(32)

00123

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

Study Programme	: Bachelor of Technology Honours in Engineering
Name of the Examination	: Final Examination
Course Code and Title	**: EEX6832/ECX6332 Power Systems Planning**
Academic Year	: 2017/18
Date	: 08th February 2019
Time	: 0930-1230hrs
Duration	: **3 hours**

General Instructions

1. Read all instructions carefully before answering the questions.
2. This question paper consists of **Eight (8)** questions in **Eight (8)** pages.
3. Answer any **Five (5)** questions only. All questions carry equal marks.
4. Answer for each question should commence from a new page.
5. Relevant charts/codes are provided.
6. This is a Closed Book Test (CBT).
7. Answers should be in clear hand writing.
8. Do not use Red colour pen.

1. **a.** What are the causes of low power factor? Discuss briefly the impacts of low power factor of industrial consumers, on both generating stations and electricity consumers. **[4 Marks]**

b. The variation of load over a day, of a 400 V, three phase, 50 Hz industrial consumer is given in Table Q1A

Table Q1A

Time (hours)	0000-0900	0900-1500	1500-2100	2100-2400
Total Load (kW)	100	300	600	100
Load Description LL- lighting load IM- Induction Motor	LL only	LL + 200 kW IM load @ 0.8 p.f.	LL+ 200 kW IM load @ 0.8 p.f. + 300 kW IM load @ 0.6 p.f.	LL only

The distribution company offers a choice of two electricity tariffs for the above consumer given in Table Q1B.

Table Q1B

Description of the Charge		Tariff-1	Tariff-2
Demand Charge (Rs/kVA)		750	600
Energy Charge (Rs/kWh)	Peak (1800-2100)	15.00	27.00
	Off peak (other time)	15.00	12.50
Fixed Charge (Rs/Month)		2000	2000

Assuming a month of 30 working days

i) Calculate the load factor of the consumer. **[1 Marks]**

ii) Determine the monthly electricity bills under Tariff-1 and Tariff-2, and advice and the consumer to select the more attractive tariff. **[3 Marks]**

iii) If the consumer working load of 300 kW operating between 1500-2100 can be shifted and uniformly distributed between 2100 and 0600 by introducing an extra working shift, calculate the new load factor. **[1 Marks]**

iv) Determine the new electricity bills under each tariff and hence advice the best tariff for the consumer. What is the **phrase** you generally use in power systems planning to describe the action taken by this consumer? **[3 Marks]**

v) Calculate the size of the capacitance/phase to be installed to improve the power factor to be unity after implementing (iii). (Assume that the capacitor banks is star connected). **[4 Marks]**

vi) What would be the payback period of the investment on such a bank of capacitors? Assume that the cost of capacitors is 2750 Rs/kVAr **[4 Marks]**

2. a. Over a period of 2 years, the following performance has been recorded in the log-sheet of a 50 MW and 100 MW generating units operating in a power system.

Table Q2

Event Description	Unit Capacity			
	50 MW		100 MW	
	1st year	2nd year	1st year	2nd year
Total operating time with full load	7200 h	7200 h	3000 h	2760 h
Total duration of planned maintenance work	900 h	700 h	720 h	740 h
Number of forced outages	12	12	15	14
Average duration of a forced outage	27.2 h	36 h	24 h	47.5 h
Fuel cost + variable maintenance cost	25 LKR/kWh		20 LKR/kWh	

Calculate Forced Outage Rate for: **1.** 50 MW & **2.** 100 MW units **[4 Marks]**

b. Two 50 MW units and a 100 MW unit (the characteristics are shown in Table Q2) are available to serve a power system, for which the load curve is shown in Figure Q2.

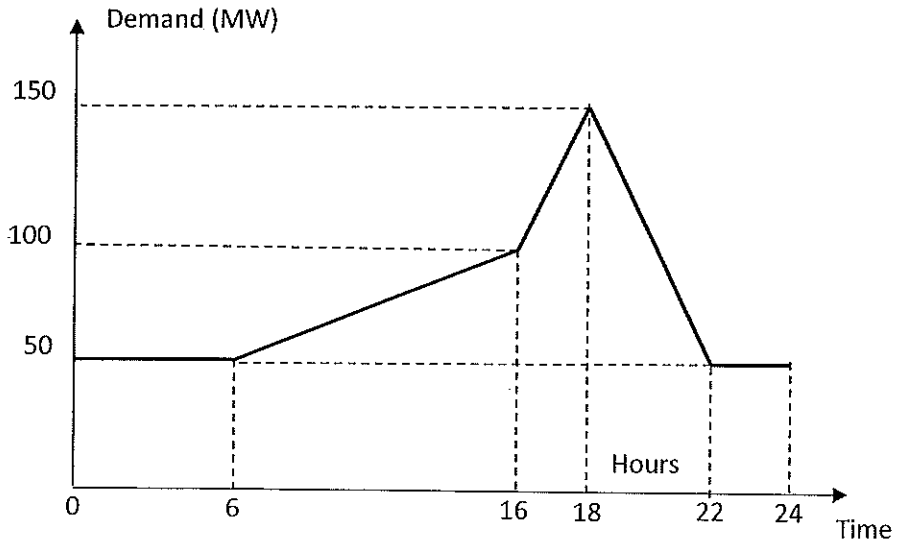


Figure Q2

Do the following:

1. Draw the Load Duration Curve **[2 Marks]**
2. Compute the plant factor, energy served and the cost of operation of each plant **[8 Marks]**
3. Compute the loss of load probability (LOLP) **[3 Marks]**
4. Compute the expected energy not served per annum (ENS) **[3 Marks]**

3. a. Without using any mathematical derivations, explain very briefly the "*incremental cost*" concept with respect to the optimum dispatch of generators in power systems. **[3 Marks]**

b. The fuel-cost curve of an i^{th} thermal generator of a group of "n" thermal generators can be written as, $C_i = a_i + b_i P_i + c_i P_i^2$ \$/h where a_i, b_i and c_i are constants and P_i is the generation in MW. Prove that the generators can be optimally dispatched to a lossless network with a total demand of (D), when the incremental cost of generation (λ) and an individual generator contribution (P_i) related with the equation given below:

$$\lambda = \frac{\sum_{i=1}^{n}\left(\frac{b_i}{2c_i}\right)+D}{\sum_{i=1}^{n}\left(\frac{1}{2c_i}\right)} \quad \text{where} \quad P_i = \frac{\lambda - b_i}{2c_i}$$ **[4 Marks]**

c. A company owns three generating units operating with cost functions with the following a, b and c parameters.

Unit	a	b	c
1	15	1.4	0.04
2	25	1.6	0.05
3	20	1.8	0.02

Making use of the equations derived in **(b)**, dispatch these three units optimally to supply a total demand of 350 MW. **[4 Marks]**

d. How would you dispatch the above three units if the company decides to buy some of the energy from the spot market at a price of 8.20 \$/MWh? **[4 Marks]**

e. In addition to supplying 350 MW of demand as dispatched in **(c)**, the company had an opportunity to sell energy to the electricity market at a price of 10.20 \$/MWh. What would be the optimal amount of power that the company could sell?

You may assume the generation limits of the three units to be as follows:

$$P_{1,max} \leq 100 \text{ MW}$$
$$P_{2,max} \leq 80 \text{ MW}$$
$$P_{3,max} \leq 250 \text{ MW}$$ **[3 Marks]**

f. What profit would the company earn from the sale calculated in **(e)** **[2 Marks]**

4. An isolated power station has the Load Frequency Control system as shown in Figure Q3. with the following parameters:

Turbine Time Constant $T_T = 0.5$ s
Governor time constant $T_G = 0.25$ s
Generator inertia time constant H = 8 s
Governor speed regulation = R per unit

The load varies by 1.6% for a 1% change in frequency, i.e., D = 1.6

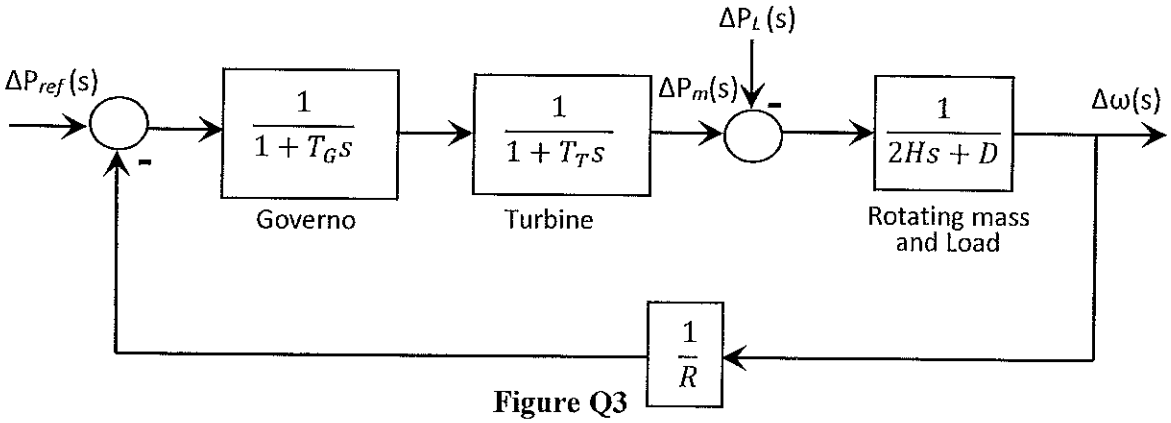


Figure Q3

a. Substitute the parameters given above and redraw the block diagram of figure Q3 with the load change $-\Delta P_L(s)$ as the input and frequency deviation $\Delta\omega(s)$ as the output. **[5 Marks]**

b. Derive the open-loop transfer function **[5 Marks]**

c. Find the range of governor speed regulation R for control of system stability **[5 Marks]**

d. The governor speed regulation of the above is set to R = 0.04 per unit. The turbine rated output is 200 MW at normal frequency of 50 Hz. A sudden load change of 50 MW (ΔP_L=0.25 per unit) occurs. Find the steady-state frequency deviation in Hz. **[5 Marks]**

5. a. Explain the importance of screening curves in generation expansion planning. **[5 Marks]**

Table Q5 shows the investment, maintenance and fuel costs of three thermal power plants.

Table Q5

	Gas fired Combined Cycle (300 MW)	Auto Diesel fired Combined Cycle (300 MW)	Nuclear Steam (600 MW)
All-inclusive capital cost (Rs/kW)	205,000	106,600	500,000
Economic life (years)	30	30	35
Annual maintenance (Rs/kW)	506	525	9,800
Fuel Cost (Rs/kWh)	10.00	18.50	1.00
Variable Maintenance cost (Rs/kWh)	0.35	0.50	1.90
P.V factor at 10%	9.43	9.43	9.64
Decommissioning cost (Rs/kW)	-	-	75,000

b. Develop the screening curve formula at a discount rate of 10% and determine the range of plant factor for which each plant is the most economical out of the three. **[15 Marks]**

6. For a uniformly distributed load on a distribution feeder, show that the total voltage drop along the full length of the line can be represented by the expression $I_s.z(l/2)$ where I_s is the rms current at the sending end and z is the impedance per unit length. l is the total length of the line. **[4 Marks]**

Also, for a line loaded with uniformly increasing load show that the above voltage drop could be represented as $I_s.z(2l/3)$. **[4 Marks]**

An equilateral triangle-shaped urban residential area shown in figure Q6 is to be fed with a distribution transformer located at the center of the area. Three main feeders will run along the road ways at an angle 120^0 to each other as shown in thick lines. Five lateral feeders connected to each main feeder run parallel to each side of the triangle. The arrangement of the housing scheme is expected to impose an area load density of 1 MW/km^2. The operating voltage is 400 V, three phase, four-wire type.

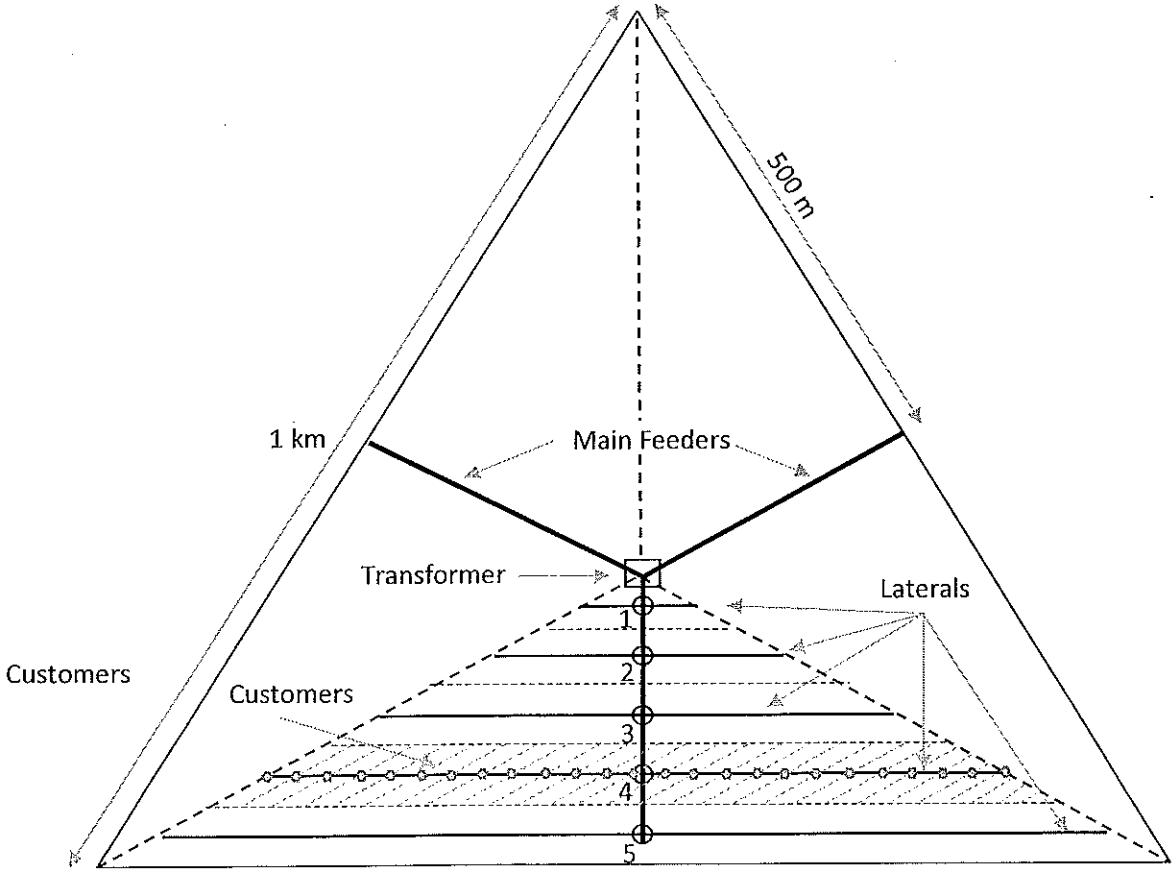


Figure Q6

If the impedance per unit length of a lateral is twice the impedance per unit length of the main feeder, calculate the impedance per unit length of the main feeder, such that the voltage drop anywhere in the residential area will be within 2.5% of the nominal voltage. **[12 Marks]**

[Hint: Assume that the loads on the laterals are uniformly distributed along the line]

7. Consider the substation configuration Fig Q7 shown below and the reliability data given in the table for each component:

N/C normally closed
N/O normally open

λ = failure rate
r = mean time to repair
s = switching time

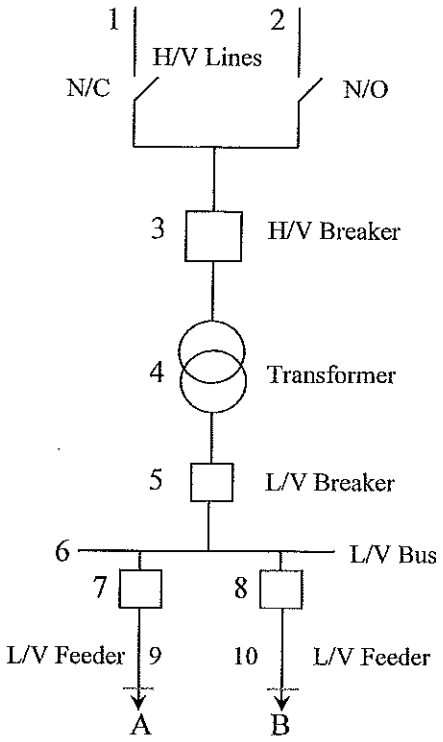


Fig. Q7

Reliability data Table Q7

Component	λ(f/yr)	r (hours)	s (hours)
H/V Line #1, Line #2	0.04	24	0.75
HV breaker #3	0.003	50	1.0
Transformer #4	0.01	240	1.0
LV breaker 5-7-8	0.006	24	1.0
LV bus bar 6	0.004	5	1.0
L/V feeder 9	0.075	5	1.0
L/V feeder 10	0.05	5	1.0

a. Evaluate the failure rate (λ), average outage duration (r), annual outage time (Unavailability) at load points A & B. **[6 Marks]**

b. If the average load connected at bus A and B is 5 MW and 6 MW respectively, calculate the total energy not served by the substation. **[6 Marks]**

c. Repair times of transformers are often very long and therefore spares are frequently kept available. If in the above case, a spare transformer is available and can be installed within 24 hours, compute:

- The failure rate (λ)
- Average outage duration (r)
- Annual outage time (Unavailability)
- Total energy not served by the substation **[8 Marks]**

8. Following are the 16 multiple type questions. Each question carries **1.25** marks. Underline the correct answer and attach the two pages 7|8 & 8|8 to your answer script.

a. A generating station has a low investment cost and high operating cost usually operated as:

1. Peak load station **2.** Base load station **3.** Medium load station **4.** None of the above

b. One million cubic meters of water is stored in a reservoir feeding a water turbine. The density of water is 993 kg/m^3. If the center of mass of water is 50 meters above the turbine and the losses are negligible, the energy stored in the volume of water is:

1. 135.3 MWh **2.** 130 MWh **3.** 120 MWh **4.** 140 MWh

c. An interconnected power system has the following power plants

(i) Nuclear (ii) Steam (iii) Gas Turbine (iv) Hydro with storage
(v) Run-of-River (vi) Pumped Storage

Which of the power plants are suitable to be used only for supplying the base load?

1. (i), (ii), (v) **2.** (iii), (vi) **3.** (iv), (v), (vi) **4.** (ii), (iii), (v)

d. The main objectives of load frequency control in a power system are:

i. To bring the steady state frequency error to zero after a load change
ii. To maintain the net tie-line flow
iii. To maintain the voltage on all buses
iv. To economize the cost of generation

1. i and ii **2.** ii and iii **3.** iii and iv **4.** i, ii, iii and iv

e. A power system has two synchronous generators. The governor-turbine characteristics corresponding to the generators are $P_1=50(50-f)$, $P_2=100(51-f)$ where f denotes the system frequency in Hz, and P1 and P2 are respectively, the power outputs (in MW) of turbines 1 and 2. Assuming the generators and transmission network to be lossless, the system frequency for a total load of 400 MW is:

1. 47.5 Hz **2.** 48.0 Hz **3.** 48.5 Hz **4.** 49.0 Hz

f. In a power plant which of the following items <u>does not</u> fall into the category of operating cost?

1. Salaries of operation and maintenance staff
2. Maintenance and repair cost
3. Salaries of supervisory staff engaged in operating the plant
4. Salaries of management and clerical staff

g. The annual load duration curve of a power supply system may be considered as a straight line from 40 MW to 8 MW. The load factor of the system is:

1. 20% **2.** 40% **3.** 60% **4.** 83.33%

h. Economic dispatch of generation is performed approximately in time steps of:

1. ½ hour **2.** 24 hour **3.** 1 second **4.** 1 week

i. In a load duration curve for an integrated power system, the uppermost crest represents the energy contributed by which one of the following?

1. Base power station
2. Major thermal stations
3. Peaking hydro or gas turbine stations
4. Non-conventional power stations

j. The most suitable location for a power factor improvement device is:

1. Near the electrical appliance which is responsible for the poor power factor.
2. At the receiving end, in case of a transmission line.
3. At the sending end
4. Anywhere in the circuit
5. Both 1 and 2.

k. During a period of 8760 hours, a generator with a scheduled maintenance duration of 336 hours gives a service (total up time) of 5724 hours. Its forced outage rate will be:

1. 0.32 **2.** 0.3 **3.** 0.15 **4.** 0.2

l. Salvage value of a power generating station inclusive of its equipment:

1. Is always positive
2. Is always negative
3. Is always zero
4. May be any of the above

m. Technically feasible projects are financially justified with the following tool/tools:

1. NPV **2.** Benefit/Cost ratio **3.** IRR **4.** All the above

n. A 3ϕ, 11 kV, 50 Hz, 200 kW load has a pf of 0.8 lag. A Δ-connected 3ϕ capacitor is used to improve the pf to unity. The capacitance per phase of the capacitor in microfarads is:

1. 3.948 **2.** 1.315 **3.** 0.439 **4.** 11.844

o. A power plant with three 25 MW identical generating units having a forced outage rate 0.1 can meet a 50 MW constant load with an approximate LOLE of:

1. 40 minutes/day **2.** 350 minutes/day **3.** 1 minutes/day **4.** 38 minutes/day

p. Out of those listed below, which is the factor that could always influence the rate of change of frequency in the Sri Lanka power system during a sudden generator tripping?

1. Whether the generator that tripped was operating at the time as a base load power plant or as a peaking plant
2. The total inertia of the remaining system
3. System voltage
4. Configuration of the transmission network