31761 - Renewables in Electricity Markets

Exercise session 5: Market participation for renewables

The aim of this exercise session is to appraise and better understand market participation for renewable energy producers (or any portfolio including a share of renewable energy). This necessarily builds on a thorough understanding of the various markets, from day-ahead to balancing, revenue calculation, as well as the game theoretical aspects of market participation. This session therefore relies on all modules up to Modules 6.

Problem 1: Calculating revenues in one-price and two-price imbalance settlement

Consider the participation of a 10MW solar power plant in the electricity market. The aim here is to compare the potential revenue of that solar power plant for the case of one-price and 2-price imbalance settlement. For a given market time unit, the prices for the day-ahead and balancing markets are summarized below.

Day-ahead price [DKK/MWh]	Down-reg. price [DKK/MWh]	Up-reg. price [DKK/MWh]
41	32	47

Based on forecast information and relevant market insight, the operator of that solar power plant had offered 7MWh in the day-ahead market for that time unit, and its offer was accepted. The actual energy generation for that market time unit is of 5MWh. The overall system is in surplus of 130MWh.

1.1   What is the overall revenue of this solar power plant operator under a one-price imbalance settlement?

1.2   What is the overall revenue of this solar power plant operator under a two-price imbalance settlement?

1.3   Under these two imbalance settlement approaches, compare these revenues to those obtained if having perfectly predicted that power production was going to be 5MWh, and having used that value as an offer. Is one of the settlement approaches yielding better revenues?

1.4   Now consider that actual energy generation is of 8MWh, while the overall system is in surplus of 130MWh. Answer again 1.1-1.3 for such conditions.

1.5   If you knew in advance that the overall system would have a surplus, what would be your optimal offer under these two imbalance settlement approaches? Do you actually need to know any of the prices (day-ahead and balancing) to decide on these offers?

The following questions are optional, for those who fancy a bit more mathematical contents...

1.6   As in 1.5, consider you could know in advance all prices, and that there could be a probability of 0.4 that the system is in surplus (therefore a probability of 0.6 it is in deficit), what is your optimal offer to maximize your expected revenue under one-price imbalance settlement?

1.7   To better understand that phenomenon, write the function for the expected revenue and find the derivative function with respect to your offer.

1.8   Find the necessary relationship between probabilities of being in surplus and deficit, resulting in all potential offers being optimal.

1.9   Deduce a set of simple rules permitting to find an optimal offer as a function of these probabilities, as well as day-ahead and balancing prices.

Problem 2: Calculation of market revenues in Matlab or R

This Problem is there to help for Assignment 2, since it will be necessary there to calculate revenues from day-ahead and balancing markets in a more automatic fashion, based on functions written in Matlab or R. Therefore as an implementation exercise in your favourite language, program a function that allows to determine such revenues for a two-price imbalance settlement approach as in the Scandinavian Nord

Pool. At this stage, such a function only needs to focus on a single market time unit.

Input variables should include the day-ahead and balancing prices, as well as the amounts of energy offered and actually generated. Information about the overall system balance may be needed too... (or not, if directly defining the two balancing prices consequently, as on the Nord Pool website).

Output variables should include day-ahead, balancing, and overall revenues.

Problem 3: Comparing 3 alternative strategies for market participation

Consider the participation of a 35MW wind farm in the electricity market. The aim here is to compare revenues obtained from different market participation strategies, using different type of forecast information as input, as well as market insight. Emphasis is placed on a single market time unit. Below are gathered the predicted prices on both day-ahead and balancing markets.

Day-ahead price [DKK/MWh]	Down-reg. price [DKK/MWh]	Up-reg. price [DKK/MWh]
35	31	47

In parallel, the forecast provider gave a set of forecasts to be used as support to decision-making. The deterministic forecast for that market time unit is that energy generated will be of 20MWh. In parallel, a probabilistic forecast was provided, consisting in a set of quantiles for various nominal levels:

Nominal level	Quantile for power generation [MWh]
0.1	9
0.25	15
0.5	22
0.75	26
0.9	29

Remember that, e.g., the quantile with nominal level of 0.1 tells that there is a probability of 0.1 that power generation will be less than 9MWh at that time.

Eventually, the wind farm operator only produces 12MWh, while the overall system is in deficit of 78MWh.

3.1 What is the overall revenue of the wind farm operator if directly using the deterministic forecast as an offer?

3.2 Deduce unit regulation costs (for up and down regulation) based on the provided price forecasts.

3.3 What is the nominal level of the quantile that would permit to maximize expected revenues?

3.4 Calculate the overall revenue for that strategy based on offering the "best" quantile from the probabilistic forecast.

3.5 Compare these revenues with that one would obtain by offering the perfect forecast.

The following question is optional, for those who fancy a bit more mathematical contents...

3.6 The optimal quantile strategy defined in the lectures and used here overlooks the probabilities of being in situations with overall system surplus and deficit. Would you be able to generalize the quantile strategy to the case for which these probabilities are also predicted?