Wind Turbine Configuration for the Offshore Environment

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Overview

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

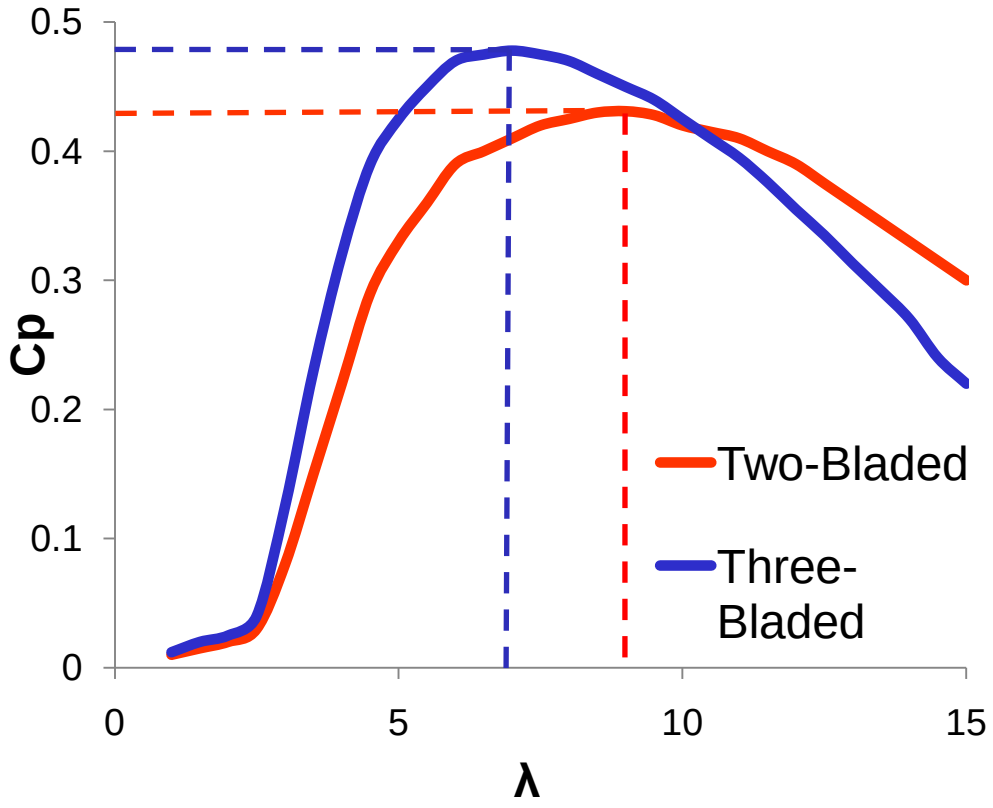
Issues

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

Implications

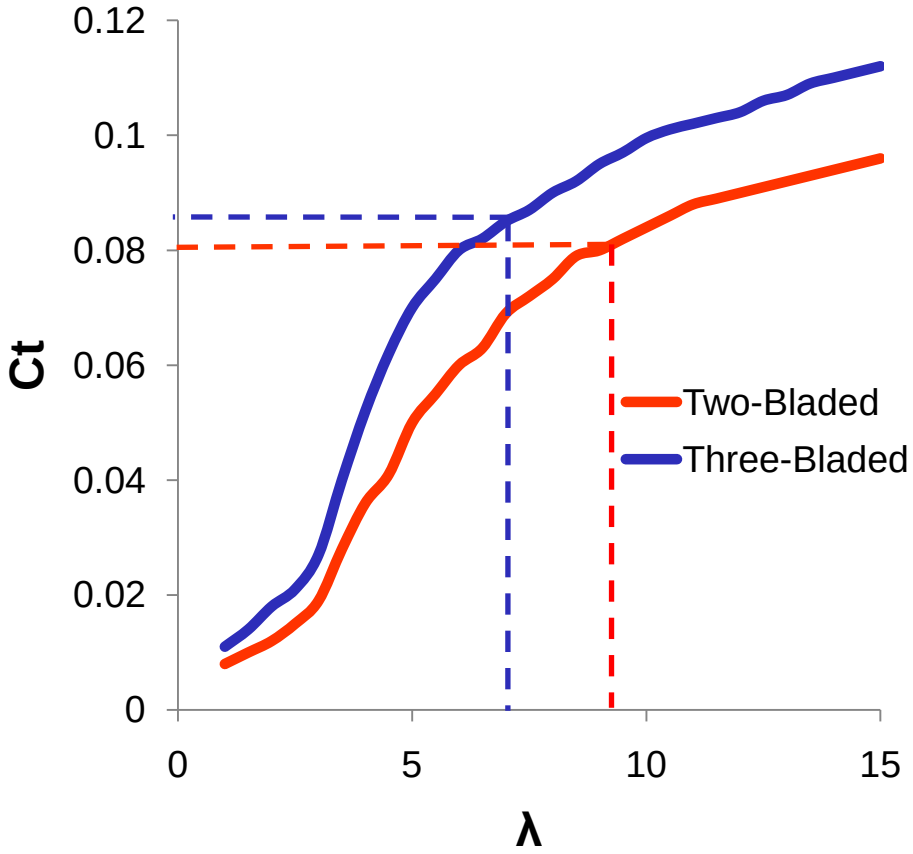
- Design
- Reliability
- Availability
- Operations and Maintenance

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...



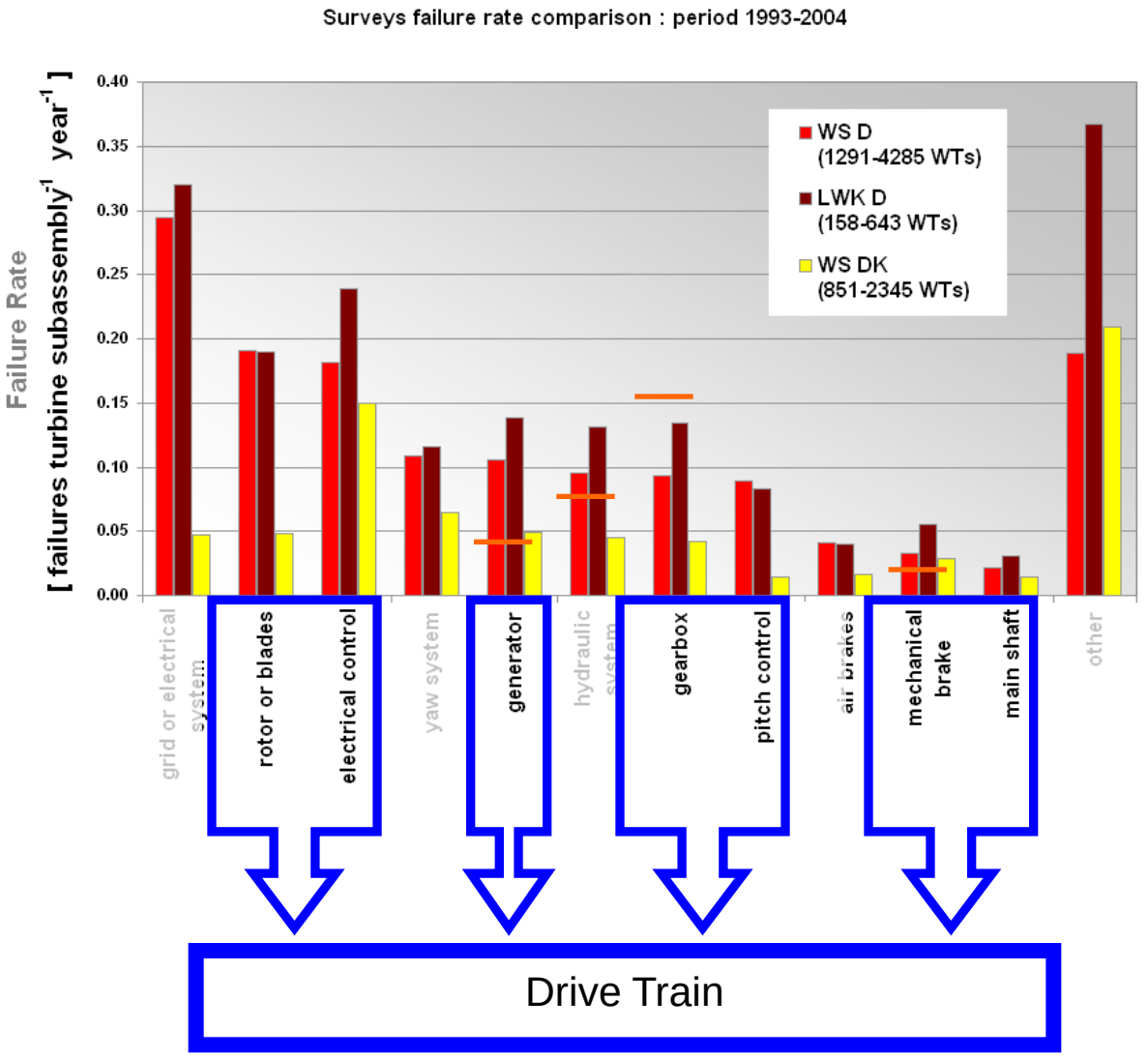
- Thrust load less for two blades

And Two Blades Can Teeter...

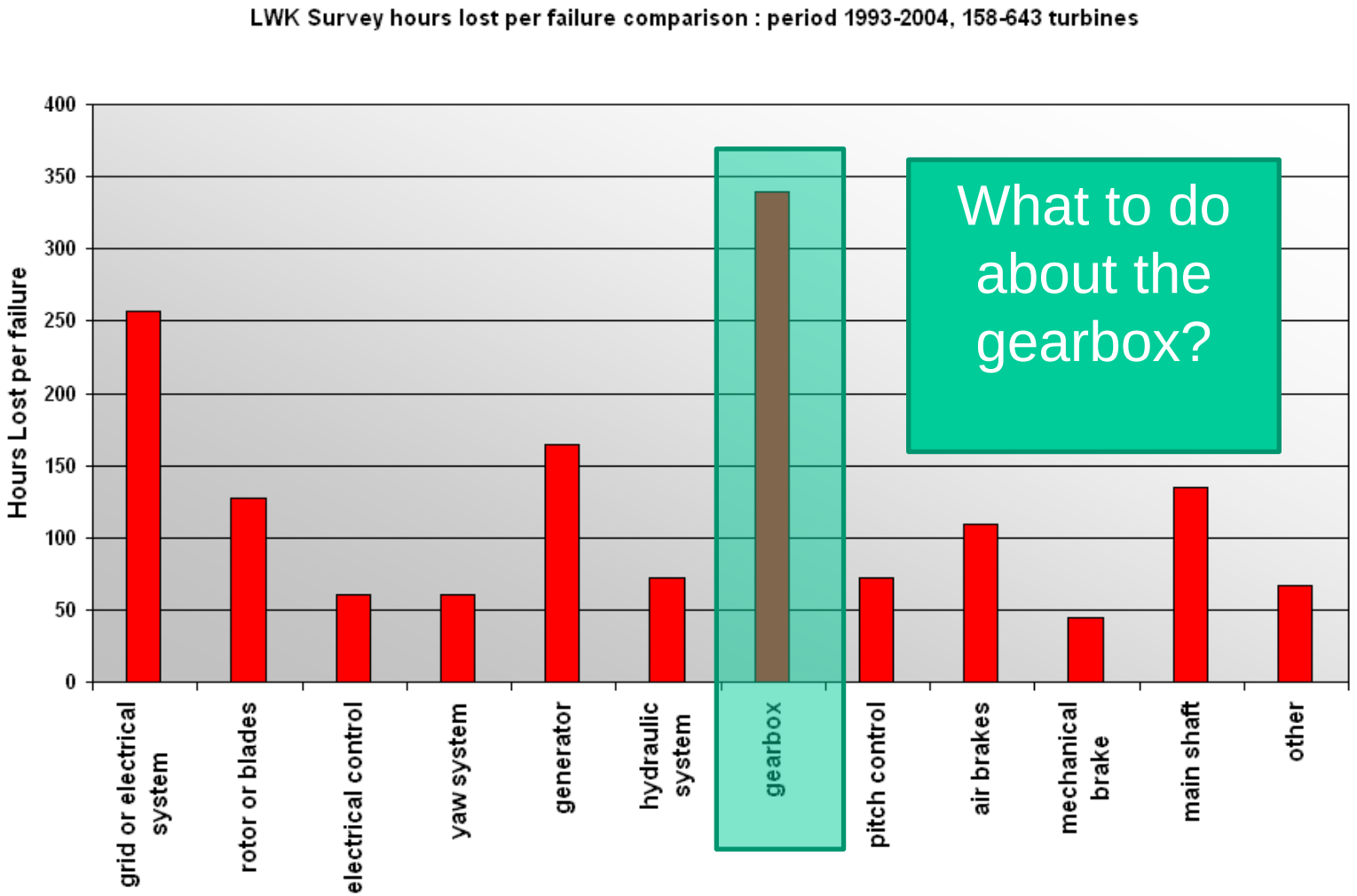
- Teetering can further reduce bending moments on the blades

Wind Turbine Reliability

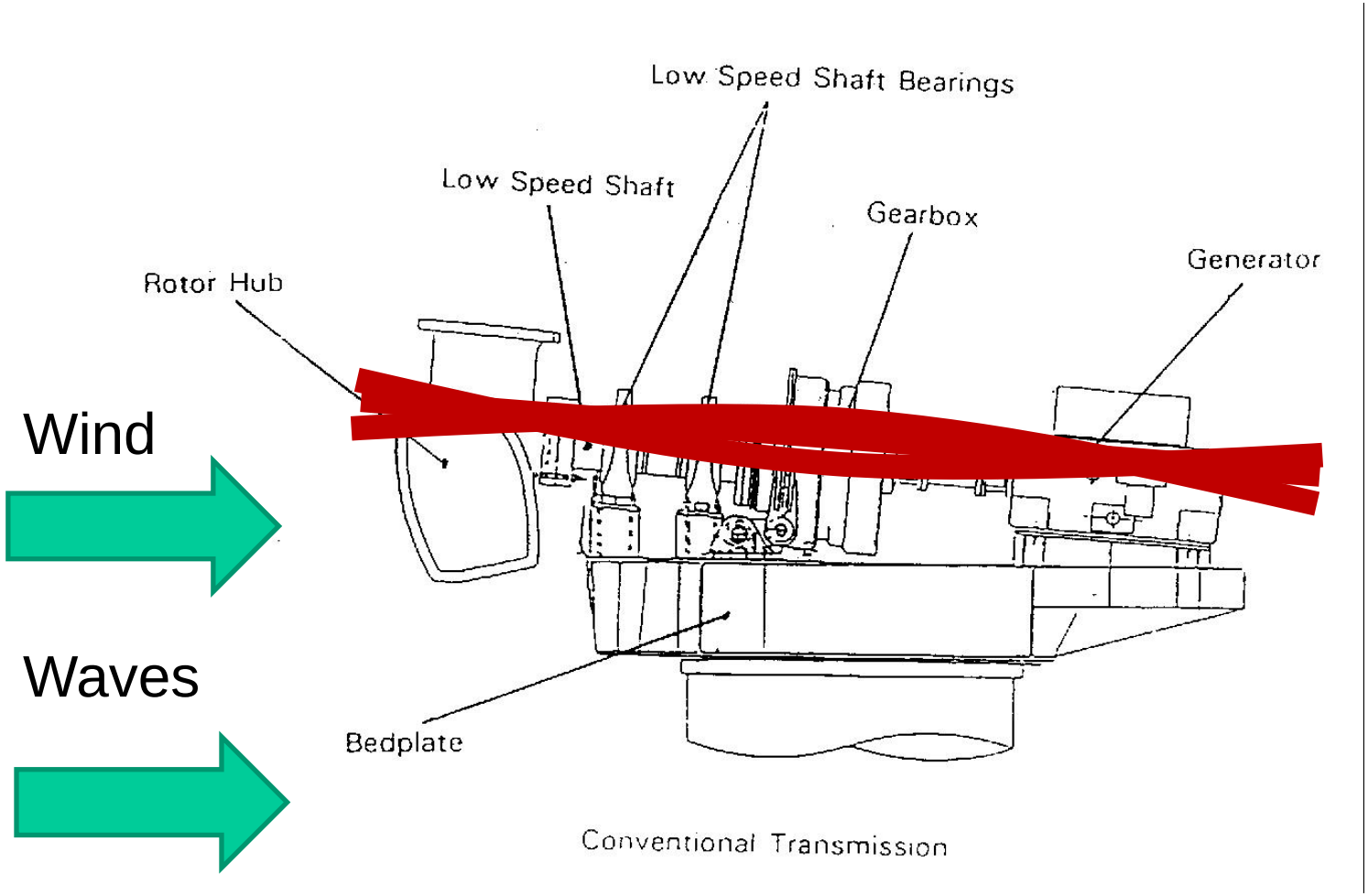
Industrial Reliability figures



Downtime


LWK Survey hours lost per failure comparison : period 1993-2004, 158-643 turbines
Hours Lost per failure
400
350
300
250
200
150
100
50
0
grid or electrical system
rotor or blades
electrical control
yaw system
generator
hydraulic system
gearbox
pitch control
air brakes
mechanical brake
main shaft
other
What to do about the gearbox?

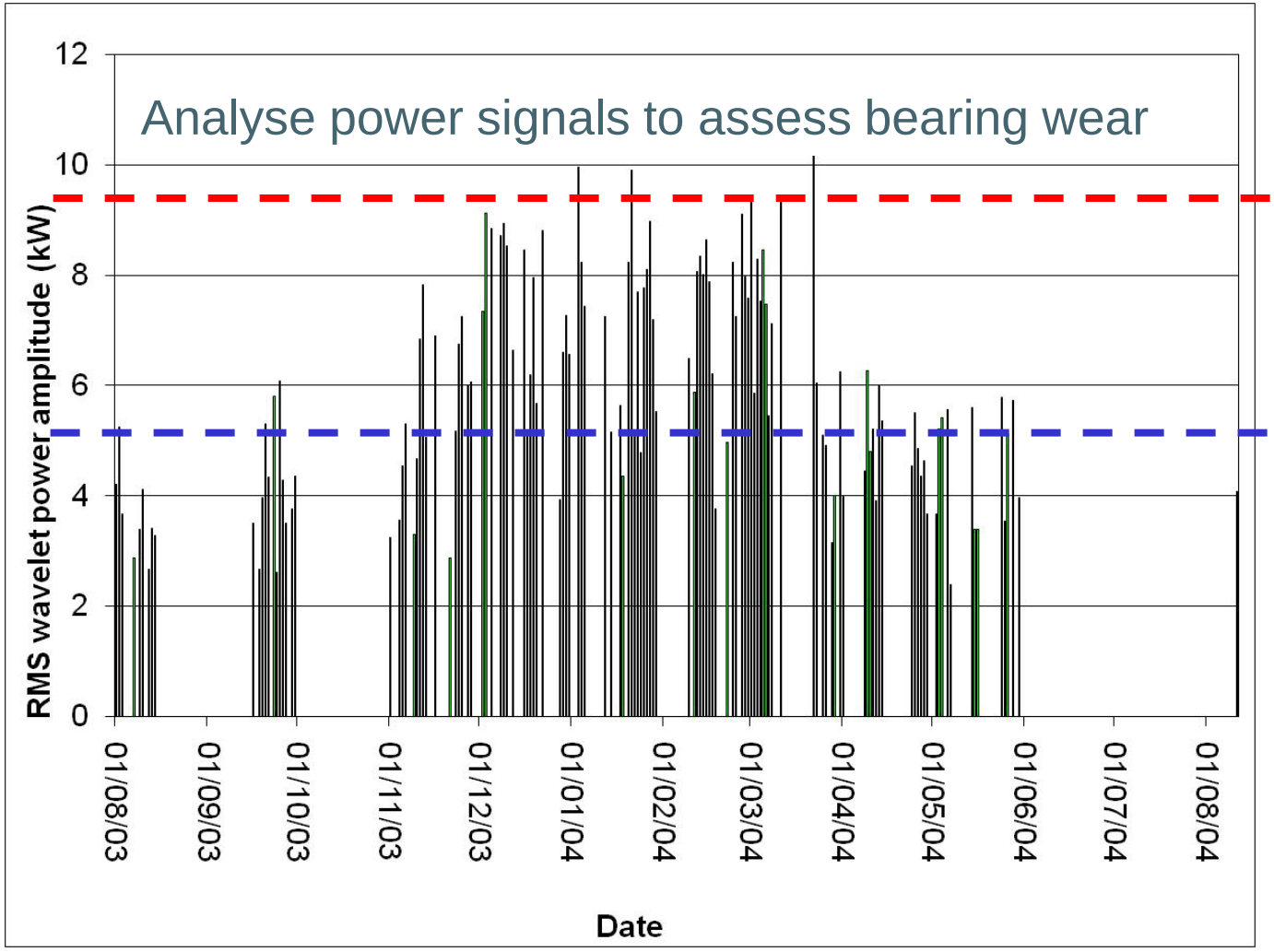
Drive Train Misalignment



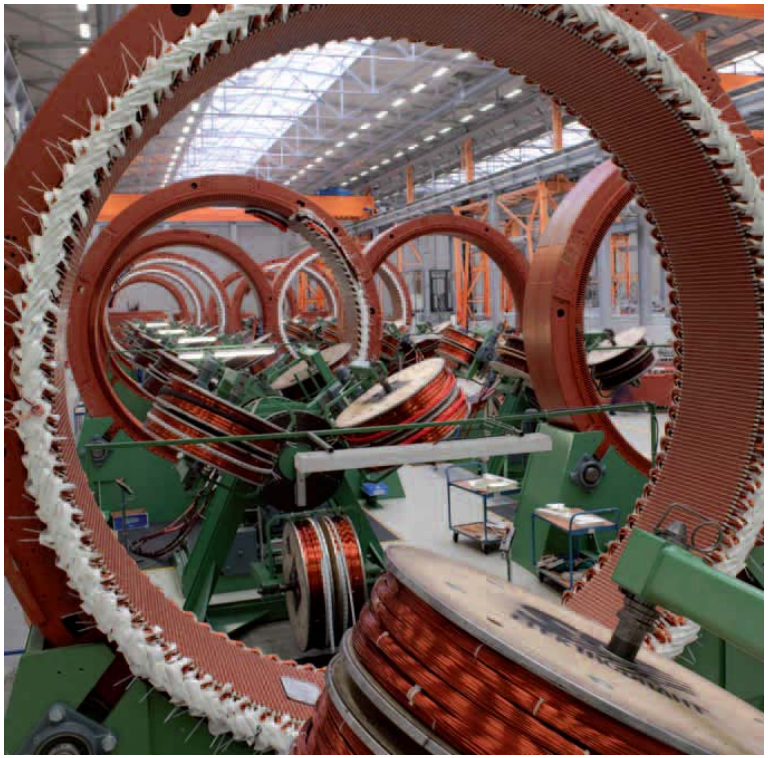
Things to Consider

- 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 ⇨ 1:83.3 ratio
- No gearbox, same rotor speed ⇨ ~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

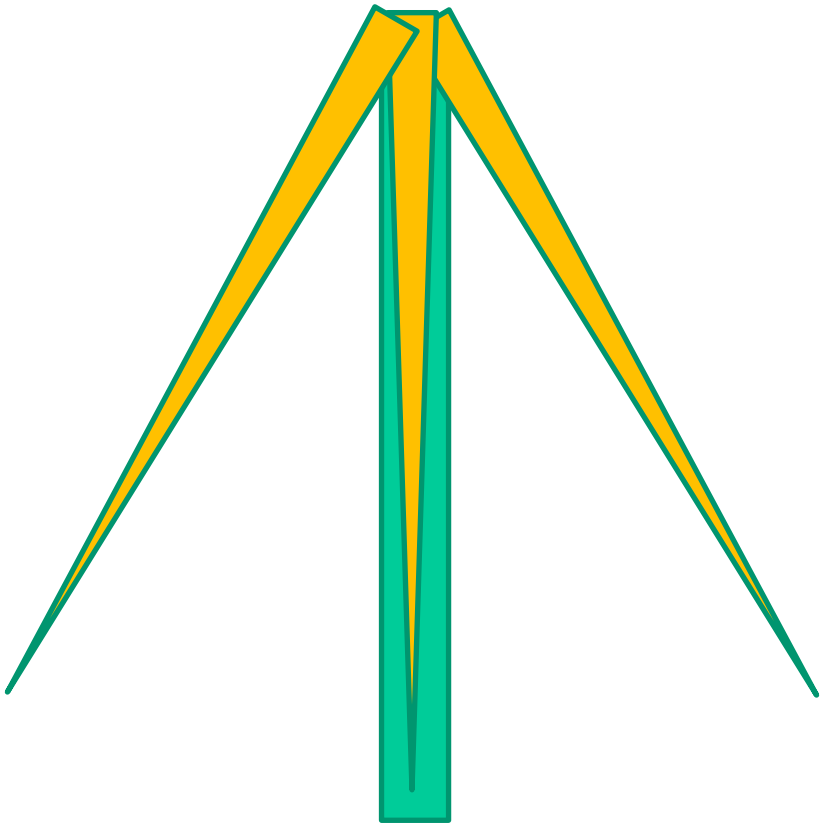
- Multiple-path drive train, i.e. more smaller gearboxes/generators, reducing loads on individual gearboxes/generators
- Loss of one gearbox/generator does not stop machine completely
- Permanent magnet generator, higher efficiency and more robust

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

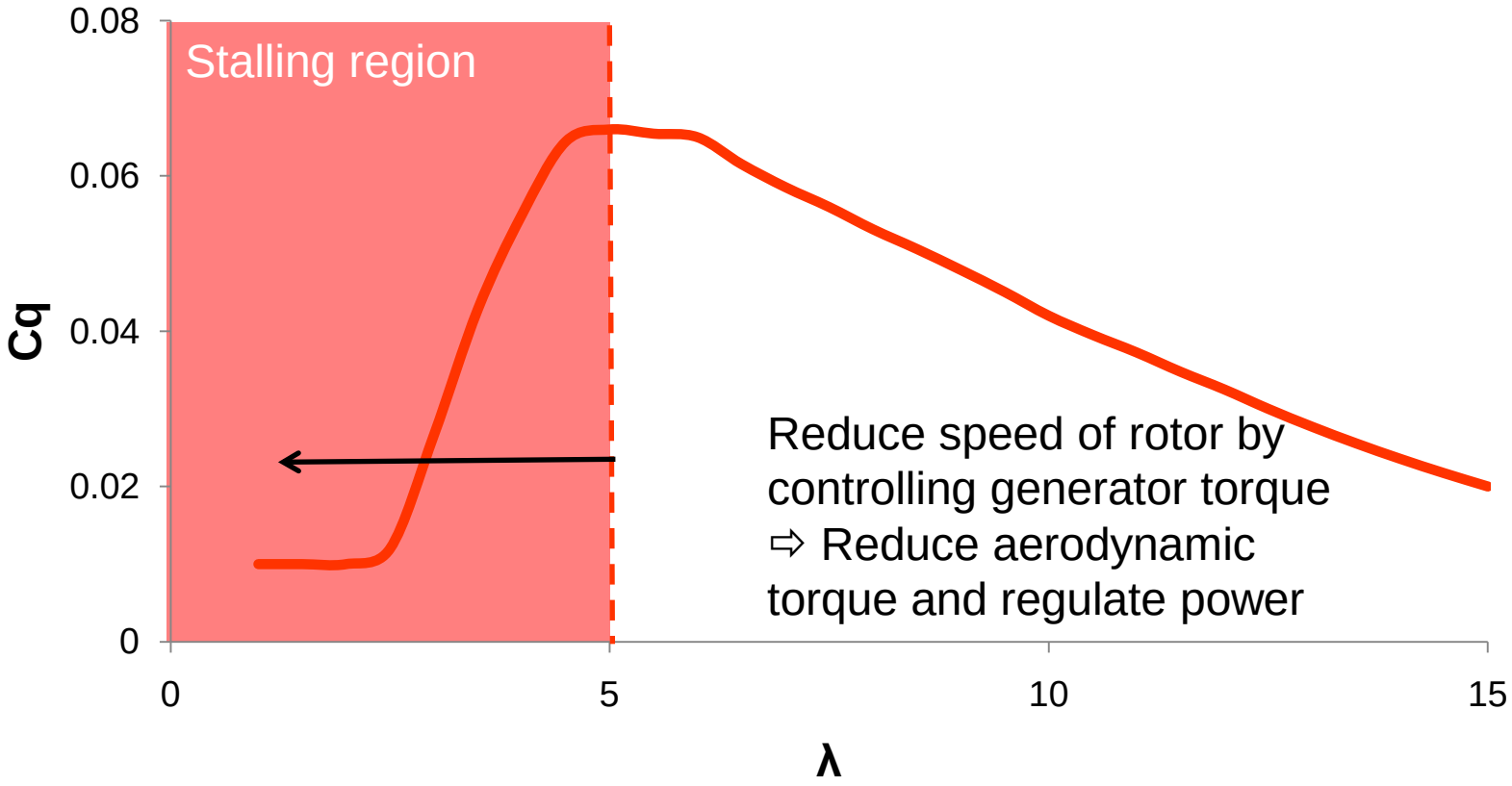
Tower Shadow



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