INTERNATIONAL UNIVERSITY OF EAST AFRICA
'Learning to Succeed'

FACULTY OF ENGINEERING

END OF SEMESTER EXAMINATIONS - APRIL 2025

PROGRAMME: BACHELOR OF ELECTRICAL AND CONTROL ENGINEERING

YEAR/SEM: YEAR 4/SEMESTER 2

COURSE CODE: ELE424X

NAME: POWER SYSTEM STABILITY

DATE: 2025-04-14

TIME: 9:00AM-12:00PM

INSTRUCTIONS TO CANDIDATES:

1. Read the instructions very carefully
2. The time allowed for this examination is STRICTLY three hours
3. Read each question carefully before you attempt and allocate your time equally between all the Sections
4. Write clearly and legibly. Illegible handwriting cannot be marked
5. Number the questions you have attempted
6. Use of appropriate workplace examples to illustrate your answers will earn you bonus marks
7. Any examination malpractice detected will lead to automatic disqualification.

DO NOT WRITE ANYTHING ON THE QUESTION PAPER

Section A Answer any two QUESTIONS FROM THIS SECTION

Question 1:

a) **Explain the role of the prime mover in power generation and how it influences the control of active power. (7marks)**

b) **Describe the methods used to control reactive power in an energy system, and explain why reactive power management is crucial for voltage stability. (7marks)**

c) **In a system with a prime mover supplying 100 MW, if the reactive power demand increases by 20 MVAR, discuss the impact on system voltage and suggest control strategies. (6marks)**

Question 2:

a) Describe the key characteristics of modern power systems. How do they differ from traditional power systems in terms of generation, transmission, and distribution? (7marks)

b) A modern power system integrates 50 MW of solar power into the grid. If the system experiences a load demand of 200 MW and other conventional sources provide 160 MW, determine whether there is a power surplus or deficit. Suggest possible solutions for balancing the system. (7marks)

c) Explain the role of smart grids and renewable energy sources in modern power systems. What are the benefits and challenges associated with integrating renewable energy into the grid? (6marks)

Question 3:

a) Define power system stability. What are the main types of stability problems encountered in modern power systems? (6marks)

b) A power system experiences a sudden fault, causing the rotor angle of a generator to change rapidly. If the initial rotor angle is 30Â°, and after 0.5 seconds, it increases to 70Â°, determine whether the system is likely to remain stable. Explain your reasoning based on power system stability concepts. (7marks)

c) Explain the significance of transient stability, steady-state stability, and voltage stability in power system operation. What measures can be taken to improve the overall stability of a power system? (7marks)

Question 4:

a) **Define reactive power and explain its role in maintaining voltage stability in AC power systems. (7marks)**

b) **Describe the difference between capacitive and inductive reactive power, and give examples of devices that generate or consume each type. (7marks)**

c) **A load draws 200 kW of real power and 150 kVAR of reactive power. Calculate the apparent power and power factor of the system. (6marks)**

Section B Answer any Three QUESTIONS from this SECTION

Question 1:

a) Describe the main causes of voltage instability in a power system. (6marks)
b) What are the key indicators used to detect voltage instability? (7marks)
c) Explain the role of reactive power in maintaining voltage stability. (7marks)

Question 2:

a) Define sub-synchronous resonance (SSR) and explain its significance in power systems. (6marks)
b) Differentiate between sub-synchronous resonance (SSR) and sub-synchronous oscillations (SSO). (7marks)
c) Explain the relationship between the electrical and mechanical frequencies in SSR using the equation: $f_{sub} = f_s - f_m$, where f_{sub}â?? is the sub-synchronous frequency, f_{s}â?? is the system frequency, and f_mâ?? is the mechanical mode frequency. (7marks)

Question 3:

a) Explain how reactive power demand affects voltage stability, using the reactive power equation:

$$Q = V\left(\frac{V_s}{X}\sin(\delta) - \frac{V}{X}\right).$$

(7marks)
b) Discuss the significance of the voltage collapse phenomenon and derive the critical voltage equation for voltage stability. (6marks)
c) The stability margin of a system can be analyzed using the voltage stability index (L-index). Explain how it is calculated and interpreted. (7marks)

Question 4:

a) Discuss the primary causes of SSR in power systems, focusing on series-compensated transmission lines. (6marks)
b) Explain the impact of SSR on turbine-generator shaft systems using the torque equation:

$$T = J\frac{d\omega}{dt},$$

where T is torque, J is the moment of inertia, and Ï? is the angular velocity. (7marks)
c) Describe how sub-synchronous oscillations can lead to instability and mechanical damage in rotating machines. (7marks)