Trading of Pumped Hydro Storages in ID Markets
Continuous Optimization – ID Price Forecasts – Market Insights

Strommarkttreffen
Berlin, 1. Juni 2018

Sebastian Braun, Senior Analyst – Power Markets
Introduction

- **Education**
  - Studied Industrial Engineering at KIT (Karlsruhe/Germany)
  - Project Management at NTNU (Trondheim/Norway)
  - Ph.D. *Hydro Power Storage Optimization and Trading Considering Short-Term Electricity Markets* at TUM (Munich/Germany)

- **Work experience**
  - ICIS Senior Analyst – Power Markets (Karlsruhe/Germany)
  - EnBW Trading and Asset Optimization (Karlsruhe/Germany)
  - EnBW Risk Management of RES (Istanbul/Turkey)
  - DLR on Concentrated Solar Power (Almeria/Spain)

- **Free Time**
  - Ski touring
  - Running
Structure Presentation Strommarkttreffen

- Motivation to revise the pumped hydro power scheduling problem
- Challenges of continuously traded intraday markets
- Approach for pump storage optimization in intraday markets
- Continuous ID price forecast
- Trading strategies to exploit the spreads between ID high and low
Motivation for Flexibilization of Pumped Storages

Comparison of the average hourly day-head auction price from Monday to Friday in 2005 with 2015 and the average quarter-hourly intraday price from Monday to Friday in 2015, data derived from EPEX Spot (2017)

Example: 500MW pumped hydro storage with efficiency of 80% and grid charges of 4€/MWh,

2005 on average:
- spread: 32.21 EUR
- pumping: 9 hours
- generating: 7 hours

2015 on average:
- spread: 21.34 EUR
- pumping: 6 hours
- generating: 5 hours

2015 (qh) on average:
- spread: 21.34 EUR
- pumping: 9 hours
- generating: 7 hours
Intraday Trading

Source: Dissertation Sebastian Braun
Intraday Screen

Screenshot of an exemplary intraday orderbook from September 16th, 2013 at 11 am including some explanations

Screenshot of the price development for one product on the continuous intraday market from September 16th, 2013 at 7 am including some explanations
General Optimization Problem

Minimize the costs for a specific period of time

\[ \min \sum_{u,t} c_{u,t}(x_{u,t}) \]

The load need to be covered at all time

\[ \sum_{u} x_{u,t} = l_t \quad \forall t \]

Reservoir balancing equation

\[ SQ_{s,t} = SQ_{s,t-1} + SQ_{\text{inflow},t} - SV_{s,t} - x_u + x_u \quad u \in \text{turbines/pump}, \forall t, s \]

Ramp-up and -down gradient

\[ |x_{u,t} - x_{u,t-1}| \leq g_{\text{max},u,t} \quad \forall u, t \]

Min and max production power

\[ p_{\text{min},u,t} \leq x_{u,t} \leq p_{\text{max},u,t} \quad \forall u, t \]

Max storage filling level

\[ 0 \leq SQ_{s,t} \leq SQ_{\text{max},s} \quad \forall t, s \]

Start and End filling levels

\[ SQ_{s,t=0} = SQ_{\text{start},s} \quad \forall t, s \]
\[ SQ_{s,t=T} = SQ_{\text{end},s} \quad \forall s \]
Challenges

- Optimization not quick enough for ID
- Shadow price steering difficult for daily pumped hydro storages
- Connection between dual variable – water value – shadow price not always clear
- How much water should be released at the level of the shadow price?
- How to consider order book data?
Intraday Algorithm for Pumped Hydro Power Storages

\[ \lambda_g = 48.91 \]
\[ \lambda_p = 31.36 \]

<table>
<thead>
<tr>
<th>Time in quarter-hours</th>
<th>Pumping Marginal Cost in €/MWh</th>
<th>Generating Marginal Cost in €/MWh</th>
</tr>
</thead>
<tbody>
<tr>
<td>[0-52]</td>
<td>29.56</td>
<td>47.82</td>
</tr>
<tr>
<td>[53-55]</td>
<td>27.26</td>
<td>46.82</td>
</tr>
<tr>
<td>[56-126]</td>
<td>29.68</td>
<td>49.13</td>
</tr>
</tbody>
</table>
How to get a price forecast for the intraday market

- Which price fits for the optimization?
  - VWAP (Volume Weighted Intraday Average Price)
  - Last trade for each product
  - Average of the first orders in the order book (two prices for bid and ask side?)
  - Price forecast

- At that time we calculated the VWAP of the last trades for each our in the future. In case there were no deals we used the results of the Intraday Auction
ICIS Continuous Intraday Forecast

**Input**
- wind forecasts
- PV forecasts
- demand forecasts
- available capacities
- market data (e.g. tick data, order books, bidding curves, balancing prices)

**Model**
- statistical models
- fundamental models
- combination

**Output**
- forecast for hourly ID1
- price range for ID1
- forecast for quarter-hourly ID1
- quarter-hourly price range for ID1
- balancing price

Forecast for the next 7 hours
Updates once per hour, planned to be every few minutes
Intraday Forecast
Intraday Forecast
Hourly ID Price Distribution

Average spread between ID high and low in €/MWh

- 2014: 16.41
- 2015: 17.95
- 2016: 14.93
- 2017: 22.79
- 2018: 25.25
Quarter-Hourly ID Price Distribution

Average spread between ID high and low in €/MWh

<table>
<thead>
<tr>
<th>Year</th>
<th>Average Spread</th>
</tr>
</thead>
<tbody>
<tr>
<td>2014</td>
<td>30.67</td>
</tr>
<tr>
<td>2015</td>
<td>31.05</td>
</tr>
<tr>
<td>2016</td>
<td>26.91</td>
</tr>
<tr>
<td>2017</td>
<td>35.61</td>
</tr>
<tr>
<td>2018</td>
<td>41.05</td>
</tr>
</tbody>
</table>
Development of ID Price Spreads

spreads between **hourly** intraday high and low price

spreads between **quarter-hourly** intraday high and low price
Development of ID Price Spreads

spreads between **hourly** intraday high and low price

--

spreads between **quarter-hourly** intraday high and low price

---

copyright © 2017 ICIS
analytics.icis.com
Growth of RES Production and Trading

installed capacity of renewable energy sources

- installed capacity in GW
- share of direct marketing in %

- hydro power
- geo thermal
- solar radiation energy
- landfill gas, sewage and mine gas
- biomas
- onshore wind energy
- offshore wind energy
- direct marketing
Intraday Forecast

Continuous intraday forecast (beta)

Current Model Run: Tuesday, 20 Mar 14:00 (CET)

- Increase from previous
- Decrease from previous
- CID min/max
- Forecast range
- CID1 forecast
- CID1 actual
- CID-1 actual
- CID actual
- DAM actual

Forecasted classes:
- Foreasted Residual Demand
- Foreasted Demand
- Foreasted PV
- Foreasted Wind
- Foreasted Residual Demand run-1
- Foreasted Residual Demand run-2
Renewable Production

As part of our daily model runs, we are estimating the expected wind and solar power feed-in into European power markets over the next days. Shown results are updated four times a day. By default, latest complete model run displayed. Select currently calculated run in dropdown.

Wind

PV
Thank you for your attention!

ICIS
Tschach Solutions GmbH
Stephanienstr. 86
76133 Karlsruhe/Germany

Sebastian Braun
Senior Analyst – Power Markets
Sebastian.braun@icis.com
http://analytics.icis.com
+49 (0) 721 205 962 939