Renewable Energies in Control Reserve Markets

Dawud Ansari | FG Energiesysteme: Neue Entwicklungen auf den Energiemärkten | July 2014
Outline

1. Renewable Energies & The Energy Trilemma
2. Basics of Control Reserves
3. Stochastics of Solar and Wind Energy
4. Integrating Renewable Technologies into the Control Reserves
5. Field Tests
6. Summary & Discussion
Energy Trilemma

Costs of Energy

Ecology

Security of Supply

Today:
Trade-off between ecological benefits and security

How can we achieve complete energy transition without risking blackouts?
Technical Basics

- Supply = Demand necessary at every point in time

- Mains frequency: 50 Hz +/- 20mHz (0.04%)
  (UCTE / Germany: [http://www.netzfrequenzmessung.de/](http://www.netzfrequenzmessung.de/))

- If frequency is above or below these values, sincere network failures may occur.

- Control reserves are then used to physically balance real-time (or short-term) deviations from that.
Positive & Negative Controls

- If supply < demand, there is the need for a positive control.
- If supply > demand, there is the need for a negative control.
- Equilibrium of supply and demand can be reached by adjusting either of them.

<table>
<thead>
<tr>
<th></th>
<th>Positive Control</th>
<th>Negative Control</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Supply Side</strong></td>
<td>Activate additional generators</td>
<td>Disconnect generators from the network</td>
</tr>
<tr>
<td><strong>Demand Side</strong></td>
<td>Reduce consumption (e.g. throttle industrial production)</td>
<td>Increase consumption (e.g. batteries)</td>
</tr>
</tbody>
</table>
Actors in the Balancing Procedure (UCTE)

Transmission System Operators (TSOs)
- Determine (ex ante), acquire & activate necessary control reserves
- Billing of control reserves (financial clearing)

Balance Responsible Parties (BRP)
- Responsible for balancing generator and / or load portfolios
- Provide the TSO with schedules (day ahead, adjustable until hour ahead)
- Financially accountable for deviations

Suppliers of Control Reserves
- Provide positive or negative control power
## Types of Reserves

<table>
<thead>
<tr>
<th></th>
<th>Primary Control</th>
<th>Secondary Control</th>
<th>Tertiary Control (Minute Reserve)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Response Time</strong></td>
<td>30 s (100%), direct (continuously)</td>
<td>5 min (100%), direct (continuously)</td>
<td>7-15 min (100%), director schedule</td>
</tr>
<tr>
<td><strong>System</strong></td>
<td>UCTE</td>
<td>Control area</td>
<td>Control area</td>
</tr>
<tr>
<td><strong>Control Variable</strong></td>
<td>Frequency deviation from 50 Hz (UCTE system)</td>
<td>Balance of the control area; Frequency deviation</td>
<td>Amount of SC⁺⁻ activated</td>
</tr>
<tr>
<td><strong>Activation</strong></td>
<td>Based on local frequency measurement</td>
<td>Centralized (TSO); active call through IT</td>
<td>Centralized (TSO); active call through phone / IT</td>
</tr>
<tr>
<td><strong>Suppliers (typically)</strong></td>
<td>Synchronized generators, (industrial consumers)</td>
<td>Synchronized generators, stand-by hydro plants, large consumers</td>
<td>Synchronized and fast-starting stand-by generators, large consumers</td>
</tr>
<tr>
<td><strong>Reserved Capacity</strong></td>
<td>3000 MW in UCTE (600 MW in Germany)</td>
<td>Decided by TSO (2500 MW in Germany)</td>
<td>Decided by TSO (2500 MW in Germany)</td>
</tr>
</tbody>
</table>

Uncertainty & Probabilistic Models

- Demand for electricity is naturally estimable but still uncertain. As well: Plants can have unforeseeable outages.

  Hence, there is a need for (positive and negative) reserves.

- Problem: Supply of the renewables is uncertain as well! (Weather, etc.)

- Question: *Can you hedge a risk with something risky?*
Uncertainty & Probabilistic Models

• Stochastic variables:
  Outages, Weather Forecast Errors, Load Forecast Errors and Load Noise

• Stochastic dependency in wind and solar park failures

• Idea: mapping between probability and reserve

• Reliability / Security Level : 99.994 %
Uncertainty & Probabilistic Models

Possible Auction Methods

- Day ahead auction or intraday auction?
- Full, partial or no collateralisation?
- Example (from Fraunhofer IWES):
  - Full collateralisation, day ahead auction
  - Wind park of 1 GW
  - nRMSE (~average error) day ahead forecast 6.4% and intraday 2.9%
  - 1307 full load hours

  ➢ The (average) supply is no more than 3.4 MW
Excursus

Question:

What is the impact of variable renewables on the control reserve?
## Excursus

<table>
<thead>
<tr>
<th></th>
<th>PC$^{+-}$</th>
<th>SC$^+$</th>
<th>SC$^-$</th>
<th>TC$^+$</th>
<th>TC$^-$</th>
</tr>
</thead>
<tbody>
<tr>
<td>2008</td>
<td>670</td>
<td>3100</td>
<td>2400</td>
<td>3200</td>
<td>1900</td>
</tr>
<tr>
<td>2009</td>
<td>670</td>
<td>2900</td>
<td>2200</td>
<td>2700</td>
<td>2700</td>
</tr>
<tr>
<td>2010</td>
<td>640</td>
<td>2400</td>
<td>2100</td>
<td>2300</td>
<td>2400</td>
</tr>
<tr>
<td>2011</td>
<td>630</td>
<td>2200</td>
<td>2100</td>
<td>2100</td>
<td>2500</td>
</tr>
<tr>
<td>2012</td>
<td>600</td>
<td>2100</td>
<td>2200</td>
<td>1700</td>
<td>2300</td>
</tr>
</tbody>
</table>


- Surprisingly, the impact is less than assumed.
- Reasons: technical and economic
Renewable Controls

Which controls can be provided by renewable energies?

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<tr>
<td>Supply Side</td>
<td>Biogas and hydro</td>
<td>Wind, biogas and hydro (potentially also solar)</td>
</tr>
<tr>
<td>Demand Side</td>
<td>Storage technologies (e.g. batteries, electrolyser)</td>
<td></td>
</tr>
</tbody>
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Inertial Response

Initial slope of decline is determined by system inertia

Virtual Power Plants

Kombikraftwerk 1

- Link and control of 36 renewable energy generators (wind, solar, biomass, hydro) throughout Germany

- 0.01% of the overall German load is provided by the ‘Kombikraftwerk 1’ at every point in time

- Result: Efficient control enables renewable energies to continuously provide a certain amount of electricity.

- Awarded with the “Deutscher Klimaschutzpreis 2009”

- However: Does this also hold for ancillary services?
Kombikraftwerk 2

- Joint venture project (SIMENS, Frauenhofer IWES, SolarWorld, etc.)

- A 80 MW pool of renewable energy sources (PV, wind, biogas) was shown to provide control reserves and to help in balancing the network.
Kombikraftwerk 2 – Results

Kombikraftwerk 2 – Results

- The ‘100% scenario’ is only possible under the usage of innovative storage technologies (e.g. batteries, methanisation, electrolyser).

- For guaranteeing system stability, weather independent generators (e.g. biogas) covering the maximal load are necessary.

- Missing inertial responses can be compensated by faster primary reserves.

- System has to be precisely optimised (positioning, dispatch) and builds on decentralising.
Summary

• Control reserves are necessary to balance the mains frequency at every point in time.

• Solar and wind energy do have the essential problem of depending on stochastic variables (weather). However, short-term forecasting provides accurate estimations.

• Within a virtual power plant, renewable energies can be controlled centrally to provide a balanced generation.

• Hedging of solar and wind risks needs huge ratios of securities. Hence, using them for positive controls is connected with (possibly utility-exceeding) costs.
Literature

- Fraunhofer IWES. (2014). Regelenergie durch Windkraftanlagen – Abschlussbericht
Discussion

Statements:

To what extent do we – in terms of the energy trilemma – only transform the security problem into a cost problem?