Experience from the Nordic Balancing Markets and Future Prospects for Auctions

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Göttingen, Auction seminar, 15 March 2018
Overview

• Nordic power market
• Nordic reserve markets, overview
• Focus on auctions
  • Frequency Controlled Reserves
  • Frequency Restoration Reserves
• Exchange of aFRR reserve capacity Norway-Sweden
• Some auction design characteristics
• Summing up
Nordic electricity generation 2015 (TWh)
Nordic reserve markets

- Frequency Controlled Reserves (FCR) (Primärregelung)
  - Normal operation (FCR-N) 600 MW
  - Disturbance (FCR-D) 1200 MW
- Manual Frequency Restoration Reserves (mFRR) (Minutenreserve)
  - 4090 MW (Statnett +600 MW)
- Automatic Frequency Restoration Reserves (mFRR) (Sekundärregelung)
  - 300 MW, few hours per day
  - Increases planned
Frequency controlled reserves

• Frequency Controlled Disturbance Reserves (FCR-D)
  • Only upward

• Frequency Controlled Normal Operating Reserves (FCR-N)
  • Symmetric
### Distribution of reserves

<table>
<thead>
<tr>
<th>Country</th>
<th>Annual consumption 2013 (TWh)</th>
<th>Frequency controlled normal operation reserve (MW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eastern Denmark</td>
<td>13.7</td>
<td>22</td>
</tr>
<tr>
<td>Finland</td>
<td>85.2</td>
<td>138</td>
</tr>
<tr>
<td>Norway</td>
<td>130.0</td>
<td>210</td>
</tr>
<tr>
<td>Sweden</td>
<td>142.5</td>
<td>230</td>
</tr>
<tr>
<td>Synchronous system</td>
<td>371.4</td>
<td>600</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Country</th>
<th>Dimensioning faults (MW)</th>
<th>Frequency controlled disturbance reserve (MW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Denmark</td>
<td>600</td>
<td>176.5</td>
</tr>
<tr>
<td>Finland</td>
<td>880</td>
<td>258.8</td>
</tr>
<tr>
<td>Norway</td>
<td>1,200</td>
<td>352.9</td>
</tr>
<tr>
<td>Sweden</td>
<td>1,400</td>
<td>411.8</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>1,200</strong></td>
<td><strong>Total</strong></td>
</tr>
</tbody>
</table>

**Manual Frequency Restoration Reserves (MW):**

- Denmark-East: 600
- Finland: 1000
- Norway: 1200 + 600
- Sweden: 1290
- **Total**: 4090 (+ 600)
Norway, reserve capacity - FCR

- Weekly auctions FCR-N
  - Six blocks
    - weekday/weekend and day/evening/night
- Daily auctions (after DA clearing), FCR-N and FCR-D
  - Hourly resolution
- All auctions paid-as-cleared (marginal price)
- Volumes per bidding zone
- Minimum bid size 1 MW
- Excess capacity may be sold to Sweden
- Voluntary participation
  - Units ≥ 10 MW that do not participate are obliged to provide
    - ≤ 12 % droop in winter
    - ≤ 6 % droop in summer
  - Administrative payment
FCR-N NO1 average daily weekday prices 2017

FCR prices normally equal for all bidding zones

1NOK ≈ 0.105 Euro
FCR-N NO1 average daily weekend prices 2017
FCR-N NO1, daily auctions, average monthly prices 2017
mFRR activation market (1)

• mFRR is the main balancing resource
  • Normally it is the only resource (besides FCR)

• Before 2000, it was only based on free bids
  • Large pool because of hydro turbine characteristics
    • Max efficiency at ~80 % of $P_{\text{max}}$, very short startup times

• Required response: full delivery within 15 minutes
  • In practice most Norwegian units much faster
mFRR activation market (2)

- Activation market paid-as-cleared (marginal pricing)
- Prices may split across bidding zones
  - Price-split may be different from day-ahead market
- Price cap 5000 €/MWh
- Same bids used for intra-zonal congestion management
  - Do not (directly) impact balancing price
  - Paid-as-bid
Spot and mFRR prices NO1 January 2017
Norway, reserve capacity – mFRR (1)

- **RCOM** – Reserve Capacity Option Market
- Bids are given in each bidding zone
  - Grid location is also provided
- **Two qualities**
  - B – limited duration (≥1 hr), resting time (≤ 8 hrs)
  - H – high quality, no constraints
  - Minimum quantity H
- Distribution between bidding zones determined by TSO
Price reductions for lower quality mFRR

• Price equal to: Dfact \cdot Rfact \cdot \text{clearing price}

<table>
<thead>
<tr>
<th>Duration (hrs)</th>
<th>≥ 4</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dfact</td>
<td>1,00</td>
<td>0,98</td>
<td>0,95</td>
<td>0,90</td>
<td>0,80</td>
</tr>
<tr>
<td>Resting time (hrs)</td>
<td>none</td>
<td>≤ 2</td>
<td>≤ 4</td>
<td>≤ 6</td>
<td>≤ 8</td>
</tr>
<tr>
<td>Rfact</td>
<td>1,00</td>
<td>0,98</td>
<td>0,95</td>
<td>0,90</td>
<td>0,80</td>
</tr>
</tbody>
</table>
Norway, reserve capacity – mFRR (2)

- Total quantity depends on TSO's expectation of free bids
- ~November – April, 05:00-24:00, 7 days per week
  - Occasionally also during night if very high load (cold!)
  - In this period there may not be sufficient free bids
- One common auction, TSO decides minimum required volume of RCOM-H
  - Weekly, Friday afternoon
  - Required RCOM-H volume may lead to price split with RCOM-B
- Bids are for capacity only
  - Successful bidders are obliged to bid in the activation market
  - Price for energy bid up to their discretion
Generation and demand week 9 2018

All time high demand
Generation and demand week 3 2018
Procured RCOM volumes 2017
RCOM weekly prices 2017
Nordic reserve capacity – aFRR (1)

- aFRR introduced in Nordic system in 2013
- Presently 300 MW
  - 04:00-08:00, working days
  - 3-4 evening hours, varying, season dependent
  - Increasing
- Procured per bidding zone
Example distribution aFRR

• Distribution based on bidding zones' historical short term imbalances
  • Varies over time

Source: Appendix 2 to Agreement on a Nordic Market for Frequency Restoration Reserves with automatic activation (aFRR)
Nordic reserve capacity – aFRR (2)

- Weekly auctions, Thursday
- Bid per "Scheduling Resource" – group of plants
- Minimum bid 5 MW, maximum 35 MW
  - Divisible in 5 MW steps
- Paid-as-cleared per bidding zone
  - In special cases (grid), deviating bids paid-as-bid
- Proportional activation
- Payment according to mFRR activation clearing price
Spot and aFRR prices Norway 2017
Test: Hasle Pilot Norway-Sweden
8-weeks test of aFRR capacity exchange

aFRR-bids for week $n$ from Norwegian and Swedish service providers

Cross Zonal Capacity forecast for week $n$

Actual spotprices week $n-1$ (proxy for forecast week $n$)

OPTIMIZATION
Comparing marginal value of exchanging aFRR with forecasted marginal value of exchange in spot

Check that pre-defined requirements are fulfilled
Increase of socio economic welfare*)

*) Socio economic costs are estimated as actual price difference \( \times \) reserved transmission capacity. Subsequent analysis showed only minor price impacts in the market.
Reserve capacity auction design
- timing and block length

• Major cost component: alternative cost
  • High spot price → lost revenues from spot
  • Low spot price → revenues do not cover operational cost

• When should auction be held?

• Block length: week – day – high/low – hour?
Auction timing

• **Before spot DA**
  - BSPs must forecast spot price to prepare bids
  - Forecast errors result in non-optimal dispatch and cost increase
  - But TSO has certainty of reserve capacity availability

• **After spot DA**
  - Price and dispatch are known, BSP can prepare optimal bids
  - Optimal dispatch (but disregarding reserves in spot clearing)
  - But no certainty for reserve capacity availability

• **Together with DA – co-optimization**
  - BSPs do not know DA spot price when preparing
  - But that should not matter if alternative cost is dominating cost component
Auction time block length

• Long blocks
  • BSPs need to reserve capacity for long period
  • May result in loss for some hours
  • Results in cost increase

• Shorter blocks → hour
  • Optimal adaptation between electricity production and reserve capacity
  • Perfect solution combined with co-optimization
Summing up

- Nordic power systems dominated by production without CO2 emissions
- Bidding zones essential part of market design
- Norway: procurement of capacity for all reserves in auctions – seasonal, weekly, daily
- Auction timing and time block length important design variables