Integration of Renewable Energy Sources into Electricity Grid from TSO Prospective

St. Petersburg, 10.11.2016

Michael Kranhold

Energetika XXI
Agenda:

The Tasks of the TSO
Energiewende
Grid Operation and Extension
TSO-DSO Cooperation
Energiewende Outlook 2035
The Tasks of the TSO
50Hertz as part of the European Electricity System

1. 50Hertz
2. TenneT TSO
3. Amprion
4. TransnetBW
Transmission grids are the technical backbone of the energy supply in Germany and in Europe

<table>
<thead>
<tr>
<th>Role</th>
<th>Responsibilities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Owner of the transmission grid</td>
<td>In charge of operation, maintenance and the development of <strong>extra-high-voltage lines</strong> and <strong>power junctions</strong> (substations) as well as for the connection of <strong>large-scale generators</strong> and <strong>consumers</strong> (including offshore)</td>
</tr>
<tr>
<td>System operator</td>
<td>Responsible for <strong>system stability</strong> of the transmission system around the clock: frequency control and voltage regulation, congestion management.</td>
</tr>
<tr>
<td>Market developer</td>
<td>Catalyst for the <strong>development of the energy market</strong>, especially in Northern and Central-Eastern Europe.</td>
</tr>
<tr>
<td>„Trustee“ for managing EEG* cash flows</td>
<td>Responsible for managing cash flows <strong>resulting from the Renewable Energy Law (EEG)</strong>.</td>
</tr>
</tbody>
</table>

* German Renewable Energy Law

Source: 50Hz
The power system in the 50Hertz grid area

- **TSO (400 kV, 220 kV)**
  - 7 TSOs
    - Amprion
    - TenneT
    - TransnetBW
    - CEPS
    - Energinet.dk
    - PSE
  - 9 Windfarms
    - 7 onshore
    - 2 offshore
  - 3 Steel Plants
  - 12 conv. power plants/storages
    - Schwarze Pumpe
    - Boxberg
    - Janschwalde
    - Lippendorf
    - Reuter West
    - Goldisthal
    - Markersbach
    - Hohenwarte II
    - Brunsbüttel (GKW)
    - Moorbarg
    - Rostock
    - Schkopau

- **DSO – 1st level (< 110 kV)**
  - Approx. 1,200 Windfarms
    - PV, biomass and other RES
  - 9 Distribution System Operators
    - E.DIS
    - ENSO Netz
    - SW Magdeburg
    - AVACON
    - MITNETZ Strom
  - 159 Distribution System Operators
    - Stromnetz Berlin
    - Stromnetz Hamburg
    - TEN
    - WEMAG Netz

- **DSO – 2nd to m. level (< 110 kV)**
  - 200 Windfarms
    - PV, biomass and other RES

- **DSO – low level (< 110 kV)**
  - PV, biomass and other RES

**Other DSOs**

**Situation end of 2015**
## 50Hertz at a glance

*As at 2015/12/31; approved figures will be available in August 2016; Source: 50Hertz*

<table>
<thead>
<tr>
<th></th>
<th>2015</th>
<th>2010</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Area</strong></td>
<td>109.589 km² (~31%)</td>
<td>109.360 km² (~31%)</td>
</tr>
<tr>
<td><strong>Total length of lines</strong></td>
<td>10.150 km (~30%)</td>
<td>9.800 km (~30%)</td>
</tr>
<tr>
<td><strong>Maximum load</strong></td>
<td>~ 16 GW (~20%)</td>
<td>~ 17 GW (~20%)</td>
</tr>
<tr>
<td><strong>Energy consumption</strong> (based on electricity supplied to end-consumers in acc. With the EEG)</td>
<td>~ 96 TWh (~20%)</td>
<td>ca. 98 TWh (~20%)</td>
</tr>
</tbody>
</table>
| **Installed capacity:**  
  - of which Renewables  
  - of which Wind     | 50.528 MW (~27%)  
  26.975 MW (~30%)  
  16.107 MW (~39%) | 38.354 MW (~35%)  
  15.491 MW (~30%)  
  11.318 MW (~40%) |
| **Workforce**       | 955                       | 650                       |
| **Turnover**        | 9.8 bn. €  
  1.4 bn. € | 5.6 bn. €  
  0.6 bn. € |
Energiewende
The German Energy Transition

What are the core elements of German „Energiewende“?
Policy-driven structural changes in the German energy system:

<table>
<thead>
<tr>
<th>Icon</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>🌈</td>
<td>Phase out of nuclear energy production by 2022</td>
</tr>
</tbody>
</table>
| 🌞 | Dynamic RES development (EEG 2.0)  
   Targets: 40-45% share of total electricity consumption until 2025, 80% until 2050 |
| 🌋 | Greenhouse gas reduction: Future of coal-fired generation in question  
   Target: 40% CO₂ reduction by 2020, 80-95% by 2050 |
| 🏠 | Energy efficiency: 50% increase of electricity efficiency by 2050 |
| 🌍 | Grid extension to transport RES energy to the big industrial centres in Southern Germany |
Challenges of „Energiewende“

- European energy policy: How to coordinate „Energiewende“ with neighbouring countries?
- Grid extension: How to speed it up and raise acceptance?
- Market design: How to find the right balance between market-based prices and secure investments in RES?
- RES integration: How to increase flexibility of producers and consumers?
- Costs: How to distribute costs equally in society?
- Combined Heat and Power (CHP): How many plants needed?
- Conventional power plants: How to accompany the structural change of the energy system
RES have developed from a niche product to a dominant energy source in the 50Hertz Hertz grid area (more than 50% share of total installed generation capacity in 2015)
RES in the 50Hertz grid area:
Present situation and forecast of installed capacity

Installed capacities in MW

<table>
<thead>
<tr>
<th>Year</th>
<th>Wind</th>
<th>Solar PV</th>
<th>Biomass</th>
<th>Others</th>
<th>Total</th>
</tr>
</thead>
</table>

Future

- Wind
- Solar PV
- Biomass
- Others
- Total

Source: 50Hertz; As at 2015/12/31
RES growth requires an adaptation of the transmission grid infrastructure

Existing extra-high voltage lines from North to South Germany are overloaded – this leads to high re-dispatch costs.

Further aggravation of the problem:

Wind power generation increases in the North. Due to the nuclear phase-out, output in the South will drop by about 8 GW.

Grid adaptation is key to successfully implement the energy transition
What key factors are essential to successfully implement the „Energiewende“?

1. Stable legal and regulatory framework conditions are essential to implement the grid expansion

2. Broad social consensus and political support at all levels as key factors to successfully implement the energy transition

3. Observing economic efficiency and avoiding and eliminating false incentives (uniform grid fees, expanding deliverables)

4. Observing European framework - we are part of a European system

5. Further development of the electricity market design

The German Federal Government has identified the crucial issues for a successful „Energiewende“. Now its implementation is what counts.
Grid Operation and Extension
Solar eclipse 2015: A successful trial-run for the future’s electricity system

Conclusions

- The market mechanisms that were developed and introduced over the last years work well

- TSOs were able to grant high system stability by adapting additional measures

- A highly flexible control system as adopted in this exceptional situation will be required on a daily basis in the future
50Hertz counter-measures to master unplanned load flows through the grid

<table>
<thead>
<tr>
<th>Re-dispatch („virtual PST“)</th>
<th>Phase shifters (physical PST)</th>
<th>Grid extension</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Reduces system-security-relevant flows</td>
<td>- Reduces system-security-relevant flows</td>
<td>- Grants security of the whole electricity system</td>
</tr>
<tr>
<td>- The challenge is to grant efficiency and cost effectiveness</td>
<td>- Requires major investments</td>
<td>- Paves the way for an integrated European market</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Short-term</th>
<th>Mid-term</th>
<th>Long-term</th>
</tr>
</thead>
</table>
Grid extension projects 50Hertz area since 2009 (as of 2016/6/30)
Federal Requirement Plan 2012 as legal basis for grid extension need


- Basis: 2012 Grid Development Plan of the TSOs
- 43 projects confirmed
- 3 HVDC corridors
- Pilot project for respectively 5 direct current and alternating current cable lines
- Current Grid Development Plan confirms Federal Requirement Plan
Progress of offshore projects in the Baltic Sea

2011: Commissioning of Baltic 1
2012: Start of construction Baltic 2
2014: Connection granted to windfarm operators in the “Westlich Adlergrund” region; first cables ordered
2015: Allocation of grid connection capacity to the OWF Wikinger (350 MW) and Arkona-Becken Südost (385 MW)
2015: Grid connection of Baltic 2
2015: Grid Connection „Westlich Adlergrund“:
Receipt of all necessary approvals for the construction of the cable connection; start of preliminary works for the sea- and landline cable laying

Steady development of wind offshore projects in the Baltic Sea – Grid connections for existing projects according to plan
TSO-DSO Cooperation
The role of the distribution systems is undergoing drastic changes

<table>
<thead>
<tr>
<th>Technological development as a result of the energy transition</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Shift of generation capacity to the distribution system</td>
</tr>
<tr>
<td>- Ancillary services can be provided by the DSOs → more decentralised control required</td>
</tr>
<tr>
<td>- Unclear division of roles for the control of the generating units</td>
</tr>
</tbody>
</table>

**OLD: centralised energy generation**

**NEW: decentralised energy generation**

- 1 million producers
- 1 million controllable loads

*Source: dena distribution system study, 2012*
Ten-point plan is milestone for cooperation by TSO and DSOs

Key elements of the agreement

- Further development of the system security through the integration of RES feed-in
- Improved coordination of the grid and system operation
- Mutual exchange of operational data
- Performance of pilot projects
- Common efforts to bring about changes in the legal and regulatory framework

http://www.50hertz.com/Portals/3/Content/Dokumente/Medien/Positionspapiere/10-Punkte-Programm_Systemsicherheit-Langfassung.pdf
Ancillary services and available measures

<table>
<thead>
<tr>
<th>Frequency control</th>
<th>Voltage control</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary control reserve</td>
<td></td>
</tr>
<tr>
<td>Secondary control reserve</td>
<td></td>
</tr>
<tr>
<td>Minute reserve supply</td>
<td></td>
</tr>
<tr>
<td>Switchable and interruptible loads</td>
<td></td>
</tr>
<tr>
<td>Automatic frequency relays</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>System restoration</th>
<th>System control</th>
</tr>
</thead>
<tbody>
<tr>
<td>Black-start and islanding potential</td>
<td></td>
</tr>
<tr>
<td>Commissioning with/without prior voltage switching</td>
<td></td>
</tr>
<tr>
<td>Coordination across grid levels (concepts)</td>
<td></td>
</tr>
<tr>
<td>Reactive power control</td>
<td></td>
</tr>
<tr>
<td>- Control of generating units</td>
<td></td>
</tr>
<tr>
<td>- Operation of compensation elements</td>
<td></td>
</tr>
<tr>
<td>Short-circuit capacity</td>
<td></td>
</tr>
<tr>
<td>Transformer stepping and switchover</td>
<td></td>
</tr>
<tr>
<td>Feed-in management</td>
<td></td>
</tr>
<tr>
<td>Redispatch / congestion management</td>
<td></td>
</tr>
<tr>
<td>Operational planning / disconnection planning</td>
<td></td>
</tr>
<tr>
<td>Back-up power plants</td>
<td></td>
</tr>
<tr>
<td>Data interchange (energy information network)</td>
<td></td>
</tr>
</tbody>
</table>

The share of renewable energy used for ancillary services needs to increase in response to the changed manner in which electricity is supplied and the rise in energy demand.
Energiewende Outlook 2035
Background and Motivation

The energy transition is in full swing, but future development remains uncertain

- Germany finds itself in an energy transition. Today, more than 30% of electricity consumption is covered by renewable energy sources, 49% in the 50Hertz area.
- The upcoming development trends of this energy transition remain uncertain (esp. with regard to the policy objective of achieving 80% of electricity usage from renewable energy sources by 2050):
  - Will prosumer models with PV-systems and small-scale systems prevail? Will power generation through large systems be located at profitable locations? How will the energy transition develop in other European countries?

50Hertz considers itself a service provider for the implementation of the energy transition.

- In this respect, 50Hertz is committed to policy objectives, socio economic welfare and efficient solutions.
- Therefore, the company is analyzing possible future developments in “50Hertz Energiewende Outlook 2035”.
The energy development paths form a wide spectrum

- For the 50Hertz Energiewende Outlook 2035, five realistic energy transition scenarios have been developed.

**Policy objectives are achieved through...**

- **Prosumer oriented energy transition**
  - ... a strong buildup of PV systems.

- **Energy transition according to the German renewable energy act**
  - ... a combination of various technologies.

- **Competitive energy transition**
  - ... large wind energy systems in profitable locations.

**Policy objectives are not achieved due to...**

- **Delayed energy transition**
  - ... planned implementation of various technologies is delayed.

- **Incomplete energy transition**
  - ... insufficient acceptance due to, for example, high costs, prevents a complete energy transition.
In all scenarios, high capacity from renewables with different technologies is expected

- Even in a delayed or incomplete energy transition, the German electricity supply in 2035 will be characterized by high shares of renewables.
Strong expansion of renewables also in other European countries like France and Italy is expected.

Simulation of all European Countries within the study.
Conclusions

A **broad range** of energy transition scenarios **is possible**: a prosumer oriented path, a renewable energy act path, a competitive manifestation, but also a delayed or incomplete implementation.

The **50Hertz** control area remains a clear **net energy exporter** in all energy transition scenarios, while Germany tends to become an energy importer.

50Hertz’s planned **grid expansion** measures for the coming years are **necessary for all possible energy transition development paths**. The robustness is proven by sensitivity simulations of major trends such as storage or gas power plant allocation.

Wind power systems are the major driver of the need for the grid extension. In contrast, the allocation of gas power plants is not relevant for the grid expansion.

Even with a decommissioning of lignite power plants by 2035, 50Hertz’s planned grid extension measures for the coming years remain necessary.

Even in a prosumer oriented energy transition, with a high number of small scale storage units combined with PV-systems, significant transmission requirements remain, and 50Hertz’s planned grid extension measures for the coming years are essential.
Spasibo
Thanks for Attention

Michael Kranhold

50Hertz
Heidestraße 2
10557 Berlin

030 – 5150 – 4502
Michael.Kranhold@50Hertz.com

www.50Hertz.com