ELEC0018-1 - Energy markets

Assignment: Operating a realistic day-ahead electricity market

September 30, 2020

General note

This assignment is greatly inspired by a similar assignment given in the class *Renewables in Electricity Markets* given by Prof. Pierre Pinson at the Danish Technical University. We thank Pierre Pinson for sharing its material with us for this class.

General considerations

This assignment focuses on day-ahead electricity markets. Your goal will be to design in your favourite modelling language (R/Python/Matlab/GAMS/etc.) a market-clearing algorithm using the knowledge acquired during the workshops. You will then simulate the market-clearing using real-world data. The results of this clearing will be presented and discussed in a short report.

This assignment aims to evaluate:

- your understanding of day-ahead electricity markets,
- your ability to model the day-ahead market mechanism,
- your ability to use real-world data as input,
- your critical analysis of the results generated.

The expected outcome of this assignment includes:

- a report of maximum 10 pages,
- the experimental code delivered as supplementary material.

This assignment is to be performed in groups composed of a maximum of 2 students.

Description of the assignment

Let us consider the real-world setup for Denmark. Denmark is split into two market areas commonly known as DK1 and DK2. Based on real demand data and wind production, we aim at simulating this market over November 2019 and January 2020. This will allow obtaining wholesale electricity prices for each hour of every day of those months, the schedule for the various participants, as well as their revenues/payments over these 2 months.

Even though some of the data is real, we will introduce a series of simplification to keep the problem tractable.

Demand

Instead of having demand curves, we consider an inelastic demand, adjusted by import and export requirements (see below). The hourly consumption data are available at the following links for 2019 and 2020. The values for DK1 and DK2 should be considered.

In the case of overproduction, supply should be curtailed, while lack of power supply in meeting the electric power load must translate to load shedding.

Transmission

The available transmission capacity between DK1 and DK2 is of 600MW. A flow-based coupling approach is to be employed for ruling the exchanges between these two areas. Besides, it should be assumed that the interactions between Denmark and neighbouring countries are simplified with fixed values for import and export of electricity:

- DK1 imports 100MW from Norway, continuously,
- DK1 exports 120MW to Germany, every day between 8 am and 3 pm (and 0 for the rest of the time),
- DK2 imports 80MW from Sweden, every day between 11 am and 5 pm (and 0 for the rest of the time).

Production

We considered a fictive set of producers divided between wind producers and conventional producers.

Wind producers

The offers from wind are available at the following links for 2019 and 2020. We assume we have two wind power producers in each area of this market (4 in total). These are called WestWind_1, WestWind_2, EastWind_1 and EastWind_2. Their share of the production and type of support are described in the table below.

Supplier name	Supplier id.	Quantity [MWh]	Support	Support [€/MWh]
WestWind_1	WW_1	80% of predicted production	none	0
WestWind_2	WW_2	20% of predicted production	premium	17
EastWind_1	EW_1	10% of predicted production	feed-in tariff	20
EastWind_2	EW_2	90% of predicted production	premium	12

These wind producers readily offer the predicted quantities to the day-ahead market. They do not try to correct the forecasts or to be more strategic. Their price offers will depend upon their support scheme and support amount though. Note that we consider that, even when prices get negative, wind farms will get the premium and/or feed-in tariffs.

Conventional producers

The full list of other power suppliers as well as their characteristics is summarized in the table below. Please note that some power suppliers divide their generation portfolio into several parts. Each of those has a unique "supplier id.". For the revenue calculation in the assignment, there is no need to consider removing the marginal cost of power generation for these various participants. Also, both plants of Nuke22 only operate for time units between 5 am and 10 pm.

Supplier name	Supplier id.	Area	Quantity [MWh]	Price [€/MWh]
FlexiGas	G_1	DK1	380	72
FlexiGas	G_2	DK1	350	62
FlexiGas	G_3	DK1	320	150
Peako	G_4	DK1	370	80
Peako	G_5	DK1	480	87
Nuke22	G_6	DK1	900	24
CoalAtLast	G_7	DK1	1200	260
Nuke22	G_8	DK2	1100	17
RoskildeCHP	G_9	DK2	300	44
RoskildeCHP	G_{10}	DK2	380	40
Avedøvre	G_{11}	DK2	360	37
Avedøvre	G_{12}	DK2	320	32
BlueWater	G_{13}	DK2	750	5
BlueWater	G_{14}	DK2	600	12
Peako	G_{15}	DK2	860	235

Market settlement

Uniform pricing is used for the settlement.

Structure and contents of the report to be delivered

The report for the assignment should include (each bullet point may be seen as a section for the report):

- A short introduction, explaining what the assignment is about (keep it short!),
- The formulation of the market-clearing as a linear program, also describing how the exchange between areas is implemented (be rigorous in the way you write this optimization problem), import/export, etc.,
- An explanation of how revenues of each market participant are calculated based on market clearing price and/or eventual support,
- An example of the clearing of the market for 2 given market time units, with and without congestion between the 2 areas, to explain how the clearing is done, to describe whether prices are the same or not in both areas, while also listing the scheduled quantities for all market participants as well as their revenues,
- An overview of the revenues of energy suppliers for the whole period, also commenting on why some receive much less money than others,

- A comparative analysis of the market outcomes over November 2019 and January 2020 containing elements about:
  - average, minimum and maximum electricity prices as a function of the hour of the day,
  - frequency of observing congestion on the DK1-DK2 connection (possibly as a function of the time of the day),
  - frequency of observing negative prices,
  - frequency of wind curtailment,
  - presence/absence of load shedding,
  - impact of wind power generation on prices in DK1 and DK2,
  - schedule of conventional generators.

  You are encouraged to explore other elements of the markets. Interesting developments will be rewarded.
- A discussion around the following points:
  - The transformation of the European electricity production portfolio, in particular the increasing share of renewable energy sources and the decommissioning of nuclear power.
  - The expansion of transmission capacity in Europe.

Suggested methodology

To successfully finish the project, the following methodology is suggested:

(a) Formulate the market-clearing as a linear program as shown in the workshops. Make sure to account for import and export needs, and possibly consider to shed the load if supply is not sufficient to meet demand.

(b) Implement this linear program with your favourite modelling tool (R/Python/Matlab/GAMS/etc.).

(c) Implement a method to compute revenues based on the market-clearing price, scheduled productions and support mechanisms.

(d) Using your implementation, clear the market for two different time units representing cases where there is congestion, and no congestion, on the link between DK1 and DK2.

(e) Loop over all market time units in November 2019 and January 2020, to obtain all relevant market clearing outcomes.

Delivery of the assignment

The assignment will have to be delivered on the 02/12/2020 via the eCampus platform.