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The Open University of Sri Lanka
Faculty of Engineering Technology
Department of Electrical and Computer Engineering

Study Programme	: Bachelor of Science Honours in Engineering
Name of the Examination	: Final Examination
Course Code and Title	**: EEX7432**
	Power Systems Planning Operation and Control
Academic Year	: 2023/2024
Date	: 11th March 2025
Time	: 0930-1230hrs

General Instructions

1. This question paper consists of **Eight (8)** questions on Nine (9) pages.
2. Answer any Five (5) questions.
3. All questions carry equal marks.
4. Attach Page **[6] to [9]** to your answer script if Question 08 is answered and write your index number in the space provided.
5. Answer to each question should commence from a new page.
6. Relevant figures and tables are attached to this question paper
7. This is a Closed Book Test (CBT).
9. Answers should be in clear handwriting.
10. Do not use Red colour pen.

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Question 01

The electricity sales in Sri Lanka from 2013 to 2022 are given in the table Q1.

Table Q1

Year	Sales (GWh)
2013	10,624
2014	11,063
2015	11,786
2016	12,785
2017	13,431
2018	14,091
2019	14,611
2020	14,286
2021	15,214
2022	16,000

a) Calculate the 10-year simple compound growth rate of electricity sales.
b) Fit a linear and exponential trend profile for the given data.
c) Determine the goodness of fit (R^2) for both models.
d) Based on the analysis, decide whether to accept or reject the models.
e) Forecast electricity sales for 2023 using both the growth rate and trend profiles.
f) The Long-Term Generation Expansion Plan (LTGEP) predicts 17,200 GWh for 2023. Explain possible reasons for the discrepancy. **[20 Marks]**

Question 02

A power system consists of three thermal generators with the following characteristics as given in Table Q2:

Table Q2

Plant	Capacity (MW)	Forced Outage Rate (FOR)	Average Cost (US$/MWh)
G1	200	0.12	1400
G2	150	0.1	1100
G3	100	0.08	1200

The system load demand over a day is represented by the load duration curve given in Figure Q2.

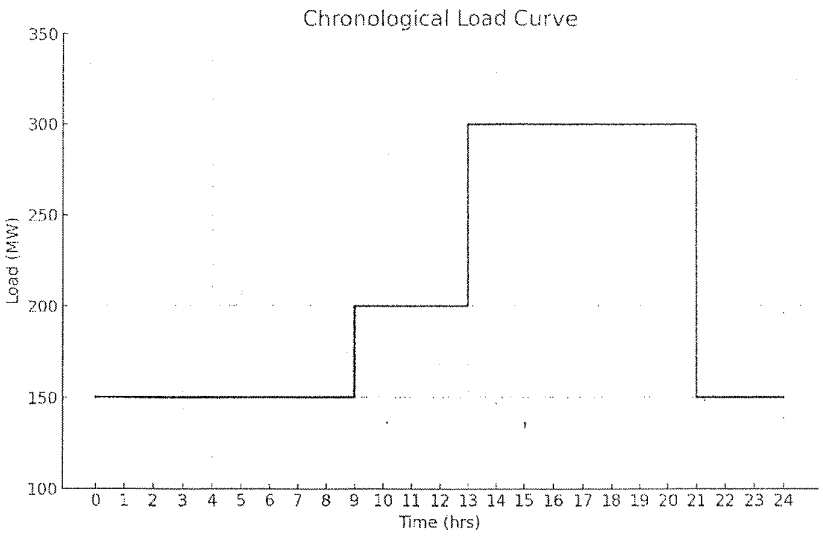


Figure Q2

a) Draw the Load Duration Curve (LDC) for the system.
b) Calculate the total daily energy demand.
c) Develop the Remaining Load Duration Curves (RLDCs) for each generator based on merit-order dispatch and estimate:
    i. Energy served
    ii. Plant factor
    iii. Expected production cost
d) Compute the Loss of Load Probability (LOLP) and Loss of Load Expectation (LOLE).
e) Determine the Energy Not Served (ENS). **[20 Marks]**

Question 03

An isolated power system has three synchronous generators operating at 50 Hz with the following characteristics as shown in Table Q3:

Table Q3

Machine	Speed Droop (%)	Speed Changer Setting
G1	4%	60% rated load
G2	5%	80% rated load
G3	6%	70% rated load

a) Draw and explain each component of the Load-Frequency Control System.
b) If the total load is 600 MW, determine the load taken by each generator.
c) If the load increases to 720 MW, find the new frequency of operation and the share of each generator.
d) Discuss the adjustments which should be made in the speed changers to restore the system to 50 Hz. **[20 Marks]**

Question 04

An industrial consumer uses electricity at 400V, 3-phase, 50 Hz, with the following daily demand pattern as given in Table Q4a:

Table Q4a

Time (hrs)	00:00-09:00	09:00-15:00	15:00-21:00	21:00-24:00
Load (kW)	120	250	600	100

The utility offers the following tariff schemes given in Table Q4b:

Table Q4b

Tariff	Peak (18:00-21:00)	Off-peak (21:00-09:00)	Day (09:00-18:00)	Fixed Charge (Rs)	Demand Charge (Rs/kVA)
T1	30	20	25	4,500	1,500
T2	35	15	28	5,000	1,200

a) Compute the Load Factor.
b) Determine the monthly electricity bill under both tariff schemes and advise on the best option.
c) If the consumer shifts 200 kW of load from 15:00-21:00 to 21:00-06:00, compute the new Load Factor.
d) Determine the new electricity bill and recommend the optimal tariff.
e) Calculate the required power factor correction capacitor size to improve the power factor to 0.95. **[20 Marks]**

Question 05

Consider the two substation configurations given in Table Q5 with the following failure rates and repair times.

Table Q5

Component	Failure Rate (f/yr)	Repair Time (hrs)
Line 1	0.05	20
Line 2	0.04	18
Transformer 1	0.02	200
Transformer 2	0.015	180
Busbar	0.005	5

a) Compute the failure rate (λ) and unavailability (U) at the load point.
b) Estimate the Energy Not Served (ENS) if the substation serves 75 MW of load.
c) If the cost of unserved energy is 250 LKR/kWh, calculate the annual economic loss.
d) Justify if upgrading the substation at an additional cost of 1.5 million LKR is economically viable. **[20 Marks]**

Question 6

A 3-bus power system has two generators connected as follows in Table Q6:

Table Q6

Generator	Marginal Cost (Rs/MWh)
G1	$25 + 0.06\ P_1$
G2	$20 + 0.04\ P_2$

a) Determine the optimal dispatch schedule for a total demand of 300 MW.

b) If line losses are estimated as $P_L = 0.002\ P_1^2 + 0.001\ P_2^2$, revise the dispatch schedule.

c) Calculate the new marginal cost of generation considering losses. **[20 Marks]**

Question 7

A power system with three thermal units has the following cost characteristics as given in Table Q7.

Table Q7

Unit	a (Rs/h)	b (Rs/MWh)	c (Rs/MW²h)	P_{min} (MW)	P_{max} (MW)
U1	3000	30	0.05	50	200
U2	2000	25	0.04	30	150

a) Determine the unit commitment schedule for a 24-hour demand profile.

b) Compute the total operating cost.

c) Assume that starting up Unit U1 incurs a fixed cost of Rs. 5000 and starting up Unit U2 incurs a fixed cost of Rs. 4000. Additionally, shutting down any unit requires Rs. 2000.

   i. Compute the total start-up and shut-down cost over a 24-hour period based on the unit commitment schedule.

   ii. How do these costs impact the overall unit commitment decision?

[20 Marks]

Index No: .....

Question 08 - Multiple Choice Questions **[20 Marks = 16*1.25 marks]**

Underline the correct answer and attach the last four pages to your answer script. Write your index number in the space given at the top of each page. Wrong attempts will not have negative impact and therefore try all questions. Each question carries **1.25 marks**.

Q1. Identify the correct statement regarding power system planning and operation:

1. Sri Lanka's first power plant was a hydroelectric station built in 1950.
2. The national grid frequency should be maintained at 60 Hz in Sri Lanka.
3. The reserve margin in a power system ensures adequate generation capacity.
4. Demand-side management is not a part of power system planning.

Q2. Identify the incorrect statements regarding power generation technologies:

(i) Gas turbine power plants have a lower efficiency than steam power plants.

(ii) Superheated steam is used in combined cycle gas turbines (CCGT).

(iii) Nuclear power plants require regular refueling every two months.

(iv) Pumped storage plants store excess energy by compressing air.

1. (i) & (ii)
2. (ii) & (iv)
3. (iii) & (iv)
4. (i) & (iii)

Q3. Which of the following statements regarding renewable energy are correct?

(i) Wave energy generation depends on the frequency and height of ocean waves.

(ii) Geothermal power plants extract thermal energy from the Earth's crust.

(iii) Large-scale battery storage is essential for integrating high levels of solar and wind energy.

(iv) Wind farms generate more power at higher altitudes due to reduced air resistance.

1. (i) & (iii)
2. (ii), (iii), & (iv)
3. (ii) & (iv)
4. (i), (ii), & (iii)

Q4. A power system has three thermal generators with the following cost functions:

$$\frac{dF_1}{dP_1} = 32 + 0.45P_1 \quad \text{(LKR/MWh)}$$

$$\frac{dF_2}{dP_2} = 28 + 0.35P_2 \quad \text{(LKR/MWh)}$$

$$\frac{dF_3}{dP_3} = 26 + 0.30P_3 \quad \text{(LKR/MWh)}$$

For a total system demand of 180 MW, what is the optimal dispatch schedule for F_1, F_2 & F_3?

1. 50, 70, 60 MW
2. 60, 50, 70 MW
3. 70, 60, 50 MW
4. 80, 50, 50 MW

Q5. Which cost component is NOT a part of the long-term generation expansion plan?

1. Fixed Operation & Maintenance Costs
2. Cost of fuel procurement
3. Transformer maintenance costs
4. Construction cost of new generation plants

Q6. A biomass power plant has an efficiency of 25% and burns 0.8 kg of wood per kWh of generated electricity. What is the calorific value of the wood fuel?

1. 7800 kcal/kg
2. 8100 kcal/kg
3. 8600 kcal/kg
4. 9000 kcal/kg

Q7. A power plant incurs an annual maintenance cost of 7 million LKR. What is the present value of 20 years of maintenance expenses assuming a 10% discount rate?

1. 68.2 million LKR
2. 74.3 million LKR
3. 62.5 million LKR
4. 71.8 million LKR

Q8. Which of the following ACSR conductors is commonly used in 400 kV transmission lines?

1. Zebra
2. Moose
3. Panther
4. Wolf

Q9. A hydropower plant has an effective head of 80 meters and a flow rate of 50 cubic meters per second. The turbine and generator efficiency is 85%. What is the estimated total energy generation capacity?

1. 32 MW
2. 38 MW
3. 42 MW
4. 45 MW

Q10. What is the required VAR compensator capacity for a ±6% voltage fluctuation at a bus with a short circuit level of 9000 MVA?

1. ±400 MVAr
2. ±200 MVAr
3. ±600 MVAr
4. ±500 MVAr

Q11. A solar power plant requires an investment of P LKR/kW, with capital disbursements as follows:

- Year 1 = 10%
- Year 2 = 25%
- Year 3 = 50%
- Year 4 = 15%

Compute the IDC at a 9% discount rate.

1. 20.7
2. 22.1
3. 18.5
4. 21.4

Q12. If two interconnected power systems have different frequency deviations, which of the following is likely to happen?

1. Power flows from higher to lower frequency area
2. Power flows from lower to higher frequency area
3. No power exchange occurs
4. Frequency in both areas remains unchanged

Q13. Which of the following are the benefits of HVDC transmission?

(i) Lower transmission losses over long distances

(ii) Reduced short-circuit current in the system

(iii) Easier integration of offshore wind farms

(iv) Lower requirement for system inertia

1. (i) & (iii)
2. (ii) & (iv)
3. (i), (ii) & (iii)
4. All of the above

Q14. Which substation busbar configuration requires a bus tie breaker for load transfer?

1. Double Bus, Single Breaker Scheme
2. Ring Bus Configuration
3. One-and-a-half Breaker Scheme
4. Mesh Bus Configuration

Q15. A 10 kW induction motor operates at 0.7 lagging power factor. A capacitor bank is installed to improve the power factor to 0.9. What is the required kVAR per phase?

1. 1.5 kVAr
2. 1.8 kVAr
3. 2.0 kVAr
4. 2.2 kVAr

Q16. A power system has a peak demand of 20 MW, with an annual load factor of 60% and a capacity factor of 50%. Determine the required reserve margin.

1. 5.0 MW
2. 6.2 MW
3. 4.8 MW
4. 5.5 MW