Development and Challenges of Permanent Magnet Wind Generators

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Electrical Power Conversion

Fixed Speed System

Variable Slip System

Doubly-Fed Variable Speed System

Full Conversion Variable Speed System

Variable Speed Systems Becoming Industry Standard at High Power
Permanent Magnet Generator

- **Stator**
- **PMs**
- **Rotor**

**Surface PM machine**

**Flux driven by PMs**

**Design Considerations**
- Excitation
- Physical Magnet protection
- Rotor mechanical
- Magnet cooling
- Demagnetization protection
- Manufacturing

**Surface PM w/ Pole cap**

**Spoke PM**

**Interior PM**
## Permanent Magnet vs. Doubly-fed Asynchronous Machines

<table>
<thead>
<tr>
<th><strong>PM</strong></th>
<th><strong>Doubly-fed</strong></th>
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<tr>
<td>• Permanent magnets on rotor</td>
<td>• Variable frequency current on rotor</td>
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<tr>
<td>• High Efficiency / Low Cost of Energy</td>
<td>• Partial power conversion</td>
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<tr>
<td>• High reliability</td>
<td>• Large rotor loss/exiting current</td>
</tr>
<tr>
<td>• Lighter machine</td>
<td>• Slipping ring</td>
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<tr>
<td>• Sample rotor pole structure – suitable for high pole number</td>
<td>• Low Reliability</td>
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<tr>
<td>• Full power conversion</td>
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Drivetrain Weight – Geared vs. Direct Drive

Drivetrain Weight (mT) vs. Input torque (kNm)

- Geared
- Direct Drive

6000

Drivetrain Weight – Geared vs. Direct Drive
Drivetrain Cost

- Gearbox stage changes as gear ratio increases
- Gearbox cost jumps as stage changes
- Generator cost decreases as speed/gear ratio increases
- Drivetrain cost varies
PM Generator Application Trend

- More PM generators, more companies with PM
- Small Wind Generators (<100kW)
  - Simple design, easy manufacturing and control
- High efficiency generator (large turbines, >2MW)
  - Low cost of energy
- Light & high pole number generator (direct drive)
  - Simple pole structure
- High reliability
  - Direct Drive, no gearbox, high pole number, simple rotor structure

ABB high speed PM Generator (2~5MW)
www.abb.com

SKT Wind PM Generator
(200W~99kW) www.alxion.com

Siemens 3MW DD PM Gen, 73mt
www.renewableenergyfocus.com

The Switch 4250Kw
15RPM DD PM Generator
www.theswitch.com

GE offshore DD turbine
inhabitat.com
PM materials

- Ferrite and rare earth
- 128MMton REO deposit has been explored in the world
- 55% of global REO deposit (>70MMton) is in China
- 90-95% of annual output from China
- 0.1MMton REO is consumed in 2008
- Existing output capability larger than 0.15MMton
- Anticipated usage in 2015: ~ 0.16MMton

Global Deposit of Rare Earth Oxide (REO) ---128 M tons in total
( Optimistic Estimation: > 200 MMtons )

NdFeB Output Growth

Challenges and Risks

Challenges and Risks

• Less experience for the industry with PM machines
• Demagnetization
• Magnet corrosion and aging loss
• Future material shortage/high price?
• Unknown risks

Ways to address

• More prototypes, more time
• Live with it, Better Gen design, or More reliable converter.
• Not an issue? Better coating?
• Optimize magnet mass

5/12/2010
WTG Assembly

Manufacturing

Site Assembly
Summary

• More PM Generators to be installed
• More Direct Drive PM generators to come
• More issues to be addressed