31761 - Renewables in Electricity Markets

Exercise session 3: Ancillary service markets - [SOLUTION]

The aim of this exercise session is to appraise and better understand the basic structure of electricity markets, and most particularly its ancillary service markets and mechanisms. The session relies on Lectures 2 and 4 mainly, available at "Lecture notes for 31761 - Renewables in Electricity Markets".

Problem 1: Participation in the primary reserve market

This problem focuses on the primary reserve market. The Table below gathers the technical data needed to solve the problem.

Supplier name	Supplier id.	Quantity up [MW]	Price up [DKK/MW]	Quantity down [MW]	Price down [DKK/MW]	Time response[s]
FlexiGas	G_1	15	67	15	77	22
Nuke22	G_2	10	29	10	29	40
RoskildeCHP	G_3	5	42	10	52	20
BlueWater	G_4	7	11	5	10	15
Darkcoal	G_5	8	54	5	34	35

1.1 What is the common name of the payment for generators availability to participate in the provision of ancillary services?

Generator's availability to participate in the provision of ancillary services is called capacity payment.

1.2 What is the common term used for some ancillary services to define that an energy payment is not considered for that service?

The term used for some ancillary services to define that an energy payment is not considered for that service is energy neutral.

1.3 Identify the suppliers that meet the technical requirements for providing primary reserves.

The suppliers that meet the technical requirements (Time response ≤ 30 seconds) for providing primary reserves are FlexiGas, RoskildeCHP and Bluewater.

1.4 What is the total amount of capacity able to participate in the primary reserve market (i.e., which of the participants actually qualify)?

The total amount of power for up regulation is 27 MW. The total amount of power for down regulation is 30 MW.

1.5 Determine the revenues for all participants in this market, considering that the up and down requirements established by the TSO is 25 MW.

Calculation of revenues for upward regulation.

The market price is 67 DKK/MW.
G1: $13\,\text{MW} \cdot 67\,\text{DKK/MW} = 871\,\text{DKK}$
G3: $5\,\text{MW} \cdot 67\,\text{DKK/MW} = 335\,\text{DKK}$
G4: $7\,\text{MW} \cdot 67\,\text{DKK/MW} = 469\,\text{DKK}$

Calculation of revenues for downward regulation.

The market price is 77 DKK/MW.
G1: $10\,\text{MW} \cdot 77\,\text{DKK/MW} = 770\,\text{DKK}$
G3: $10\,\text{MW} \cdot 77\,\text{DKK/MW} = 770\,\text{DKK}$
G4: $5\,\text{MW} \cdot 77\,\text{DKK/MW} = 385\,\text{DKK}$

1.6 Assuming now that all suppliers in the Table above are able to participate in the primary reserve market, re-determine the revenues of all participants for the same up and down requirements established by the TSO.

Calculation of revenues for upward regulation.

The market price is 54 DKK/MW.
G2: $10\,\text{MW} \cdot 54\,\text{DKK/MW} = 540\,\text{DKK}$
G3: $5\,\text{MW} \cdot 54\,\text{DKK/MW} = 270\,\text{DKK}$
G4: $7\,\text{MW} \cdot 54\,\text{DKK/MW} = 378\,\text{DKK}$
G5: $3\,\text{MW} \cdot 54\,\text{DKK/MW} = 162\,\text{DKK}$

Calculation of revenues for downward regulation.

The market price is 52 DKK/MW.
G1: $10\,\text{MW} \cdot 52\,\text{DKK/MW} = 520\,\text{DKK}$
G3: $5\,\text{MW} \cdot 52\,\text{DKK/MW} = 260\,\text{DKK}$
G4: $5\,\text{MW} \cdot 52\,\text{DKK/MW} = 260\,\text{DKK}$

Problem 2: Revenues from the secondary reserve market

For the secondary reserve market, the remuneration mechanism is based on bilateral contracts between the TSO and suppliers, for their availability, plus a premium for energy provision.

Let us assume that the supplier "FlexiGas" is qualified to provide secondary reserve services. The agreement with the TSO establishes that it may provide 20 MW (in both up and down directions) at 50 DKK/MW. In addition, the spot market was cleared at 120 DKK/MWh. The balancing price may vary in the following questions.

2.1 Determine the revenue of "FlexiGas" in case it is asked to provide an upward regulation service (energy fully delivered), with a balancing price of 150 DKK/MWh.

FlexiGas: $20\,\text{MW} \cdot 50\,\text{DKK/MW} + 20\,\text{MWh} \cdot (120\,\text{DKK/MWh} + 100\,\text{DKK/MWh}) = 5400\,\text{DKK}$

(The price per energy unit is of (120+100) DKK/MWh since the difference between spot and balancing price ($\lambda^B - \lambda^S$) is of less than 100 DKK/MWh)

2.2 Re-determine that revenue if there is a need for down regulation instead (also with energy fully provided), with a balancing price of 10 DKK/MWh.

FlexiGas: $20\,\text{MW} \cdot 50\,\text{DKK/MW} - 20\,\text{MWh} \cdot 10 DKK/MWh = 800\,\text{DKK}$

(The price per energy unit is directly the balancing price (10 DKK/MWh) since the difference between spot and balancing price ($\lambda^S - \lambda^B$) is greater than 100 DKK/MWh)

2.3 Re-determine 2.1. and 2.2 assuming that the balancing market price is 250 DKK/MWh in the upward regulation case, and 90 DKK/MWh in the downward regulation case.

Upward regulation case:
FlexiGas: $20\,\text{MW} \cdot 50\,\text{DKK/MW} + 20\,\text{MWh} \cdot 250\text{DKK/MWh} = 6000\,\text{DKK}$

(The price per energy unit is directly the balancing price (250 DKK/MWh) since the difference between spot and balancing price ($\lambda^B - \lambda^S$) is greater than 100 DKK/MWh)

Downward regulation case:
FlexiGas: $20\,\text{MW} \cdot 50\,\text{DKK/MW} - 20\,\text{MWh} \cdot (120\,\text{DKK/MWh} - 100\,\text{DKK/MWh}) = 600\,\text{DKK}$

(The price per energy unit is of (120-100) DKK/MWh since the difference between spot and balancing price ($\lambda^S - \lambda^B$) is of less than 100 DKK/MWh)

Problem 3: Tertiary reserve market: clearing and revenues

Remember that the market mechanism for payment of suppliers of tertiary reserves comprises both a capacity payment based on uniform pricing and energy payment based on the balancing price. The Table below gathers the capacity offers of the various participants in the tertiary reserve market. Energy payments are obtained a posteriori when these participants are activated eventually.

Supplier name	Supplier id.	Quantity up [MW]	Price up [DKK/MW]	Quantity down [MW]	Price down [DKK/MW]
FlexiGas	G_1	25	30	20	40
Nuke22	G_2	20	15	10	35
RoskildeCHP	G_3	15	35	20	30
BlueWater	G_4	17	25	25	15
Darkcoal	G_5	18	20	15	25

3.1 Draw the supply curves and identify the suppliers that are scheduled to provide the service, considering that the service requirement for up and down regulation is of 50 MW.

The supply curves are illustrated in Figure 1 and Figure 2.

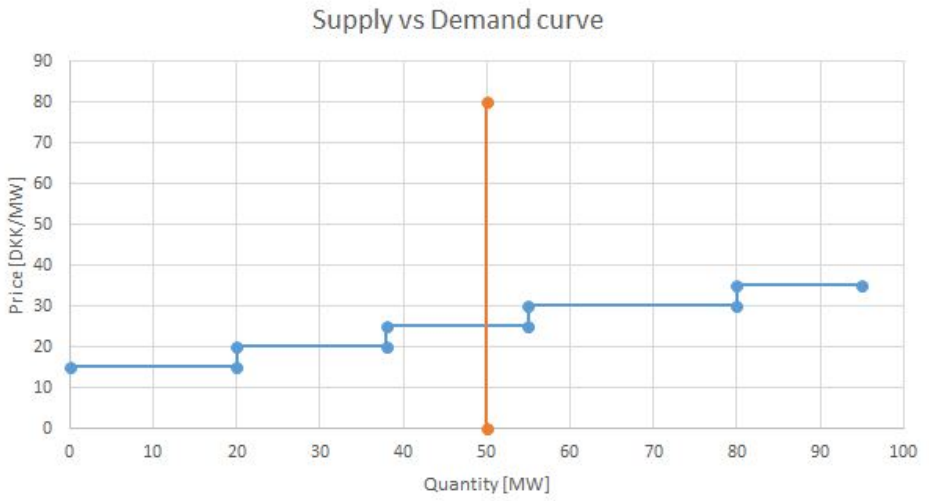

Figure 1: Supply and demand curve for up regulation

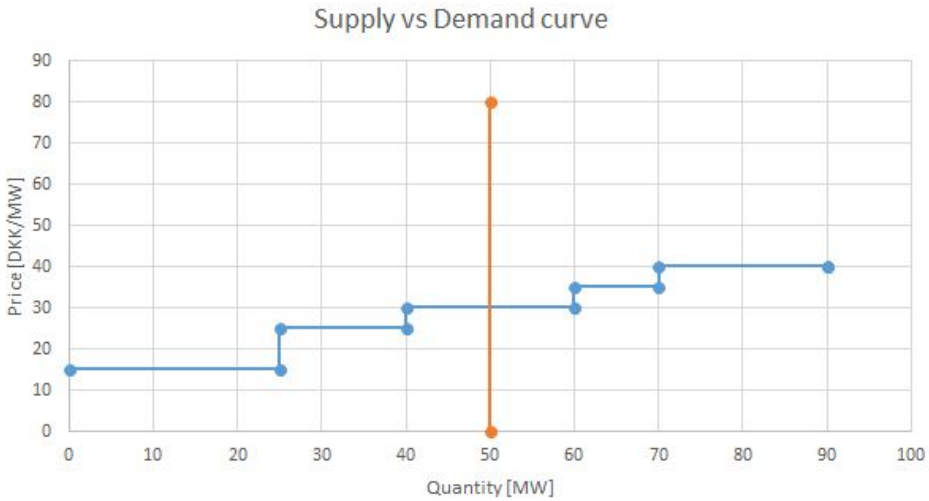

Figure 2: Supply and demand curve for down regulation

For up regulation the suppliers that are scheduled are G2, G5 and G4.

The market price is 25 DKK/MW
Nuke22 - 20 MW
Darkcoal - 18 MW
Bluewater - 12 MW

For down regulation the suppliers that are scheduled are G4, G5 and G3.

The market price is 30 DKK/MW
Bluewater - 12 MW
Darkcoal - 18 MW
RoskildeCHP - 10 MW

3.2 Determine the revenue for each supplier for up regulation (service fully provided) considering upward regulating price of 20 DKK/MWh.

G2: $20\,\text{MW} \cdot 25\,\text{DKK/MW} + 20\,\text{MWh} \cdot 20\,\text{DKK/MWh} = 900\,\text{DKK}$
G5: $18\,\text{MW} \cdot 25\,\text{DKK/MW} + 18\,\text{MWh} \cdot 20\,\text{DKK/MWh} = 810\,\text{DKK}$
G4: $12\,\text{MW} \cdot 25\,\text{DKK/MW} + 12\,\text{MWh} \cdot 20\,\text{DKK/MWh} = 540\,\text{DKK}$

63.3 Determine the revenue for each supplier for down regulation (service fully provided) considering downward regulating price of 18 DKK/MWh. (tip: considers negative energy deviation as a positive value)

G4: $25\,\text{MW} \cdot 30\,\text{DKK/MW} + 25\,\text{MWh} \cdot 18\,\text{DKK/MWh} = 1200\,\text{DKK}$
G5: $15\,\text{MW} \cdot 30\,\text{DKK/MW} + 15\,\text{MWh} \cdot 18\,\text{DKK/MWh} = 720\,\text{DKK}$
G3: $10\,\text{MW} \cdot 30\,\text{DKK/MW} + 10\,\text{MWh} \cdot 18\,\text{DKK/MWh} = 480\,\text{DKK}$

3.4 Calculate the revenues for 3.2 and 3.3 considering that only half of the service requirement was used in the system.

Revenue for 3.2

G2: $20\,\text{MW} \cdot 25\,\text{DKK/MW} + 20\,\text{MWh} \cdot 20\,\text{DKK/MWh} = 900\,\text{DKK}$
G5: $18\,\text{MW} \cdot 25\,\text{DKK/MW} + 5\,\text{MWh} \cdot 20\,\text{DKK/MWh} = 550\,\text{DKK}$
G4: $12\,\text{MW} \cdot 25\,\text{DKK/MW} + 0\,\text{MWh} \cdot 20\,\text{DKK/MWh} = 300\,\text{DKK}$

Revenue for 3.3

G4: $25\,\text{MW} \cdot 30\,\text{DKK/MW} + 25\,\text{MWh} \cdot 18\,\text{DKK/MWh} = 1200\,\text{DKK}$
G5: $15\,\text{MW} \cdot 30\,\text{DKK/MW} + 0\,\text{MWh} \cdot 18\,\text{DKK/MWh} = 450\,\text{DKK}$
G3: $10\,\text{MW} \cdot 30\,\text{DKK/MW} + 0\,\text{MWh} \cdot 18\,\text{DKK/MWh} = 300\,\text{DKK}$