

WORKSHOP ON NEXT-GENERATION WIND POWER
May 12, 2010
Rensselaer Polytechnic Institute

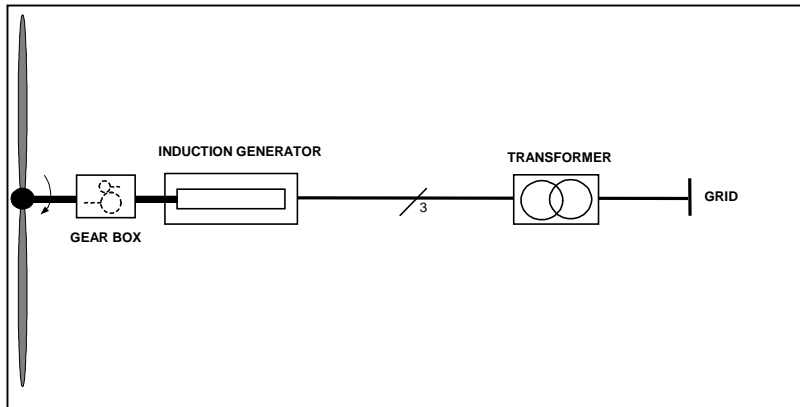
Development and Challenges of Permanent Magnet Wind Generators

Ronghai Qu

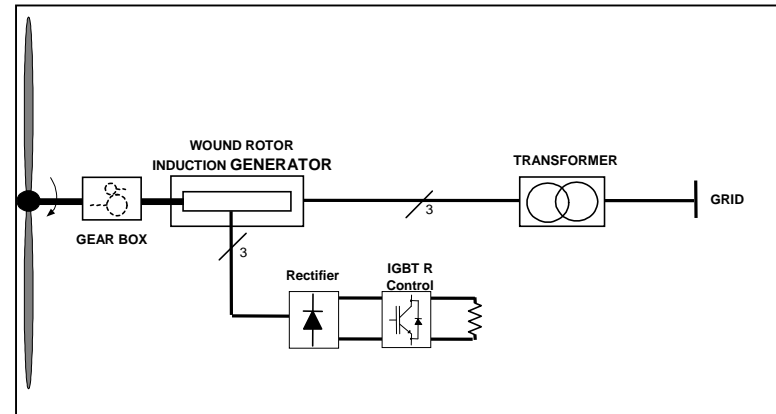
GE Global Research Center

Electrical Power Conversion

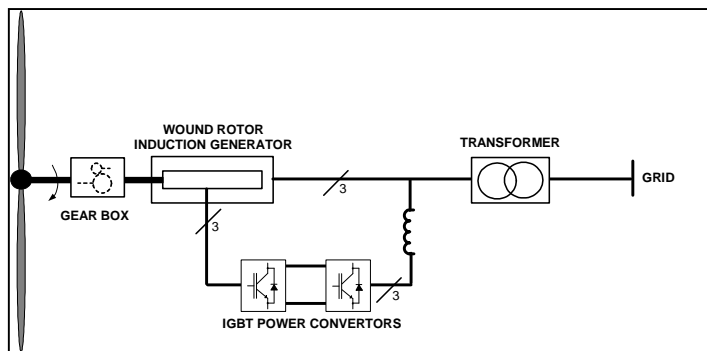
Fixed Speed System



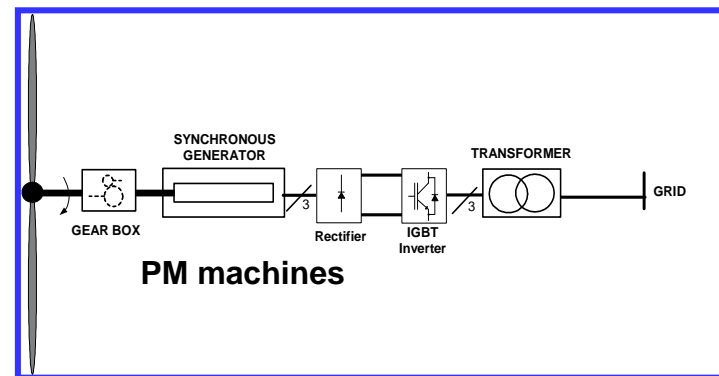
Variable Slip System



Doubly-Fed Variable Speed System

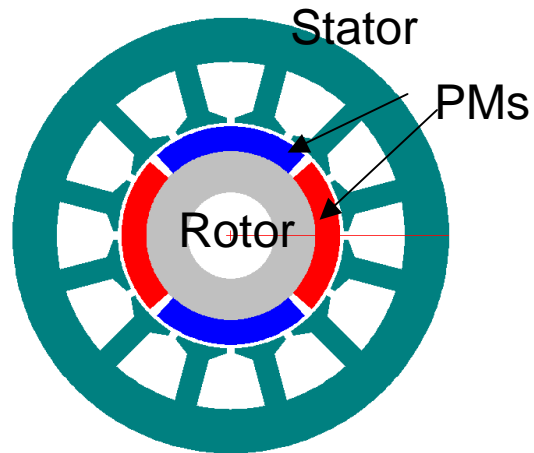


Full Conversion Variable Speed System

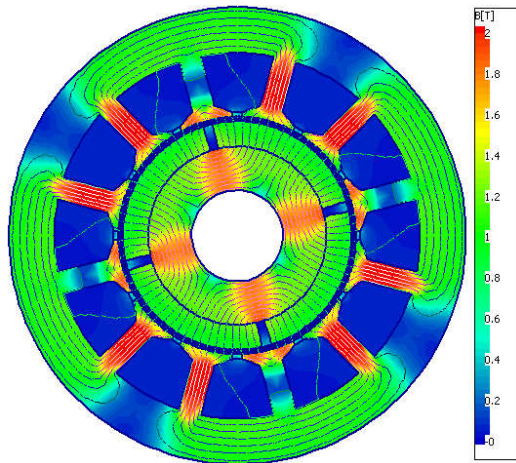


Variable Speed Systems Becoming Industry Standard at High Power

Permanent Magnet Generator

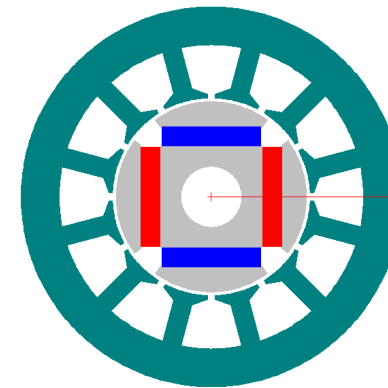


Surface PM machine

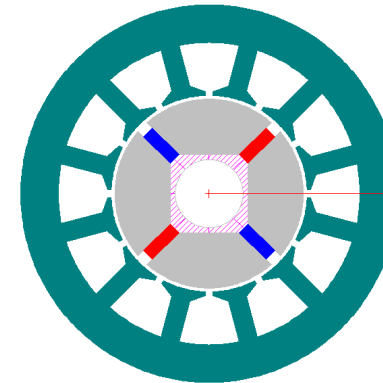


Flux driven by PMs

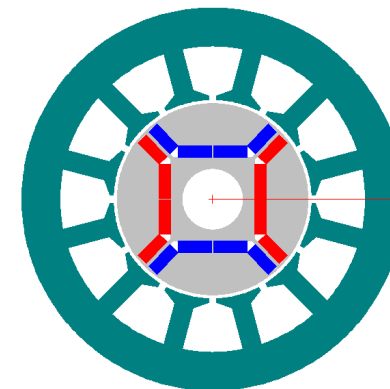
- Design Considerations**
- Excitation
 - Physical Magnet protection
 - Rotor mechanical
 - Magnet cooling
 - Demagnetization protection
 - Manufacturing



Surface PM w/
Pole cap



Spoke PM



Interior PM

Permanent Magnet vs. Doubly-fed Asynchronous Machines

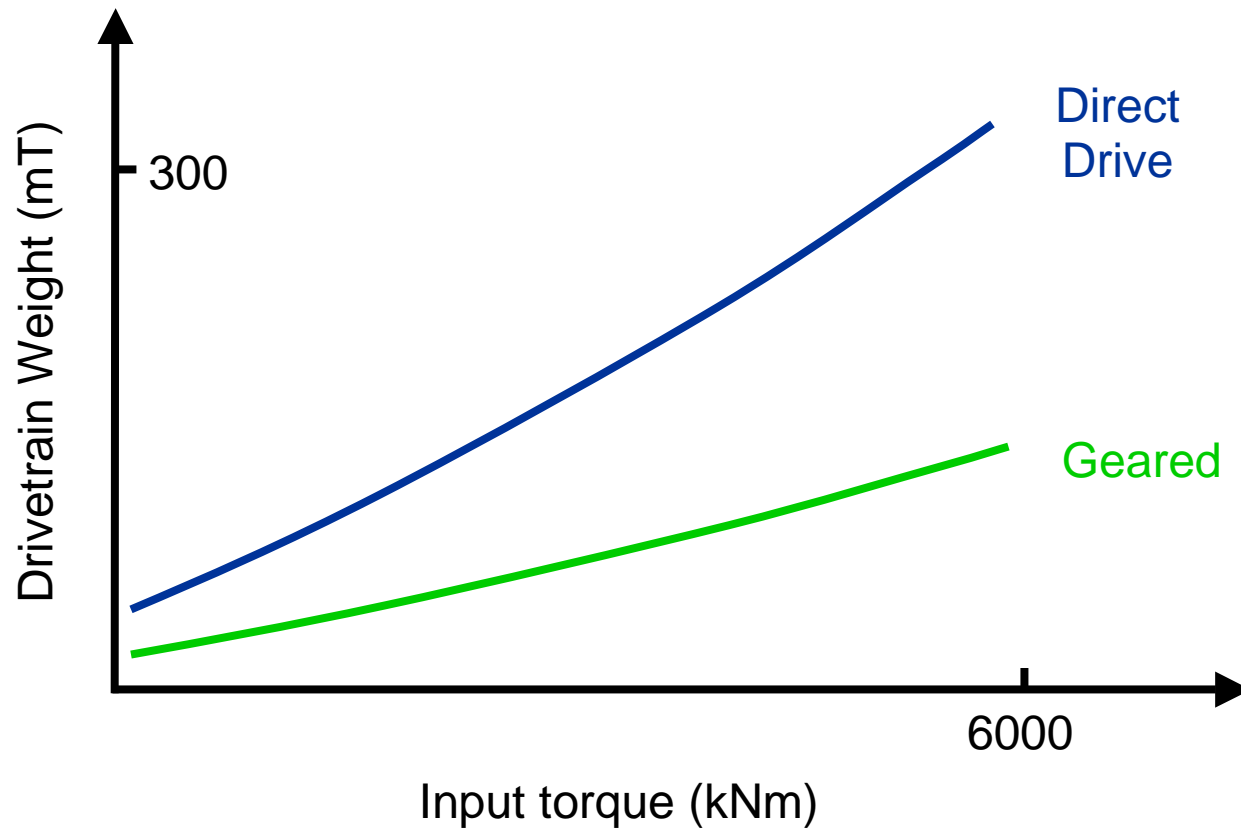
PM

- Permanent magnets on rotor
- High Efficiency / Low Cost of Energy
- High reliability
- Lighter machine
- Simple rotor pole structure – suitable for high pole number
- Full power conversion

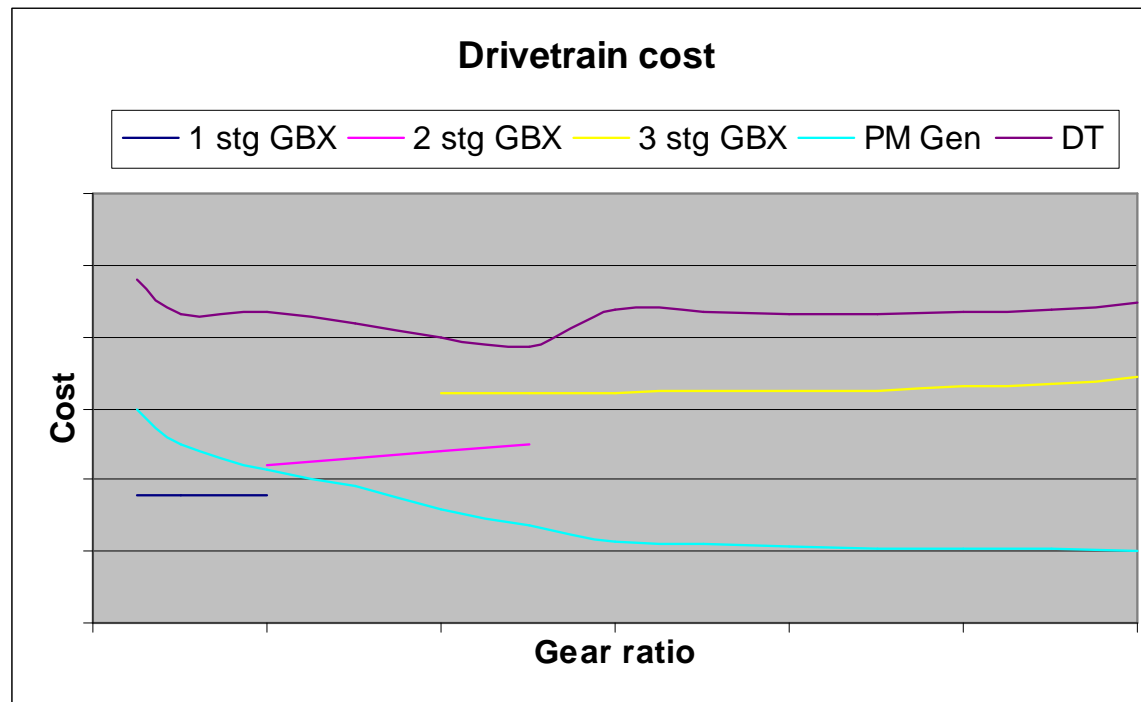
Doubly-fed

- Variable frequency current on rotor
- Partial power conversion
- Large rotor loss/exciting current
- Slipping ring
- Low Reliability

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



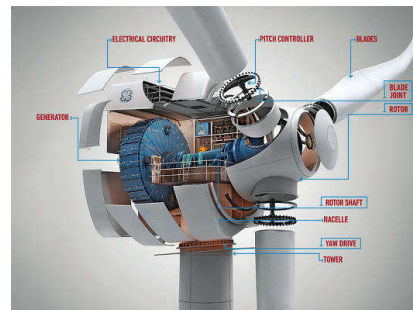
SKT Wind PM Generator
(200W~99kW) www.alxion.com



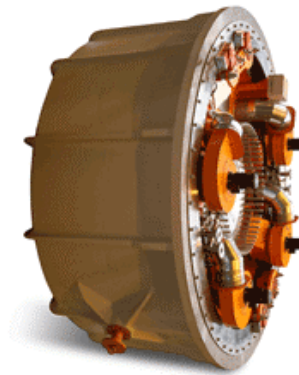
Siemens 3MW DD PM Gen, 73mt
www.renewableenergyfocus.com



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



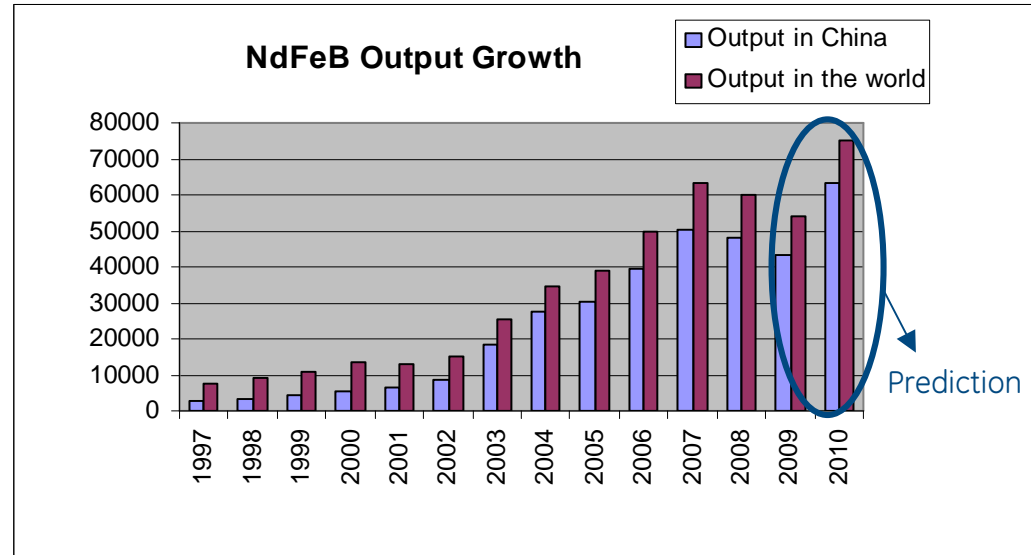
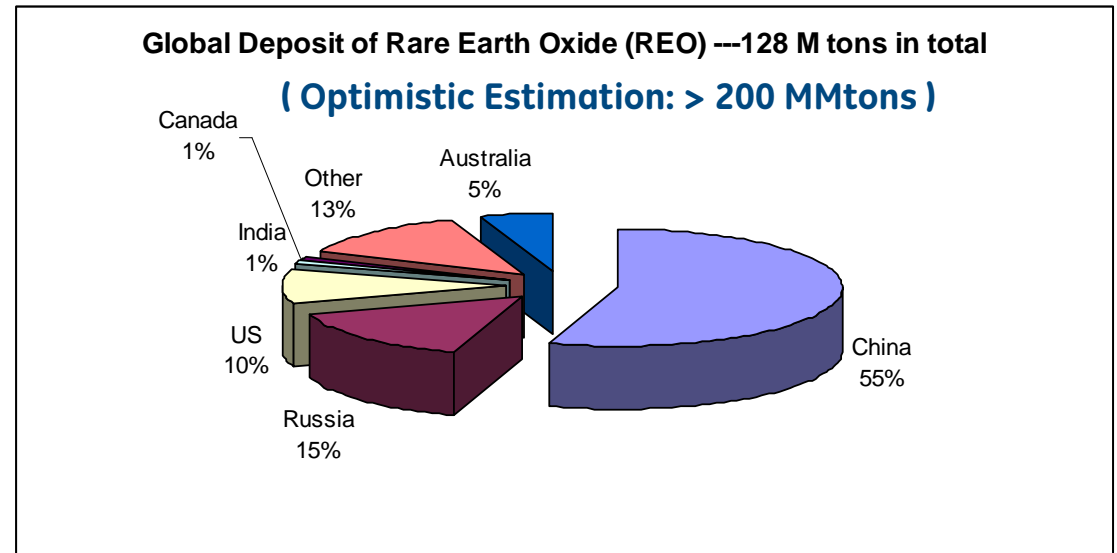
GE offshore DD turbine
inhabitat.com



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



www.marketwatch.com; www.businessinsider.com; www.smenet.org; geo-nsdi.er.usgs.gov

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



WTG Assembly

Manufacturing



Site Assembly



Summary

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

