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IMPERIAL COLLEGE LONDON

DEPARTMENT OF ELECTRICAL AND ELECTRONIC ENGINEERING
EXAMINATIONS 2008

EEE PART IV: MEng and ACGI

Corrected Copy

POWER SYSTEM ECONOMICS

Friday, 16 May 10:00 am

Time allowed: 3:00 hours

There are SIX questions on this paper.

Answer TWO questions from Section A and TWO questions from Section B.

All questions carry equal marks.

Use separate answer books for Sections A and B.

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

Examiners responsible	First Marker(s) :	C.A. Hernandez-Aramburo, G. Strbac
	Second Marker(s) :	G. Strbac, C.A. Hernandez-Aramburo

Section A. Answer any two questions from this section.

1. Answer the following questions.

a) Explain why the spot prices of electricity are often volatile. Aid your explanation with typical supply and demand curves for electricity.

[4]

b) Explain why a managed spot market is needed in a competitive electricity market.

[2]

c) What are the "Distribution Network Use of Service" and "Transmission Network Use of Service" charges in the electricity supply industry? Who sets them in the UK?

[2]

d) Show, from first principles and using a Cournot model of competition, that the marginal cost of a certain producer can be expressed as a function of the market price, the producer's market share and the price elasticity of the demand.

[4]

e) The bids made by generators in a unit commitment-based pool market normally have several components in addition to price and quantity. List at least three of these additional components.

[2]

f) First sketch typical supply-demand curves for a generic perfect competitive market. Consider next that the suppliers suffer a small increase in their production costs (which they wish to pass on to the consumers) and, at the same time, the consumers collectively lose a significant amount of interest in buying the product.

i) draw on top of your original plot the new demand-supply curves for the new market conditions.

[2]

ii) with the aid of the original and new supply-demand curves, explain how the original consumers' surplus is re-distributed.

[2]

iii) with the aid of the original and new supply-demand curves, explain how the original suppliers' profits are re-distributed.

[2]

2. Answer the following questions.

a) Sketch a diagram showing the "cash flow" between market participants in the UK electricity market, and explain it briefly. Differentiate between small and large consumers. Neglect any deviations from contractual positions.

[4]

b) Briefly explain why electricity markets may lend themselves to be imperfect competitive markets.

[3]

c) Explain why producers taking part in a pool market do not have any incentives to bid at a price different to their marginal cost of production.

[2]

d) Briefly explain the obstacles to increase the elasticity of the electricity demand.

[3]

e) Assume that there are only two firms (A and B) supplying a certain electricity market, and that they compete against each other. Their respective production costs are as follows:

$C_A = 30 * P_A$ [£/h]

$C_B = 40 * P_B$ [£/h]

P_A and P_B represent the energy production (in MWh) of firms A and B, respectively. The inverse demand curve for this market is given by:

$\pi = 120 - D$ [£/MWh].

Where π is the market price and D is the demand quantity.

Using a Cournot model of competition, calculate the following:

i) The values for P_A and P_B at the Nash equilibrium point.

[6]

ii) The amount of demand supplied and the market price at this equilibrium point.

[2]

3. Answer the following questions.

a) In the short term, the demand of electricity does not change considerably with respect to price, why does electricity have such a low elasticity?

[4]

b) When is it said that a firm is exercising its market power?

[1]

c) For the current British market structure, briefly explain what the system prices are, and what the market index price is.

[3]

d) Consider that the following conditions for a particular trading session in the British market:

- The Market Index Price (MIP) is 55.30 [£/MWh]
- The System Sell Price (SSP) is 42.27[£/MWh]
- The System Buy Price (SBP) is 55.30 [£/MWh]

i) Note that the MIP has the same value as the SBP, what can you infer from this coincidence in respect to the balancing operations?

[4]

ii) Calculate the amount paid (or charged) to a generator that delivered 20MWh less than the amount specified in its contractual position.

[2]

iii) Calculate the amount paid (or charged) to a consumer who consumed 30MWh less than the amount specified in its contractual position.

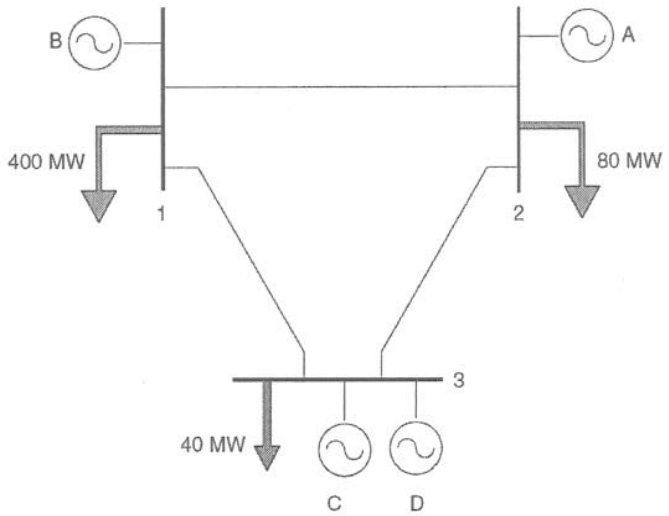
[2]

e) Briefly explain two major challenges for the integration of the Pan-European electricity market.

[4]

Section B. Answer any two questions from this section.

4. Consider the three-bus power system shown in Figure Q4 below. The tables below the diagram show the data about the generators connected to this system and the characteristics of the transmission system (line reactances and capacities).



Generator	Capacity (MW)	Marginal Cost ($/MWh)
A	150	12
B	200	15
C	150	10
D	400	8

Branch	Reactance (p.u.)	Capacity (MW)
1-2	0.2	250
1-3	0.3	250
2-3	0.3	250

Figure Q4 A three-bus system and its parameters

a) Calculate the unconstrained economic dispatch and the nodal prices. [2]

b) Calculate the network flows that would result if the generating units were dispatched as calculated in a) and identify all the violations of network constraints. [3]

c) Determine the two ways in which the constraint violations can be removed by redispatching the generating units (*i.e.* by engaging unit A, or unit B). Which redispatch is preferable? [7]

d) Calculate the nodal prices for the preferable redispatch of the generating units from c). [5]

e) Calculate the total congestion surplus and show that it is equal to the sum of the surpluses associated with each of the transmission lines. [3]

5. Two areas, A and B, of the Borduria power system are linked by a transmission system operated by the Borduria Transco. The transmission system consists of two transmission lines, with a capacity of 900 MW each. It is assumed that the transmission system is operated according to the security criteria, *i.e.* that it is loaded so that it can continue operating even if one of the lines suddenly goes out of operation. The system load is concentrated in area B. In winter, the load is 3,500 MW, while during the summer the load is 2,000 MW. The cost of generation in the areas can be modelled by the following expressions:

$C_A(P_A) = P_A + 0.001P_A^2$ [£/h] for area A,

$C_B(P_B) = 2P_B + 0.002\,P_B^2$ [£/h] for area B.

a) Determine the optimal levels of generation in areas A and B for winter and summer, neglecting the impact of the transmission system.

[3]

b) If necessary, modify the levels of generation calculated in a) to take into consideration the capacity of the existing transmission link and the security criterion. What are the new marginal costs in areas A and B in summer and in winter?

[3]

c) Assuming that the duration of the winter and summer periods are 2,500 h and 6,260 h respectively, calculate:

i) The total annual generation costs.

[2]

ii) The total annual revenue received by the generators, and the charge imposed on the customers if the electricity is priced at locational short-run marginal prices.

[3]

iii) The total annual transmission revenue received by Borduria Transco in this case.

[2]

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

[7]

6. A simple two-bus system is depicted in Figure Q6. The two buses are connected by a line having the capacity of 800 MW. At each bus there is a load, and a generator of infinite capacity. The cost functions for the two generators can be expressed as follows:

$$C_X(P_X) = 10P_X + 0.01P_X^2 \text{ [\$/h]}$$

$$C_Y(P_Y) = 20P_Y + 0.015P_Y^2 \text{ [\$/h]}$$

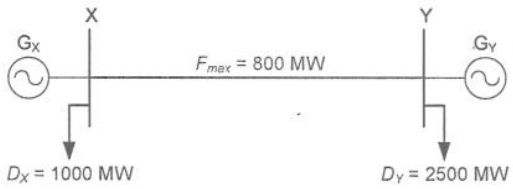


Figure Q6 A simple two-bus power system

a) Calculate the generator outputs and marginal prices at buses X and Y for the case of unconstrained transmission.

[2]

b) Modify the dispatch of generators in a) so that the flow does not exceed transmission link capacity. Calculate the new set of nodal marginal prices at X and Y and profits of generators in both areas, assuming that electricity is sold and bought at locational marginal prices.

[3]

c) Assume that in the given situation generator at X and a customer in Y wish to enter into a Contract for Differences (CfD) in order to lock in the price of electricity. Contract volume is 650 MW, and the strike price is 60 \$/MWh. Calculate the discrepancies between the intended and actual cash flows for both the generator and customer, assuming they have not purchased Financial Transmission Rights (FTR).

[4]

d) Calculate the cash flows for the generator and the customer in case that the generator acquired 680 MW of FTR.

[5]

e) Assume that the capacity of the transmission corridor is temporarily limited to 500 MW because of maintenance. Find the marginal nodal prices and calculate the generator revenues and profits. Also calculate the cash flows associated with the contract and customer payments and receipts. Assume that the same CfD and FTRs are in force as in d).

[6]