Module 6 – Participation of Renewables in Electricity Markets

6.1 What is a market participation strategy?

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The setup

- Students of the course 31761 ("Renewables in Electricity Markets") got convinced to join forces and start an energy trading company: Rogue Trading (RT®)
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- And, the course responsible suggested you first invest in that new-generation wind farm...
  
  - **Nominal capacity**: 350 MW
  
  - Energy production sold through the Nord Pool (Western Denmark area)
  
  - Balance responsibility

- From early 2016, you are to trade your energy generation through the Nord Pool.
How to proceed

What should we do before to get into the market?

1. Understand how the electricity market works! It should be fine... if not, please go back to Modules 0-5

2. Get all necessary data/info to make informed decisions, for instance:
   - get a good grip of market prices (e.g., how they can be influenced by neighboring zones, or the local generation mix)
   - gain knowledge of price and volume dynamics through historical data analysis
   - find ways to know how much your wind farm is going to produce for every time unit

3. Design your offering strategy, which can consist of:
   - a totally improvised approach to market participation (you named your company Rogue Trading after all...)
   - a set of expert rules to decide on what to do when,
   - a well-thought optimization model
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Sample trading day

27 March 2016 - 11am

- Your forecast provider gave you this wind power forecast for tomorrow: \( \hat{y}_i \), \( i = 1, \ldots, 24 \)

- From power generation estimates, one readily deduces 24 blocks of energy offered to the market

- However, how much will you actually offer?
### Strategy 1

- We call it "**Let’s trust the forecast!**": directly take the forecasts and make them our offers \((E_i, i = 1, \ldots, 24)\) for the 28th of March

\[ E_i = \hat{y}_i, \quad i = 1, \ldots, 24 \]

<table>
<thead>
<tr>
<th>hour 1</th>
<th>129 MWh</th>
<th>hour 7</th>
<th>138 MWh</th>
<th>hour 13</th>
<th>159 MWh</th>
<th>hour 19</th>
<th>122 MWh</th>
</tr>
</thead>
<tbody>
<tr>
<td>hour 2</td>
<td>110 MWh</td>
<td>hour 8</td>
<td>137 MWh</td>
<td>hour 14</td>
<td>127 MWh</td>
<td>hour 20</td>
<td>108 MWh</td>
</tr>
<tr>
<td>hour 3</td>
<td>96  MWh</td>
<td>hour 8</td>
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<td>hour 15</td>
<td>112 MWh</td>
<td>hour 21</td>
<td>94 MWh</td>
</tr>
<tr>
<td>hour 4</td>
<td>117 MWh</td>
<td>hour 10</td>
<td>180 MWh</td>
<td>hour 16</td>
<td>111 MWh</td>
<td>hour 22</td>
<td>81 MWh</td>
</tr>
<tr>
<td>hour 5</td>
<td>132 MWh</td>
<td>hour 11</td>
<td>198 MWh</td>
<td>hour 17</td>
<td>116 MWh</td>
<td>hour 23</td>
<td>67 MWh</td>
</tr>
<tr>
<td>hour 6</td>
<td>136 MWh</td>
<td>hour 12</td>
<td>187 MWh</td>
<td>hour 18</td>
<td>124 MWh</td>
<td>hour 24</td>
<td>68 MWh</td>
</tr>
</tbody>
</table>

- Now, we wait for market-clearing, to receive our cash...
Settlement after market clearing

- 28 March 2016 - prices after market clearing

- Revenue: $R_{DA} = \sum_{i=1}^{24} \lambda_i^S \times E_i$
- In the present case: $R_{DA} = 88,334,49\text{€}...$ not a bad day!
Actual production from the wind farm

- **28 March 2016** - Comparing forecasts ($\hat{y}_i$, $i = 1, \ldots, 24$) and power measurements ($y_i$, $i = 1, \ldots, 24$)

Is there a chance our revenue reduces due to balancing costs?
Balancing needs and prices

28 March 2016 - Nord Pool & Energinet data:

- Need for downregulation on most of the hours of the day
Rules for settlement after balancing

- Remember the basic rules of the two-price balancing system:
  - If producing more than expected \( y_i > \hat{y}_i \), each extra energy unit is sold at down-regulation price
  - If producing less than expected \( y_i < \hat{y}_i \), each missing energy unit is bought at up-regulation price
  - When the system is in balance, one simply buys (if \( y_i < \hat{y}_i \)) or sell (if \( y_i > \hat{y}_i \)) at the spot price \( \lambda^S \)
  - Only those putting the system off-balance are to be penalized!

- Resulting revenue from the balancing market:

\[
R_B = \sum_{j \in \mathcal{L}_{\text{down}}} \lambda_j^\downarrow (y_j - \hat{y}_j) - \sum_{i \in \mathcal{L}_{\text{up}}} \lambda_i^\uparrow (\hat{y}_i - y_i)
\]

- From the graph in slide 7:

\[\mathcal{L}_{\text{up}} = \{1, 2, \ldots, 6, 17, 18, \ldots, 24\}\]
\[\mathcal{L}_{\text{down}} = \{7, 8, \ldots, 16\}\]
Balancing settlement

Based on:

- rules described in the previous slide
- differences between hourly contracts and actual delivery
- hourly balancing prices

we can calculate balancing revenues and costs for every market time unit.

<table>
<thead>
<tr>
<th>hour 1</th>
<th>hour 7</th>
<th>hour 13</th>
<th>hour 19</th>
</tr>
</thead>
<tbody>
<tr>
<td>-837.93 €</td>
<td>684.11 €</td>
<td>558.90 €</td>
<td>-789.32 €</td>
</tr>
<tr>
<td>hour 2</td>
<td>hour 8</td>
<td>hour 14</td>
<td>hour 20</td>
</tr>
<tr>
<td>-934.85 €</td>
<td>1536.80 €</td>
<td>1020.60 €</td>
<td>-877.61 €</td>
</tr>
<tr>
<td>hour 3</td>
<td>hour 8</td>
<td>hour 15</td>
<td>hour 21</td>
</tr>
<tr>
<td>-787.80 €</td>
<td>1262.94 €</td>
<td>997.60 €</td>
<td>-613.58 €</td>
</tr>
<tr>
<td>hour 4</td>
<td>hour 10</td>
<td>hour 16</td>
<td>hour 22</td>
</tr>
<tr>
<td>-1171.28 €</td>
<td>318.80 €</td>
<td>321.86 €</td>
<td>-468.69 €</td>
</tr>
<tr>
<td>hour 5</td>
<td>hour 11</td>
<td>hour 17</td>
<td>hour 23</td>
</tr>
<tr>
<td>-931.60 €</td>
<td>132.50 €</td>
<td>-272.80 €</td>
<td>-188.58 €</td>
</tr>
<tr>
<td>hour 6</td>
<td>hour 12</td>
<td>hour 18</td>
<td>hour 24</td>
</tr>
<tr>
<td>-423.00 €</td>
<td>100.04 €</td>
<td>-769.44 €</td>
<td>-322.56 €</td>
</tr>
</tbody>
</table>

This gives an overall balancing cost $R_B = -2.454,89€$

And therefore a revenue for that day of $R_{DA} + R_B = 85.879,60€$

Are you satisfied with your revenue?
Understanding and analysing revenues

- The optimal revenue one could get from **BOTH**
  - day-ahead market, **AND**
  - balancing market

  is obtained if being able to offer your *actual* renewable energy generation to the day-ahead market...

\[ R_{DA}^* = R_{DA} + R_B = 86.627,50€, \text{ (with } R_B = 0) \]

- Let us then define a *performance ratio* for our trading strategies:
  \[ \gamma = (R_{DA} + R_B) / R_{DA}^*, \quad 0 < \gamma < 1 \text{ (then expressed in percentage)} \]
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  \gamma = \frac{(R_{DA} + R_B)}{R^*_{DA}}, \quad 0 < \gamma < 1 \quad \text{(then expressed in percentage)}
  \]

- The performance ratio for Strategy 1 ("Let’s trust the forecast!") is \( \gamma_1 = 99.1\% \) (quite good already since forecast error is low...)

- **Having perfect foresight will never happen** - Is there any other way to improve our revenue?
  - your proposal for a strategy no. 2 (*hint*: increase a bit your offer)
  - your proposal for a strategy no. 3 (*hint*: let’s be bold)
  - etc.
Strategy 2

- We call it "Let’s tweak a bit the forecast!": makes a small adjustment to the forecasts, to reflect your gut feeling about potential balancing needs and costs.
- Offers \( (E_i, i = 1, \ldots, 24) \) for the 28th of March then become

\[
E_i = \tau \hat{y}_i, \quad i = 1, \ldots, 24
\]

with \( \tau \) close to 1.
- For instance with \( \tau = 1.05 \) (increase offers by 5%):

<table>
<thead>
<tr>
<th>hour 1</th>
<th>135 MWh</th>
<th>hour 7</th>
<th>145 MWh</th>
<th>hour 13</th>
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<td>hour 12</td>
<td>197 MWh</td>
<td>hour 18</td>
<td>130 MWh</td>
<td>hour 24</td>
<td>71 MWh</td>
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</tbody>
</table>

- The results from this trading strategy are:

\[
R_{DA} = 92.751,21\text{€} \quad R_{B} = -6.680,79\text{€} \quad R_{DA} + R_{B} = 86.070,42\text{€}
\]

\[\gamma_2 = 99.3\%\]
Strategy 3

- We call it "Let’s just be bold about it!": fully trust your gut feeling and push it to the bound...

- Offers \((E_i, \ i = 1, \ldots, 24)\) for the 28th of March then become

\[ E_i = 350\text{MWh}, \quad i = 1, \ldots, 24 \]

- The results from this trading strategy are:

\[
\begin{align*}
R_{DA} &= 243.449, \quad 50€ \\
R_B &= -156.822€ \\
R_{DA} + R_B &= 86.627, \quad 50€
\end{align*}
\]

\[ \gamma_3 = 100\% \]

(Isn’t it a nice miracle?)

- This most certainly deserves a little discussion and explanation...
Key assumptions and issues

- In this practical example, we only illustrated the potential (monetary) consequences of our own decisions, all the rest being the same, i.e.,
  - prices (both day-ahead and balancing)
  - energy volumes
  - others’ offering strategies

- Is that realistic? ...

- Definition:

  A market participant is a **price taker** if his decisions and resulting offers (buying or selling) do not affect the market outcomes

You can then imagine what a **price maker** is...

- Also, **you will never know the balancing prices in advance!!!**
Use the self-assessment quizz to check your understanding!