OPTIMIZATION STRATEGIES FOR THE OPERATION OF RENEWABLE ENERGY UNITS IN SMART MARKETS

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Fraunhofer IEE
AGENDA

Topic – Unit Commitment
- Part I – Markets Today
  - Specifications of Biogas CHP
  - Unit Commitment in the Day Ahead and Intraday Market
- Part II – Smart Markets
  - Smart Market Concepts
  - Unit Commitment Considering Smart Markets

Topic – FRR Pooling
- Part III – Flexibility Capacity of Energy Unit Portfolios Including Volatile Producers
Part I – Markets Today
# Part I – Markets Today

## Overview Major Markets

<table>
<thead>
<tr>
<th>Market type and time</th>
<th>FRR Auctions (aFRR, mFRR)</th>
<th>Day Ahead Auction EPEX Spot</th>
<th>Intraday Auction EPEX Spot</th>
<th>Intraday Trading EPEX Spot</th>
<th>Intraday Trading XBID</th>
</tr>
</thead>
<tbody>
<tr>
<td>Market type and time</td>
<td>10.00 a.m</td>
<td>12.00 p.m.</td>
<td>3.00 p.m.</td>
<td>Beginning at 3.00 / 4.00 p.m.</td>
<td>Beginning at 10 p.m.</td>
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</tbody>
</table>
Biogas CHP, biogas boiler, gas storage and thermal storage

*BP: Balancing Point – bg: biogas – el: electric power – th: thermal power
Part I – Markets Today
CHP System for Unit Commitment

- CHP specifications
  - $P_{el}: 11 \text{ MW}; P_{th}: 11.5 \text{ MW}$
  - Biogas fueled
  - Remuneration scheme: market premium for biogas plants (EEG 2014)
  - Startup and operational costs
  - Non-linear efficiency rates in electrical and thermal output
  - Load following rate
- Peak load heat boiler
  - $P_{th}: 17.5 \text{ MW}$
- Thermal storage
  - $Storage_{max}: 30 \text{ MWh}$ – up to 6 hours thermal output of CHP
Part I – Markets Today
Optimization Approach for Unit Commitment

- Mixed integer linear programming (MILP)
- Optimization model microSCOPE (optimization core of IEE.ems)
- Optimization modelling language Pyomo (Python)
- Solver: Gurobi
- Objective function, maximizing gains:

\[
\text{maximizing } g := \sum_{t \in T} (i_t - c_t)
\]
Part I – Markets Today

Unit Commitment Day Ahead and Intraday

Day ahead schedule CHP

Intraday schedule CHP
Part I – Markets Today
Unit Commitment Day Ahead and Intraday

Thermal load and output day ahead

Thermal load and output intraday
Part I – Markets Today
Unit Commitment Day Ahead and Intraday - Gain and Price Comparison

Price comparison day ahead & intraday including premium

Day ahead profits

Intraday profits
Part I – Markets Today

Introducing maxprice: Maximum of Day Ahead Price and Intraday Price (FC)
Part I – Markets Today
Unit Commitment Maxprice
Part I – Markets Today
Trade at Intraday Market

Generation shifting - day ahead and maxprice optimization schedule CHP

<table>
<thead>
<tr>
<th>Time</th>
<th>Day ahead</th>
<th>Intraday</th>
<th>Maxprice</th>
</tr>
</thead>
<tbody>
<tr>
<td>11-22 01:00</td>
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<tr>
<td>11-22 05:00</td>
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<tr>
<td>11-22 09:00</td>
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<td>11-22 13:00</td>
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<td>11-22 17:00</td>
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<td>11-22 21:00</td>
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<td>11-23 01:00</td>
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<td>11-23 21:00</td>
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<tr>
<td>11-24 01:00</td>
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</tr>
</tbody>
</table>

**Gains EUR**
- Day ahead: 1524 EUR
- Intraday: 4724 EUR
- Maxprice: 5317 EUR

*Added value through intraday trading: 3793 EUR*
Part II – Smart Markets
“Smart Market is the area beyond the grid in which energy volumes or services derived from them are traded between different market participants on the basis of the available grid capacity.”

– BNetzA 2011 (Federal Grid Agency Germany)
Part II – Smart Markets
Defining Smart Markets

“[here,] smart markets are defined as a coordination mechanism that mediates between the market and the grid sphere […] smart markets are characterized by a temporal and spatial component, since they eliminate and avoid regional grid congestion.”

– Agora 2017 (Fraunhofer IEE & Ecofys)
Part II – Smart Markets
Congestion Incident and Units Providing Flexibility
Part II – Smart Markets

Smart Market Concept Examples

- ENKO - “energy coordinated intelligently“
  - Day ahead auction
- C/Sells market platform
  - Day ahead auction
- Grid Integration market platform
  - Intraday auction with fixed lead time to forecasted congestion
Part II – Smart Markets
Example – Smart Market Concept ENKO

- Flexibility auction takes place between day ahead and intraday auctions

<table>
<thead>
<tr>
<th>Market type and time</th>
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<th>Flexibility Auction ENKO</th>
<th>Intraday Auction EPEX Spot</th>
<th>Intraday Trading EPEX Spot</th>
<th>Intraday Trading XBID</th>
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</thead>
<tbody>
<tr>
<td>Market overview</td>
<td>10.00 a.m</td>
<td>12.00 p.m.</td>
<td>2.30 p.m.</td>
<td>3.00 p.m.</td>
<td>Beginning at 3.00 / 4.00 p.m.</td>
<td>Beginning at 10 p.m.</td>
</tr>
</tbody>
</table>
Part II – Smart Markets
Example – Smart Market Concept ENKO

Source: Schleswig-Holstein Netz AG, Arge Netz GmbH
Part II – Smart Markets

Congestion Incident

[Graph showing power (MW) and curtailment signal (%)]

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Part II – Smart Markets

Congestion Incident (Forecast)

- Congestion/curtailment incidents
  - 22.11.2015, 09.15 a.m. to 12.15 p.m.
  - 22.11.2015, 16.45 p.m. to midnight
- Flexibilities are tendered on the market platform for the indicated times
Part II – Smart Markets

CHP System for Unit Commitment Including Smart Market

microSCOPE – optimization core IEE.ems

<table>
<thead>
<tr>
<th>Sources</th>
<th>Energy Units &amp; Storages</th>
<th>Sinks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biogas</td>
<td>Biogas CHP</td>
<td>EPEX Spot Electricity</td>
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<tr>
<td></td>
<td>El: 11 MW Th: 11.5 MW</td>
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<tr>
<td>Biogas storage</td>
<td>Biogas boiler</td>
<td>Smart Market</td>
</tr>
<tr>
<td></td>
<td>Th: 17.5 MW</td>
<td></td>
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<tr>
<td></td>
<td>Thermal storage</td>
<td>Heat network</td>
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<tr>
<td></td>
<td>Th: 30 MWh</td>
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</tr>
</tbody>
</table>

*BP: Balancing Point  bg: biogas  el: electric power  th: thermal power
Part II – Smart Markets
Unit Commitment Including Flexibility Supply

Smart market schedule CHP

Thermal load and output smart market
Part II – Smart Markets
Generation Shifting

Generation shifting - maxprice and smart market optimization schedule CHP

<table>
<thead>
<tr>
<th>Time</th>
<th>Flex provision CHP MWh</th>
<th>Gains [EUR]</th>
<th>Difference (abs.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>11-22 01:00</td>
<td>0</td>
<td>5317</td>
<td>476</td>
</tr>
<tr>
<td>11-22 05:00</td>
<td>0</td>
<td>4841</td>
<td></td>
</tr>
<tr>
<td>11-22 09:00</td>
<td>38.5</td>
<td></td>
<td></td>
</tr>
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<td>11-22 13:00</td>
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Part II – Smart Markets
Unit Commitment Including Flexibility Supply

### 4 MW

<table>
<thead>
<tr>
<th>Min/Max</th>
<th>Flexibility</th>
<th>Difference maxprice</th>
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</thead>
<tbody>
<tr>
<td>Provision CHP MWh</td>
<td>28.5</td>
<td>28.5</td>
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<tr>
<td>Gains [EUR]</td>
<td>5022</td>
<td>295</td>
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</tbody>
</table>

### 6 MW

<table>
<thead>
<tr>
<th>Min/Max</th>
<th>Flexibility</th>
<th>Difference maxprice</th>
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</thead>
<tbody>
<tr>
<td>Provision CHP MWh</td>
<td>20.5</td>
<td>20.5</td>
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<td>Gains [EUR]</td>
<td>5069</td>
<td>248</td>
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</table>
Part II – Markets Today
Developing Portfolio to Increase Flexibility Potential – P2H

<table>
<thead>
<tr>
<th>Sources</th>
<th>Energy Units &amp; Storages</th>
<th>Sinks</th>
</tr>
</thead>
<tbody>
<tr>
<td>EPEX Spot Electricity</td>
<td></td>
<td>Electric boiler Th: 3.5 MW</td>
</tr>
<tr>
<td>Biogas</td>
<td>Biogas CHP El: 11 MW Th: 11.5 MW</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Biogas boiler Th: 17.5 MW</td>
<td>EPEX Spot Electricity</td>
</tr>
<tr>
<td></td>
<td>Thermal storage Th: 30 MWh</td>
<td>Smart Market</td>
</tr>
<tr>
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<td></td>
<td>Heat network</td>
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</tbody>
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Part II – Smart Markets
Unit Commitment Including Flexibility Supply – P2H

- Providing further flexibility through electric boiler
  - Flexibility option 1: reducing CHP output
  - Flexibility option 2: using P2H to draw electric output of CHP
  - Flexibility option 3: using P2H to offer additional load flexibility

- Minimum price for P2H flexibility:
  - Flexibility option 2: fuel costs for electric output of CHP + missed market revenues → not economic
  - Flexibility option 3: electricity price + surcharges for load + CHP generation shifting costs
Part II – Smart Markets
Unit Commitment Including Flexibility Supply – P2H

![Diagram of thermal load and output smart market](image)

<table>
<thead>
<tr>
<th></th>
<th>No supply</th>
<th>Scenario I</th>
<th>Scenario II</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flex provision CHP [MWh]</td>
<td>-</td>
<td>38.5</td>
<td>38.5</td>
</tr>
<tr>
<td>Flex provision boiler [MWh]</td>
<td>-</td>
<td>25</td>
<td>35.9</td>
</tr>
<tr>
<td><strong>Total supply [MWh]</strong></td>
<td>-</td>
<td><strong>63.5</strong></td>
<td><strong>74.4</strong></td>
</tr>
<tr>
<td>Gains [EUR] (incl. el. costs boiler)</td>
<td>5317</td>
<td>4318</td>
<td>3770</td>
</tr>
</tbody>
</table>
Part III

Flexibility Capacity of Energy Unit Portfolios Including Volatile Producers – Use Case FRR
Part III – Flexibility Capacity VPP

Background and Motivation

- With decreasing number of conventional plants new FRR providing units are required
- Current pilot phase for mFRR provision by wind farms (by German TSOs)
- Problem statement: high day ahead feed-in uncertainty of volatile producers leads to high risk in FRR provision
- Solution: using synergies in back-up security of FRR providing pool
Part III – Flexibility Capacity VPP
Approach – Mathematical Convolution of Input PDFs

- Input for FRR capacity dimensioning
- Applying a mathematical convolution on probability density functions
Part III – Flexibility Capacity VPP

Results

- Result I: current (conventional) pool reliability: 99.859%
- Result II: holding the reliability (or grid security) constant:
Take away

- Regional smart market concepts are gaining in importance
- Including (current) baseload CHP units can access and provide flexibilities
- If CHP provides flexibility, missed spot market revenues define price
  - Marginal costs decrease with fuel costs
  - The maximum price for smart market flexibility are alternative curtailment costs (compare: Rosenberg problem in illiquid markets)
- Additional flexibilities can be accessed through different boiler types
- Energy unit portfolios (VPP) including volatile producers can increase their flexibility potential using pooling-synergies
More Information on FRR Pooling Concept

Thank you for your attention.

Contact:
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