The German energy transition & integration of renewable energy

Dispatching and evacuation of RE generation

Manila, June 5th 2017
Dr. Niels Ehlers, Head of Concepts and System Strategy, 50Hertz
Elia Grid International – TSO consultancy

- Flow-based market coupling ENTSO-E (2010-2016)
- Reorganization of TSO towards EU target model (2016)
- Review WAPP Operational Manual (2012-2013)
- RES integration study & training course (2017)
- Grid code and RES forecasting projects (2015-2016)
- Gap analysis on maintenance practices (2016)
- Workshop on energy markets and congestion management for the SAPP (2016)
- Technical Due Diligence (2015)
- Capacity building TSO for ENTSO-E membership (2016-2017)
- MoU for future collaboration (2017)
- Grid code review (2016)
- TSO assessment (2017)
- RES integration (2016)
- Topics on balancing market/regulation (2016)

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Energy Transition & Renewable Energy Integration

System operations & grid development

Market development and regulatory framework

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2 Elements of a successful energy transition
50Hertz as part of the European Electricity System

1. 50Hertz
2. TenneT TSO
3. Amprion
4. TransnetBW
50Hertz at a glance

<table>
<thead>
<tr>
<th></th>
<th>2016</th>
<th>2010</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Grid area</strong></td>
<td>109.589 km² (~31%)</td>
<td>109.360 km² (~31%)</td>
</tr>
<tr>
<td><strong>Length of lines</strong></td>
<td>10.215 km (~30 %)</td>
<td>9.800 km (~30 %)</td>
</tr>
<tr>
<td><strong>Max. Load</strong></td>
<td>ca. 16 GW (~20%)</td>
<td>ca. 17 GW (~20 %)</td>
</tr>
<tr>
<td><strong>Power consumption</strong></td>
<td>~ 96 TWh (~20 %)</td>
<td>ca. 98 TWh (~20 %)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
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<tr>
<td><strong>Installed capacity:</strong></td>
<td>51.686 MW (~26%)*</td>
<td>38.354 MW (~35%)</td>
</tr>
<tr>
<td>- of which Renewables</td>
<td>28.435 MW (~30%)*</td>
<td>15.491 MW (~30%)</td>
</tr>
<tr>
<td>- of which Wind</td>
<td>17.129 MW (~37%)*</td>
<td>11.318 MW (~40%)</td>
</tr>
<tr>
<td><strong>RES share in power consumption</strong></td>
<td><strong>47,8%</strong></td>
<td>ca. 25%</td>
</tr>
<tr>
<td><strong>Turnover</strong></td>
<td>9.5 bln. €</td>
<td>5.6 bln. €</td>
</tr>
<tr>
<td>- of which grid</td>
<td>1.3 bln. €</td>
<td>0.6 bln. €</td>
</tr>
</tbody>
</table>

Source: 50Hertz; As of 2016/12/31 - *preliminary figures – final figures will be available on 2017/08/31
What are the core elements of German „Energiewende“?
Policy-driven structural changes in the German energy system:

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

Massive RES growth in Germany since the introduction of the Renewables Energy Law (EEG) in 2000 – with Wind and PV as the main growth drivers

- 2000
  - ~ 30,000 plants
  - 1.665* MW installed wind in Germany

- 2006
  - ~ 221,000 plants
  - 2.233* MW installed wind in Germany

- 2016
  - ~ 1,600,000 plants
  - 45.910* MW inst. wind

Source: 50Hertz, TenneT, Amprion, TransnetBW, Google Earth

* BWE Figures
We encountered overlapping infeed of wind and PV of up to 50 GW.
On April 30th 2017 13-15h, 85% of the load in Germany were covered by RES (and the lights stayed on)
1 Introduction 50Hertz and the German „Energiewende“

2 Dispatching and evacuation of RE generation
Elements of a successful energy transition
(or how to avoid mistakes we made)

1. Efficient RES support
   - Volume control / Transparency
   - Synchronization with grid infrastructure

2. Rights and responsibilities for RES
   - Grid connection codes
   - Active market participation
   - Ancillary services from RES

3. Market design to accommodate for RES
   - Balancing (in different timeframes)
   - Congestion management
   - Ancillary services from RES
   - System adequacy
In Germany, a major of RES installations had to be retrofitted in order to avoid sudden curtailment at a fixed over- or underfrequency (49,5 Hz or 50,2 Hz)

Other important grid connection requirements include:
- Fault Ride Through Capability
- Reactive power behaviour
- Dynamic grid stabilization
- Power Quality / Harmonics

Grid connection codes are necessary for all generators and loads, not just RES and are needed to reflect physical realities!

By designing grid connection codes right for all market participants, large follow-up costs can be saved.
Handing over responsibility to RES generators - Market Premium Model

Former Feed-in tariff (set by government/Determined in tenders)

Market Premium (paid as subsidy)

Market value (revenues at the market)

The market premium is calculated by the TSO as the difference of the "feed-in tariff" and the market value.

The market value is the weighted average wholesale price of an average generation profile (technology-specific monthly value).

With the incentives set right, market participants have proven capable of self-balancing their volatile RES portfolio.
Solar eclipse 20th of March 2015: Successful system test

- The market products that were developed and introduced over the last years worked properly.
- RES owners are able to manage their balancing groups themselves.
- Less demand for balancing by TSO
Ancillary services from RES

- Wind power plants are technically capable to provide balancing energy. 50Hertz is currently involved in pilot projects in Germany to test this within the German market framework.

- Current challenges are the definition of the baseline and the design of the balancing market (daily tendering, hourly products...)

- Other pilot tests have shown that RES can contribute effectively to stabilize the voltage if faults occur in the system.

- Further pilot projects will even include black-starting a system with RES installations.
Elements of a successful energy transition
(or how to avoid mistakes we made)

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3. Market design to accommodate for RES
   - Balancing (in different timeframes)
   - Congestion management
   - Ancillary services from RES
   - System adequacy
# Balancing the grid in different timeframes

## RES volatility

<table>
<thead>
<tr>
<th>Days to Hours</th>
<th>Implemented solutions</th>
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<tbody>
<tr>
<td></td>
<td>- New auctions for <strong>strategic reserves</strong></td>
</tr>
<tr>
<td></td>
<td>- Contracting of <strong>reserve power plants</strong></td>
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<tr>
<td></td>
<td>- <em>Capacity market if necessary</em></td>
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<th>Hours to Minutes</th>
<th>Implemented solutions</th>
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<td></td>
<td>- International <strong>market coupling</strong></td>
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<tr>
<td></td>
<td>- Introduction of a <strong>liquid intraday market</strong></td>
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<td></td>
<td>- Usage of <strong>15-min products</strong></td>
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<table>
<thead>
<tr>
<th>Minutes to Seconds</th>
<th>Implemented solutions</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>- <strong>International imbalance netting</strong> (<em>IGCC</em>&lt;sup&gt;+&lt;/sup&gt;)</td>
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<td></td>
<td>- Allow new market participants in the balancing market (battery storages, loads, wind turbines)</td>
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<td></td>
<td>- Dynamic allocation of balancing capacity</td>
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*International Grid Control Cooperation*
Grid control cooperation – avoiding counteractive balancing

Module 1 - IGCC:
Avoid Counteractivation

Module 2:
Common Dimensioning

Module 3:
Common Procurement of capacity

Module 4 – National GCC:
Activation based on common Merit Order List

The grid control cooperation helped to reduce the balancing demand significantly and saved already > 330 Mio. USD of balancing activations
New providers of control power are very welcome: Electric boilers and a steel mill prequalified in the 50Hertz control area

**Electric boilers Stadtwerke Schwerin**
- Three electric boilers prequalified for secondary control (aFRR) provision
- Up to 10 MW aFRR
- Start of aFRR marketing in December 2013

**Steel mill Hamburg**
- Electric furnace 3 of ArcelorMittal Hamburg GmbH prequalified for tertiary control provision (mFRR)
- Up to 70 MW mFRR
- Start of mFRR marketing in 2010

Sources: Stadtwerke Schwerin, ArcelorMittal Hamburg GmbH
Elements of a successful energy transition

1. Efficient RES support and grid enforcement

2. Rights and responsibilities for RES

3. Market design to accommodate for RES

There are challenges, but with right coordination, you can have green energy and high security of supply
Thank you for your attention!

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