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 system planning, operation and control**
Academic Year	:	2024/25
Date	:	13th March 2026
Time	:	0930-1230h
Duration	:	3 hours

General instructions

1. Read all instructions carefully before answering the questions.
2. This question paper consists of **Seven (7)** questions in **Seven (7)** pages.
3. Answer **any five (5)** questions.
4. All questions carry equal marks.
5. Answer for each question should commence from a new page.
6. This is a Closed Book Test (CBT).
7. Any type of calculator is allowed to be used.

Question 1

The Table Q1a below shows the variation of demand as a percentage of total demand for the primary energy sources in Sri Lanka for 6 years starting from 2010.

Table Q1a

	2010	2015	2019	2020	2021	2022
Biomass (%)	42.8	36.6	33.2	34.3	32.2	36.4
Petroleum (%)	43.0	39.0	44.0	39.6	38.3	32.5
Coal (%)	0.6	10.9	11.5	14.1	13.1	12.6
Major hydro (%)	11.9	10.3	7.5	7.9	10.6	11.7
New Renewable Energy (%)	1.8	3.2	3.7	4.1	5.7	6.8
Total demand (PJ)	421.9	477.2	508.6	501.2	536.1	463.0

(a) Which primary energy source shows the highest average growth rate during this period? State possible reasons for this growth? [4 Marks]

(b) Which primary energy source shows the greatest average decline rate during this period? State possible reasons for this decline? [4Marks]

(c) Which primary energy source shows the highest growth in absolute energy demand during this period? State possible reasons for this growth? [4 Marks]

(d) Which primary energy source shows the greatest decline in absolute energy demand during this period? State possible reasons for this decline? [4 Marks]

(e) Determine the Per Capita Total Energy Consumption of Sri Lanka for the given years in kWh/person if the population figures are as follows in Table Q1b. (1 PJ = 277.778 GWh) [4 Marks]

Table Q1b

Year	2010	2015	2019	2020	2021	2022
Midyear Population (thousands)	20,675	20,970	21,803	21,919	22,156	22,181

Question 2

The following table Q2a shows the historical data of total electricity sales from the year 2014 to 2023.

Table Q2a

Year	Total Sales GWh		Year	Total Sales GWh
2014	11,063		2019	14,611
2015	11,786		2020	14,286
2016	12,785		2021	15,214
2017	13,431		2022	14,520
2018	14,091		2023	14,153

(a) Calculate the compound growth rate of total electricity sales for the period from 2014 to 2023. [5 Marks]

(b) Fit a trend profile using linear & exponential variations for the data above.
Hint: Use the trend line $y=a+b.x$ with the least square error fit formula given below. [5 Marks]

(c) Compound growth rate of electricity sales over the last 20 years was 4.0%. Compare the 10 year compound growth rate obtained in section (a) and provide possible reasons for the increase/decrease in the growth rate. [5 Marks]

(d) Forecast the electricity demand (total sales) in the year 2024 using the exponential smoothing method where the relevant formula is $F_T = F_{(T-1)} + s(A_{T-1} - F_{T-1})$, in which F_T is the forecast for the T th year and A_T is the actual value for the T th year. The values for s, F_{2013} and A_{2013} are given in the following table Q2b.

Table Q2b

Value of s	Total Sales GWh	
	F_{2013}	A_{2013}
0.20	10,600	10,621

Hint: [5 Marks]

$$a = \left[\sum_{i=1}^{n} y_i \times \sum_{i=1}^{n} x_i^2 - \sum_{i=1}^{n} x_i \times \sum_{i=1}^{n} (x_i y_i)\right] \Big/ \left[n \times \sum_{i=1}^{n} (x_i^2) - \left(\sum_{i=1}^{n} x_i\right)^2\right]$$

$$b = \left[n \times \sum_{i=1}^{n} (x_i y_i) - \sum_{i=1}^{n} x_i \times \sum_{i=1}^{n} y_i\right] \Big/ \left[n \times \sum_{i=1}^{n} x_i^2 - \left(\sum_{i=1}^{n} x_i\right)^2\right]$$

Question 3

(a) What is meant by Levelised Cost of Energy (LCOE)? State two advantages and two limitations of using LCOE to compare electricity generation technologies.

[5 Marks]

(b) The following figure Q3 illustrates the variation of levelised cost of electricity (LCOE) with plant factor for three typical thermal power generation technologies, labelled A, B, and C.
Compare these technologies in terms of their capital cost and operating (fuel) cost characteristics and identify the most likely technology represented by each curve.

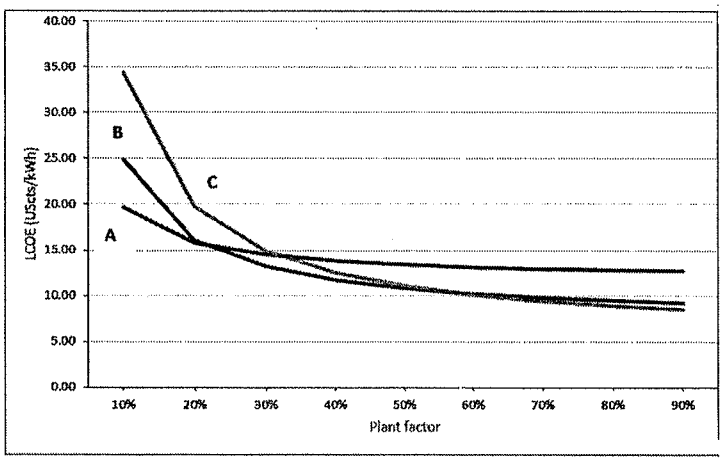


Figure Q3

[5 Marks]

(c) A small 100 kW wind power plant is to be constructed in a village where the analysis of wind pattern has shown that the plant could have an annual capacity factor of 0.3. It has the following capital expenses and expected operation & maintenance costs.

Capital expenditure in year 0 = Rs. 8 million
Capital expenditure in year 1 = Rs. 12 million
Operation and maintenance costs = Rs. 2 million per annum

The plant is expected to be fully commissioned in year 2 and has a lifetime of 20 years after that. Assume a discount rate of 12.5% per annum.

Calculate the specific cost per kWh of electricity produced from the wind plant.

$$PV = \frac{1}{(1+r)^n}$$ [5 Marks]

(d) If the discount rate was taken as 10%, what would you expect to happen to the specific cost calculated in (b)? Give your comments without recalculating. [5 Marks]

Question 4

The load duration hours calculated for a 7-day period for a small power system consisting of 3 generators A, B and C is shown in the Table below.

Load Range (MW)	0-25	26-50	51-75	76-100	101-125	126-150	151-175	176-200
Number of Hours	1	2	15	48	54	31	16	1

(a) Construct the LDC from the above data and plot it. [4 Marks]

(b) Calculate weekly energy to be served. [4 Marks]

(c) The forced outage-rate (FOR) and capacity of each of the generators are given in the Table Q4 below. The merit order of dispatch is A, B and C.

Table Q4

Generator Unit	Capacity (MW)	FOR
A	100	0.05
B	50	0.1
C	50	0.1

Using the load duration curve and generator data given, develop the Remaining Load Duration Curves (RLDCs) for each generator and estimate: Energy served and plant factor for each generator.

[6 Marks]

(d) Calculate the LOLP, LOLE and ENS using the Remaining Load Duration Curve (RLDC) method. [6 Marks]

Question 5

a) Over a period of one year, the following performance has been recorded in the log sheet of a 150 MW generating unit in a large power system. Extracted from log-sheet data,

- Plant operates at full load for 6720 hours.
- Forced to shut-down completely 5 times for a total of 600 hours.
- The plant has been taken out of service, for 250 hours to conduct planned maintenance.
- Plant was de-rated twice to 40% of maximum capacity for a total of 100 hours, and de-rated once to 50% for 50 hours, due to partial forced outages.

Estimate the following,

1. Forced outage rate and equivalent FOR [02 marks]
2. Planned outage rate [02 marks]
3. Equivalent availability [02 marks]
4. Annual capacity factor (using equivalent full load operating hours) [02 marks]
5. Maximum energy output for the period [02 marks]
6. Expected maximum energy output [02 marks]

b) Table Q5 below is a re-production of a part of typical interruption data from a power utility for a feeder circuit for a period of one year. It serves 3,200 customers with a total load of 5 MW. Momentary interruption events are omitted. Calculate the SAIFI, SAIDI, CAIDI and ASAI for this feeder. [08 marks]

Table Q5

Date	Time		Duration (minutes)	No. of customers interrupted
	Start	End		
11-Jan-25	1:11 AM	4:15 AM	184	523
05-Mar-25	11:26 AM	12:26 PM	60	682
06-Mar-25	10:10 AM	10:12 AM	02	254
08-Apr-25	8:59 AM	9:14 AM	15	423
09-Aug-25	6:23 AM	6:43 AM	20	528
20-Aug-25	8:20 AM	8:35 AM	15	1145
10-Nov-25	3:45 AM	7:00 AM	195	875
19-Dec-25	6:10 AM	1:50 PM	460	1980
		Total	951	

Use following definitions as appropriate

$$SAIFI = \frac{\sum Total\ number\ of\ customers\ interrupted}{Total\ number\ of\ customers\ served}$$

$$SAIDI = \frac{\sum Customer\ interruption\ duration}{Total\ number\ of\ customers\ served}$$

$$ASAI = \frac{Customer\ hours\ service\ availability}{Customer\ hours\ service\ demands}$$

$$CAIDI = \frac{SAIDI}{SAIFI}$$

Question 6

The demand variation throughout a day of an industrial consumer using electricity at 400 V, three phase ac and 50 Hz, is given in Table Q6a (Assume a power factor of 0.8)

Table Q6a

Time	00:00-09:00	09:00-15:00	15:00-21:00	21:00-24:00
Load (kW)	100	300	600	100

The utility offers a choice between two electricity tariff schemes for the above consumer as given under in Table Q6b.

Table Q6b

Tariff	Peak (18:00 21:00)	Off-peak (21:00 09:00)	Day (09:00 18:00)	Fixed Charge (Rs)	Demand Charge (Rs/kVA)
Indus-1	25	25	25	4000	1500
Indus-2	35	15	29	4000	1000

Assuming a month of 30 working days:

a) Calculate the load factor of the above consumer. [02 Marks]

b) Determine the monthly electricity bills under Indus-1 & Indus-2 and hence advice and help the consumer to select the most attractive tariff. [03 Marks]

c) If a portion of the working load, amounting to 375 kVA operating between 15:00 – 21:00 hrs can be shifted and uniformly distributed between 21:00 and 06:00 hrs by an extra working shift, under a newly introduced load management program, calculate the new load factor. [05 Marks]

d) Determine the new electricity bills under Indus-1 & Indus-2 for the new scenario and hence advise the best tariff for the consumer. [05 Marks]

e) What is the phrase used in power system planning to describe strategy of load shifting action taken by this customer? Also list other strategies of this initiative. [05 Marks]

Question 7

a) What is meant by "Unit commitment"? [02 Marks]

b) The heat input function of three committed generators using the same fuel is shown below in Table Q7.

Table Q7

Generator type	No of committed units	a	b	c	Rated output (MW)	Minimum output (MW)	Maximum output (MW)
1	1	249.0	8.7	2.85×10^{-3}	400	100	420
2	1	485.2	8.4	1.04×10^{-3}	620	150	630
3	4	202.3	9.2	2.55×10^{-3}	70	20	75

$F = a + b.P + c.P^2$ GJ/hour ; P is the generator gross output in MW

Derive the fuel cost function for each generator if the common fuel price is 250 Rs/GJ. [03 Marks]

c) In power system economic dispatch, what is "incremental cost" often denoted by λ ? Where, $\lambda = \frac{\partial F}{\partial P} = b + 2\,c \times P$ [03 Marks]

d) If the common load is 1100 MW, calculate the loading of each generator for most economic dispatch within power plant operating range. [08 Marks]

e) Calculate the total hourly operating cost and average cost of generation of the system? [02 Marks]

f) Calculate the spinning reserve of the system at the specific hour? [02 Marks]

All right reserved