THE OPEN UNIVERSITY OF SRI LANKA
DEPARTMENT OF ELECTRICAL AND COMPUTER ENGINEERING
BACHELOR OF TECHNOLOGY
ECX 6332-POWER SYSTEMS PLANNING
FINAL EXAMINATION - 2014/2015 CLOSED BOOK

Duration - 3 Hrs.

Date: 08th of September 2015 **Time: 0930-1230 hrs.**

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

1. Daily electricity demand pattern (including week ends & holidays) of a small scale industrial customer metered at 400V/230V, working on three shifts is shown in figure Q1. Characteristics of the operating loads during three shifts are shown on the figure itself. Assume a month of 30 working days:

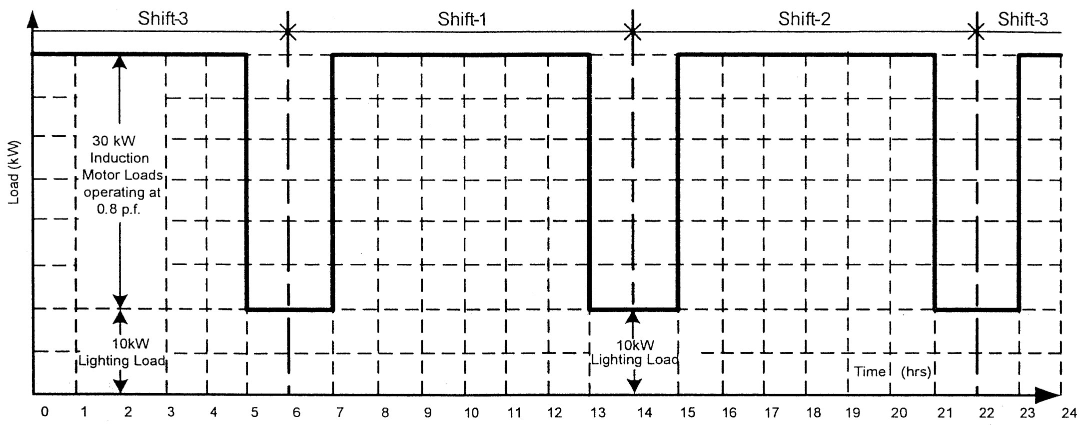


Figure Q1

i) What would be the monthly electricity bill of this customer in accordance with the tariffs structure given below in Table-1? **[4 Marks]**

ii) Compute the monthly cost saving, if the consumer improves the power factor of the industry to 0.95 **[4 Marks]**

iii) Calculate the required size of the capacitance in **μF** to be installed to improve the power factor to 0.95. (Assume that the capacitor banks are delta connected). **[4 Marks]**

iv) What would you suggest this customer to do from the DSM point of view with respect to his shift schedules so that he can further increase his annual savings? Determine the additional savings based on your suggestion, assuming the power factor has been already been improved to 0.95. **[8 Marks]**

Table-1 (Tariff applicable for Industrial Customers)

Customer Category	Conditions	Maximum Demand Charge (LKR/kVA) Per month	Energy Charge (LKR/kWh)	Fixed Charge (LKR/Month)
Industrial	Metered at 400V/230V, contract demand more than 42 kVA	1100	12.00 bet. 06.00-19.00 20.00 bet. 19.00-22.00 6.00 bet 22.00-06.00	3000

2. A power system consists of two generating units having costs and availabilities given in Table Q2 (a). They are to serve a LDC of which the characteristics are given in Table Q2 (b).

   a. Draw the LDC and compute the annual energy demand in MWh **[4 Marks]**

   b. Determine the expected production costs of each generator **[12 Marks]**

   c. Compute the Loss of Load probability (LOLP) index **[2 Marks]**

   d. Calculate the Unserved Energy (ENS). **[2 Marks]**

Table Q2 (a):

Generator	Average Costs (LKR/MWh)	Capacity (MW)	Availability (1-F.O.R)
Unit-1	1000	80	0.95
Unit-2	1500	40	0.9

Table Q2 (b): Load Duration Curve Data

Time(p.u.)	0.0-0.2	0.2-0.8	0.8-1.0
Load (MW)	100	80	40

3. For a uniformly distributed load on a distribution feeder, show that the total voltage drop 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. **[5 Marks]**
Also, for a line loaded with uniformly increasing load show that the above could be represented as $I_s.z(2l/3)$. **[5 Marks]**
A hexagonal-shaped urban residential area shown in figure Q3 is to be fed with a distribution transformer located at the centre of the area. Six main feeders will run along the road ways at an angle 60^0 to each other as shown in thick lines. Five lateral feeders connected to each main feeder run parallel to each side of the hexagon. 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.

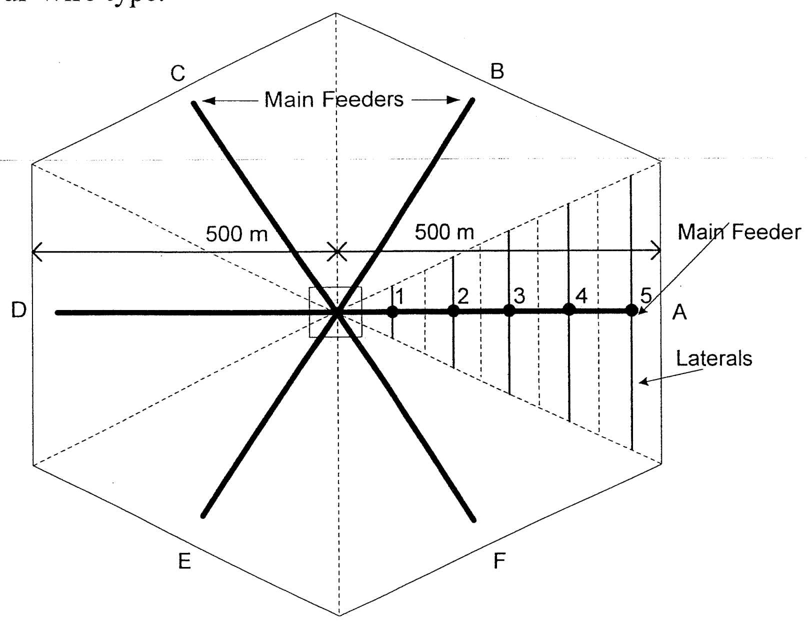


Figure Q3

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 5% of the nominal voltage. **[10 Marks]**

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

4. a) The electricity intensity E_i in the national economy is defined as $E_i = \frac{\overline{Y}}{\overline{S}}$ where $\overline{S}$ is the electricity sold per person per year, and $\overline{Y}$ is the national gross domestic product (GDP) per person per year. Table Q4 shows the historic variation of sales and GDP in a developing country. Estimate the electricity intensity in each year during 2005-2014, and comment on the result. **[10 Marks]**

Table Q4

Year	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
GDP	114261	115922	119050	121729	129244	135204	140990	150783	157115	165286
Electricity Sold (GWh)	2232	2253	2371	2353	2608	2742	2916	3270	3565	3886

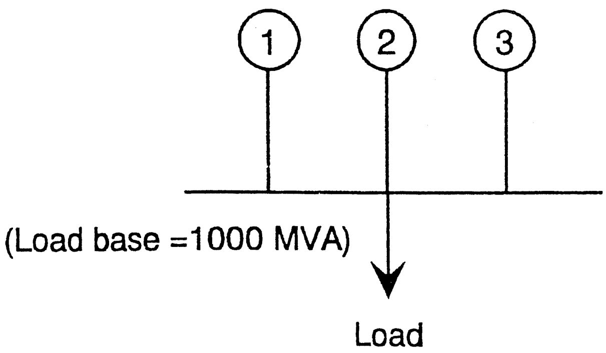
GDP (million of constant value currency)

b) *"The income elasticity of demand for electricity is expected to be positive in a developing economy, initially at a high value and then approaching values in the range of 0.8 to 1.1 as the country reaches a significant level of development"*

Considering that GDP reasonably represents the development of national income, estimate the income elasticity of demand every year over 2006-2014, using the information given in table Q4. In the context of the above statement given in b), discuss the possible reasons for the fluctuations. **[10 Marks]**

5. A single area with three generating units is shown in Figure Q5.

Unit	*Rating*	*Speed droop R (per unit on unit base)*
1	*100 MVA*	*0.01*
2	*500 MVA*	*0.015*
3	*500 MVA*	*0.015*



The units are initially loaded as follows. $P_1 = 80$ MW, $P_2 = 300$ MW, $P_3 = 400$ MW

a) What would be the steady-state frequency deviation and the new generation of each unit for a load increase of 50 MW, when D= $\left(\frac{\partial P_D}{\partial f}\right)$ = 0.0 for the system, i.e. no frequency dependent loads. **[8 Marks]**

b) If the load varies 1% for every 1% change in frequency, i.e. D= $\left(\frac{\partial P_D}{\partial f}\right)$ = 1.0 p.u. (i.e. 1.0 p.u. on load base). Find the steady-state frequency deviation and the new generation on each unit. **[8 Marks]**

c) Compute the amount of load released owing to the decrease in frequency? **[4 Marks]**

6. Consider the typical substation configurations Figure Q6 (a) & Figure Q6 (b) shown below and the reliability data given in the table for each component:

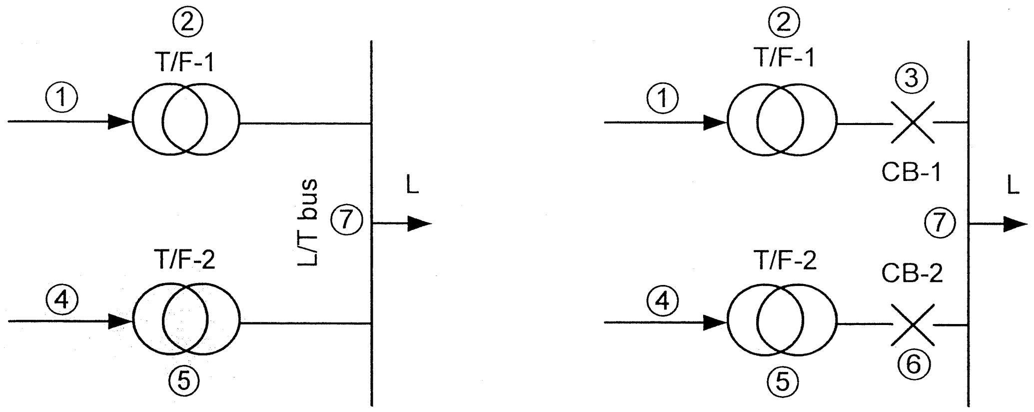


Figure Q6 (a) **Figure Q6 (b)**

Reliability data table

Component	λ(f/yr)	r (hours)	λ_a (f/yr)	S (hours)
1 & 4 (Lines)	0.09	8	0.09	1.0
2 & 5 (T/Fs)	0.1	50	0.10	1.0
7 (L/T bus bar)	0.024	2	0.024	-
3 & 6 (breakers)	0.02	3	0.01	1.0

λ_a= Active failure rate s = Switching time

a) Neglecting any coordinated/un-coordinated maintenance work performed in this system, Evaluate the failure rate (λ), average outage duration (r), annual outage time (Unavailability) at load point L for both substation configurations. If the average load connected at bus #7 is L1=30 MW, calculate the total energy not served for both the configurations. **[12 Marks]**

b) If the un-served energy cost is estimated to be 80 LKR/kWh and the extra cost involved in converting the substation shown in Figure Q6(a) to Figure Q6(b) is estimated to be 1 million LKR, what would be the simple pay-back period of the extra cost involved in converting the substations. **[8 Marks]**

7. a) What does Interest During Construction (IDC) means in project evaluation? **[2 Marks]**

b) An 80 MW hydroelectric plant is expected to cost 300000 LKR/kW to construct. Construction period is about 4 years and the IDC is calculated to be about 20% of the construction cost. Its maintenance cost is estimated to be Rs. 28 million LKR per year. Under average hydrological conditions, it is expected to generate electricity at an annual plant (capacity) factor of 45%. The estimated economic life is 50 years. Calculate the life-cycle cost at discount rates of 5% and 15%. **[14 Marks]**

b) What do you observe as the effects of the lower and higher discount rates? **[4 Marks]**

Assume:

$S = \left[\frac{(1+r)^n - 1}{r(1+r)^n} \right]$ *Where S is the Present Value Factor and r is discount rate for an interval. n is the total number of intervals.*

8. a) What does kilowatt peak (kWp) actually mean in a solar power module? **[2 Marks]**

b) How would you orient the house shown in figure Q8 (a) with respect to North-East & South-West directions for a best performing photovoltaic installation? **[2 Marks]**
[Mark it on the paper itself and attach to your answer script]

c) The following data relates to a solar power photovoltaic installation:

Total installation capacity proposed = 10 panels of 30 kWp = 300 kWp
Total installation cost of solar module = 5000000 LKR
Performance ratio of the panels at the premises = 85%
Equivalent sunny hours/day considering all the weather factors and rainy days = 3.6
Annual maintenance cost = 1% of the total capital cost
Inverter efficiency = 98%
Life time of the total installation = 20 years

Assume 5% degradation for first 10 years and 15% degradation for next 10 years for solar panels as shown in Figure Q8 (b)

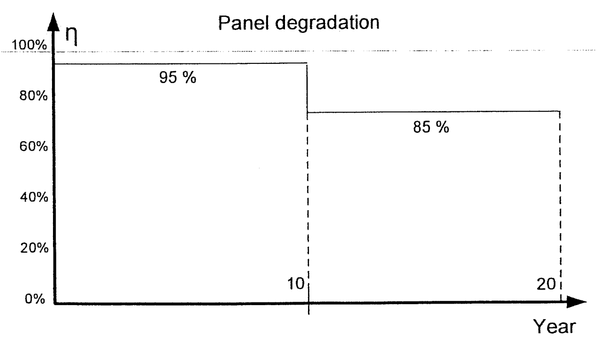


Figure Q8 (b)

Calculate the specific life cycle cost (LCC) in LKR/kWh of a solar unit at the above installation? **[16 Marks]**

[Assume 10% discount rate while performing the above calculation]

Assume:

$$S = \left[\frac{(1+r)^n - 1}{r(1+r)^n} \right]$$ *Where S is the Present Value Factor and r is discount rate for an interval. n is the total number of intervals.*

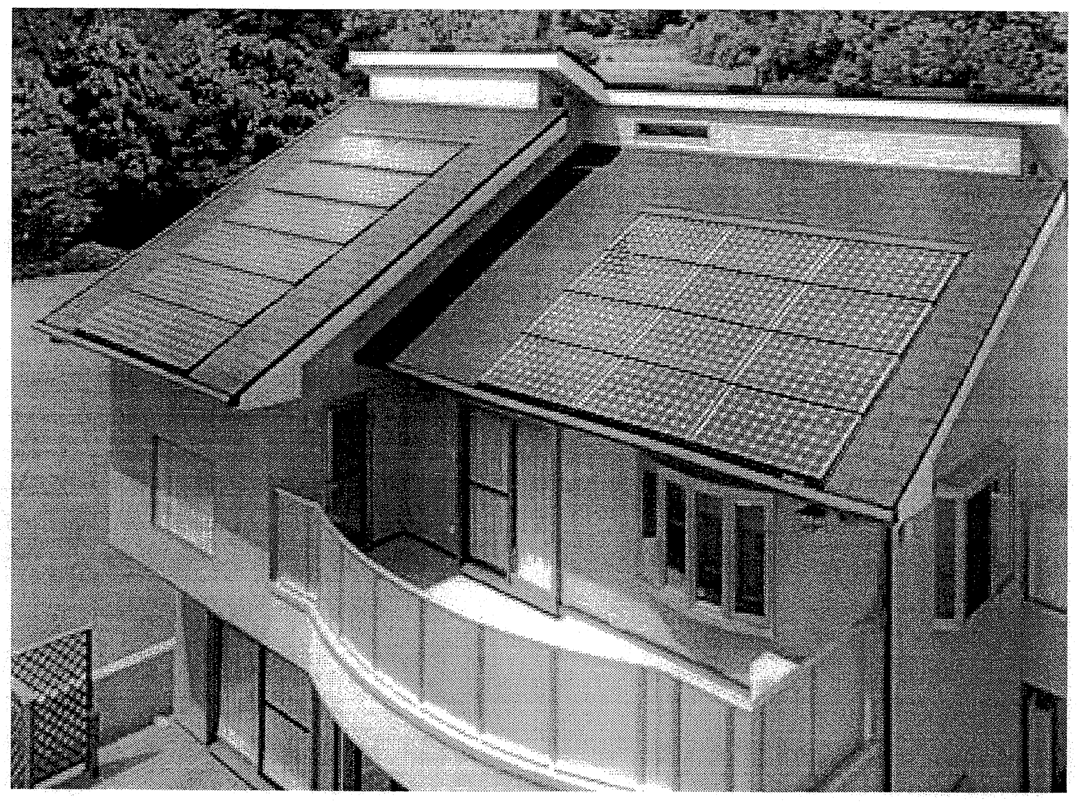


Figure Q8 (a)