This document includes instructions for the participants and the master (system operator) in the roleplay representing an electricity market. Technology capacities and demands are similar to those existing in the Danish power system, with some additions, such as including reservoir hydropower capacities. The role-play is used in the course "Renewable Energy Systems" taught in Aarhus University, Department of Engineering in Fall 2020. The course instructor is Marta Victoria.

Every round of can be solved using the attached spreadsheet "Roleplay_electricity_market".

Instructions for the system operator:

1) Distribute the card with the instructions to every participant or group. You can briefly mention the constraints that apply to every technology.

2) Explain that 5 rounds of the wholesale electricity market will be celebrated. You will act as the system operator. Before every round, you will provide information on the expected demand and the weather conditions. The latter determines the available solar and wind electricity. Then, you will collect all the bids from different technologies, show the aggregated offer curve and determine the clearing-market price. While collecting the bids you can turn off the projector so that the bids are secrets.

3) Provide a brief explanation on how the clearing-market price is determined, *i.e.,* the price where the aggregated offer curve and demand curve meet. Every technology that had made an offer below the clearing-market price will sell its electricity and receive the clearing-market price for it, regardless the offer that he/she made.

4) Indicate that, after every round, every participant/group needs to calculate their benefits as the difference between market revenues and costs. At the end of the game, the participants can say out loud their cumulative benefits.

5)

1st ROUND: 06:00

Cold weather, wind resource at 20%, irradiance at 10%

Demand prevision 3,000 MWh.

2nd ROUND: 11:00

The sun is shining, solar resource at 90%, but it is also windy, wind resource at 50%

Demand prevision 4,000 MWh.

3rd ROUND: 17:00

Solar resource at 20% and wind at 10%

A coal power plant has a problem, reducing available coal capacity by 500 MW.

Demand prevision 4,500.

4th ROUND: 20:00

Solar resource 20%, wind resource 80%.

Peak demand prevision 5,500 MW

5th ROUND: 04:00

Solar resource 0%, wind resource 100%

Demand prevision 2,000 MW

Participant: COAL

You are responsible for half of the coal-based generation capacity in the market, which represents a total generation capacity of 1,200 MW.

You need to bid a certain amount of electricity at a certain price. For instance, you can offer 1,200 MWh at 50 €/MWh. You can also make compound bids such as offering 500 MWh at 40 €/MWh and increasing to 1,200 MWh if the market price reaches 80 €/MWh.

The minimum value for your bid (floor) is 0 €/MWh. The maximum value (cap) is 180 €/MWh.

Take into consideration that:

The unitary variable cost associated with your generation is 30 €/MWh.

For example, if you sell 500 MWh and the market-clearing price is 40 €/MWh:
· You get 500 x 40 = 20,000 M€ (market revenues)
· You pay 50 x 30 = 15,000 M€ (variable cost)
· Thus, in overall, **you earn 20,000-15,000 = 5,000 M€.**

Participant: GAS

You are responsible for half of the gas-based generation capacity in the market, which represents a total generation capacity of 1,100 MW.

You need to bid a certain amount of electricity at a certain price. For instance, you can offer 1,100 MWh at 80 €/MWh. You can also make compound bids such as offering 1,000 MWh at 70 €/MWh and increasing to 1,100 MWh if the market price reaches 100€/MWh.

The minimum value for your bid (floor) is 0 €/MWh. The maximum value (cap) is 180 €/MWh.

Take into consideration that:

The unitary variable cost associated with your generation is 50 €/MWh.

For example, if you sell 500 MWh and the market-clearing price is 80 €/MWh:
· You get 500 x 80 = 40,000 M€ (market revenues)
· You pay 500 x 50 = 25,000 M€ (variable cost)
· Thus, in overall, **you earn 40,000-25,000 = 15,000 M€.**

Participant: HYDRO

You are responsible for half of the hydropower capacity in the market, which represents a total generation capacity of 1,000 MW.

You need to bid a certain amount of electricity at a certain price. For instance, you can offer 800 MWh at 40 €/MWh. You can also make compound bids such as offering 500 MWh at 30 €/MWh and increasing to 1,000 MWh if the market price reaches 60€/MWh.

The minimum value for your bid (floor) is 0 €/MWh. The maximum value (cap) is 180 €/MWh.

Take into consideration that:

1) The unitary variable cost associated with your generation is 20 €/MWh.

For example, if you sell 500 MWh and the market-clearing price is 40 €/MWh:
· You get 500 x 40 = 20,000 M€ (market revenues)
· You pay 50 x 20 = 10,000 M€ (variable cost)
· Thus, in overall, **you earn 20,000-10,000 = 10,000 M€.**

2) The amount of water in your reservoir is equivalent to 3,000 MWh, so if you sell that electricity in the initial hours, you cannot offer it afterwards.

3) Some of your power stations include Pumped Hydro Storage (PHS). It means that you can offer to buy electricity at some hours to store it in your reservoirs and sell it later if it is cost-effective for you. The maximum pumping capacity that you can use is 300 MW.

Participant: ONSHORE WIND

You are responsible for half of the onshore wind generation capacity in the market, which represents a total generation capacity of 1,900 MW.

You need to bid a certain amount of electricity at a certain price. For instance, you can offer 1,900 MWh at 20 €/MWh. You can also make compound bids such as offering 500 MWh at 10 €/MWh and increasing to 1,900 MWh if the market price reaches 30 €/MWh.

The minimum value for your bid (floor) is 0 €/MWh. The maximum value (cap) is 180 €/MWh.

Take into consideration that:

1) The unitary variable cost associated with your generation is zero. This is because you already paid for the turbines when they were installed, and we consider operation and maintenance cost to be negligible.

For example, if you sell 500 MWh and the market-clearing price is 40 €/MWh:
· You get 500 x 40 = 20,000 M€ (market revenues)

2) Before every round, you will get information on the wind resource that will indicate what share of you installed power can be delivered.

Participant: OFFSHORE WIND

You are responsible for half of the offshore wind generation capacity in the market and represents a total generation capacity of 600 MW.

You need to bid a certain amount of electricity at a certain price. For instance, you can offer 600 MWh at 20 €/MWh. You can also make compound bids such as offering 500 MWh at 10 €/MWh and increasing to 600 MWh if the market price reaches 30€/MWh.

The minimum value for your bid (floor) is 0 €/MWh. The maximum value (cap) is 180 €/MWh.

Take into consideration that:

1) The unitary variable cost associated with your generation is zero. This is because you already paid for the turbines when they were installed, and we consider operation and maintenance cost to be negligible.

For example, if you sell 500 MWh and the market-clearing price is 40 €/MWh:
· You get 500 x 40 = 20,000 M€ (market revenues)

2) Before every round, you will get information on the wind resource that will indicate what share of you installed power can be delivered.

Participant: SOLAR PHOTOVOLTAICS

You are responsible for half of the solar photovoltaics generation capacity in the market which represents a total generation capacity of 400 MW.

You need to bid a certain amount of electricity at a certain price. For instance, you can offer 400 MWh at 20 €/MWh. You can also make compound bids such as offering 300 MWh at 10 €/MWh and increasing to 400 MWh if the market price reaches 30€/MWh.

The minimum value for your bid (floor) is 0 €/MWh. The maximum value (cap) is 180 €/MWh.

Take into consideration that:

1) The unitary variable cost associated with your generation is zero. This is because you already paid for the solar panels when they were installed, and we consider operation and maintenance cost to be negligible.

For example, if you sell 500 MWh and the market-clearing price is 40 €/MWh:
· You get 500 x 40 = 20,000 M€ (market revenues)

2) Before every round, you will get information on the solar resource that will indicate what share of you installed power can be delivered.