00036

The Open University of Sri Lanka
Bachelor of Technology
ECX 6332-Power Systems Planning
Final Examination 2012/2013

Duration Three Hours

Date: 13th August 2013 Time: 0930-1230 hrs.

This paper contains Eight (8) questions. Answer any Five. All questions carry equal marks.

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

b) A load variation throughout a day of a 400 V, three phase, 50 Hz industrial consumer is given in Table Q1A

Table Q1A

<table>
<tr><th>Time (hours)</th><th>0000-0900</th><th>0900-1500</th><th>1500-2100</th><th>2100-2400</th></tr>
<tr><td>Total Load (kW)</td><td>100</td><td>300</td><td>600</td><td>100</td></tr>
<tr><td rowspan="3">Load Description
LL- lighting Load
IM- Induction Motor</td><td>LL only</td><td>LL</td><td>LL+</td><td>LL only</td></tr>
<tr><td rowspan="2"></td><td>200 kW
IM load @ 0.8 p.f.</td><td>200 kW
IM load @ 0.8 p.f.</td><td rowspan="2"></td></tr>
<tr><td></td><td>300 kW
IM load @ 0.9 p.f.</td></tr>
</table>

A distribution company offers a choice of two electricity tariffs for the above consumer and it is 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 above consumer. **[1 Marks]**

ii) Determine the monthly electricity bills under Tariff-1 and Tariff-2 and hence advice and help the consumer to select the more attractive tariff. **[4 Marks]**

iii) If the consumer working load of 300 kW operating between 1500-2100 can be shifted and uniformly distributed between 2100 and 0600 hrs by introducing an extra working shift, calculate the new load factor? **[1 Marks]**
Determine the new electricity bills from the two tariffs and hence advice the best tariff for the consumer. What is the **phrase** you generally use in power system planning to describe the action taken by this consumer? **[5 Marks]**

iv) 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 are star connected). What would be the payback period of the investment on such a bank of capacitors? Assume that the cost of capacitors is 2000 Rs/kVAr **[5 Marks]**

2. A Power system has three generators. Generator data are as given in Table Q2. If the system load curve is as shown in figure Q2, compute the following:

Table Q2

Generator	Incremental Cost (Rs/MWh)	Capacity (MW)	Forced Outage Rate
G-1	800	100	0.1
G-2	1000	50	0.15
G-3	1200	50	0.15

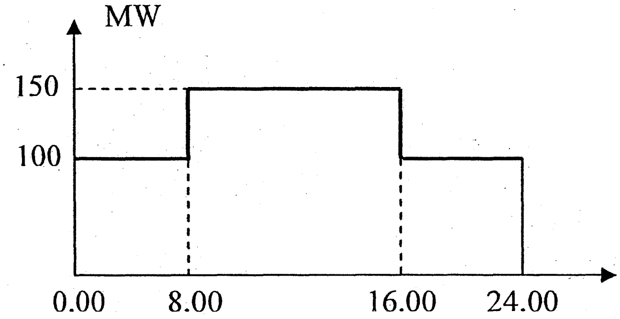

Figure Q2

(a) Annual energy served, plant factor, production cost of each plant? **[5 Marks]**
(b) LOLP and LOLE of the system? **[5 Marks]**
(c) Expected energy not served per annum (ENS)? **[5 Marks]**
(d) Comment on possible changes to the answers in (a) if the two 50 MW generators are replaced with a single 100 MW new generator having an incremental cost of 1100 Rs/MWh and the generator availability data as given below: **[5 Marks]**

New 100 MW Generator Data

Capacity (MW)	0	50	100
Availability	0.0225	0.2550	0.7225

3. A wind farm is now in operation in Puttalam area along the cost where their foundations are at sea level. Assume the entire wind farm is shifted from Puttalam area to a location near Ambewela for some reason, where the same wind profile/direction as in Puttalam is available, but with the turbines installed at a high altitude. Would the power generated be the same or not. If not why? **[3 Marks]**
If ρ = density of air (1.201 kg/m^3), U= mean air velocity (m/s), A= swept area of blades (m^2)

Show that the theoretical wind power is given by $P = \frac{1}{2}.\rho.A.U^3$ Watts. **[3 Marks]**

However the real wind power formula is given by $P = \frac{1}{2}.C_P.\rho.A.U^3$ what is C_P? **[2 Marks]**

What would be the theoretical maximum value of C_P? **[2 Marks]**
If C_P varies between 0.25 and 0.45, calculate the approximate number of wind generators required to produce the equivalent of a 100 MW Combine Cycle Gas Turbine. Assume an average wind speed to be 50 km/h, blade diameter to be 20 m and a suitable value for C_P. **[5 Marks]**

Discuss the advantages and disadvantages of wind power schemes. **[5 Marks]**

4. Prove that $\frac{\partial C_i(P_i)}{\partial P_i} = \lambda\left[1 - \frac{\partial P_L}{\partial P_i}\right]$ where the notations have their usual meanings. **[5 Marks]**

Consider the two-bus system shown in figure Q4. The incremental production costs at the two generating stations are given by

$$\frac{dC_1}{dP_1} = 0.005P_1 + 5 \quad \& \quad \frac{dC_2}{dP_2} = 0.004P_2 + 7$$

The B coefficients are shown in matrix form as

$$B = \begin{bmatrix} 0.0002 & -0.00005 \\ -0.00005 & 0.0003 \end{bmatrix}$$

Determine the penalty factors at both the buses, given $\lambda = 8$

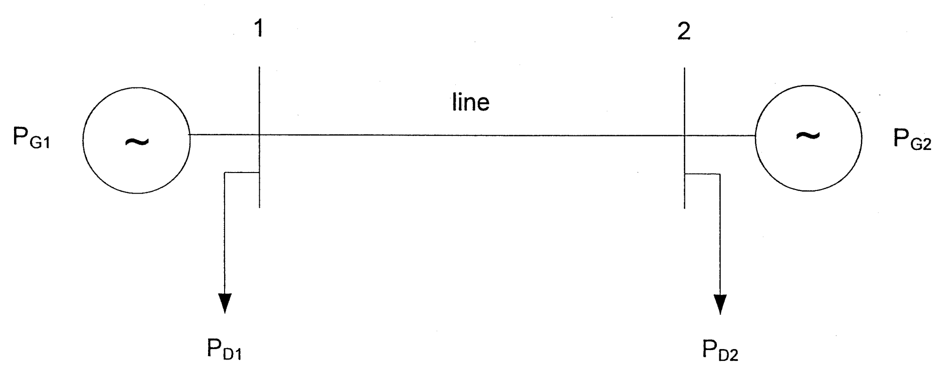

Figure Q4 **[15 Marks]**

5. What is **"spinning reserve"** & **"reserve margin"** of a power system. **[5 Marks]**

A typical daily load and reserve requirements of a power system are as given below:

Hours(hr)	10 P.M.- 10 A. M.	10 A.M.- 6 P. M.	6 P.M.- 10 P. M.
Load(MW)	10	12	15
Reserve(MW)	2	3	4

The system has three thermal power plants with capacities and cost data as follows:

Plant	Capacity (MW)	Marginal energy cost ($/MWh)	Fixed Losses ($/h)	Start-up Cost ($)	Shutdown cost ($)
A	10	50	30	100	20
B	10	100	20	150	10
C	5	150	10	80	5

Find the total minimum operating cost, optimum hourly unit commitment schedule and the corresponding short run marginal costs. (You may assume merit order dispatching of power plants and the start-up costs are independent of whether the boilers are banked or not. Ignore transmission and distribution losses). **[15 Marks]**

6. Most of the feeders emanating from the secondary grid substations are radial lines. Consider the radial distribution network shown below, only with the first order events.

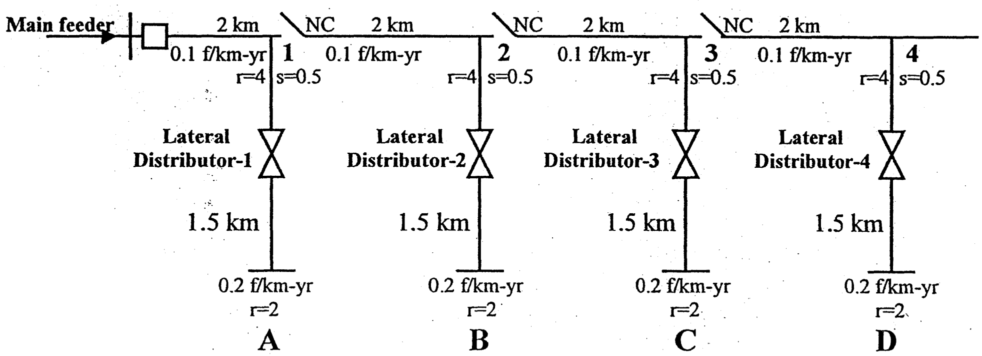

Figure Q6a

Data pertaining to the above radial circuit are:

Main feeders failure rate = 0.1 f/km-yr
Average repair time = 4 h
Each feeder section length = 2 km
Time to manually isolate a feeder section = 0.5 h

lateral distributor failure rate = 0.2 f/km-yr
Average repair time = 2 h
Each lateral distributor length = 1.5 km

The Operating principle would be:

All feeder section failures will cause the main breaker to open but a lateral distributor failure will cause only its fuse switch to operate. When a feeder section fails, the nearest isolator is opened and the breaker is re-closed.

On the basis of above, compute the reliability indices at load points A, B, C & D? **[6 Marks]**

If the previous network is equipped with an alternative source of supply into section 4 as shown in Figure Q6b, re-compute the reliability indices at load points A, B, C & D? **[4 Marks]**

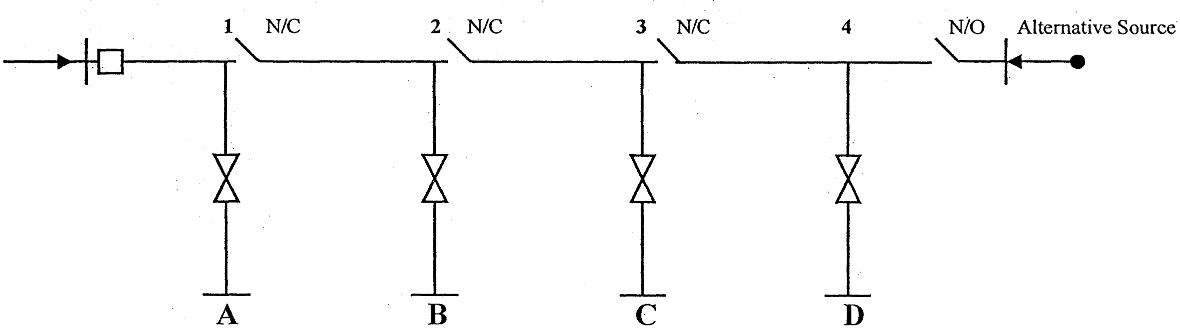

Figure Q6b

Compute the customer interruption index before and after connecting the alternative supply to the above radial line, if 200 customers are connected at each load point? **[4 Marks]**

Also, compute the energy not supplied before and after connecting the alternative supply? **[3 Marks]**

The cost of energy not supplied is 56 Rs/kWh and the investment on the alternative supply connected at feeder #4 is about 1 million Rs. What would be the simple pay back period? **[3 Marks]**

Five lateral feeders are connected to a main feeder. The arrangement of the housing units is expected to impose an area load density of 1.5 MW/km^2. The operating voltage is 400 V, three phase, four-wire type.

If the impedance per unit length of a lateral is half the impedance per unit length of a 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 5% of the nominal voltage. **[15 Marks]**

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

7. What is "*Life Cycle Cost*" & "*IRR*" in project evaluation? **[5 Marks]**
A 500 kW, small hydroelectric power plant is expected to be installed in a remote area and electricity generated is proposed to be sold to the consumers living in a village of this area. The proposed selling price of a kWh is about Rs. 5.00.

Following are the costs involved in constructing the said electric power plant:

- Plant capital cost = Rs. 25 million of which Rs. 10 million is a bank loan.
- A bank loan of Rs. 10 million is approved for the construction of the above project subject to the payment of bank loan + interest = Annual payment of Rs. 2.5 million for 10 years starting from the end of 5^{th} year after completion of the project. [*i.e. Five (5) year grace period for both capital and interest*]
- Operation & Maintenance cost = 480000 Rs/year
- Economic life of the power plant = 25 years
- Expected plant factor = 0.3

Ignoring the proposed selling price, compute the specific cost per kWh of the power plant and the benefit-cost ratio. Assume a discount rate of 10% **[15 Marks]**

(Present worth factor table for your use is attached at the end of this question paper.)

8. For a uniformly increasing load on a distribution feeder, show that the voltage drop can be represented by the expression $V_d = I_s \times z \times \left[\frac{1}{3}l\right]$ where I_s is the rms current at the sending end and z is the impedance per unit length at nominal frequency. l is the length of the line. **[5 Marks]**
A square-shaped urban residential area of 1 km^2 is to be fed with a distribution transformer located at the centre of the square shown in Figure Q7. Four main feeders emanating from the transformer are running along the road ways, parallel to each side of the square.

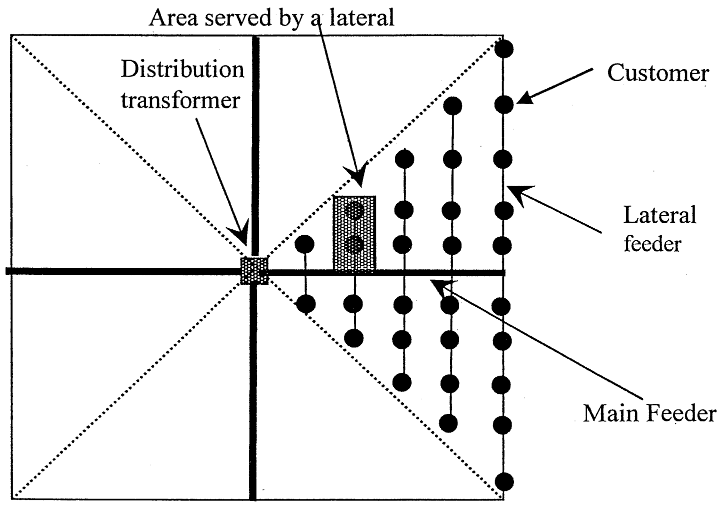

Figure Q7

Present Worth Factors

No. of years	Discount rate(%)									
	2	4	6	8	10	12	14	16	18	20
1	0.98	0.96	0.94	0.93	0.91	0.89	0.88	0.86	0.85	0.83
2	1.94	1.89	1.83	1.78	1.74	1.69	1.65	1.61	1.57	1.53
3	2.88	2.78	2.67	2.58	2.49	2.40	2.32	2.25	2.17	2.11
4	3.81	3.63	3.47	3.31	3.17	3.04	2.91	2.80	2.69	2.59
5	4.71	4.45	4.21	3.99	3.79	3.60	3.43	3.27	3.13	2.99
6	5.60	5.24	4.92	4.62	4.36	4.11	3.89	3.68	3.50	3.33
7	6.47	6.00	5.58	5.21	4.87	4.56	4.29	4.04	3.81	3.60
8	7.33	6.73	6.21	5.75	5.33	4.97	4.64	4.34	4.08	3.84
9	8.16	7.44	6.80	6.25	5.76	5.33	4.95	4.61	4.30	4.03
10	8.98	8.11	7.36	6.71	6.14	5.65	5.22	4.83	4.49	4.19
11	9.79	8.76	7.89	7.14	6.50	5.94	5.45	5.03	4.66	4.33
12	10.58	9.39	8.38	7.54	6.81	6.19	5.66	5.20	4.79	4.44
13	11.35	9.99	8.85	7.90	7.10	6.42	5.84	5.34	4.91	4.53
14	12.11	10.56	9.29	8.24	7.37	6.63	6.00	5.47	5.01	4.61
15	12.85	11.12	9.71	8.56	7.61	6.81	6.14	5.58	5.09	4.68
16	13.58	11.65	10.11	8.85	7.82	6.97	6.27	5.67	5.16	4.73
17	14.29	12.17	10.48	9.12	8.02	7.12	6.37	5.75	5.22	4.77
18	14.99	12.66	10.83	9.37	8.20	7.25	6.47	5.82	5.27	4.81
19	15.68	13.13	11.16	9.60	8.36	7.37	6.55	5.88	5.32	4.84
20	16.35	13.59	11.47	9.82	8.51	7.47	6.62	5.93	5.35	4.87
21	17.01	14.03	11.76	10.02	8.65	7.56	6.69	5.97	5.38	4.89
22	17.66	14.45	12.04	10.20	8.77	7.64	6.74	6.01	5.41	4.91
23	18.29	14.86	12.30	10.37	8.88	7.72	6.79	6.04	5.43	4.92
24	18.91	15.25	12.55	10.53	8.98	7.78	6.84	6.07	5.45	4.94
25	19.52	15.62	12.78	10.67	9.08	7.84	6.87	6.10	5.47	4.95
26	20.12	15.98	13.00	10.81	9.16	7.90	6.91	6.12	5.48	4.96
27	20.71	16.33	13.21	10.94	9.24	7.94	6.94	6.14	5.49	4.96
28	21.28	16.66	13.41	11.05	9.31	7.98	6.96	6.15	5.50	4.97
29	21.84	16.98	13.59	11.16	9.37	8.02	6.98	6.17	5.51	4.97
30	22.40	17.29	13.76	11.26	9.43	8.06	7.00	6.18	5.52	4.98
31	22.94	17.59	13.93	11.35	9.48	8.08	7.02	6.19	5.52	4.98
32	23.47	17.87	14.08	11.43	9.53	8.11	7.03	6.20	5.53	4.99
33	23.99	18.15	14.23	11.51	9.57	8.14	7.05	6.20	5.53	4.99
34	24.50	18.41	14.37	11.59	9.61	8.16	7.06	6.21	5.54	4.99
35	25.00	18.66	14.50	11.65	9.64	8.18	7.07	6.22	5.54	4.99
36	25.49	18.91	14.62	11.72	9.68	8.19	7.08	6.22	5.54	4.99
37	25.97	19.14	14.74	11.78	9.71	8.21	7.09	6.22	5.54	4.99
38	26.44	19.37	14.85	11.83	9.73	8.22	7.09	6.23	5.55	5.00
39	26.90	19.58	14.95	11.88	9.76	8.23	7.10	6.23	5.55	5.00
40	27.36	19.79	15.05	11.92	9.78	8.24	7.11	6.23	5.55	5.00