page for Question 3

QUESTION 3 (15 marks)

Q3.1 A 60-Hz synchronous generator having an inertia constant of 5 MJ/MVA and a direct axis transient reactance of 0.3 pu is connected to an infinite bus through a purely reactive circuit as shown in Figure 3 below. Reactances are marked on this diagram on a common system base. The generator delivers a real power of 0.8 pu and a reactive power of 0.074 pu to the infinite bus at a voltage of 1 pu. A three phase fault occurs at the middle of one of the lines, the fault is cleared, and the faulted line isolated. Determine the critical clearing angle by using equal area criterion. Do not use the formula for critical angle given ini the formula sheet. **(14 marks)**

Q3.2 Now use the available formula and determine the angle. **(1 mark)**

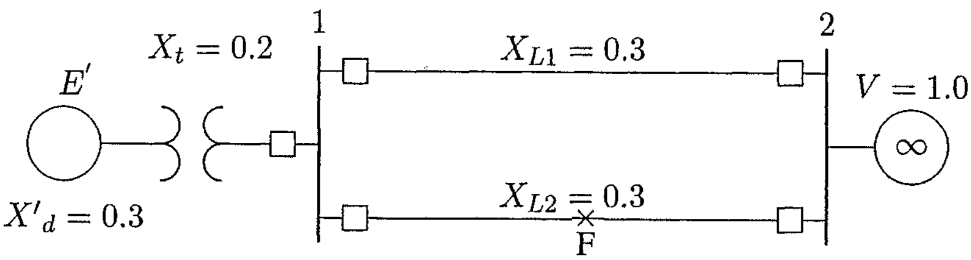

Figure 3. Single line diagram for the system in Question 3.
(Ref. H. Saadat, Power System Analysis, McGraw-Hill, 2002)

QUESTION 4 (15 marks)

A three-phase system has the following phase voltages.

$V_A = 240\ \underline{/0^0}$ volts; $V_B = 250\ \underline{/90^0}$ volts; $V_C = 260\ \underline{/-135^0}$ volts

Q4.1 Determine the corresponding sequence voltages. **(3 marks)**

Q4.2 Combine the sequence voltages to get back the original phase voltages. **(2 marks)**

Q4.3 Both series and shunt capacitors can be used in a transmission system to improve the voltage. What are the criteria to select one over the other? **(5 marks)**

Q4.4 Name 2 Australian HVDC transmission systems. Mention their voltage and power ratings.

(5 marks)

THE END

FORMULAS

(Symbols have their usual meanings in the context of the particular formula)

Three phase circuits $S = \sqrt{3} V_L I_L$; $P = S \cos\varphi$; $Q = S \sin\varphi$

Per unit system $Z_{base} = \frac{(kV_{base})^2}{MVA_{base}}$; $Z_{pu2} = Z_{pu1} \times \frac{MVA_{base2}}{MVA_{base1}} \times \frac{(kV_{base1})^2}{(kV_{base2})^2}$

Lines $L = 0.2 \times \ln\frac{D_m}{D_s}$ mH/km; $C_N = \frac{1}{18 \times \ln\frac{D_m}{D_{sC}}}$ μF/km; $Z_0 = \sqrt{\frac{z}{y}}$; $\gamma = \sqrt{z\,y}$.

ABCD parameters

	Short Line	Medium length line		Long Line	Long Line
		Nominal Pi Model	Nominal Tee Model	Exact Model	Approximate Model
A	1	1+YZ/2	1+YZ/2	$\cosh(\gamma\lambda)$	1+YZ/2
B	Z	Z	Z(1+YZ/4)	$Z_0 \sinh(\gamma\lambda)$	Z(1+YZ/6)
C	0	Y(1+YZ/4)	Y	$(1/Z_0) \sinh(\gamma\lambda)$	Y(1+YZ/6)
D	1	1+YZ/2	1+YZ/2	$\cosh(\gamma\lambda)$	1+YZ/2

AD – BC = 1; A = D $P = \frac{E\,V}{X}\sin\delta$ $\Delta V \cong \frac{X\,Q}{V}$

	2-conductor bundle	3-conductor bundle	4-conductor bundle
D_s^b	$\sqrt{D_s \times d}$	$\sqrt[3]{D_s \times d^2}$	$1.09 \times \sqrt[4]{D_s \times d^3}$
D_{sC}^b	$\sqrt{r \times d}$	$\sqrt[3]{r \times d^2}$	$1.09 \times \sqrt[4]{r \times d^3}$

$$\text{Voltage Regulation} = \frac{|\text{No load voltage}| - |\text{Full load voltage}|}{|\text{Full load voltage}|} \times 100\%$$

$\sum P_{ij}\, X_{ij} = 0$; $[\mathrm{I}] = [\mathrm{Y}][\mathrm{V}]$; $P = \frac{|E|\,|V|}{X_s}\sin\delta$; $M = \frac{G\,H}{180\,f}$ MJ-sec / deg-elec

$M\,\frac{d^2\delta}{dt^2} = P_a = P_{mech} - P_{elec}$; $X_s = \frac{1}{\text{S.C.R.}}$

Power flow equations : $\mathrm{V}_i = \frac{1}{\mathrm{Y}_{ii}}\left(\frac{P_i - jQ_i}{\mathrm{V}_i^*} - \sum_{\substack{k=1\\k\neq i}}^{m} \mathrm{Y}_{ik}\,\mathrm{V}_k\right)$; $\mathrm{Q_i} = -\mathrm{Im}\left\{\mathrm{V_i^*} \times \sum_{k=1}^{m} \mathrm{Y_{ik}}\,\mathrm{V_k}\right\}$

Symmetrical components

$$\begin{bmatrix} V_a \\ V_b \\ V_c \end{bmatrix} = \begin{bmatrix} 1 & 1 & 1 \\ 1 & a^2 & a \\ 1 & a & a^2 \end{bmatrix} \begin{bmatrix} V_{a0} \\ V_{a1} \\ V_{a2} \end{bmatrix} \qquad \begin{bmatrix} V_{a0} \\ V_{a1} \\ V_{a2} \end{bmatrix} = \frac{1}{3} \begin{bmatrix} 1 & 1 & 1 \\ 1 & a & a^2 \\ 1 & a^2 & a \end{bmatrix} \begin{bmatrix} V_a \\ V_b \\ V_c \end{bmatrix}$$

Stability

$$\cos \delta_{cr} = \frac{P_0(\delta_0 - \delta_2) + P_1 \cos \delta_0 - P_2 \cos \delta_2}{P_1 - P_2}$$

Trigonometry:

$$\sin(A \pm B) = \sin A \cos B \pm \cos A \sin B \qquad \cos(A \pm B) = \cos A \cos B \, \mu \sin A \sin B$$

$\sinh(\gamma l) = \sinh(\alpha l + j\beta l) = \sinh(\alpha l)\cos(\beta l) + j\cosh(\alpha l)\sin(\beta l)$

$\cosh(\gamma l) = \cosh(\alpha l + j\beta l) = \cosh(\alpha l)\cos(\beta l) + j\sinh(\alpha l)\sin(\beta l)$

$$\text{Taylor series expansion : } f(x_1, x_2) \cong f^0(x_1, x_2) + \frac{\partial}{\partial x_1}\left(f(x_1, x_2)\right) \cdot \Delta x_1 + \frac{\partial}{\partial x_2}\left(f(x_1, x_2)\right) \cdot \Delta x_2$$