IMPERIAL COLLEGE LONDON

DEPARTMENT OF ELECTRICAL AND ELECTRONIC ENGINEERING
EXAMINATIONS 2009

EEE PART IV: MEng and ACGI

Corrected Copy

p1 of 4

POWER SYSTEM ECONOMICS

Monday, 11 May 10:00 am

Time allowed: 3:00 hours

There are SIX questions on this paper.

Answer Question ONE and THREE other questions

All questions carry equal marks.

Any special instructions for invigilators and information for candidates are on page 1.

Examiners responsible First Marker(s) : G. Strbac
Second Marker(s) : B.C. Pal

Power System Economics

Question 1:

Question Compulsory

competition

(i) Give two reasons for the introduction of ~~completion~~ in electricity supply and explain how these objectives can be achieved?

[2.5]

(ii) How is the value of the spot electricity price determined? Why spot electricity prices vary with time and location?

[2.5]

(iii) What is the purpose of contracts for differences?

[2]

(iv) Define cost of constraints, congestion costs, short run value of transmission network and explain how these can be quantified (calculated)?

[4]

(v) Demand function of a transmission interconnector is in the form of: $\pi_T = 15 - 0.1F$ (π_T is expressed in (£/MWh) and F (capacity of the interconnector) is in MW). Determine the capacity that would maximise the revenue to the transmission operator.

[3]

(vi) If the total investment cost of building this interconnector (in ~~vii~~) can be expressed as a linear function of its capacity C = 300,000xF [£], estimate the optimal capacity that should be built.

[3]

(vii) Why transmission network business should be regulated? How does the regulator fulfil their responsibilities?

[3]

Question 2

(a) The demand curve, in terms of quantity Q (kWh) bought by a consumer, in a given period, as a function of price π (p/kWh) is given by the following expression: $\pi = -0.01Q + 5$. The production cost in the period under consideration is given by

$C = 0.0075Q^2 + 1.3Q$ [£/h]

(i) Calculate the level of consumption at π=3.5p/kWh, consumer surplus, demand charges and revenue received by suppliers. What is price elasticity of demand at this point?

[2]

(ii) If the producer decides to reduce the price by 10%, determine the change in consumption and the new revenue received by the producer.

[2]

(iii) Determine the expression for marginal production cost and then find the equilibrium price and demand at which the social welfare is maximised.

[2]

(iv) Calculate producer revenue, profit and average cost at the equilibrium point. What is producer surplus?

[2]

(v) Would it be worth for this producer to artificially increase the price for 20%? What would be the total consumer and producer surpluses in these cases? How do they compare with the equilibrium calculated in (iii). What can you conclude from this comparison?

[3]

(b)

(i) What are sources of risk involved in trading? Explain how contracts help to reallocate, share and spread risk.

[3]

(ii) What are forward and futures contracts?

[3]

(iii) Explain how option contracts operate and the meaning of exercise price and option fee.

[3]

Question 3:

Borduria Generation owns three generating units that have the following cost functions:

$C_A = 15 + 1.4P_A + 0.04P_A^2$ [\$/h]
$C_B = 25 + 1.6P_B + 0.05P_B^2$ [\$/h]
$C_C = 20 + 1.8P_C + 0.02P_C^2$ [\$/h]

(i) How should these units be dispatched if Borduria Generation must supply a load of 350MW at minimum cost? What is the generation marginal price and the profit made by the company?

[5]

(ii) How would the dispatch in [i] change if Borduria Generation had the opportunity to buy some of this energy on the spot market at a price of 8.20 \$/MWh?

[5]

(iii) If, in addition to supplying a 350MW load as in [i], Borduria Generation had the opportunity to sell energy on the electricity market at a price of 10.20 \$/MWh, what is the optimal amount of power that it should sell? What profit would it derive from this sale?

[5]

(iv) How the dispatch in [i] would change if the outputs of the generating units are limited as follows:

$P_A^{\max} = 150MW$
$P_B^{\max} = 70MW$
$P_C^{\max} = 250MW$

What would be marginal price in this situation and generator profits?

[5]

Question 4

a) Explain why in a real (imperfect) market each company must consider the possible actions of others when selecting their strategy?

[5]

b) Consider a market for electrical energy that is supplied by two generating companies whose costs are:

$C_a = 35\ P_a$ [£/h]
$C_b = 45\ P_b$ [£/h]

The inverse demand function is given by: $p = 120 - D$

(i) Assuming Bertrand competition, calculate production of each of the companies, market price and profits made.

[5]

(ii) To examine the market share between the companies assuming Cournot competition, calculate market price and demand for different levels of productions Pa (15MW, 20MW, 25MW, 30MW) and Pb (10MW, 15MW, 20MW) of the two companies and determine profits made. What is the optimal amount of production of each of the companies that maximises their profits?

[6]

(iii) Explain the differences in the solution in (i) and (ii)

[4]

Question 5

Consider the three-bus power system shown on Figure Q3.

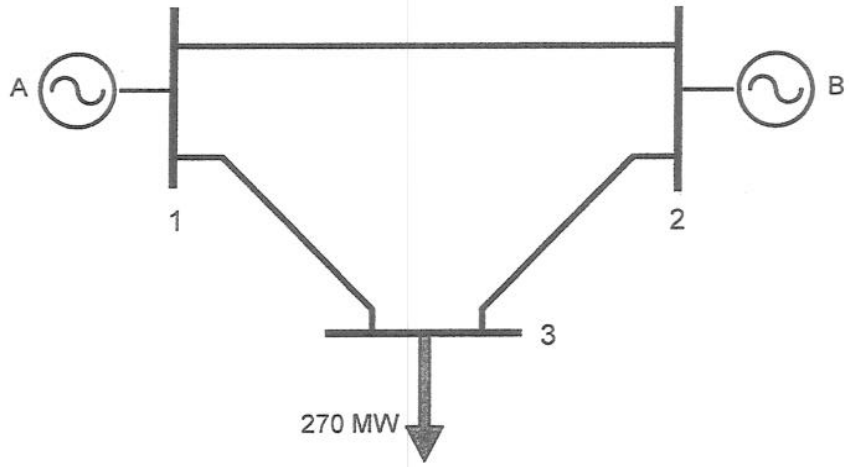

Figure Q3

Assume that:

- Generating units A and B have the following marginal production costs:

$$MC_A = 12 \text{ [£/MWh]}$$
$$MC_B = 9 + 0.1P_B \text{ [£/MWh]}$$

- All three transmission lines have the same impedance

a. Calculate the unconstrained optimal dispatch for these conditions [2]

b. Calculate the hourly cost of this unconstrained dispatch [1]

c. Calculate the power that would flow in each line if this dispatch was implemented [4]

d. What is the marginal cost of energy at each node under these conditions [1]

e. How should this unconstrained dispatch be modified if the flow in line 1-3 is limited to 150 MW for security reasons? [4]

f. Calculate the hourly cost of this constrained dispatch and the hourly cost of security [2]

g. What is the marginal cost of energy at each node when the constraint on the flow on line 1-3 is taken into consideration? [6]

Question 6:

a. Consider two regions of a small power system that are not connected. Generators 1 and 2 (belonging to Borduria Power) are located in the Northern Region while generators 3 and 4 (belonging to Syldavia Gen) are located in the Southern Region. The load in the Northern Region is 100 MW and the load in the Southern Region is 420 MW. Marginal cost of these generators are:

Northern Region

$$MC_1 = 3 + 0.02P_1 \quad [£/MWh]$$
$$MC_2 = 4 + 0.04P_2 \quad [£/MWh]$$

Southern Region

$$MC_3 = 3.6 + 0.025P_3 \quad [£/MWh]$$
$$MC_4 = 4.2 + 0.025P_4 \quad [£/MWh]$$

Calculate the marginal costs in both regions and the corresponding generation dispatches, generator payments and demand charges. What is the marginal value of transmission?

[4]

b. A proposal to build a 450km long transmission link between the two regions is considered. The annuitised investment cost of transmission (including the allowable profit) is 37£/MW.km.year. The local consultant has proposed two schemes to be considered: (i) 80 MW and (ii) 150MW link. For each of the schemes calculate:

- marginal prices in the Northern and the Southern region
- generator payments, demand charges and congestion surplus
- network revenues if the transmission company charges for the use of link on the basis of short-run marginal cost

[8]

c. The optimal capacity of the transmission link to be built will depend on the objectives and interests of the potential investors. Consider three cases, and for each of these determine the optimal capacity that would be built:

(c1) Merchant transmission company that makes money from buying electricity in the North and selling it in the South
(c2) Regulated transmission company that maximizes the benefit of transmission for the entire country
(c3) Company formed of generators in the North and Demand in the South wishing to maximize their profits.

[8]