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(University of Choice)

MASINDE MULIRO UNIVERSITY OF SCIENCE AND TECHNOLOGY (MMUST)

MAIN CAMPUS

UNIVERSITY EXAMINATIONS
2023/2024 ACADEMIC YEAR

FIFTH YEAR FIRST SEMESTER EXAMINATIONS

FOR THE DEGREE
OF
BACHELOR OF SCIENCE IN ELECTRICAL AND COMMUNICATION ENGINEERING

COURSE CODE: ECE 511E

COURSE TITLE: POWER SYTSEM ANALYSIS

DATE: THURSDAY 07/12/2023 **TIME:** 3: 00 PM – 5:00 PM

INSTRUCTIONS TO CANDIDATES

ANSWER QUESTION ONE AND ANY OTHER TWO QUESTIONS.
QUESTION ONE CARRIES 30 MARKS AND ALL OTHERS 20 MARKS EACH.

TIME: 2 Hours

MMUST observes ZERO tolerance to examination cheating

Question 1 (30 Marks)

(a) Explain under what circumstances we can use small signal analysis in analyzing power system stability and a technique that is used therein. (5 marks)

(b) A 6000 bus system has 900 generators, all of which are modeled in a power flow program with specified terminal voltage and reactive limits, i.e., they are voltage-controlled buses, and there are no other voltage-controlled buses besides these 900 generator buses. At the beginning of the Newton Raphson solution procedure (initialization of iteration 1), answer the following:

- i How many type PV buses are there in the power flow model?. (1 mark)
- ii How many type PQ buses are there in the power flow model?. (1 mark)
- iii How many bus voltage magnitudes are unknown? (1 mark)
- iv How many bus voltage angles are unknown? (1 marks)
- v What is the number of power flow equations used? (2 marks)

(c) Use Gauss-Seidel method to find the solution to the following equations, use initial estimates $x_1^{(0)} = 1$, $x_2^{(0)} = 2$, perform 2 (two) iterations (4 marks)

$$x_1 + x_1 x_2 = 10$$
$$x_1 + x_2 = 6$$

(d) A 50-Hz synchronous generator has a transient reactance of 0.2 per unit. The generator is connected to an infinite bus through a transformer and a double circuit transmission line, as shown in Figure 1. Resistances are neglected and reactances are expressed on a common MVA base and are marked on the diagram. The generator is delivering a real power of $P_e = 0.77$ per unit to bus bar 1. Voltage magnitude at bus 1 is 1.1. The infinite bus voltage $V = 1.0\angle 0^0$ per unit.Determine

- (a) power angle δ_1 in degrees (2 marks)
- (b) current, I flowing between buses 1 and 2 in rectangular form. (2 marks)
- (c) The excitation voltage of the generator, E' in polar from. (2 marks)

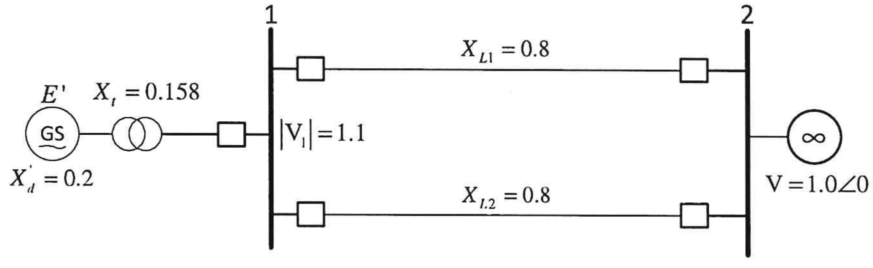

Figure 1: Single Machine Infinite bus

(e) A single area consists of two generating units, rated at 400 and 800 MVA, with speed regulation of $R_1 = 4\%$ percent and $R_2 = 5\%$ on their respective ratings. The units are operating in parallel, sharing 700 MW. Unit 1 supplies 200 MW and unit 2 supplies 500 MW at 1.0 per unit (50 Hz) frequency. The load is increased by 130 MW.

(a) Express the governor speed regulation of each unit and the load change to a common 1000 MVA base. (2 marks)

(b) the per unit steady-state frequency deviation. (2 marks)

(c) the new system frequency. (2 marks)

(d) the change in generation for each unit in MW (3 marks)

Question 2 (20 Marks)

(a) Write the power flow equations in polar form for buses $i = 1, 2, \ldots .n$; and explain why they cannot be solved using direct methods. (4 marks)

(b) The power-angle relationship for the network of Fig. 2 is given as $P_e = \frac{V_g V_b}{X} \sin\delta = 2.087 \sin\delta$. A short circuit occurs in the middle of the line L_2

i draw the equivalent circuit indicating the reactances during the short circuit. (3 marks)

ii determine the power-angle relationship during the short circuit in the middle of the line . (4 marks).

iii Determine the power-angle relationship after the fault is cleared by outage of line L_2 (4 marks)

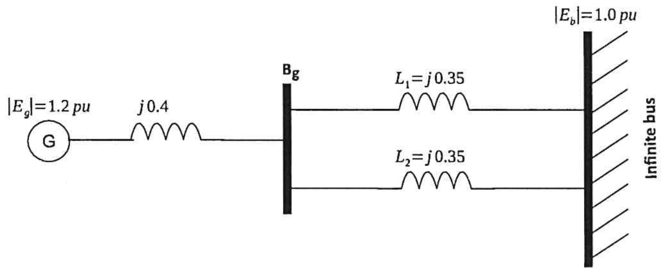

Figure 2: Single machine infinite bus system

(c) Define a *voltage controlled bus* as used in a power flow study and explain what quantity is allowed to change in such a bus during computations and in what manner. (4 marks)

Question 3 (20 Marks)

(a) A set of linear algebraic equations representing a power system in matrix format is given as **Ax=y**, the determinant det(**A**) is found to be negative. Will such a system of equations converge when performing load flow? Briefly explain. (4 marks)

(b) In the two-bus system shown in Fig. 3, bus 1 is a slack bus with $V_1 = 1.0\angle 0°$. A load of 100 MW and 50 MVAR is taken from bus 2. The line impedance is as indicated on a base of 100 MVA. Initial estimate of $V_2^{(0)} = 1.0$ p.u. and $\delta_2^{(0)} = 0°$.

- i Express the load in per unit. (1 mark)
- ii Determine Y_{bus} in polar form . (1 mark)
- iii Write the power flow equations for P and Q in polar form (use the admittance values obtained in (ii) above). (2 marks)
- iv Determine the Jacobian elements of (iii) above. (4 marks)

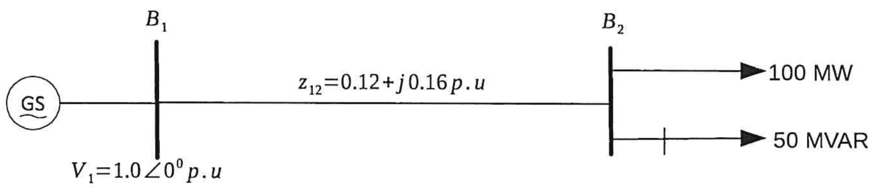

Figure 3: Single line diagram of two bus system

(c) Briefly explain why generator frequency rather than electric torque T_e or electrical power P_e is used as a control signal to indicate/detect power imbalance in a power system. (4 marks)

(d) Explain critical clearing time and critical clearing angle. (4 marks)

Question 4

(a) Explain principle underlying the approach of the fast-decoupled load flow (FDLF), use appropriate Jacobian matrix elements in your explanation. (8 marks)

(b) In terms of critical clearing angle δ_{cc}, briefly explain the importance of critical clearing time, t_{cc} on transient stability. (5 marks)

(c) A generator delivers power of 1.0 p.u. to an infinite bus through a purely reactive network. The maximum power that could be delivered by the generator is 2.0 p.u. A three-phase fault occurs at the terminals of the generator which reduces the generator output to zero. The fault is cleared after time, t_c second. The original network is then restored. The maximum swing of the rotor angle is found to be $\delta_{max} = 110°$ electrical degree. Find the rotor angle in electrical degrees at $t = t_c$. (7 marks)

Question 5

(a) Derive the swing equation as used in power system stability studies,and state what class of stability studies it is used for. (8 marks)

(b) A 50 Hz interconnected power system has two areas denoted area 1 and area 2, where the area frequency response characteristics are given by $\beta_1 = 100$ MW/Hz and $\beta_2 = 100$ MW/Hz. The total power generated in each of these areas is 500 and 250 MW, respectively. Each area is initially generating power in steady state with $\Delta P_{tie1} = \Delta P_{tie2} = 0$ when the load in area 1 suddenly increases by 60 MW. Compute the resulting steady state change in frequency Δf as well as the steady state changes in tie–line flows ΔP_{tie1} and ΔP_{tie2} with Load frequency control (LFC). (8 marks)

(c) Briefly describe what is meant by the transient state of a power system, and when a power system is said to be the transiently stable. (4 marks)