Wind Turbine Generators with Reduced Reliance on Rare Earth Magnets

Henriksen, Matthew Lee; Jensen, Bogi Bech

Publication date: 2012

Document Version
Publisher's PDF, also known as Version of record

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Citation (APA):
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Matthew L Henriksen, Bogi B Jensen
Center for Electric Power and Energy, Technical University of Denmark

Introduction

▶ Motivation and goal
- Recent volatile trends in the rare earth supply chain have been observed.
- Powerful rare earth permanent magnets (REPM) are the key ingredients to many modern, highly-efficient wind turbine generators (WTG).
- In this three-year project, finding the best wind turbine topology to use in the event that REPM usage becomes impractical is the ultimate goal.

▶ Strategy
- Establish the baseline performance of wind turbines employing REPM.
- Optimize some alternative generators and compare to the baseline results.
- Pick a winner, and verify the concept through design and construction of a scaled prototype.

Wind turbine drivetrains: to gear, or not to gear?

▶ Many drivetrain configurations are currently being marketed:
  - High-speed gearing (classic solution)
  - Direct-drive (newer)
  - "Hybrid" drivetrain (newest)

▶ Wind turbine gearboxes can be very reliable, however reducing the number of stages or removing the gearbox may increase the overall system reliability.

▶ A “hidden cost” associated with the direct-drive concept is the need for a robust support structure to maintain the air gap.

▶ Air gap deformation should be limited to 10-20%, which presents a significant challenge.

Baseline study: synchronous machines with REPM

▶ Advantages:
  - Torque density
  - High efficiency at partial load

▶ Disadvantages:
  - Rare earth prices
  - Demagnetization can occur.

Future Work

▶ Consider additional generator concepts:
  - Induction machines
  - Electrically-excited synchronous machines
  - Others?

▶ Endorsement of best option or options

▶ Construction and testing of scaled prototype

Acknowledgement

▶ Thanks to DONG Energy for their contributions in funding and advising of this project.

Testing of the prototype machine will take place at PowerLabDK.

Figure 1: Generalized trends. Note that little information on reliability of modern commercial wind turbines is available.

Figure 2: Wind turbine gearboxes are composed of one or more planetary or parallel stages.

Figure 3: Examples of support structures for a rotor and stator of a direct-drive wind turbine.

Figure 4: Estimated displacement (m) due to attractive force between rotor and stator of a direct-drive wind turbine.

Figure 5: Cross sectional view of a 3MW DDPMSG. Radius at air gap is 2.3m, length is 1.6m, rated torque is 1.9MNm. Plot on left shows flux lines and flux density at no-load.

Figure 6: Cross sectional view of a 3MW SynRM. Radius at air gap is 0.7m, length is 0.8m, rated torque is 28kNm. Plot on left shows flux lines and flux density at full-load.

Figure 7: Ferrite magnets arranged in a spoke manner can produce an air gap flux density higher than their remanent flux density, which is likely to be 0.3-0.4 Tesla.