



Wind Turbine Configuration for the Offshore Environment

Simon Watson
Loughborough University



Overview

- The Issues
- Rotor
- Drive Train
- Control
- Electricals
- Summary

Issues



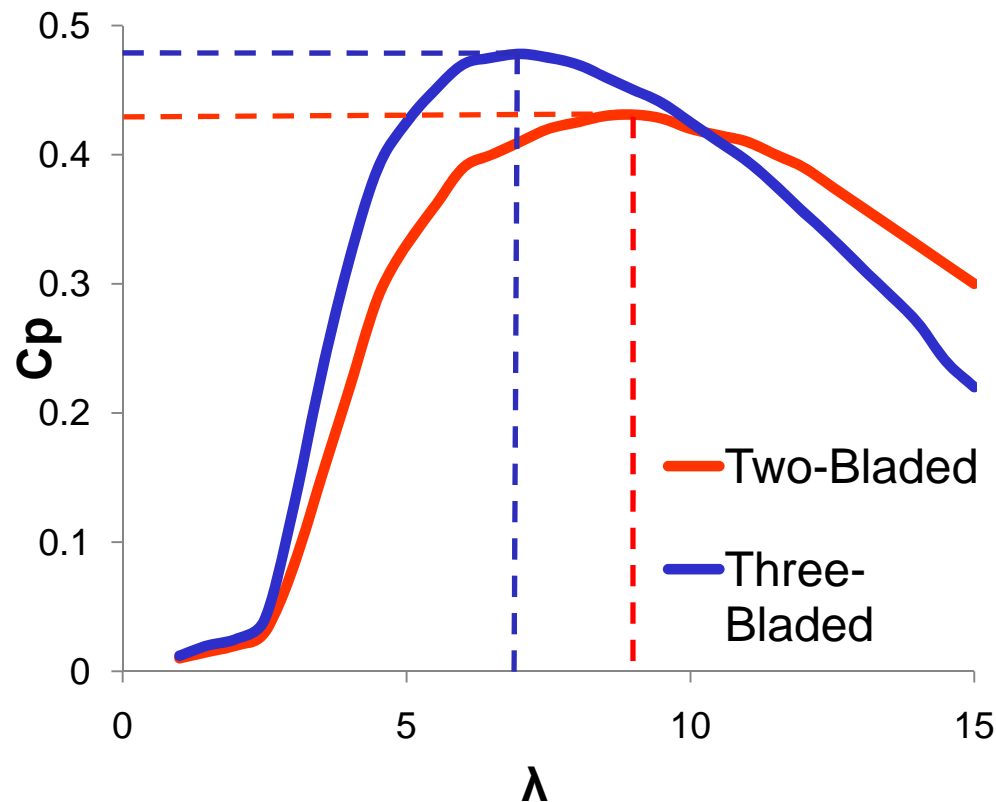
- Higher winds
- Wind shear
- Wave loading
- Tidal currents
- Water depth
- Corrosion



Implications

- Design
- Reliability
- Availability
- Operations and Maintenance

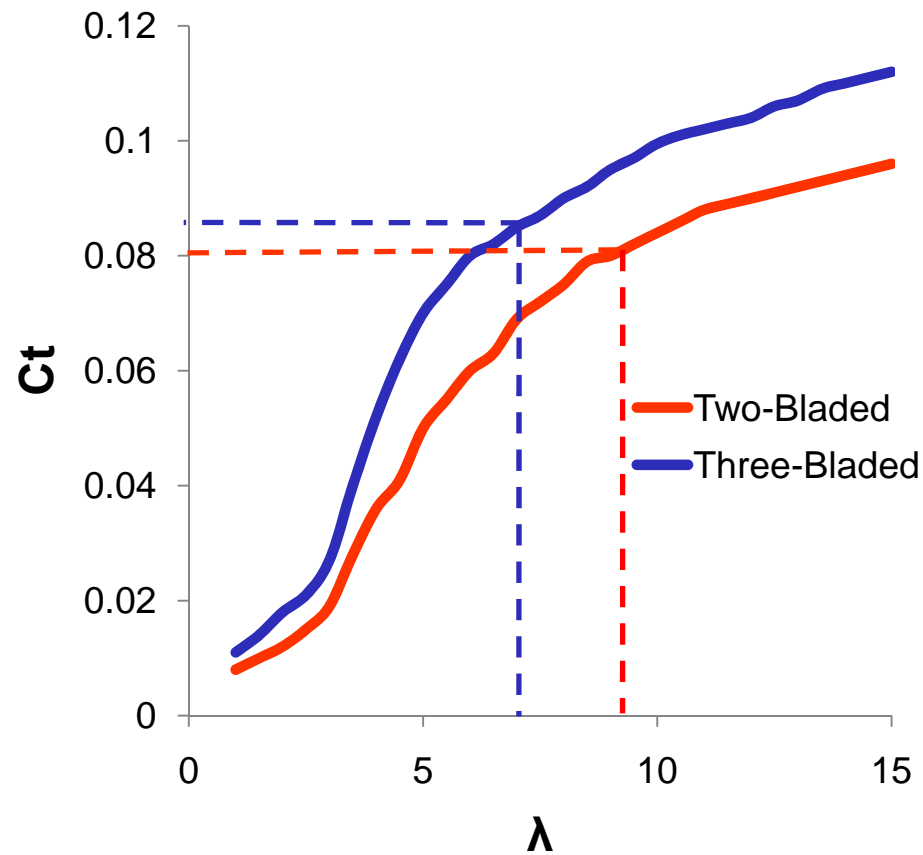
Two Blades or Three?



- Three blades more efficient
- Three blades maximum efficiency at lower tip speed ratio
- But running at higher speed reduces torque

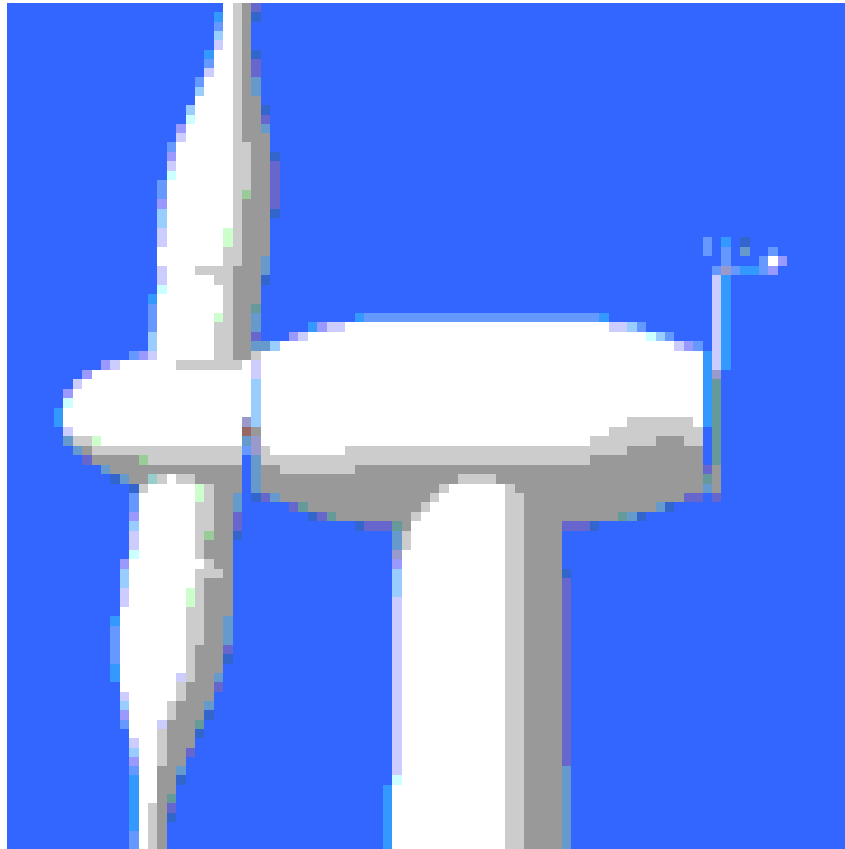


Consider Loading...



- Thrust load less for two blades

And Two Blades Can Teeter...

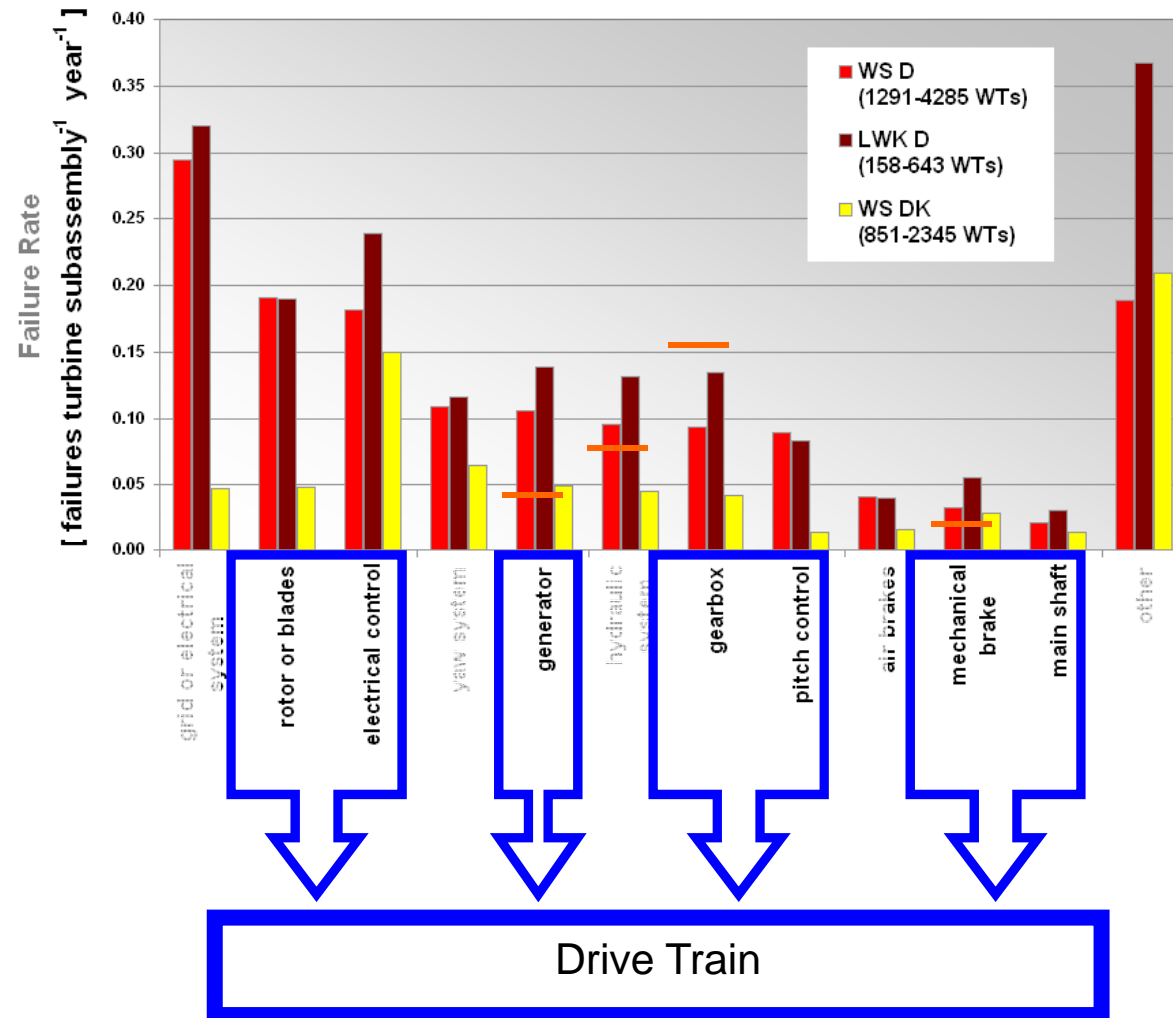


- Teetering can further reduce bending moments on the blades

Wind Turbine Reliability



Surveys failure rate comparison : period 1993-2004

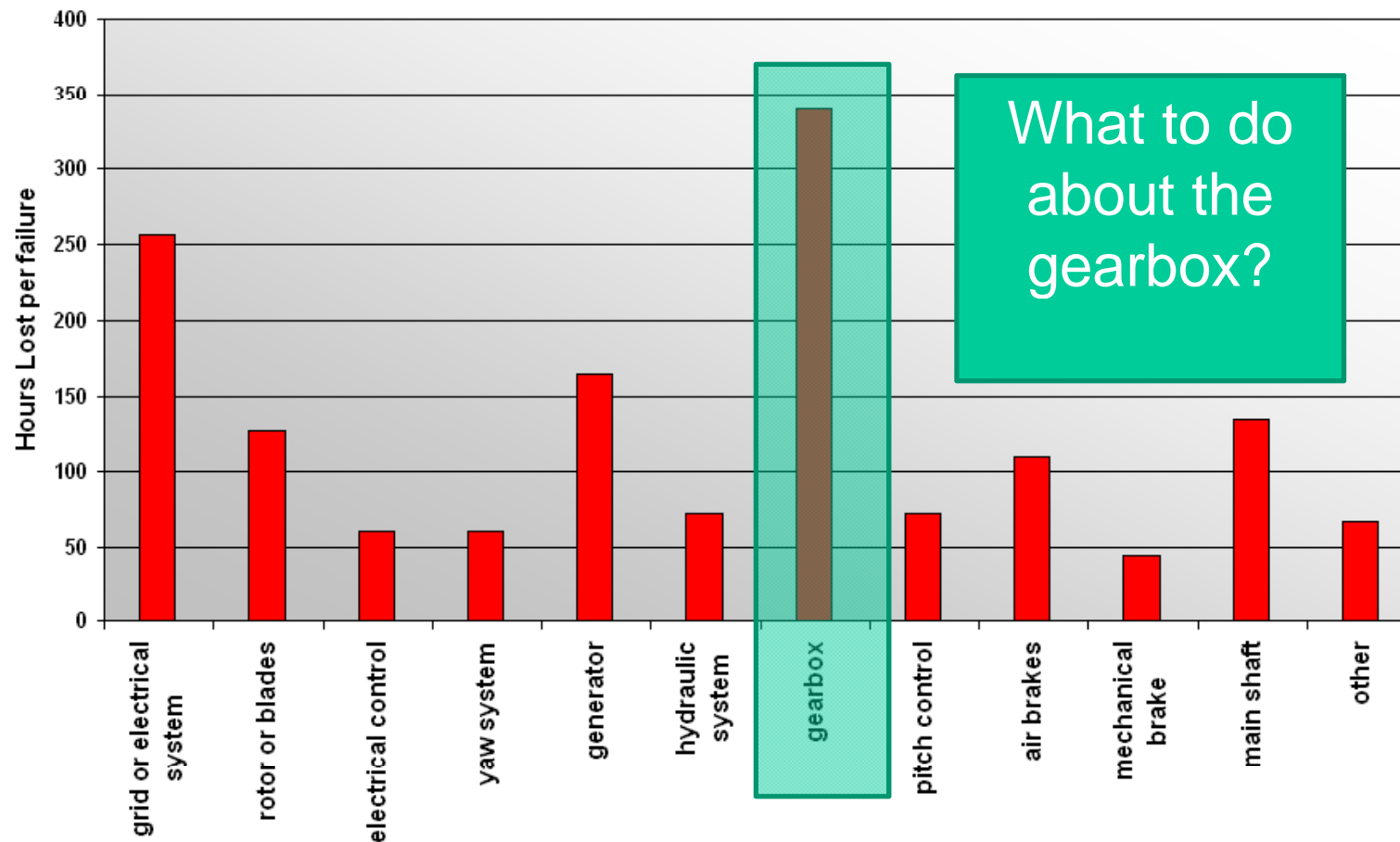


Industrial Reliability figures

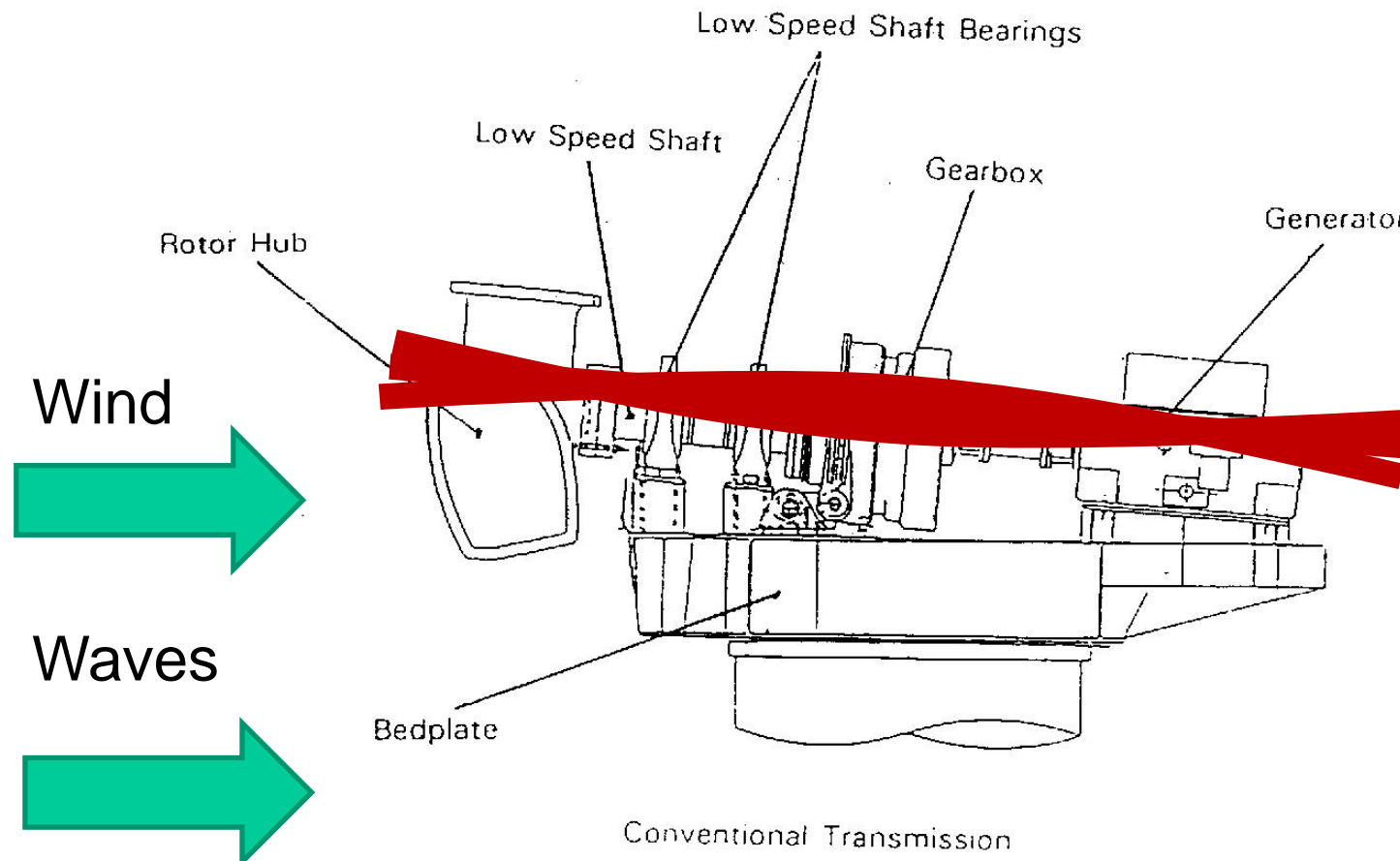


Downtime

LWK Survey hours lost per failure comparison : period 1993-2004, 158-643 turbines



Drive Train Misalignment

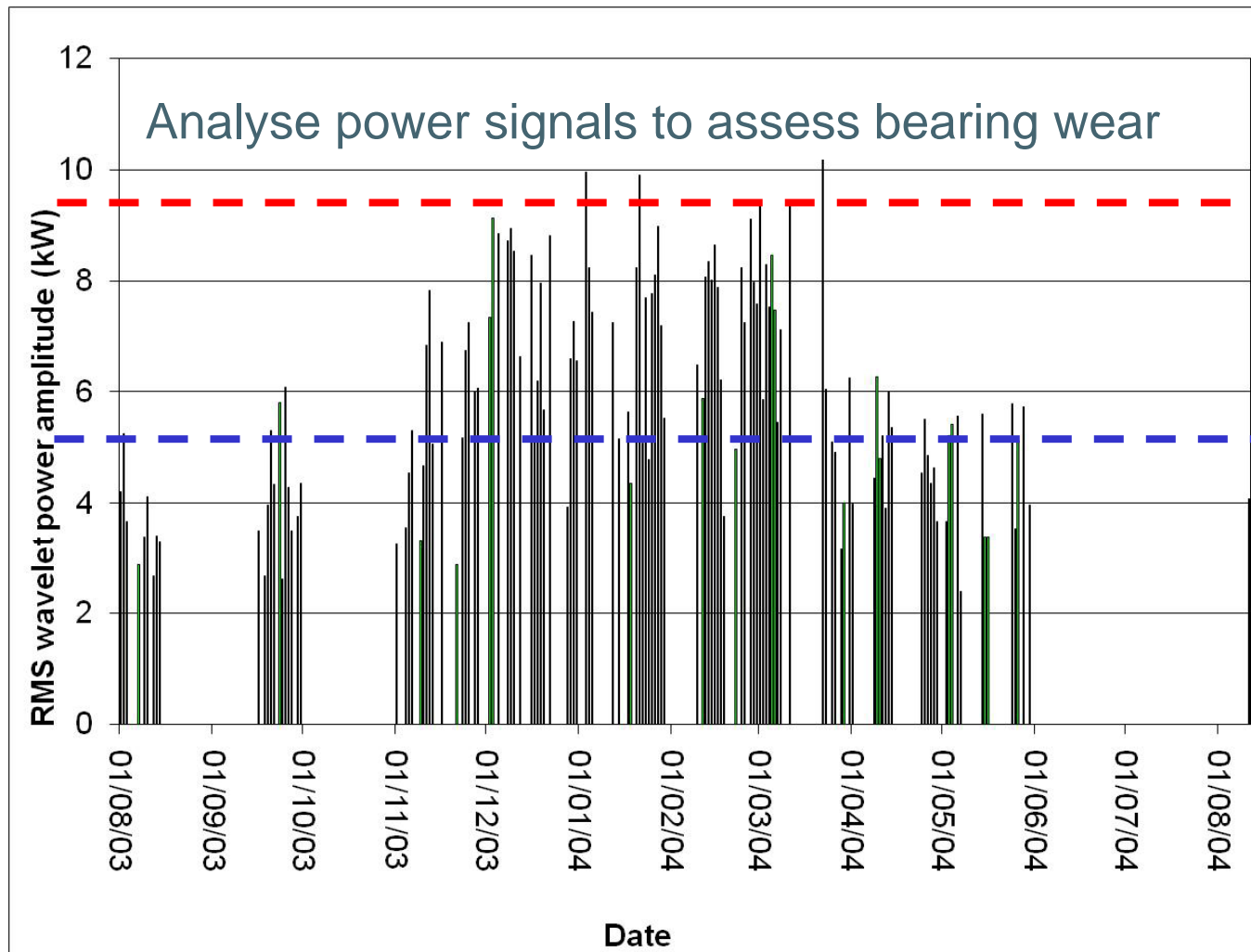




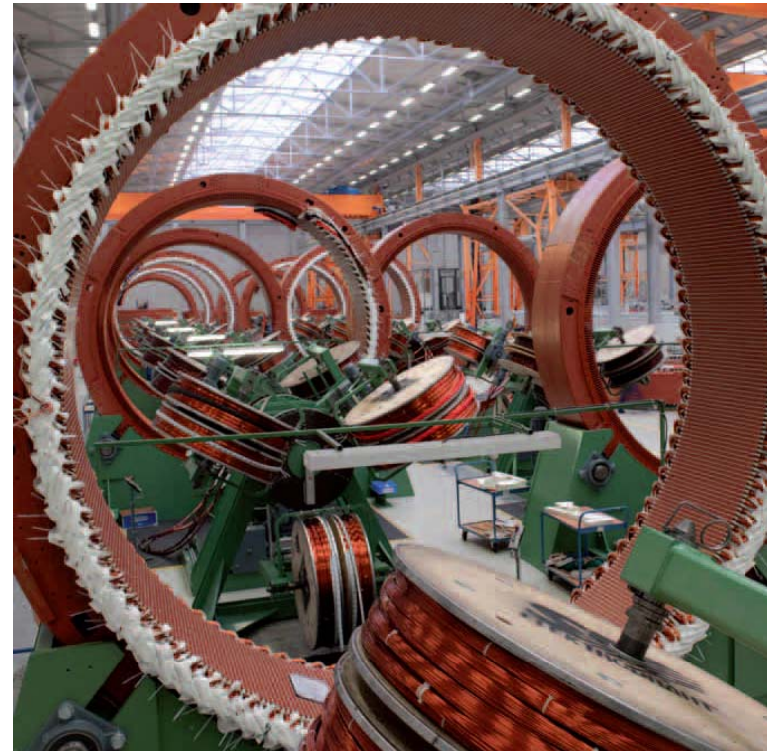
Things to Consider

- More rigid base plate
- Bearings designed to be fit for purpose
- Condition monitoring
- Reduce complexity of drive train

Condition Monitoring System Embedded within SCADA



Do Away with the Gearbox!



Enercon annular multipole generator



The Maths...

- Wind turbine with gearbox: from aerodynamics, rotor rotates at ~ 12 rpm
- 3-pole pairs means gearbox must achieve 1000rpm at generator \Rightarrow 1:83.3 ratio
- No gearbox, same rotor speed \Rightarrow ~ 250 pole pairs!



Drawbacks

- Power proportional to square of the machine air gap diameter
- So needs large and heavy generator
- Small air gap needs to be maintained
- Heavy and more costly engineering...
- ...but potentially more reliable



Other Possibilities

- Multiple-path drive train, i.e. more smaller gearboxes/generators, reducing loads on individual gearboxes/generators
- Loss of one gearbox/generator does not stop machine completely
- Permanent magnet generator, higher efficiency and more robust



For Example: Clipper Turbine



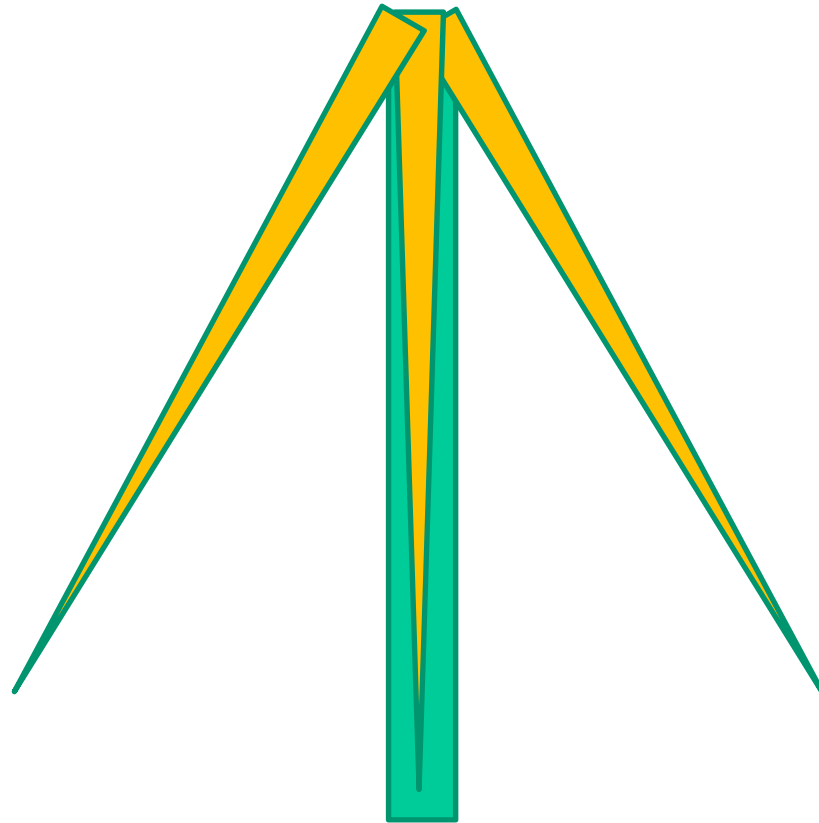


Pitch Control

- Until recently, all blades pitch by the same amount depending on the wind speed
- Increasing interest in allowing blades to pitch independently
- Or even to alter shape of individual blades to alleviate loads on the blades



Tower Shadow

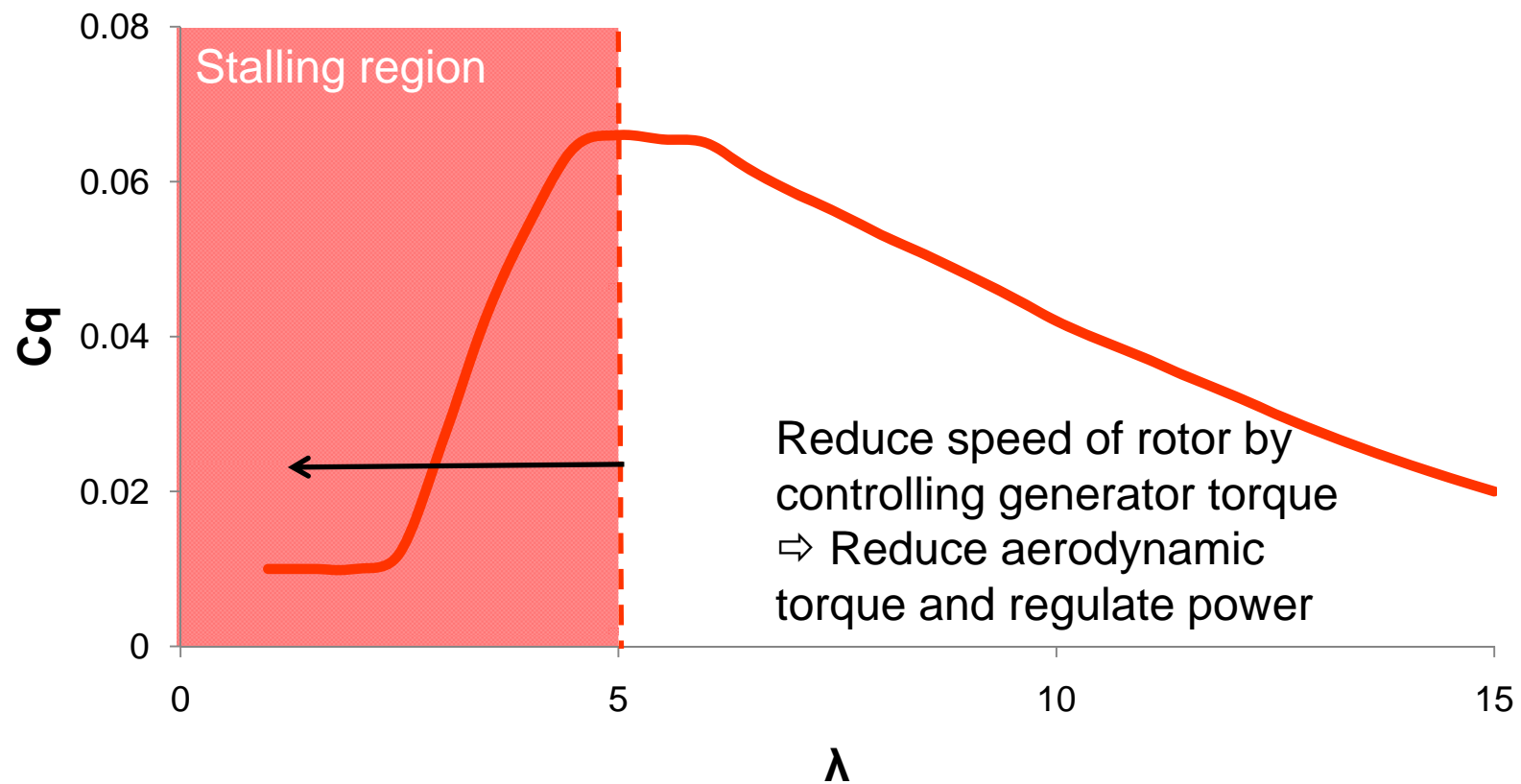




Complexity or Simplicity?

- Sophisticated pitch and blade surface actuators may reduce loads
- But there is more to go wrong and historically electrical failures have been quite frequent
- Would it be better to do away with any blade movement?

Variable Speed Stall Regulation





Pros and Cons

- No moving blade parts ✓
- Just use generator torque to brake rotor ✓
- Unstable control region ✗
- Stall not wholly understood or predictable ✗
- Research required to optimise controller ✗
- High thrust and fatigue loads when rotor stopped in high winds ✗



Power Conversion

- Variable speed means conversion of variable frequency from generator to fixed grid frequency
- Requires power electronic converter
- 100s of components!
- But modularisation and homogenisation can give good reliability
- Good QA required!

Summary



- Possible move to two blades?
- Direct drive or multiple path drive train
- Permanent magnet synchronous generator
- Active blade control to reduce loads – or variable speed stall regulation
- Modular converter
- Better understanding of loads
- Embedded intelligent condition monitoring
- Good QA