IMPERIAL COLLEGE LONDON

DEPARTMENT OF ELECTRICAL AND ELECTRONIC ENGINEERING
EXAMINATIONS 2014

EEE PART IV: MEng and ACGI

Corrected Copy

POWER SYSTEM ECONOMICS

Correction 10:50 - 1c

Thursday, 22 May 10:00 am

Time allowed: 3:00 hours

Correction 12:00 - 4a

There are FOUR questions on this paper.

Answer ALL questions.

All questions carry equal marks.

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

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Second Marker(s) : B.C. Pal

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Power System Economics

Question 1

(a) List and explain the key objectives of unbundling and liberalisation of electricity markets.

[2]

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

[3]

(c) The electricity demand Q (kWh) in a given period is a function of price π (p/kWh) and is given by the following expression: π = -0.01Q +9.5 [p/kWh]. The production cost in the period under consideration is given by $C = 0.0075Q^2 + 1.3Q$ [p/h]

* Correction at: 10:30

(i) Calculate at π=6.8p/kWh, the level of consumption, consumer surplus, demand charges and revenue received by suppliers and the total social welfare.

[4]

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

[4]

(d) Northern and Southern regions of a small power system are connected via a transmission circuit of 200MW. Given that the load in the Northern Region is 100 MW and the load in the Southern Region is 420 MW, while the cost of generation in these regions is respectively:

$$C_N(P_N) = 577 + 8.08 * P_N + 0.17 * P_N^2 \left[\frac{£}{h}\right]$$

$$C_S(P_S) = 310 + 7.99 * P_S + 0.20 * P_S^2 \left[\frac{£}{h}\right]$$

Calculate

- Corresponding generation dispatches and the marginal costs in both regions
- Generator payments and demand charges
- Cost of transmission network constraints
- Congestion costs
- Short run value of transmission network

[4]

(e) Answer the following questions with brief statements:

- Why spot electricity prices may vary with location?
- What is the purpose of financial transmission rights?
- How is the value of financial transmission rights assessed?

[3]

* c) (i) For π = 6.8p/kwh find Q
For Q find C, from $C = .0075Q^2 + 1.3Q$
(ii) for π = 1.2 × 6.8p repeat (i) and compare

Question 2

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

Unit A: $C_A(P_A) = 15 + 1.4P_A + 0.04P_A^2$ [\$/h]

Unit B: $C_B(P_B) = 25 + 1.6P_B + 0.05P_B^2$ [\$/h]

Unit C: $C_C(P_C) = 20 + 1.8P_C + 0.02P_C^2$ [\$/h]

(a) How should these units be dispatched if Syldavia Generation supplies a load of 350MW at minimum cost?

[4]

(b) How would the dispatch change if Syldavia Generation had the opportunity to buy some of this energy on the spot market at a price of 8.20 \$/MWh?

[6]

(c) If, in addition to supplying a 350MW load, Syldavia 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?

[6]

(d) Repeat problem (c) if the outputs of the generating units are limited as follows:

$P_A^{MAX} = 100$ [MW]

$P_B^{MAX} = 80$ [MW]

$P_C^{MAX} = 250$ [MW]

[4]

Question 3

Consider a market for electrical energy that is supplied by two generating companies (A and B) with the following cost functions:

$$C_A(P_A) = 25 \cdot P_A + 0.40 \cdot P_A^2 \ [\frac{£}{h}]$$

$$C_B(P_B) = 27 \cdot P_B + 0.30 \cdot P_B^2 \ [\frac{£}{h}]$$

(P_A and P_B are production levels of the two generating companies respectively)

Inverse demand function for this market is estimated to be:

$$\pi = 210 - 1.3 \cdot D \ [\frac{£}{MWh}]$$

(π and D are the electricity price and demand respectively)

(a) Assuming perfect competition, calculate the electricity price, level of demand and the profits made by the generating companies

[5]

(b) List key characteristics of the models that are used for the analysis of markets with imperfect competition.

[4]

(c) Assuming a Cournot model of competition:

(i) Write the expressions for profits of the two generating companies as a function of their production levels

[4]

(ii) Write the optimality conditions for the evaluation of the exact equilibrium point of this market

[4]

(ii) Calculate the equilibrium price, level of demand, production levels and profit of each generating company.

[3]

Question 4

(a) Two areas, A and B, of the Borduria power system are connected by a 1200MW transmission link operated by the Borduria Transco. System load is concentrated in area B. In winter, the load is 3,500MW while summer load is 2,000 MW. The cost of generation in the areas can be modelled by the following expressions:

$C(P_A) = 1 \cdot P_A + 0.001 P_A^2$ [£/h] for area A, and
$C(P_B) = 2 \cdot P_B + 0.002 P_B^2$ [£/h] for area B.

Correction at 12:00

Determine the optimal levels of generation in areas A and B for each of the seasons neglecting the impact of the transmission system.

[4]

= assume infinite capacity between regions

(b) If necessary, modify the levels of generation computed in (a) to take into consideration the capacity of the transmission link. What are the electricity prices in areas A and B in each of the seasons?

[4]

(c) Assuming that the duration of the winter and summer period is 2,700h and 6,060h respectively, calculate:

(i) The total annual generation costs [2]
(ii) The total annual revenue received by the generators and the charge imposed on demand if electricity is priced at locational short-run marginal prices. [2]
(iii) The total annual transmission revenue received by Borduria Transco in this case. [2]

(d) Borduria Transco has proposed to the Borduria Regulator to reinforce the line between the two areas by 900 MW. Assuming that the annuitised investment cost of the additional line is 5,000,000 £/year, determine if this proposed investment is justified.

[6]