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THE INSTITUTION OF ENGINEERS, SRI LANKA

IESL Engineering Course

Part III Examination

308 POWER SYSTEMS II

Time Allowed: **3 hours** October 2012

Answer any **five** Questions. All Questions carry equal marks.

Q1

(a) Describe at least two different factors other than the direct cost factor, that need to be considered in selecting power plants for construction out of a list of candidate plants. [30]

(b) Explain the concept of present value used in evaluating financial feasibility of long life engineering projects. An income of x per year is generated annually for a period of N consecutive years. If the present value of the total income generated is represented by px under a discount rate of r show that

$$p = \frac{(1+r)^N - 1}{r(1+r)^N}$$ [30]

(c) Calculate the specific cost of generation (Rs/kWh) of a proposed hydroelectric power plant, based on the following data neglecting inflation and possible price escalations. Clearly state the assumptions you make.

Rated Power output	: 75 MW
Investment with interest during construction	: 160,000 Rs/kW
Economic life	: 50 years
Operation & Maintenance cost	: 13 million Rs/year
Expected average generation	: 270 GWh/year
Discount rate	: 10 %
Scrap value at the end of economic life	: negligible

[40]

Q2

a) Develop a simple transfer function for a power system modeled by a generator load system. [20]

b) Draw block diagram representations of a single area power system with governor action. [20]

c) A power system operating at 50 Hz has the inertia constant H = 5.0 s and the governor droop characteristic R = 2.0 Hz/pu active power. The load characteristic $D = \partial P/\partial f$ is equal to 10^{-2} pu active power/Hz. Calculate the time constant of the system in responding to a small change of the load neglecting the time constant of the governor and the turbine/generator combination. [60]

Q3

a) Explain what is meant by cost of unserved energy in relation with electrical power systems. [20]

b) The demand curve of a power system for an average working day is approximated in the table below:

Time period (hrs of the day)	load (MW)
0.00 -5.00	100
5.00 – 6.00	200
6.00 – 9.00	150
9.00 – 12.00	400
12.00 – 18.00	200
18.00 – 24.00	100

Draw the load duration curve $P^0(x)$ for the system. [10]

c) Four generators are available to meet the above demand and the generator characteristics are given in the following table:

Generator	Capacity (MW)	Forced Outage Rate (FOR)	Cost (units/kWh)
G1	200	0.05	1.0
G2	150	0.08	1.5
G3	100	0.10	2.5
G4	50	0.12	3.0

Calculate the remaining load duration curve $P^1(x)$ after dispatching the most economical Generator. [30]

d) Calculate LOLP and the cost of generation for this system. [40]

Q4

(a) Using usual notation obtain an expression for the shape of the curve taken by a transmission line conductor in x-y coordinates. [30]

(b) What approximations can be made if the sag is less than 10% of the span? [20]

(c) Also obtain approximated expressions for the maximum sag and span. [20]

(d) Explain how sag templates are used in positioning towers along the route at the design stage of a new transmission line. [30]

Q5

(a) Why is it desirable to operate grid connected, partially loaded generators at the same incremental cost? [10]

(b) A thermal power station operates three units with following cost functions. For unit i, F_i denotes the cost of operation in Currency Units (CU) when serving a load P_i.

$$F_1 = 173.0 + 8.7P_1 + 0.0023P_1^2 \qquad 50 \le P_1 \le 250MW$$
$$F_2 = 180.0 + 9.0P_2 + 0.0026P_2^2 \qquad 50 \le P_1 \le 150MW$$
$$F_3 = 165.0 + 9.2P_3 + 0.0020P_3^2 \qquad 50 \le P_1 \le 150MW$$

Prepare a merit order list considering per MWh cost of each unit at its maximum possible load. [20]

(c) Determine the loading of each of the units to meet a total load of 350 MW using merit order loading. Also calculate the total cost. [30]

(d) If the dispatch is done using the incremental cost method what would be the individual loading of the units? What is the total cost under this method? [30]

(e) Explain why merit order dispatch does not always give the optimum solution. [10]

Q6

(a) Describe a method available for the solution of the transient stability of a synchronous generator connected to an infinite bus. [30]

(b) Data of a synchronous generator connected to an infinite bus is shown in figure Q6. When the system is working at steady state at an angle of 30° determine the frequency of oscillations of the rotor for a small disturbance. [40]

(c) Explain the concept of under-frequency load shedding and how it helps to avoid possible total blackouts in a contingency situation. [30]

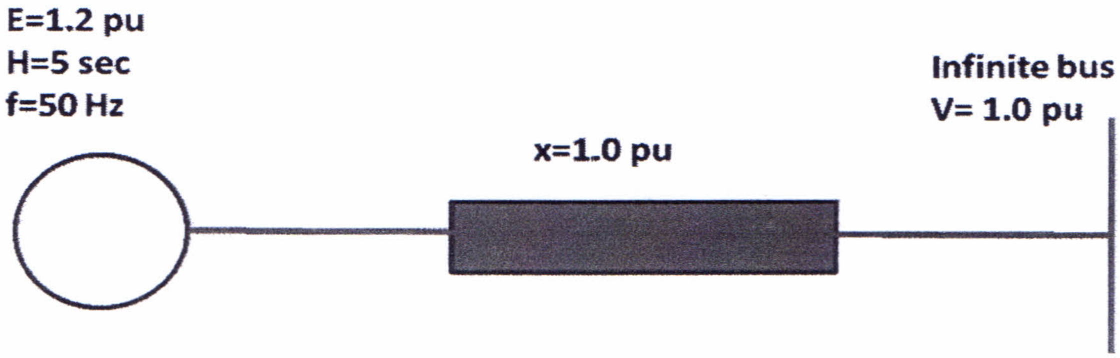


Figure Q6

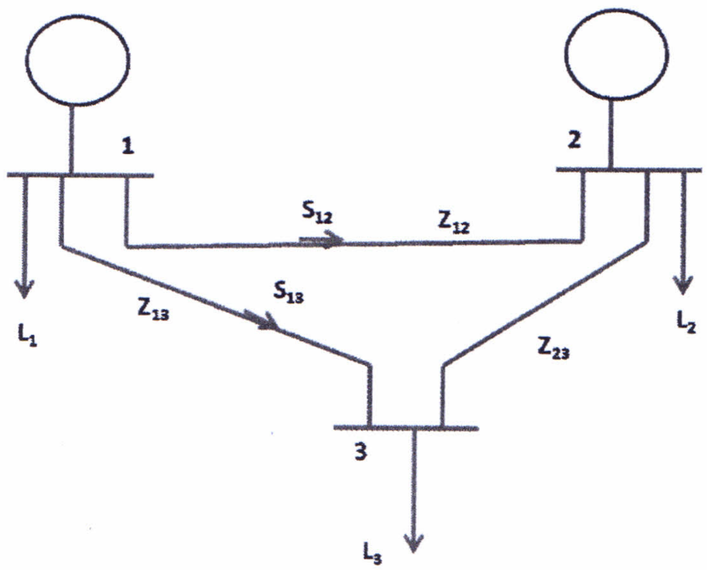
Q7

(a) Develop an expression for the complex voltage difference between two bus-bars in a power system in terms of P and Q flow, along the line connecting the two bus-bars, and R and X values of the line. [20]

(b) Use the above expression to determine the complex voltages of nodes 2 and 3 of the three node power system shown in figure Q7. All relevant data are indicated in the figure in pu. [30]

(c) In general power flows are unknown and the generation injected and loads connected to bus bars are known. Describe the Gauss-Seidel method of solution to solve this problem assuming line resistances are negligible. [20]

(d) Propose a faster method for the solution of this problem deriving necessary mathematical expressions. [30]



$$S_{12} = 0.018 - j0.5$$
$$S_{13} = 0.605 + j0.047$$
$$Z_{12} = Z_{23} = Z_{13} = 0.02 + j0.08$$

Figure Q7