Denmark Generation Development

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Offshore

Wind Turbines
- Wind turbine market situation
- Project size - and turbine size - constraints?
- Modern turbine capabilities - wind farms as power plants

Grid Integration Issues
- What are the technical grid challenges?
- How can they be handled?
- Institutional / administrative / economic obstacles?
- How can they be handled?
Growth in size of commercial wind turbines
W turbine development: Cost

<table>
<thead>
<tr>
<th>Year</th>
<th>Rotor (Meter)</th>
<th>KW</th>
<th>Total Cost</th>
<th>Cost/kW</th>
<th>MWh</th>
</tr>
</thead>
<tbody>
<tr>
<td>1981</td>
<td>10</td>
<td>25</td>
<td>$65</td>
<td>$2,600</td>
<td>45</td>
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<tr>
<td>1985</td>
<td>17</td>
<td>100</td>
<td>$165</td>
<td>$1,650</td>
<td>220</td>
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<tr>
<td>1990</td>
<td>27</td>
<td>225</td>
<td>$300</td>
<td>$1,333</td>
<td>550</td>
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<tr>
<td>1996</td>
<td>40</td>
<td>550</td>
<td>$580</td>
<td>$1,050</td>
<td>1,480</td>
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<td>1999</td>
<td>50</td>
<td>750</td>
<td>$730</td>
<td>$950</td>
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<td>2004</td>
<td>77</td>
<td>1,500</td>
<td>$1,200</td>
<td>$800</td>
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</table>
Offshore
Denmark 1985

18 large power plants
13 smaller distributed power plants
Small wind contribution 47 MW
Denmark 2009

18 large power plants
> 300 distributed power plants
Large wind contribution
3,465 MW = 30%
Genaration penetration

Small penetration levels (5%): No major impacts, no need for heavy grid code requirements. Load following & regulation impacts are small.

At increasing (10-20%) penetration levels, small but measurable increase in ramping requirement can generally be met by existing generation with modest cost increase.

At higher (>30% levels) minimum load problems may appear:
- Large markets (energy, ancillary services, price responsive load)
- More flexible generation options
- Larger balancing areas and stronger interconnections
- Curtailment
- Energy storage (large hydro & pumped storage)
Safeguarding life, property and the environment

www.dnv.com
Findings and Discussions:

1. Project Development barriers
   - Technology selection (i.e. 2 vs. 3 blade turbines)
   - Size of equipment, like weights, transportation and cranes
   - Life span of the equipment
   - Equipment behavior under intensive climate conditions, i.e. extreme winds and temperatures.
   - Adaptation of technology to project site and local working conditions (which have lead to improvement in designs and performances)
   - Harvesting depends on wind speed and swept area

2. Tools:
   - Standards for common problems through common cooperation of developers, manufacturers and utilities in different countries.
   - Backbone available for balancing the system.
Findings and Discussions:

3. Penetration into the grid
- Penetration proportional to smooth system planning, especially grid development and assignment of responsibilities among stakeholders.
- Transmission is a public good: not everybody can go through
- Who is assuming the costs of TL implementation is a barrier
- New developments i.e. permanent magnet generator + frequency converter guarantees a 100% quality output of electricity.
- Planning for penetration shall look into utility area of influence first rather than the national context only.
- Difficult to indentify generation by sources
- ADB as facilitator to coordinate the regions input to discussion, harmonization's, grid codes, standard PPAs, standard
Findings and Discussions:

ADB as facilitator

- to coordinate the regions input to discussion
- harmonization's
- grid codes
- standard PPAs
- Standard Purchase contracts incl O&M