Aalto University
School of Electrical
Engineering

ELEC-E8406 Electricity Distribution and Markets

Calculation Exercise 06 – online tutorial

Markets

Q1 – a small optimization following a site visit many years ago…

A small company has its own CHP and heat only production, and of course the ability to purchase electricity through Nordpool.

Its average energy demand on a cold winter's day is 120 MW electricity and 100 MW heat, its heat plant operates at 87% efficiency and CHP plant at 85% (1 part electricity for 1 part heat), but the CHP plant uses natural gas at an equivalent price of C_{gas} €/MWh and the heat plant uses a biofuel/peat/oil mix of C_{bio} 8.50 €/MWh. The electricity spot price including the transmission tariff is 35 €/MWh. The transmission tariff does not have to be paid for electricity generated by the company itself.

Assuming that the spot price for electricity and the price of biofuel remains relatively steady, what price does natural gas have to drop to before it becomes economically feasible to run the company's CHP generation? Let's say the minimum total output of a CHP plant is 20 MW.

Answer to question 1

First, let's assess what can supply the demand, which is both thermal (heat, *h*) and electrical (*el*).

Electricity can either be imported or produced by the company's own CHP unit

$$P_{el} = P_{el\_import} + P_{el\_chp} = 120 \text{ MWh/h} \qquad (1)$$

Heat can either be produced by the company's heat-only plant or by the CHP

$$P_{heat} = P_{ho} + P_{h\_chp} = 100 \text{ MWh/h} \qquad (2)$$

A1 continued

Costs: $C_{tot} = C_{ho} + C_{h\_chp} + C_{el\_imp} + C_{el\_chp}$ €/h

$$= C_{bio}\frac{P_{ho}}{\eta_{ho}} + C_{gas}\frac{P_{h\_chp}}{\eta_{chp}} + C_{spot}P_{el\_import} + C_{gas}\frac{P_{el\_chp}}{\eta_{chp}} \qquad (3)$$

Substituting (2) and (1) into (3) =>

$$= C_{bio}\frac{P_{heat} - P_{h\_chp}}{\eta_{ho}} + C_{gas}\frac{P_{h\_chp}}{\eta_{chp}} + C_{spot}\left(P_{el} - P_{el\_chp}\right) + C_{gas}\frac{P_{el\_chp}}{\eta_{chp}} \qquad (4)$$

If the CHP is not producing: $C_{tot} = C_{bio}\frac{P_{heat}}{\eta_{ho}} + C_{spot}P_{el}$

$$= 8.50\frac{100}{0.87} + 35 \cdot 120 = 5177 \text{ €/h}$$

A1 continued

For the CHP to become feasible, solving (1) for C_{gas}:

$$C_{gas} < \frac{C_{tot} - \left(C_{bio} \dfrac{P_{heat} - P_{h\_chp}}{\eta_{ho}} + C_{spot} \left(P_{el} - P_{el\_chp} \right) \right)}{\left(\dfrac{P_{chp} + P_{el\_chp}}{\eta_{chp}} \right)}$$

… for the minimum CHP production of 20 MW (= 10 MW heat + 10 MW electricity)

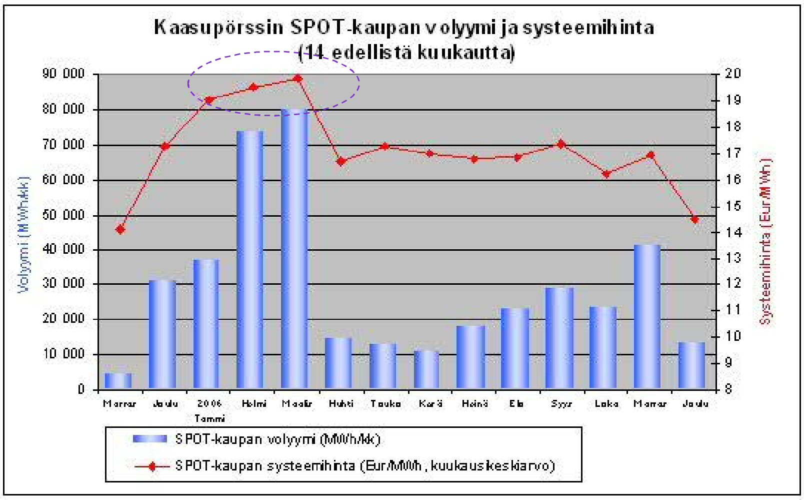
$$\frac{5177 - \left[C_{bio} \dfrac{100-10}{0.87} + C_{spot}(120-10) \right]}{\dfrac{10+10}{0.85}} = 19.03€$$

And even if the CHP would be run at full capacity, the break even point is:

$$\frac{5177 - C_{spot}(120-100)}{\dfrac{100+100}{0.85}} = 19.03€$$

A1 – final slide

So if the price of gas falls below 19.03 €/MWh, then CHP becomes viable for this utility - according to this extremely rough analysis!



source: http://www.gasum.com/

Q2 (taken, with superficial changes, from Problem 3.3 in Fundamentals of Power System Economics, by Kirschen and Strbac).

Six companies in the EBEY (Exploit us before we Expoit You) electricity market are as follows:
Gen1: A power producer with a range of generating plant producing up to 1.5 GW max.
Gen2: Another power producer with a range of generating plant producing up to 800 MW max.
Ret1: An electrical energy retailer, with a solid customer base
Ret2: An electrical energy retailer, with a solid customer base
Trad1: A trading company with no physical assets
Trad2: A trading company with no physical assets

The hour of physical delivery we are concerned "that hour" with was Feb 20, 2021, between 12.00 and 13.00

Load forecasts
Ret1 and Ret2 forecast, based on historical data, global warming and the projected market penetration of large-scale home entertainment centres and Tesla automobiles, that their respective customers will consume 1500 MW and 1850 MW respectively during that hour.

Q2 Continued

Long-term contracts

- Gen1 has a long-term contract covering the hour of delivery for the supply of 800 MW at 35 €/MWh
- Gen2 has a long-term contract for the supply of 500 MW at 38 €/MWh during that hour
- Ret1 has a contract for that month to purchase 900 MW at 36 €/MWh
- Ret2 has a contract for that month to purchase 850 MW at 35 €/MWh

Futures contracts

Date	Company	Type	Amount (MW)	Price (€)
1/11/20	Trad1	Buy	50	35.00
10/11/20	Trad2	Sell	150	35.25
25/11/20	Ret2	Buy	250	35.75
30/11/20	Trad1	Buy	150	36.00
4/12/20	Gen1	Sell	200	35.50
6/12/20	Gen2	Sell	300	36.50
19/12/20	Ret1	Buy	250	36.50
23/12/20	Trad2	Buy	50	35.50
2/1/21	Trad1	Sell	210	36.50
7/1/21	Ret2	Buy	250	35.00
15/1/20	Ret1	Buy	450	36.00
25/1/20	Gen1	Sell	250	36.25
29/2/21	Gen1	Sell	200	36.25
4/2/21	Ret1	Sell	100	36.25
10/2/21	Trad2	Sell	50	35.25
14/2/21	Trad1	Buy	100	35.00
16/2/21	Ret2	Buy	250	35.25
17/2/21	Gen1	Buy	300	36.75
18/2/21	Trad1	Sell	150	38.00
18/2/21	Trad2	Buy	100	36.00
19/2/21	Ret2	Buy	100	35.00

Options

At the end of December, 2020, Gen1 bought a put option for 250 MWh at €35.50 and the option fee was €75.

In January 2021, Ret2 bought a call option for 150 MWh at 36.25 €/MWh. The option fee was €50.

On the day

The system price turned out to be 36.50 €/MWh between 12.00 and 13.00 on Feb 20, 2021.

Gen1 could only produce 1000 MW at 32 €/MWh because of an enforced safety check on one of its nuclear reactors.

Gen2 was able to produce at its full capacity of 800 MW at 33.50 €/MWh.

Ret1's demand was 1500 MW, which it retailed at 38.00 €/MWh.

Ret2's demand was 1900 MW, with its retail price set, on average, at 37.50 €/MWh.

All imbalances were settled at the system price (which was the same as the area price for the parties concerned at the time in question).

The task

Calculate the profit or loss made by each party.

The answer(s)

Gen1:

+ 800*35 “Gen1 has a long-term contract covering the hour of delivery for the supply of **800 MW** at **35 €/MWh**”

+ 200*35.5

4/12/14	Gen1	Sell	200	35.50

+ (250+200)*36.25

25/1/14	Gen1	Sell	250	36.25
29/2/15	Gen1	Sell	200	36.25

– 300*36.75

17/2/15	Gen1	Buy	300	36.75

– 75 (put option fee)

+ (250*35.5 if worth it but it’s not!) “At the end of December, 2014, Gen1 bought a put option for 250 MWh at 35.50€ and the option fee was 75€”

– (1150 – 1000)*36.5 (commitment – actual production = ((800+200+450-300) – 1000)

– 1000*32 Gen1 could only produce 1000 MW at 32 €/MWh because of an enforced safety check on one of its nuclear reactors

= 2837.50 €

And, similarly, for the other parties:

Gen2: 500*38 + 300*36.5 – 800*33.5 = 3150.00 €

Ret1: -900*36 – 250*36.5 – 450*36 + 100*36.25 + 1500*38 – (1500 – 1500)*36.5 = 2900.00 €

Ret2: -850*35 – 250*35.75 – 250*35 – 250*35.25 – 100*35 – 50 – (150*36.25 if worth it and it is!) – 50*36. 5 + 1900*37.5 = 4187.50 €

Trad1: -50*35 – 150*36 + 150*36.5 – 100*35 + 150*38 = 525.00 €

Trad2: +150*35.25 – 50*35.5 + 50*35.25 – 100*36 – 50*36.5 = - 150.00 € (ouch!)