The Open University of Sri Lanka
Bachelor of Technology
ECX 6332-Power Systems Planning
Final Examination 2011/2012

Duration Three Hours

Date: 13th March 2012 Time: 1400-1700 hrs.

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

1. Obtain the economic schedule for the two generating units, where the production costs are given below, to supply a load of 40 MW, in steps of 10 MW.

$$C_1 = 0.8P_1^2 + 25P_1 \text{ Units}$$

$$C_2 = 1.2P_2^2 + 22P_2 \text{ Units}$$

If only a load of 30 MW is to be supplied, how are the units to be committed?
Compute the same for loads of 20 MW and 10 MW respectively and obtain the unit commitment schedule based on the results. Use dynamic programming method. **[15 Marks]**
Do you think your answer is accurate enough? If not, how do you improve the accuracy? **[5 Marks]**

2. If the governor of a generator rated at P_1 MW has k_1 percentage speed droop and the governor of another generator rated at P_2 MW has k_2 percentage speed droop, ($P_2>P_1$ & $k_2>k_1$) explain how this could affect the load sharing among the generators for a change in total load from 0 MW to (P_1+P_2) MW. (Assume that the speed changers of both generators are fixed) **[8 marks]**
Deduce from the above, that when speed droop characteristics of generators are equal then the load sharing is proportional to generator capacities. **[2 Marks]**

Two generators rated 200 MW and 400 MW are operating in parallel. The droop characteristics of their governors are 4% and 5% respectively from no-load to full-load. The speed changers are so set that the generators operate at 50 Hz sharing a load of 600 MW in the ratio of their ratings. If the load reduces to 400 MW, how will it be shared among the generators and what will be the system frequency? Assume free governor operation. The speed changers of the governors are now re-set so that the load of 400 MW is shared among the generators at 50 Hz in the ratio of their ratings. What are the no-load frequencies of the generators? **[10 Marks]**

3. The load duration curve for a typical heavy load being served by a combined hydro-thermal system may be approximated by a straight line, the maximum and minimum loads being 60 MW and 20 MW, respectively. Hydropower available at the time of minimum regulated flow is just sufficient to deliver 50 MWh per day. It is observed that it will be economical to pump water from the tail race to the reservoir by utilizing the steam power plant during the off-peak periods and thus running the station at 100% plant factor. Determine the maximum capacity of each type of plant.
Assume that the cycle efficiency of pumping and generation of the steam power plant" to be 60%. **[20 Marks]**

4. A two-bus system is shown in fig Q4. If a load of 125 MW is transmitted from plant 1 to the load, a loss of 15.625 MW is incurred. Determine the generation schedule and the load served if the cost of received power is Rs. 24/MWh. Solve the problem using coordination equations and the penalty factor method approach. The incremental production costs of the plants are:

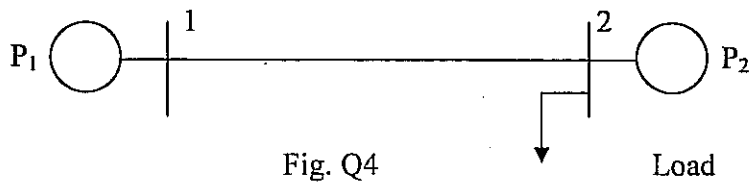


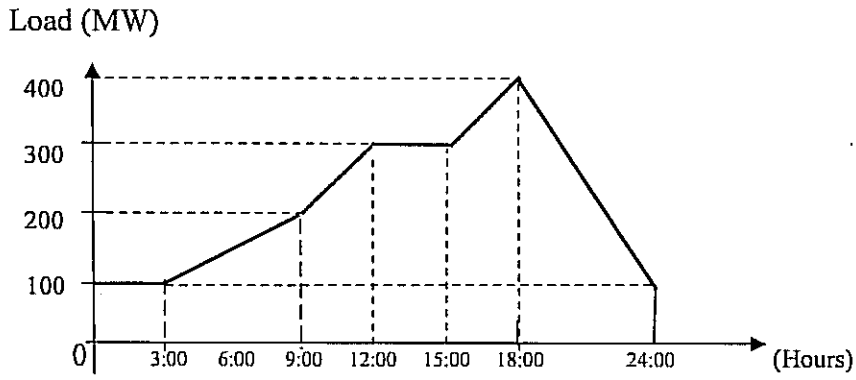
Fig. Q4

$$\frac{dF_1}{dP_1} = 0.025P_1 + 15 \qquad \frac{dF_2}{dP_2} = 0.05P_2 + 20$$ **[20 Marks]**

5. A power system is served by five generators where the installed capacities and forced outage rates are tabulated below:

Merit order loading	Plant ID.	Installed Capacity (MW)	Forced outage rate
1	A	100	0.1
2	B	100	0.1
3	C	100	0.1
4	D	100	0.1
5	E	100	0.1

If the generating system above is serving a load described by the following chronological load curve:



Sketch: Load duration curve **[2 Marks]**

Calculate: Daily Energy to be served **[3 Marks]**

Develop the Remaining Load Duration Curves for each generator (RLDCs) and estimate:

- Loss of Load Expectation) LOLE **[5 Marks]**
- Energy not Served(ENS) **[5 Marks]**
- Energy served & plant factor for each generator **[5 Marks]**

6. Read the following section carefully before answering the question:
The majority of utilities calculate distribution reliability indices based on the *number of customers per outage* and the *duration of the outage*. Some utilities calculate indices based on the *amount of load that is lost.*

SAIDI stands for System Average Interruption Duration index-which is the average total duration of interruptions of supply that a customer experiences in the period.

$$SAIDI = \sum \frac{(\text{Duration of Outage}) \times (\text{No. of customers interrupted})}{\text{Total no of customers}}$$

measured in *hours/connected customer. year*

SAIFI is stands for System Average Interruption frequency Index-which is the average number of Interruptions of supply that a customer experience in the period.

$$SAIFI = \frac{(\text{No.of csustomers interrupted per interruption}) \times (\text{No.of interruptions})}{\text{Total no of customers}}$$

measured in *interruptions/connected customer. year*

CAIDI is stands for Consumer Average Interruption Duration Index-which is the average duration of an interruption of supply for consumers who experienced an interruption of supply in the period.

$$CAIDI = \sum \frac{(\text{Duration of Outage}) \times (\text{No. of customers interrupted})}{\text{Total no of customer interruptions}}$$

measured in *hours/customer interrupted*

Assume you are the only customer connected to a substation that has the failure rate and outage duration characteristics shown in Fig. Q 6-A. The Public Services Commission asks you to assess the effect of adding a re-closer to the mid-point of the feeder (see location R on Fig. Q 6-B) by calculating SAIFI, SAIDI and CAIDI before and after the addition of the re-closer. Proceed with required calculations and derive the above indices.

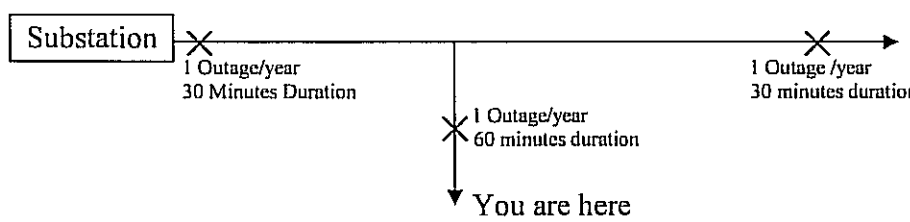


Fig. Q6-A

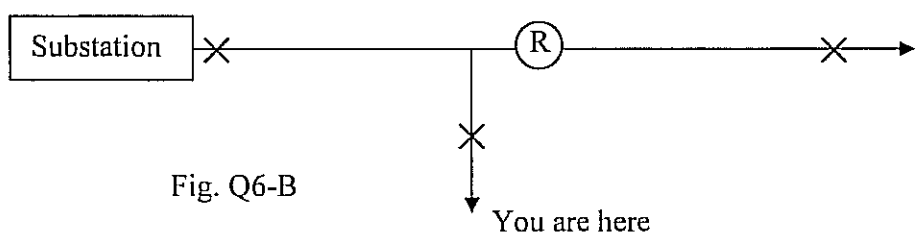


Fig. Q6-B

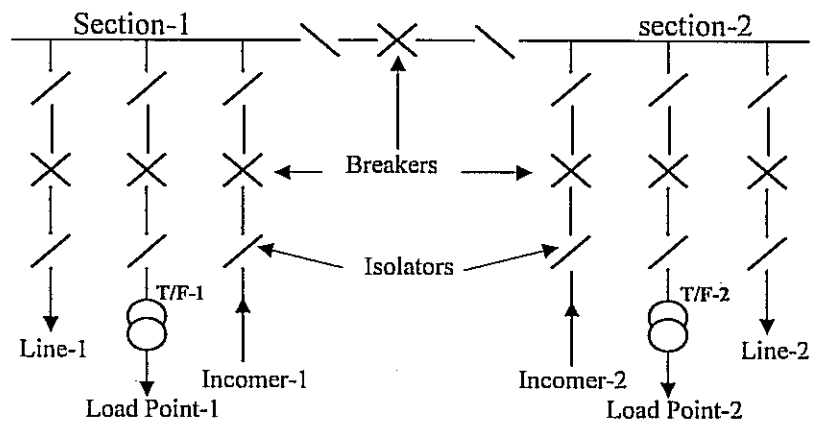
[20 Marks]

7. (a) State and Draw four commonly used bus-bar arrangements. **[5 Marks]**

(b) Explain why two isolators and a circuit breaker are commonly used to connect a circuit to a bus-bar. **[5 marks]**

(c) State six technical considerations when deciding on the bus-bar arrangement at a substation. **[5 Marks]**

(d) Identify the bus-bar arrangement shown below. State one of the disadvantages of this bus-bar arrangement. Can we not use a single isolator to couple the two sections? Explain your answer. **[5 Marks]**



8. A long distance overhead single circuit transmission line delivering power from one end to the other end has reached its limits, be it voltage at the end, thermal overloading or stability etc. How would you overcome this limitation?

(a) If the right-of-way is not restricted along the line **[2 Marks]**

(b) If the right-of-way is restricted **[2 Marks]**

A long distance overhead transmission line is delivering P_{OLD} MW load at $V_1\angle\delta_1$ sending end voltage and $V_2\angle\delta_2$ receiving end voltage. Show that the required capacitance to be installed in series with the overhead transmission line to achieve y% of the total line compensation is $\frac{100P_{OLD}}{2\pi f V_1 V_2 y Sin(\delta_1-\delta_2)}$ F.

[10 Marks]

Hence show that the new power that can be delivered is 2.5 times P_{OLD}, if the line compensation is 60 %. **[4 Marks]**

Explain why it is not possible to increase y to achieve full compensation (i.e. 100%) of the line. **[2 Marks]**