Integrating Wind & Solar power in a Grid

ELIA GROUP INTERNATIONAL
A strong, reliable and sustainable partner

Symposium Getting Power from Wind and Sun

Tokyo, March 8th 2018
One Group

Two TSOs (transmission system operators) with International Activities

The Elia Group is expanding its international activities through Elia Grid International
50Hertz at a glance

Grid area
109,589 km² (~31 %)

Length of lines
10,215 km (~30 %)

Max. Load
~ 16 GW (~20 %)

Power consumption (based on electricity supplied to end-consumers in acc. with Renewables Energy Law “EEG”)
~ 96 TWh (~20 %)

Installed capacities:
- of which Renewables
52,268 MW (~26 %)
- of which Wind
29,017 MW (~30 %)
17,236 MW (~37 %)

RES share in power consumption
47.8%

Turnover
- of which grid
9.449 bn€
1.290 bn€

Figures (50Hertz share in Germany) as of 2016/12/31
Activities of 50Hertz as a German TSO

<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 surcharge systems</td>
<td>Responsible for the <strong>financial management of renewable energies (EEG)</strong>.</td>
</tr>
</tbody>
</table>
The power system in the 50Hertz grid area

TSO (400 kV, 220 kV)
- TenneT
- CEPS
- PSE
- Energinet.dk
- Svenska kraftnät

5 neighbouring TSOs

DSO – 1st level (< 110 kV)
Approx. 1,200 Windfarms
PV, biomass and other RES

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

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

9 Windfarms
- 7 onshore
- 2 offshore

3 Steel Plants

10 Distribution System Operators
- AVACON
- E.DIS
- ENSO Netz
- SW Magdeburg

12 conv. power plants/storages
- Schwarze Pumpe
- Boxberg
- Jänschwalde
- Lippendorf
- Reuter West
- Goldisthal
- Markersbach
- Hohenwarte II
- Brunsbüttel (GKW)
- Moorbürg
- Rostock
- Schkopau

159 Distribution System Operators

159 Distribution System Operators

CHP and IPP

CHP and IPP

CHP and IPP

CHP and IPP

Other DSOs
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

- ~ 30,000 plants
- 1,665* MW installed Wind in Germany

- ~ 221,000 plants
- 2,233* MW installed Wind in Germany

- ~ 1,600,000 plants
- 45,910* MW installed wind in Germany

* BWE Figures
RES development in the 50Hertz grid area

50Hertz is world-leading in the integration of intermittent RES with an integration rate of ~48% in 2016 – with respect to ~32% in Germany.

Source: Company information
TCC – Visitors coming from all over the world

Since 2012 visitors from 70 countries have been in Neuenhagen
50Hertz has been investing intensely in system operations and runs a state-of-the-art system for well trained and highly reliable operators.
Part of the 50Hertz IT-infrastructure builds the backbone of successful system operation.
Challenges and solutions within system and markets

Current Situation

- Fast RES growth not synchronized with grid development
- Shift “central” into a highly “decentral” energy landscape

Resulting challenges

- Grid congestion
- Decentralization with distributed generation and active customers
- RES intermittency
- Increasing energy costs for customers

50Hertz solutions

- Fast and efficient grid development
- Innovative congestion management concepts
- Market development
- Foster cooperation on EU level
50Hertz grid area is main exporter of electricity in Germany and Europe (~ 40 TWh).
Significant redispatch is needed – also cross border – to master congestion

Scheduled flow versus physical flows (after redispatch)

During high wind periods Germany’s potential commercial export is much higher than physical export capacities allow. Exceeding power flows are turned back by redispatch.
50Hertz has been successfully reducing redispatch costs with extension and innovation.

- Grid development and process improvements are showing to be effective.
- **Risk**: ACER/European Commission request for higher trading capacities can significantly increase costs for congestion management.

### Redispatch and RES Curtailment Costs in m€

<table>
<thead>
<tr>
<th>Year</th>
<th>Plan 2017</th>
<th>FC 10/2017</th>
<th>Plan 2018</th>
</tr>
</thead>
<tbody>
<tr>
<td>2014</td>
<td>69</td>
<td>205</td>
<td>94</td>
</tr>
<tr>
<td>2015</td>
<td>73</td>
<td>107</td>
<td>146</td>
</tr>
<tr>
<td>2016</td>
<td>120</td>
<td>115</td>
<td>180</td>
</tr>
<tr>
<td>2017</td>
<td>85</td>
<td>130</td>
<td>250</td>
</tr>
<tr>
<td>2018</td>
<td>75</td>
<td>175</td>
<td>200</td>
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### Redispatch and RES Curtailment Amounts in GWh

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<th>Plan 2015</th>
<th>Plan 2016</th>
<th>FC 2017</th>
<th>Plan 2018</th>
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<tr>
<td>2014</td>
<td>2,888</td>
<td>2,621</td>
<td>50</td>
<td>950</td>
<td>5,000</td>
</tr>
<tr>
<td>2015</td>
<td>9,544</td>
<td>7,082</td>
<td>800</td>
<td>5,000</td>
<td>5,000</td>
</tr>
<tr>
<td>2016</td>
<td>6,381</td>
<td>6,450</td>
<td>800</td>
<td>5,000</td>
<td>5,000</td>
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First effects of commissioning of SWCL.
Grid extension reduces congestion and redispach costs
Phase Shift Transformers (PSTs) at the Polish and Czech borders help steering power flow and reduce congestion

Main functionalities of PSTs

- Limit/regulate (unplanned) cross-border flows at the German-Polish and German-Czech borders
- Prevent congestion at interconnectors and in the network close to the border

Implementation

- **Hagenwerder-Mikułowa (DE-PL):** Polish PSTs in operation since 2016
- **Vierraden-Krajnik (DE-PL):** Two step approach:
  - commissioning of two PSTs and upgrade of the interconnector on 380 kV in 2018
  - final state with four PSTs is foreseen for 2020
- **Roehrsdorf-Hradec (DE-CZ):** German and Czech PSTs in operation since 2017
Challenges and solutions within system and markets

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### Resulting challenges

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<td>Increasing energy costs for customers</td>
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### 50Hertz solutions

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European market design is based on a zonal concept with bidding zones coupled via power exchanges.

- **Price Coupling** successful on the Day Ahead spot market, step-by-step expansion towards a common European Price Coupling.
- Ongoing project to introduce **European Price Coupling in the Intraday spot market**.
- Ongoing project to introduce **Flow-based Market Coupling** in Central Europe (exp. 2020)

European market integration has been very successful and facilitates the integration of volatile renewables.
Development of short-term and balancing markets is in the focus of the market development strategy.
Operational Challenges from PV:
Solar Eclipse 2015 March 20

Lessons learned:
- The market products developed and introduced in the last years worked properly (15min products)
- TSOs properly secured the system via additional security measures
- Need for increased flexibility shown by this kind of situation as we will face similar needs on a more regular basis in the future

PV-forecast – Live extrapolation Germany

German TSOs can count on market mechanism for basic balancing.
Day-ahead forecasts for wind and solar leave room for improvement intraday.

50Hertz build up strong competences in short term forecasting and intraday trading.

Estimates are applied where real time data are not available.

Service providers deliver online data and forecasts. They are continuously benchmarked against each other.

Remaining deviations after market closure are to be levelled out by TSOs by activating control power.
## Challenges and solutions within system and markets

### Current Situation

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<th>Solution</th>
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### Resulting challenges

- Grid congestion
- RES intermittency
- Increasing energy costs for customers

### 50Hertz solutions

- Fast and efficient grid development
- Innovative congestion management concepts
- Foster cooperation on EU level
New players with low opportunity costs will offer flexibility on a competitive market of limited size.

Distributed flexibility requires the system’s further digitilization. Increasing competition on the flexibility market complicates business cases for storage.
The cooperation between DSOs and TSOs is being refined.

Guiding principles for integration of distributed flexibilities

- Striving for the socio-economic optimum using flexibilities on different voltage levels.
- Going for market oriented competitive solutions - while observing market power issues.
- Implementing new transparent processes for flexibility providers and network operators.
- Developing coordination concepts that take DSO constraints into account.
- Using digitalization for innovative solutions.
Within the ministry’s SINTEG program 50Hertz leads the WindNODE project

**Overview of the five SINTEG projects**

- **Project goal:** develop and demonstrate solutions for energy transition, enabling intelligent communication and interaction among different players for an efficient renewables integration

- **WindNode support:** about 40 m€ over 4 years, since 12/2016

- **Project partners:** about 70 partners from industry, utilities, academics, …

Quelle: BMWi, WindNODE, Websites der anderen Konsortien
Challenges and solutions within system and markets

### Current Situation
- **RES intermittency**: Fast RES growth not synchronized with grid development
- **Grid congestion**: Shift “central” into a highly “decentral” energy landscape

### Resulting challenges
- **Grid congestion**: Decentralization with distributed generation and active customers
- **RES intermittency**: Increasing energy costs for customers

### 50Hertz solutions
- **Fast and efficient grid development**: Innovative congestion management concepts
- **Market development**: Foster cooperation on EU level

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**Overview**

- **Shift “central” into a highly “decentral” energy landscape**
- **Decentralization with distributed generation and active customers**
- **Innovative congestion management concepts**
- **Foster cooperation on EU level**
50Hertz is well engaged and committed in the European context

- **RSCs across the European grid system as service-providers to TSOs**
  - CORESO (2008)
  - TSC (2008)
  - SCC (2015)
  - Baltic RSC (2016)
  - SEE-Thessaloniki RSC (2016)
  - Nordic RSC (2016)
  - TSO in TSC and Nordic RSC
  - TSO in TSC and CORESO
  - TSO procuring services from TSC

- **Joint entities for commercial operation of interconnectors**

- **Regular bilateral meetings/contracts**

- **ENTSO-E as main platform**

- **Design and successful implementation of market coupling**

- **Successful development of grid codes**

• There are already well-functioning regional and European TSO cooperations on technical and commercial level.
Challenges and solutions within system and markets

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Grid fees account for 25% of household electricity prices being the only part that differs from region to region.

**Split of household prices in 2017**

<table>
<thead>
<tr>
<th>Component</th>
<th>Percentage</th>
</tr>
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<tr>
<td>Taxes, fees, levies</td>
<td>55%</td>
</tr>
<tr>
<td>Procurement, sales</td>
<td>19.3%</td>
</tr>
<tr>
<td>Grid fees</td>
<td>25.7%</td>
</tr>
<tr>
<td>Grid fees DSO</td>
<td>~ 20%</td>
</tr>
<tr>
<td>Grid fees TSO</td>
<td>~ 6%</td>
</tr>
</tbody>
</table>

**Grid fees (€) electricity in January 2016**

Average composition of the electricity prices 2017, German household with yearly consumption of 3,500 kWh.
Development of average TSO grid fees for 2018
Basis: temporary grid fees 2018, situation as of October 2017 [ct/kWh¹]

- 50Hertz’ initiative for unified TSO grid fees will lead to strongly decreasing grid tariffs within next five years.

¹Calculated with average grid fees of EHV and EHV / HV with annual utilisation time of 1,000 hours, 3,000 hours and 5000 hours

* Rough estimate
Strong increase of surcharges due to renewables development

EEG-surcharge is the main component

Surcharges for households in ct/kWh

2013
- EEG-Surcharge: 5.982
- KWK-Surcharge (CHP): 0.126
- §19 StromNEV-Surcharge: 0.329
- Offshore liability surcharge: 0.250
- Surcharge for interruptable loads: 0.000

2014
- EEG-Surcharge: 6.769
- KWK-Surcharge (CHP): 0.178
- §19 StromNEV-Surcharge: 0.250
- Offshore liability surcharge: 0.092
- Surcharge for interruptable loads: 0.000

2015
- EEG-Surcharge: 6.615
- KWK-Surcharge (CHP): 0.254
- §19 StromNEV-Surcharge: 0.237
- Offshore liability surcharge: 0.005
- Surcharge for interruptable loads: 0.000

2016
- EEG-Surcharge: 7.217
- KWK-Surcharge (CHP): 0.445
- §19 StromNEV-Surcharge: 0.378
- Offshore liability surcharge: 0.040
- Surcharge for interruptable loads: 0.000

2017
- EEG-Surcharge: 7.684
- KWK-Surcharge (CHP): 0.438
- §19 StromNEV-Surcharge: 0.388
- Offshore liability surcharge: 0.011
- Surcharge for interruptable loads: 0.006

2018
- EEG-Surcharge: 7.600
- KWK-Surcharge (CHP): 0.390
- §19 StromNEV-Surcharge: 0.370
- Offshore liability surcharge: 0.037
- Surcharge for interruptable loads: 0.011

+28%
Thank you for your attention