Experience in Wind Power Integration at the German TSO Amprion

Hendrik Neumann (Amprion GmbH, Germany)
hendrik.neumann@amprion.net

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European Interconnected System

- UCTE Region*
- Synchronous operation with UCTE Region
- Asynchronous

500 Million

*ENTSO-E RG Continental Europe
Main Control Centre of Amprion at Brauweiler nearby Cologne
Operational areas of German transmission system operators

<table>
<thead>
<tr>
<th></th>
<th>Amprion</th>
<th>Transpower</th>
<th>50Hertz</th>
<th>EnBW</th>
</tr>
</thead>
<tbody>
<tr>
<td>Network length [km] (380 kV)</td>
<td>5.200</td>
<td>5.400</td>
<td>6.700</td>
<td>1.936</td>
</tr>
<tr>
<td>Network length [km] (220 kV)</td>
<td>6.100</td>
<td>5.300</td>
<td>2.865</td>
<td>1.721</td>
</tr>
<tr>
<td>Served area [km²]*</td>
<td>73.100</td>
<td>139.400</td>
<td>109.000</td>
<td>34.600</td>
</tr>
<tr>
<td>Annual transmission [TWh]</td>
<td>175</td>
<td>138</td>
<td>85</td>
<td>76</td>
</tr>
<tr>
<td>Share load [%]**</td>
<td>38</td>
<td>30</td>
<td>19</td>
<td>13</td>
</tr>
</tbody>
</table>

* in Germany
** Renewable Energy Act load compensation
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Background of Renewable Energies

- Germany and the EU aim to strongly increase their use of renewable energies.
- Germany: Increase the share of renewable energy sources in electricity supply to at least 30 percent by the year 2020 and continuously increase that share thereafter.
- Generating structure and generating performance different from conventional generating facilities; generation from renewables: dispersed, volatile, far from consumers
- Creation of a legal basis, regulatory rules and technical guidelines
Current Status of Renewable Energies in Germany (April 2010)

<table>
<thead>
<tr>
<th>Energy Source</th>
<th>Capacity [MW]</th>
<th>Production [TWh]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydropower</td>
<td>4.760</td>
<td>19 *</td>
</tr>
<tr>
<td>Biomass</td>
<td>5.889</td>
<td>30.52</td>
</tr>
<tr>
<td>Photovoltaics</td>
<td>9.800</td>
<td>6.2</td>
</tr>
<tr>
<td>Windpower</td>
<td>25.704</td>
<td>37.8</td>
</tr>
<tr>
<td>Pump Storage</td>
<td>7.479</td>
<td></td>
</tr>
</tbody>
</table>

*) without share of Pump Storage

Source: BMU, internal

~33% of the German peak load
Wind Power Development in Germany

12/2009; Source: ISET, IWET

Development of Capacity
Accumulated Capacity

MW

MW

0 500 1000 1500 2000 2500 3000

0 2000 4000 6000 8000 10000 12000 14000 16000 18000 20000 22000 24000 26000 28000 30000


25365 25000 24629 24250 23875 23500 23125 22750 22375 22000 21625 21250 20875 20500 20125 19750 19375 19000 18625 18250 17875 17500 17125 16750 16375 16000 15625 15250 14875 14500 14125 13750 13375 13000 12625 12250 11875 11500 11125 10750 10375 10000 9625 9250 8875 8500 8125 7750 7375 7000 6625 6250 5875 5500 5125 4750 4375 4000 3625 3250 2875 2500 2125 1750 1375 1000 625

12/2009; Source: ISET, IWET
Forecast of development until 2020

- **Onshore**
- **Repowering (growth)**
- **Offshore**

Uncertainty due to offshore development

Source: DEWI / dena-study
Wind Power in Germany

Data source: ISET, IWET

location of installed wind turbines

capacity per area
Monthly Production of Wind Energy in Germany
2006 to 2009

Source: Online Extrapolation German TSO
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General Conditions of Grid Integration of Renewable Energies

- **Legal Basis**
  - Renewable Energy Source Act: Came into force on 1 January 2009, replaces the previous act of 2004

- **Regulatory Background**
  - Equalisation Scheme ordinance: Entered into force on 17 July 2009
  - Equalisation Scheme Execution Ordinance: Entered into force on 27 February 2010

- **Grid Code**
  - Guidelines: Renewables-based generating facilities on the HV and EHV grid
Renewable Energy Sources Act (1)

- **Connection and purchase, transmission & distribution**
  - Obligation of the grid system operators to connect the installation to the nearest connection point of their grid
  - Grid connection costs are generally to be paid by the installation operator; excepted Offshore installations (RESA §13, Energy Industry Act § 17 (2a))
  - Obligation also applies if the purchase of the electricity is only made possible by optimising, boosting or expanding the grid system
  - Obligation of the grid system operators to purchase, transmit and distribute the entire available quantity of electricity from renewables
  - Grid system operator is not obliged if capacity expansion economically unreasonable
Renewable Energy Sources Act (2)

Capacity expansion and feed-in management

- Installations with a capacity of over 100 kilowatts to be provided with remote control of the infeed power
- Grid system operator is allowed to take technical control over installations over 100 kW in case of system overloading
- Ancillary services bonus for a period of five years by 0.7 cents for wind turbines in operation before 2014 (behaviour in case of faults, delivery of reactive power, maintaining frequency)
Renewable Energy Sources Act (3)

- **Payment claims, Direct selling & Tariffs**
  - Obligation of grid system operators to pay installation operators tariffs according to the “special provisions regarding tariffs“
  - Direct selling of the electricity by the installation operators to third parties on a monthly agreement with the grid system operator
  - Various tariffs for the different kinds of renewable energy sources, i.e.
    - Hydropower
    - Biogas
    - Geothermal energy
    - Wind energy, onshore
    - Wind energy, offshore
    - Solar radiation
Renewable Energy Sources Act (4)

- Equalisation scheme
  - Nationwide equalisation scheme
    - Delivery to transmission system operator
    - Tariffs paid by transmission system operator
    - Equalisation amongst transmission system operators
  - Ordinance on the Further Development of the Nationwide Equalisation Scheme – Equalisation Scheme Ordinance
Ordinance on the Further Development of the Nationwide Equalisation Scheme
Equalisation Scheme Ordinance – AusglMechV

- **Basic principles:**
  1. The *transmission system operators* are not obliged to transmit the electricity to downstream utility companies.
  2. The utility companies are not obliged to purchase and pay tariffs for electricity from their regular *transmission system operators*.
  
    - The electricity generated by renewable energy is fully integrated in the electricity delivery in total.
  3. The *transmission system operators* are obliged to market the electricity.
  4. The *transmission system operators* can claim reimbursement from the utility companies for delivering electricity to final consumers
    -> *Renewable Energy Act surcharge*
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Role of the TSOs in Germany

TSOs are obliged to take off the energy, bring it to market and balance the infeed.
Equalisation Scheme started in 2010

1) Renewable Energy Sources Act
2) European Energy Exchange
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Correlation

Wind Energy Production ↔ Control Program DE

Source: Amprion GmbH
Correlation

Wind Energy Production ↔ Day-ahead Price EPEX

October 2009: day-ahead -500 C/MWh, intra-day: -1,500 C/MWh !!!

Source: Amprion GmbH
Commercial vs. physical flows in Europe (19-11-2008, 13h30)

Windpower generation DE 13.300 MW

+ Export / - Import all values in MW

commercial
physical
Loop flows in Europe (19-11-2008 at 13h30)

Loop flow = physical flow – commercial flow

all values in MW
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Wind Power Prediction
Size of the Forecast Area

Root mean square error (rmse) of a single day ahead forecast model for wind power (% of installed capacity):

- Single Wind Farm: 10% to 20%
- Single Control Area (400 km x 400 km): 7.5% to 10%
- All German Control Areas (800 km x 1000 km): 5% to 7%
- With Combination of Forecasts: 4.2% (2009)
Wind Power Prediction

Day ahead prediction - combining different weather models

- Wind power prediction systems commonly use only one single numerical weather prediction model (NWP)

- But the NWP models have strengths and weaknesses in different weather situations
  
  e.g.: convection is over-estimated by one model, which leads to increase in the predicted wind speed

Approach

- Combine different deterministic NWP models to minimize the error of wind power forecasts. The wind power forecast is calculated as the optimal combination of several single forecasts for the specific weather situation.
Wind Power Prediction
What the Combination Tool does

Classification of the Weather Situation

Optimal Forecast of Wind Power for specific Weather Situation

Weighting of the Forecasts and Combination
Optimisation of wind power forecast process (1)
Predictions, Amprion Share, Day Ahead, 8:00
Optimisation of wind power forecast process (2)
Predictions & Measurement, Amprion Share, Actual Day, 24:00
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- The ambitious plans of the EU and the German government lead to a very high amount of renewables in Germany, wind energy takes a dominant part (26 GW).

- The “Renewable Energy Source Act” is the legal basis for the integration of renewables. It defines the grid connection and purchase, transmission & distribution, capacity expansion and feed-in management, direct selling & tariffs.

- The TSO plays an important role. He has to purchase the energy from renewables at fixed tariffs and has to market the energy on the spot market.

- The massive infeed from renewables has a big impact on the energy market and on the load flows in Germany and the surrounding countries.

- A good wind power forecast is of great importance for the TSO. By combining different forecast models a higher forecast quality can be achieved.
Thank you for your attention.