The Open University of Sri Lanka
Bachelor of Technology
ECX 6332-Power Systems Planning
Final Examination 2005

020

Duration Three Hours
Date: 17th March 2006 **Time: 0930-1230 hrs.**

This paper contains Seven (7) questions. Answer any Four. All questions carry equal marks. Graph papers will be available on request.

1. A topographic map of an area 'X' is shown in the attached figure-1. The contour lines are marked and elevations are marked in meters above the mean sea level. Annual average surface run-off of the area of interest is approximately 136 million cubic meters (MCM). A river flows as shown in the figure. Using the given data, do the following:-

   a. Identify the best location for a dam and mark-up the reservoir full storage surface area.
   b. Identify the best location for a hydro power plant fed from the above reservoir and mark-up the tunnel way (if required) and penstock path.
   c. Sketch the catchment area for the reservoir corresponding to the identified dam site in (a)
   d. What type of a turbine would you initially consider to be suitable for your estimated head/flow and how many generators would you recommend to install. Justify your answer.
   e. Estimate the capacity of the power plant (assume the annual plant factor to be 0.6 and the efficiency of the turbine & the generator to be 0.95 & 0.89 respectively.)
   f. The estimated maximum reservoir storage = 120 MCM
   Estimated minimum reservoir storage = 20 MCM and the
   Maximum turbine discharge = 40 MCM/month, and if
   You are requested to maintain 40 GWh (target) in every month, Use your computed data and the monthly inflow pattern for the first four months given in the 1st row of the following matrix to fill up the full matrix for the period February to April. Neglect head loss due to tunnel. (Assume: One month = 730 h.)

Month	Jan.	Feb.	Mar.	Apr.
Inflow (MCM)	40	0	0	0
Initial reservoir Storage (MCM)	100			
Intermediate reservoir storage (MCM)	120			
Initial reservoir release (MCM)	20			
Generation from initial release (GWh)	23.16			
Balance required to meet the target (GWh)	16.84			
Release from the reservoir required (MCM)	14.54			
Total output (GWh)	40			
Final storage (MCM)	105.46			
Spill Volume (MCM)	0			
Energy deficit (GWh)	-			

2. What is **"spinning reserve"** and **"reserve margin"** of a power system?

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

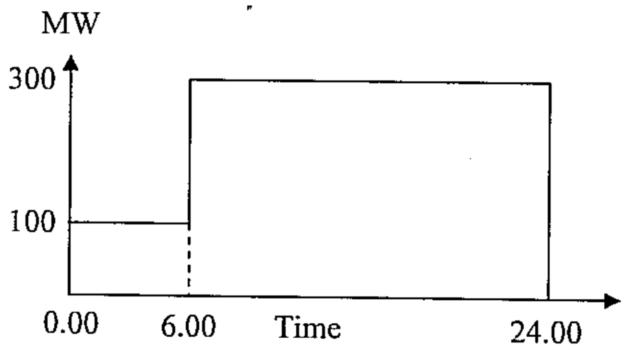
Hours	0000-0800	0800-1900	1900-2400
Load(MW)	8	12	15
Reserve(MW)	2	4	6

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	15	100	40
B	10	55	12	80	35
C	8	70	5	50	20

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

3. There are two independent power systems. Power system 'ABC' has three 100 MW generators and one 200 MW generator. Power system 'XYZ' has five 100 MW generators. The forced outage rates of the 100 MW and 200 MW generators are 10% and 20 % respectively. If each system serves a variable load curve as shown in figure 4, calculate the following:



(i) Loss of load probabilities (LOLP) and loss of load expectations (LOLE) of each system?

(ii) Expected energy not served per annum (ENS) for each system?

(iii) Identify the most reliable generating system based on your answers?

4. In the recent past there have been concerns that optimum economic dispatch among the coal power plants was not the best from an environmental point of view. Following is a problem based on a real situation that occurred in the mid western United States. Two coal-fired steam power plants have input-output curves as follows:

$$H_1 = 420 + 5.25P_1 + 0.0105P_1^2 \quad GJ/h, \quad 20 \le P_1 \le 200 \quad MW$$
$$H_2 = 630 + 4.2P_2 + 0.0158P_2^2 \quad GJ/h, \quad 20 \le P_2 \le 200 \quad MW$$

Both power plants burn coal with a heat content of 26750 kJ/kg that cost 15 monetary units per one metric ton (1 metric ton = 1000 kg). The combustion process in each unit results in 11.75% of the coal by weight going up the stack as fly ash.

a. Calculate the net heat rates of both units at 200 MW
b. Calculate the incremental heat rates and schedule each unit for optimum economy to serve a total load of 250 MW with both on-line.
c. Calculate the total cost of supplying that load in monetary units.
d. Calculate the rate of emission of fly ash for that case in kg/hr, assuming no fly ash removal devices are in service.
e. Plant 1 has a precipitator installed that removes 85% of the fly ash; Plant 2's precipitator is 89% efficient. Reschedule the two units for the minimum *total fly ash emission* rate with both on-line to serve a 250 MW load.
f. Calculate the rate of emission of ash and the cost for this schedule to serve the 250 MW load. What is the cost penalty?
g. Where does all that fly ash go?

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

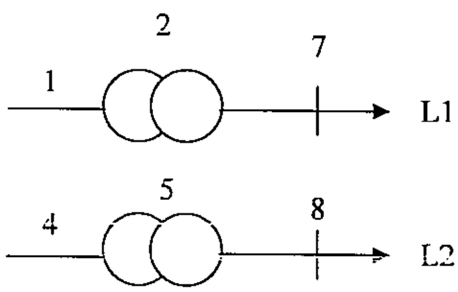


Fig. (a)

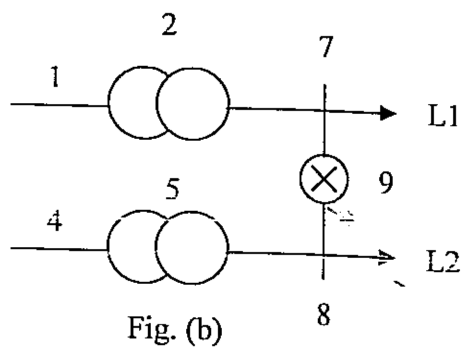


Fig. (b)

Reliability data table

Component	λ(f/yr)	r (hours)	λ_a (f/yr)	s (hours)
1 & 4 (Lines)	0.09	7.33	0.09	1.0
2 & 5 (T/Fs)	0.1	50	0.10	1.0
7 & 8 (bus bars)	0.024	2	0.024	-
9 (breaker)	0.02	3	0.01	1.0

λ_a= Active failure rate s = Switching time

Bus tie circuit breaker (9) is operating at normally open position and neglect 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 points "L1 & L2" for both substation configurations (a) & (b). If the average load connected at bus #7 & #8 are L1=10 MW and L2 =10 MW respectively, calculate the total energy not served for both configurations.

6. Compare the specific life cycle cost of two types of power plant to be built in Sri Lanka based on the prevailing fuel prices/other data shown in the table given below. One is coal and the other one is diesel (using residual oil as primary fuel supply). Assuming both power plants have equal impact on the environment on a per kWh basis,

a) Calculate the specific life cycle cost in Rs/kWh for each type of power plant?
b) Calculate the financial loss, if a 300 MW coal power plant is delayed by one year in the long term plan and replaced by three100 MW diesel power plants instead, in the short term?
c) What are the impacts on the environment in case of having a coal power plant as against diesel? Discuss the steps that you recommended to reduce the same.

Item/Description	Diesel	Coal
Residual Oil Price	233.0 US$/Metric Ton	-
Coal Price	-	67.3 US$/Metric Ton
Annual Plant factor	0.8	0.8
Maintenance Cost	1 US cent/kWh	1.5 US cent/kWh
Power Plant efficiency	39.5%	37.5%
Heat rate	10300 kcal/kg	6000 kcal/kg
Life time	10 years	20 years
Capital Cost	700 US$/kW	1000 US$/kW

Assume 1 kJ= 4.182 kcal & 1 US$= 100 Rs.

7. The demand for electricity in a district from 2000-2004 is given below:

Year	Sales (GWh)
2000	3200
2001	4250
2002	4750
2003	5000
2004	5250

a) Calculate the 5 year simple compound growth rate using the above figures
b) Fit a trend profile to the above data using both linear & exponential variations of the form

$\text{Sales} = a \times \text{Time} + b$ and $\text{Sales} = a \times e^{(k\,.\,\text{Time})}$

c) Check the goodness of fit (R^2) for the two models you have developed under (b). Would you accept the profiles (if so which, on what basis). Or reject?

d) Using the simple compound growth rate and the profiles you have developed, forecast the electricity sales for the year 2005?

e) Explain the limitations of the technique you have used in the above calculations and describe how you would overcome these limitations?

You may use the following statistical formulae applicable in least-square estimation method:

For Y= a + b.X of the form

$$a = \left\{ \frac{\sum_{i=1}^{n} y_i \sum_{i=1}^{n} x_i^2 - \sum_{i=1}^{n} x_i \sum_{i=1}^{n} x_i y_i}{n\sum_{i=1}^{n} x_i^2 - \left(\sum_{i=1}^{n} x_i \right)^2} \right\}$$

$$b = \left\{ \frac{n\sum_{i=1}^{n} x_i y_i - \sum_{i=1}^{n} x_i \sum_{i=1}^{n} y_i}{n\sum_{i=1}^{n} x_i^2 - \left(\sum_{i=1}^{n} x_i \right)^2} \right\}$$

$$R^2 = \frac{\text{explained variation}}{\text{total variation}} = \frac{\sum_{i=1}^{n} (y_i^e - \bar{y})^2}{\sum_{i=1}^{n} (y_i - \bar{y})^2}$$

Figure - 1

TOPOGRAPHICAL LAYOUT OF AREA 'X'