Market challenges in the future
Nordic Power System

Event on renewables integration in Lund 17 December 2013
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Electric Power Systems, KTH, Sweden

Pricing challenges in the future
Nordic Power Market with large amounts of renewable low marginal cost units.
In 2012 the Nordic hydro power production was 237 TWh.

This corresponds to an inflow of around 4.5 TWh/week.

A heavy rain every second week implies 9 TWh.

Pricing in power systems:

- **Thermal power systems:** Price is set by marginal cost.
  
- **Hydro power:** Price is set by the water value = the expected marginal cost in the future to which the water could be stored.
  
- **Wind power:** Price is set by marginal cost = negative subsidy, since subsidy is only obtained at production (e.g. -2 Euro-cent if certificate price is 2 Euro-cent.)
  
Nordic hydro power

Price is set by the water value = the expected marginal cost in the future to which the water could be stored.

Price is not set in Norway!
Pricing in power systems:

Sweden

Hydro + Nuclear + wind (90%)
Large part of the rest is CHP (industrial and distr. heat)
Price is set by the water value = the expected marginal cost in the future to which the water could be stored.
Price is not set in Sweden!

Denmark

2020: High wind power (50%)
A part of the rest is CHP (industrial and distr. heat)
When it is windy, then the prices will be low
High prices are often not set in Denmark!

Finland

Nuclear + hydro + wind (58% - now)
CHP + more nuclear in the future
At wind and low demand, then the prices will be low
Prices are then often not set in Finland!

Pricing in future Nordic power systems:

Much more often: Prices are not set by Nordic power plants.
At wind and low demand, then the prices can be really low
There is then a challenge to get prices that are high enough to finance all power plant.
Enough transmission to high MC areas essential
Balancing challenges in a future Swedish power system based on 100% renewable power.

- The government in UK has agreed with EDF group about an offer to construct new nuclear power in UK.
- The key terms include a “Strike Price” of £89.50 /MWh (96-99 öre/kWh)
- A contract difference payment duration of 35 years, from the earlier of the point at which each reactor at Hinkley Point C becomes commercially operational.
- [Source](https://www.gov.uk/government/news/initial-agreement-reached-on-new-nuclear-power-station-at-hinkley)

Identified wind power projects in Sweden:
- **45000 MW** (≈ 100 TWh/year)

Today capacities:
- **Hydro Power**: 16000 MW (≈ 65 TWh)
- **Nuclear power**: 9000 MW (≈ 65 TWh)
- Total of 25000 MW

Swedish Power production: Total 145.6 TWh
(same as 2011)
Current (2011) Swedish Power System

<table>
<thead>
<tr>
<th>Source</th>
<th>TWh - 2011</th>
<th>Energy % - 2011</th>
<th>MW-capacity - 2011</th>
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<tbody>
<tr>
<td>Hydro</td>
<td>66,0</td>
<td>44,9</td>
<td>16197</td>
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<tr>
<td>Nuclear</td>
<td>58,0</td>
<td>39,5</td>
<td>9363</td>
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<tr>
<td>Wind</td>
<td>6,1</td>
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<tr>
<td>Solar</td>
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<td>0</td>
<td>0</td>
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<tr>
<td>CHP-Ind</td>
<td>6,4</td>
<td>4,4</td>
<td>1240</td>
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<tr>
<td>CHP-distr.</td>
<td>9,4</td>
<td>6,4</td>
<td>3551</td>
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<td>Condens</td>
<td>1,01</td>
<td>0,7</td>
<td>3197</td>
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<tr>
<td>Total</td>
<td>146,9</td>
<td>100</td>
<td>36447</td>
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</table>

Studied Swedish Power System

<table>
<thead>
<tr>
<th>Source</th>
<th>TWh</th>
<th>Energy %</th>
<th>MW-max</th>
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</thead>
<tbody>
<tr>
<td>Hydro</td>
<td>65,7</td>
<td>45,1</td>
<td>12951</td>
</tr>
<tr>
<td>Nuclear</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Wind</td>
<td>46,8</td>
<td>32,1</td>
<td>15633</td>
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<tr>
<td>Solar</td>
<td>11,6</td>
<td>8,0</td>
<td>9148</td>
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<tr>
<td>CHP-Ind</td>
<td>6,4</td>
<td>4,4</td>
<td>1240</td>
</tr>
<tr>
<td>CHP-distr.</td>
<td>13,9</td>
<td>9,5</td>
<td>4127</td>
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<tr>
<td>Other</td>
<td>1,3</td>
<td>0,9</td>
<td>5081</td>
</tr>
<tr>
<td>Total</td>
<td>139,9</td>
<td>100</td>
<td>48180</td>
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New report: Published
21 Oktober 2013

Studies:
• Balancing from hour to hour in "isolated" Sweden!
• High wind+solar / low consumption
• Low wind+solar / high consumption
• Hydro power regulation
• Can be downloaded from KTH:s home page
• EXCEL-file for calculat.

Three challenges in power systems with large amounts of solar + wind:

C1: Keep the continuous balance
C2: Handle situations with large amounts of variable production
C3: Handle situations with small amounts of variable production

http://kth.diva-portal.org/smash/record.jsf?searchId=1&pid=diva2:657544
C1: Changes within 1 hour
Swedish consumption 2011, (+ 2300 MW)

Today hydro power, (+ 2500-3500 MW)

60 TWh wind+solar:
Hydro power: Change during 1 hour
During 2008 changes hour-to-hour: 3500 MW
During 2008 changes between 4 hours 7000 MW

Hydro power: Duration curve
Min level: 1875 MW: Needed during 860 hours
Max level: 12951 MW: Needed during 765 hours
Deficit situation
low solar+wind: January

High wind → decrease CHP

Deficit situation
(yearly basis)
Max nivå: 5081.27 MW
Antal timmar med behov: 765 h
Energi: 1.259 TWh
Cost for this: 1,5 öre/kWh

Surplus situation (August)
Not OK: 83% limit, min-hydro, min-CHP

Surplus situation (August)
Now OK: 83% limit, min-hydro, min-CHP
Peak capacity responsibility challenges.

Peak capacity responsibilities

Norway: TSO-Statnet is responsible for “enough capacity”
Finland: TSO-Fingrid is NOT responsible for “enough capacity”
Sweden: TSO-Svenska Kraftnät is NOT responsible for “enough capacity”. But: “up to 2000 MW”
Denmark: TSO-Energinet.dk is responsible for “enough capacity”

Surplus during a year

Max nivå: 9510 MW
Antal timmar med överskott/möjlighet till export: 860 h
Energivolym: 1.63 TWh

Peak loads in Sweden 1992-2011

Year 1992 - 2011
Peak capacity responsibilities example 1

1. Assume that there is a “capacity problem” in South Sweden and Denmark exports 1000 MW to Sweden.
2. Assume that there is an outage in Denmark so they have to decrease consumption.
3. According to EU legislation “non-discrimination” Denmark cannot prioritize Danish consumers before Swedish ones.
4. Does this have as a consequence that Denmark is also responsible for Sweden?

Peak capacity responsibilities example - 2

1. There are discussions of capacity payments to a rather large volume in UK
2. Probably this then leads to comparatively low energy prices compared to a case with no cap. payments
3. Both Norway and Denmark plan new cables to UK.
4. Does this mean that Denmark and Norway can import and only pay the energy price?

High load reserves in Sweden
“Selective capacity market”

TSO responsible to purchase “up to 2000 MW” of “reserves” for peak load situations.

There is a bidding process where the cheapest offers are accepted.

Pricing:
The bids are placed on Nordpool spot. They are only used if all other bids are accepted.
The Net Regulation Price should not be allowed to exceed 5,000 Euro/MWh.

TSO can immediately impose a Disconnection Price in The event of Critical Power Shortage of 20 000 SEK/MWh \(\approx 2300\) Euro/MWh.

Australia: Max price 12000 AUD \(\approx 9000\) Euro/MWh

Reserves in Sweden 2012-13
Consumers accepted to reduce consumption

<table>
<thead>
<tr>
<th>Company</th>
<th>Area</th>
<th>MW</th>
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<tbody>
<tr>
<td>Stora Enso AB</td>
<td>3-4</td>
<td>210</td>
</tr>
<tr>
<td>Höganäs Sweden AB</td>
<td>4</td>
<td>25</td>
</tr>
<tr>
<td>Rottneros Bruk AB</td>
<td>3</td>
<td>27</td>
</tr>
<tr>
<td>Befesa Scandust AB</td>
<td>4</td>
<td>18</td>
</tr>
<tr>
<td>Vattenfall AB</td>
<td>3-4</td>
<td>92</td>
</tr>
<tr>
<td>Göteborg Energi AB</td>
<td>3</td>
<td>25</td>
</tr>
<tr>
<td>AV Reserveffekt</td>
<td>3-4</td>
<td>+ 67</td>
</tr>
</tbody>
</table>

TOTAL 464
Summary of (some) Nordic market challenges

Risk for prices so low so power plants cannot be financed
Large amounts of renewables \(\rightarrow\) often very low prices
But still other units are needed \(\rightarrow\) need of either (very) high prices or some kind of capacity payment mechanism.
Large amount of transmission is one part solution, but perhaps also large amounts of solar/wind power on the other end?

Idea to market solution to “last” unit

There should be a (renewable) unit (biogas?) with MC as

High operation cost (or bid price) essential

- Call it a “market maker unit” \(\rightarrow\) reduced need of cap. payment.
- If DSM is cheaper then it will be used instead
- As low LOLP as requested can be obtained (= size of unit)

Integration of RES – Focus Wind Systems

Bonus slides

Slutsatser:

- Detaljsimulering av extremsituationer har gjorts
- Vattenkraften klarar dessa situationer med den modell som använts (tim-simulering inkl domar)
- Viktigt att vattenkraften kan regleras (dagens domar)
- Ännu inga oöverstigliga hinder funna
- Dock intressanta utmaningar / möjliga effektviseringar. Dvs Hur ska man göra?
Nästa steg =
= planer inför Version 4:

• Samarbete med Swecos Nord-Europa-modell
• Beakta transmissions-begränsningar inom Sverige / behov av utbyggnad
• Kombination: Kraftvärme-minskning + elpatroner i fjärrvärme vid ”överskott”
• Möjlig laststyrnings-uppskattning vid ”underskott”
• Fler viktiga förslag?

Balancing solutions and competition

Assume a system with large price variation:

Three types of "business opportunities”

• More trading with neighbors
• Demand side management
• Flexible plants

• There is a competition between these methods.
• Much transmission reduces price changes ➔ less interest in DSM