31761 - Renewables in Electricity Markets

Assignment 1: Build and operate a realistic day-ahead electricity market

General considerations

Assignment 1 concentrates on day-ahead electricity markets, following the lectures, exercise sessions, games and reading material from the first 4 weeks of the course. The work to undertake involves a bit of mathematical modelling, implementation in your favourite modelling language (R/Matlab/GAMS/etc.), generation and discussion of results, as well as presentation of the work in a short report.

The aim of Assignment 1 is 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 Assignment 1 includes:

- a report of maximum 10 pages (excluding appendices),
- code pasted in the appendix or delivered as supplementary material.

Assignment 1 is to be performed in groups, where a group is to be composed of 2 students. In special cases groups may reach 3 students, or alternatively have 1 student only.

The **evaluation of Assignment 1 will count for 30% of the final grade**. Individual contributions to the assigment must be clearly stated in the report. If not, equal contribution will be assumed.

Description of the Assignment

Let us consider the real-world setup for Denmark, which is split into two market areas commonly known as DK1 and DK2. To make things easier, we will simplify the interactions between Denmark and neighboring countries with set values for imprt and export of electricity. In case of overproduction, supply should be curtailed, while lack of power supply to meet the electric power load must translate to load shedding. 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. In addition, it should be assumed that:

- DK1 imports 150MW from Norway, in a continuous manner,
- DK1 exports 100MW to Germany, every day between 10am and 2pm (and 0 for the rest of the time),
- DK2 exports 50MW to Sweden, every day between 4pm and 7pm (and 0 for the rest of the time).

We aim at simulating it over the whole month of January 2017, in order to obtain wholesale electricity prices for each hour of every day of that month, the schedule for the various participants, as well as their revenues/payments over the month.

1. *Set-up for the electricity market*

Here is the set-up for our day-ahead electricity markets:

- Instead of having demand curves, the consumption is assumed to be one block to be satisfied based on the list of supply offers. The hourly consumption data are available at the following link. The values for DK1 and DK2 should be considered;
- The offers from wind are available at the following link. We assume here we have two wind power producers in each area of this market (so 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 [€]
WestWind_1	WW_1	1/2 of predicted production	none	0
WestWind_2	WW_2	1/2 of predicted production	premium	17
EastWind_1	EW_1	2/3 of predicted production	none	0
EastWind_2	EW_2	1/3 of predicted production	feed-in tariff	25

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.

- The full list of other power suppliers, location, 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 have a unique "supplier id.";

Supplier name	Supplier id.	Area	Quantity [MWh]	Price [€]	Offering strategy
FlexiGas	G_1	DK1	415	70	Operates/offers for all time units
FlexiGas	G_2	DK1	300	64	Operates/offers for all time units
FlexiGas	G_3	DK1	315	145	Operates/offers for all time units
Peako	G_4	DK1	410	81	Operates/offers for all time units
Peako	G_5	DK1	540	93	Operates/offers for all time units
Nuke22	G_6	DK1	1000	25	Only operates/offers for time units between 5am and 10pm
Nuke22	G_7	DK2	1200	21	Only operates/offers for time units between 5am and 10pm
RoskildeCHP	G_8	DK2	320	42	Operates/offers for all time units
RoskildeCHP	G_9	DK2	340	38	Operates/offers for all time units
Avedøvre	G_{10}	DK2	370	36	Operates/offers for all time units
Avedøvre	G_{11}	DK2	350	30	Operates/offers for all time units
BlueWater	G_{12}	DK2	700	10	Operates/offers for all time units
BlueWater	G_{13}	DK2	600	15	Operates/offers for all time units

- Uniform pricing is used for the settlement.

2. *Steps towards completion of the Assignment*

2.1 Formulate the market-clearing as a linear program, along the lines of the Problems in Exercise session 1.
2.2 Implement this linear program with your favorite modelling tool (R/Matlab/GAMS/etc.).
2.3 Use the list of offers and data indicated in the above to clear the market for a given market time unit (e.g., 2.1.2017, between 10am and 11am). Obtain the market price, list of scheduled power producers, as well as energy quantities to be produced.
2.4 Deduce revenues of power suppliers for this given market time unit.
2.5 Loop over all market time unit in January 2017, to obtain the same results as in 2.3 and 2.4 for this single market time unit.
2.6 Calculate overall revenues for each market participant over January 2017.
2.7 Make a rapid analysis of electricity prices over that period, e.g. calculate minimum, maximum and average prices (overall and as a function of the time of the day), by plotting an histogram for these prices.

Advice(!):
First go through the points 2.1 to 2.4 assuming that there is infinite transmission capacity between DK1 and DK2 (as if there was only one market area for the whole Denmark). Then go through these points again by additionally considering the transmission limitation.

Structure and contents of the report to be delivered

The report for the assignment should include:

- The formulation of the market clearing as a linear program, also describing how the exchange between areas is implemented;
- An explanation of how revenues of each and every market participant is calculated based on market clearing price and/or eventual support;
- An example of the clearing of the market for a given market time unit (e.g., 2.1.2017, between 10am and 11am, though it could be another one), also listing the revenues of the various participants for that market time unit;
- An overview of the revenues of power suppliers for the whole month, also commenting on why some receive much less money than others;
- A short analysis of the electricity prices over the month of January 2017 (e.g., average electricity price as a function of the hour of the day, minimum and maximum prices observed in January as a function of the hour of day, frequency of observing congestion on the DK1-DK2 connection, frequency of observing negative prices, impact of wind power generation on prices in DK1 and DK2, etc.);
- The code in an Appendix (if not provided separately)

Delivery of the Assignment

Assignment 1 is to be uploaded through campusnet before the **final deadline of 5.3.2017** (all day included). It should take the form of a zip or tar.gz archive with naming convention "31761-Assignment1-Name1-Name2.zip" (or ".tar.gz"), where "Name1" and "Name2" are the names of the students in the group. More or less students in a group obviously means more or less names to be used in the naming convention.