IAEW
Institute of Power Systems and Power Economics

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Introduction of the Institute

Institute of Power Systems and Power Economics (IAEW) – Fields of Research

Simulation and optimization of energy systems – focusing on electrical energy
Analysis and evaluation of current and future concepts of energy supply
Integration of renewables in markets and grids

Research Focus

Power Generation & Energy Markets
- European market simulation (scheduled, reserve, capacity)
- Storage technologies, VPP and demand side management
- Power-to-gas

Network Planning & Network Operation
- Network development and simulation of network operation
- Overlay grid
- Smart grids

System Stability & Security of Supply
- Network security and reliability of supply
- Voltage and frequency stability
- Regulation
Central question:

“What are the advantages from having access to Norwegian hydropower flexibility and what business models can incorporate these?”

Regarding balancing, system costs as well as supply side (utilities) can benefit from the access to flexible generation

- Cost reduction from optimized purchasing and activation of balancing power
  → Cross-border balancing markets
- Marketing opportunities of Norwegian hydropower for utilities on (balancing) markets in Europe
  → Long term contracts enable access to hydropower plants
Overview of the Work Packages

Aim

- Quantification of benefits from
  - Cross-border purchasing and activation of balancing power
  - Participation of Norwegian storage on German market for different generation portfolios

Work Package 1 – Macroeconomic Investigations

- Simulation of system with and without optimization of cross-border reserve provision
- System benefit of cross-border balancing markets
- Simulation of spot prices for different weather years
- Simulation of German ¼-hourly prices and prices for reserve power and energy

Work Package 2 – Microeconomic Investigations

- Optimization of portfolio dispatch and trading based on simulated market prices
- Contribution margin of storage and portfolio effect in different generation portfolios
- Impact of forecast errors on benefit from additional storage
Investigation Approach

European Market Simulation
- Simulation of European system with coverage of load and reserve constraints
- Determination of cross border flows between market areas
- Simulation of different weather years

Results
- Cross-border exchanges
- Participation of Norwegian storages on German market

Detailed Simulation German System
- Consideration of load coverage, provision of reserve power and reserve energy in different products
- Identification of price indicators

Results
- Market prices for energy, reserve power and reserve energy

WP3.2 Portfolio Dispatch & Trading
Main Differences between Scenario B and C

- Scenario for 2050 mainly based upon the EU Trends study and the ENTSO-E TYNDP with increased RES feed-in and reduced nuclear power capacity

<table>
<thead>
<tr>
<th>Conventional generation</th>
<th>Scenario B „Big Hydro“</th>
<th>Scenario C „Niche Storage“</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>• Reduced fossil/nuclear capacity by 10%</td>
<td>• Increased hydro capacity by 10%</td>
</tr>
<tr>
<td></td>
<td>• 60 GW of hydro power in Norway</td>
<td>• 50 GW of hydro power in Norway</td>
</tr>
<tr>
<td></td>
<td>• Secured peak load in Europe</td>
<td>• Secured peak load for each country</td>
</tr>
</tbody>
</table>

| Alternative flexibilities | | |
|---------------------------| | |
|                         | • Little DSM and inflexible CHP | • Increased DSM and flexible CHP |
|                         | • No PtG storages | • 20 GW of PtG storages in Europe |
|                         | • Passive operation of distributed storages | • Market-orientated operation of distributed storages |

| Transmission capacities | | |
|-------------------------| | |
|                         | • Up to 30 GW cable capacity from and to Norway necessary for export | • Up to 20 GW cable capacity from and to Norway necessary for export |
|                         | • Increased transmission capacities by 50% | |

| Integration of Markets | | |
|------------------------| | |
|                         | • Cross-border reserve markets → Optimal allocation of resources | • National reserve markets |
Strong increase in RES generation in comparison to 2013 data
Increase in thermal generation in Scenario C, especially nuclear and lignite
Electricity Prices

- Lowest prices in Scenario C
  - More generation from hydro and nuclear power in Scenario C leading to lower price level in all countries
  - Scandinavian price level lower due to less transfer capacities to mainland market areas
- Alignment of prices in Scenario B
WP 1 – Reserve Exchange Variations

- No Reserve Exchange
  - Transfer capacity reserved for import and export of energy

- Optimal
  - Utilization of NTC both for energy and reserve provision
  - Cost based optimization of NTC reserve share for each hour

→ Difference of system costs is benefit of integrated European balancing markets
Optimal allocation of transfer capacities leads to slightly reduced variable system costs.

Cost reduction in Scenario C lower due to higher hydro capacity (except NO).

Cost reduction only marginal (between 0.08% and 0.43% of total costs) since reserve provision is no subject to scarcity.
Regarded Portfolio

Portfolio „RES“

<table>
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<tr>
<th>Technology</th>
<th>Capacity [MW]</th>
<th>Reserve provision</th>
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<tbody>
<tr>
<td>Solar</td>
<td>429</td>
<td>-</td>
</tr>
<tr>
<td>Wind</td>
<td>516</td>
<td>TR</td>
</tr>
<tr>
<td>Biomass</td>
<td>55</td>
<td>SR, TR</td>
</tr>
</tbody>
</table>

Portfolio with 1 GW of installed capacity and proportions according to RES share in Germany

Potential for flexible hydro power to compensate volatile RES feed-in
Additional Contribution Margin from Norwegian PSP

- Comparison of portfolio CM compared to market situation without Norwegian PSP taking part in German market

- CM of RES Portfolio slightly higher when NO PSP not in German market
- Highest benefits from additional storage for RES Portfolio and Scenario B (+575.1 Mio.€/a)
RES Portfolio – Portfolio Effect

- Portfolio effect with steady reserve between 0.7% and 0.9%
- Effect from optimizing reserve provision

SUM Portfolio – Portfolio Effect

SR RP  | SR RE  | TR RP  | TR RE  | ΔSpot

Mio. €a


Portfolio

NO PSP

Separate

sum of CM from separate optimization
Summary

Motivation and Background
- RES development in Europe triggers need for flexibility in the power system
- Possible provision of the needed flexibility from Norwegian hydropower
- Possible benefit from having access to Norwegian hydropower for utilities and TSO to be investigated

Results of Macroeconomic Investigations
- Alignment of prices between Scandinavia and Northern Europe of approx. 100 €/MWh
- Benefit from optimal allocation of transfer capacity to exchange reserve power and scheduled energy amounts to 345 mio. €/a in scenario B and 70 mio. €/a in scenario C
- Higher additional value on macroeconomic scale from short- and long-term balancing for scenarios with low flexibility in the rest of Europe

Results of Microeconomic Investigations
- Additional pumped storage increases contribution of portfolio
- Increasing additional value for portfolios with decreasing inherent flexibility (e.g. wind and solar plants), especially considering prognosis errors