Wind – challenges, opportunities, and PCS

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Global Research & Innovation,
Vestas
…if I had more time, I would have written a shorter letter…Goethe
**Vestas:**
The largest wind turbine manufacturer in the world

### Top 10 Global Wind Manufacturers 2005, 2010

<table>
<thead>
<tr>
<th>Year</th>
<th>Company</th>
<th>Country</th>
<th>Production (GW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2005</td>
<td>Vestas</td>
<td>Denmark</td>
<td>3.2</td>
</tr>
<tr>
<td></td>
<td>Enercon</td>
<td>Germany</td>
<td>2.7</td>
</tr>
<tr>
<td></td>
<td>Gamesa</td>
<td>Spain</td>
<td>1.9</td>
</tr>
<tr>
<td></td>
<td>GE Wind</td>
<td>US</td>
<td>1.3</td>
</tr>
<tr>
<td></td>
<td>Siemens</td>
<td>Denmark</td>
<td>1.1</td>
</tr>
<tr>
<td></td>
<td>Suzlon</td>
<td>India</td>
<td>0.9</td>
</tr>
<tr>
<td></td>
<td>Repower</td>
<td>Germany</td>
<td>0.9</td>
</tr>
<tr>
<td></td>
<td>Goldwind</td>
<td>China</td>
<td>0.7</td>
</tr>
<tr>
<td></td>
<td>Nordex</td>
<td>Germany</td>
<td>0.5</td>
</tr>
<tr>
<td></td>
<td>Ecotecnica</td>
<td>Spain</td>
<td>0.3</td>
</tr>
<tr>
<td>2010</td>
<td>Vestas</td>
<td>Denmark</td>
<td>6.3</td>
</tr>
<tr>
<td></td>
<td>GE Wind</td>
<td>US</td>
<td>6.0</td>
</tr>
<tr>
<td></td>
<td>Sinovel</td>
<td>China</td>
<td>5.3</td>
</tr>
<tr>
<td></td>
<td>Gamesa</td>
<td>Spain</td>
<td>4.4</td>
</tr>
<tr>
<td></td>
<td>Goldwind</td>
<td>China</td>
<td>3.6</td>
</tr>
<tr>
<td></td>
<td>Suzlon</td>
<td>India</td>
<td>3.5</td>
</tr>
<tr>
<td></td>
<td>Enercon</td>
<td>Germany</td>
<td>3.4</td>
</tr>
<tr>
<td></td>
<td>Dongfang</td>
<td>China</td>
<td>3.0</td>
</tr>
<tr>
<td></td>
<td>Repower</td>
<td>Germany</td>
<td>2.9</td>
</tr>
<tr>
<td></td>
<td>Nordex</td>
<td>Germany</td>
<td>2.4</td>
</tr>
</tbody>
</table>

### Vestas in Top 10 Markets

<table>
<thead>
<tr>
<th>Market</th>
<th>MW</th>
<th>No. 1</th>
<th>No. 2</th>
<th>No. 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>China</td>
<td>18,928</td>
<td>Sinovel</td>
<td>Goldwind</td>
<td>Dongfang</td>
</tr>
<tr>
<td>USA</td>
<td>5,115</td>
<td>GE Wind</td>
<td><strong>Vestas</strong></td>
<td>Siemens</td>
</tr>
<tr>
<td>India</td>
<td>2,139</td>
<td>Suzlon Group</td>
<td>Enercon-India</td>
<td><strong>Vestas</strong></td>
</tr>
<tr>
<td>Germany</td>
<td>1,551</td>
<td>Enercon</td>
<td><strong>Vestas</strong></td>
<td>Suzlon Group</td>
</tr>
<tr>
<td>UK</td>
<td>1,522</td>
<td>Siemens</td>
<td><strong>Vestas</strong></td>
<td>Gamesa</td>
</tr>
<tr>
<td>Spain</td>
<td>1,516</td>
<td>Gamesa</td>
<td><strong>Vestas</strong></td>
<td>GE Wind</td>
</tr>
<tr>
<td>France</td>
<td>1,186</td>
<td>Enercon</td>
<td>Suzlon Group</td>
<td><strong>Vestas</strong></td>
</tr>
<tr>
<td>Italy</td>
<td>948</td>
<td>Gamesa</td>
<td><strong>Vestas</strong></td>
<td>Suzlon Group</td>
</tr>
<tr>
<td>Canada</td>
<td>690</td>
<td>Siemens</td>
<td>GE Wind</td>
<td>Enercon</td>
</tr>
<tr>
<td>Sweden</td>
<td>604</td>
<td><strong>Vestas</strong></td>
<td>Enercon</td>
<td>Siemens</td>
</tr>
</tbody>
</table>

Source: BTM Consult – part of Navigant Consulting – March 2011

**Market share of top 10 suppliers**

- China: 96%
- USA: 91%
- Spain: 84%
- Germany: 81%
- Sweden: 79%
- UK: 80%

Source: BTM Consult – part of Navigant Consulting – March 2011

*Wind. It means the world to us.*
On the way up…

On the way *not* up…

bigger was better…
Over the last 25 years, the output of a single Vestas turbine increased 100x – total annual energy increased 330x

Our fleet:
39,000 Turbines delivered
= Total required power in Spain

Wind. It means the world to us.™
Today one turbine produces 3000 kW

25 years ago, this was 3000 kW

Today, 1 turbine is enough
One V112 = 3.8 Statues of Liberty…

…and its rotor alone won’t fit in a football field
How big will be the recently announced V164?

V-164 7MW – rotor diameter: 164m
Airbus A380 – wingspan: 80 m, length: 73m
London Eye – diameter: 135m.
On the way up...

On the way *not* up...

participants becoming mature...

policy assistance shrinking...
The curve of maturity...

Turbine Scaling & Reliability
30kw to 3MW

- Supplier proliferation
- Negative press
- Supplier consolidation
- 2nd generation & services
- <5% of adoption

Power plant optimization
Grid management

- High growth adoption (20-30%)
- Best practices

Expectations

R&D
1st Gen: Customization

Technology Trigger
Peak of Inflated Expectations
Trough of Disillusionment
Slope of Enlightenment
Plateau of Productivity

Source: Gartner's hype cycle
“Prostitution, horse racing, gambling and electricity are irresistible to politicians.”

John Rowe, CEO of Chicago-based utility Exelon
US policy approach...

Federal Subsidies

PTC: $22/MWhr (expires '12)
ITC: 33% capital costs (expired '11)

State Renewable Portfolio Standards

Renewable energy Credit: $17/MWhr

Tax Policies
Effects to the business...

Annual Wind Installed [MW]

Companies need long-term business case certainty for sustained investment

Source: AWEA

Wind. It means the world to us.™
Challenges with Wind

Opportunities with Wind

- Impediments for wide proliferation of wind assets are cost of wind generation (capital and maintenance), and risks associated with variability of wind (intermittency and unpredictability)

comparative LCOE

variability at grid interface
Wind industry participants have been focused on selling turbines in the PPA market. Financial models are based on double digit EBIT through high contribution margins. Elimination/reduction of PTC for renewable generation will limit contribution margins. Way to profitability will be in making wind LCOE (w/o PTC) less than LCOE with gas. Falling gas prices will further challenge competitive advantage with wind generation.

**Challenge 1: Levelized Cost of Energy**

![Graph showing Estimated Levelized Cost of New Electricity Generating Technologies in 2016 (2009$/megawatt hour)](Image)

Challenge 2: Variability at Grid Interface

- Variability at grid interface is caused due to intermittency and unpredictability of wind.
- Improved forecasting techniques quantify/limit the risks associated with variability.
- Energy storage relieves short term variability, however increases system costs.
- Low cost, high efficiency transmission (e.g. HVDC) further balances variability at grid.
Challenges with Wind

Opportunities with Wind

reaching 20% proliferation
Besides cost of wind generation that will gain 5% market, impediments for wider (20%) proliferation of wind assets are variability of wind (unpredictability and intermittency), barriers for transmission (transportability), and compliance with smart grid infrastructure.
Components of a turbine…

ENERGY CONVERSION (DRIVE TRAIN)
- CoolerTo
- Gearbox
- Main-bearing housing
- Yaw System
- Transformer
- Generator (Back-to-back Converter)

ENERGY CAPTURE (ROTORS)
- Main Shaft
- Blade

ENERGY DISTRIBUTION (GRID MANAGEMENT)
- Gear box
- Generator
- Stator Side filter
- Grid Side filter
- Grid Interface
- Transformer
- Cable in tower
- Switch gear

Wind. It means the world to us.
Main drive train topologies and their advantages

<table>
<thead>
<tr>
<th>Geared</th>
<th>Gearless</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lower cost</td>
<td>High reliability (yet to be proven)</td>
</tr>
<tr>
<td>Lower weight</td>
<td></td>
</tr>
<tr>
<td>Proven technology</td>
<td></td>
</tr>
</tbody>
</table>

The technology adoption will be influenced by
- Cost
- Reliability in very long term operation > 20 years
- Scalability > 10MW

On-going R&D on power conversion topics
- Crossover from low voltage to medium voltage to HVDC
- Do not use power electronics all together? E.g. hydraulic transmissions with synchronous generators coupled to the grid.
- 1.6MW energy storage combined with 30MW wind power plant
- Offers energy buffer for wind to participate in ancillary services market
- Challenge is in making the system attractive from RoI perspective
PCS in energy collection...maximize efficiency

DC turbines combined with DC collection has a potential to offer up to 30% improvement in reducing energy losses. This improvement is obtained through reduction of turbine-side and station-side converters. However, the challenge is in realizing such high power DC/DC converters.
HVDC is appearing to be the technology of choice to transport power from wind power plants over long distances (e.g. from deep water offshore to onshore). However, significant challenges are in protection and control of such DC architectures.