Decision Making as the Wind Blows

- A Perspective on Wind Energy Control

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2003 MSc.EE. From Aalborg University, DK, Automatic Control

2009 PhD, Lund University, SE, Automatic Control
Resource control for Internet web servers

2010 - Vestas Wind Systems, DK, Control Development
Control and coordination of wind turbines

What I will Cover

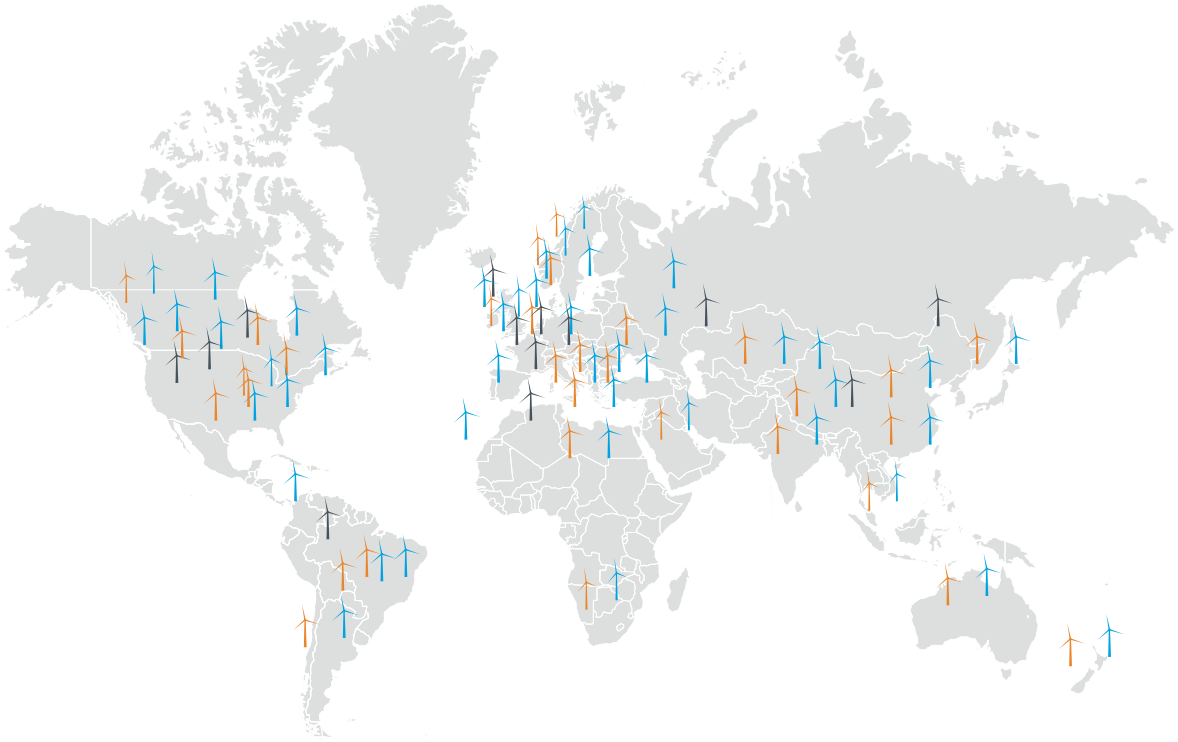
1. Vestas (I got some slides from Marketing)
2. What is a Wind Turbine
3. How do you control it?
4. What is in the future?

About Vestas

Vestas at a glance

Vestas **designs**, **produces**, **commissions**, and **services** wind turbines and wind turbines farms.

Today, we have installed over **46,000** turbines in **69** countries around the world.



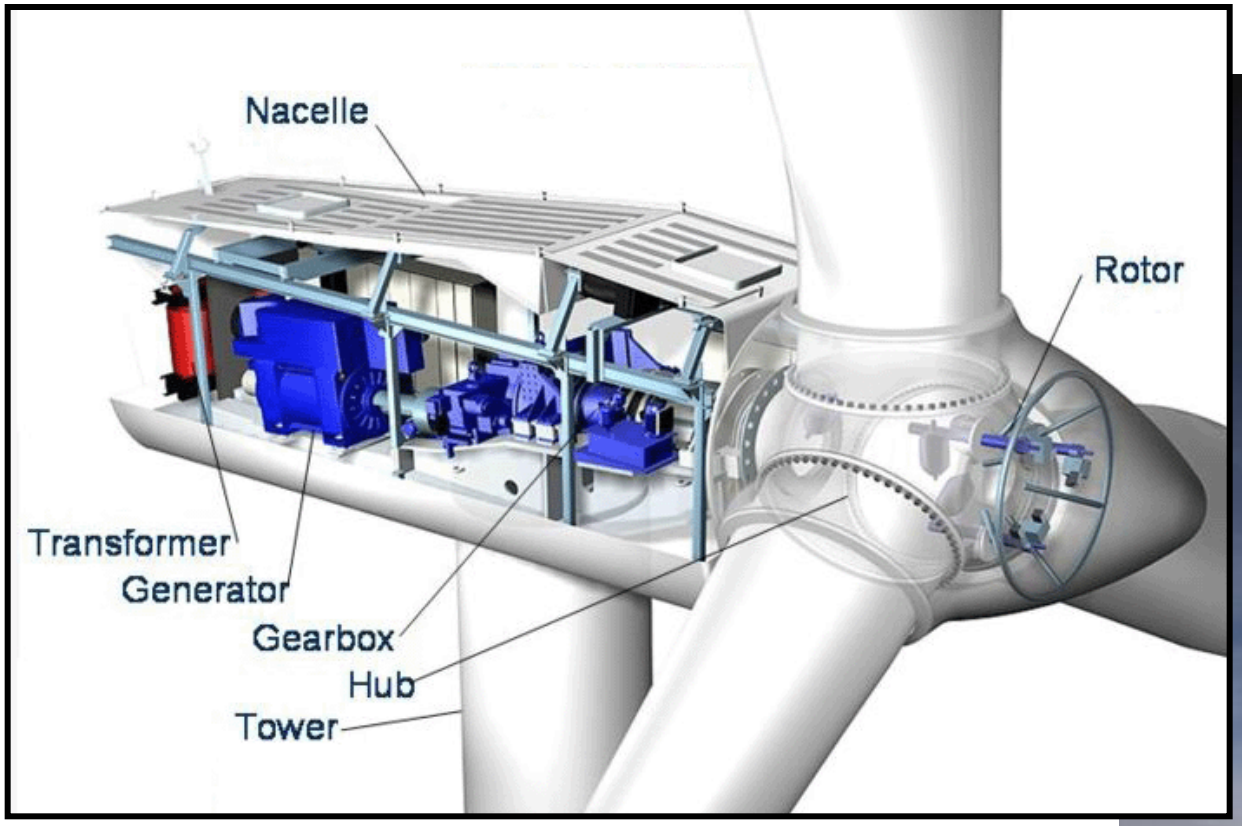
About Vestas

Vestas people

More than **20,000 people** committed to wind, representing more than **85 nationalities**.

Approx. **2,000 people** in R&D

What is a Wind Turbine Generator?



Trends in the Wind Area

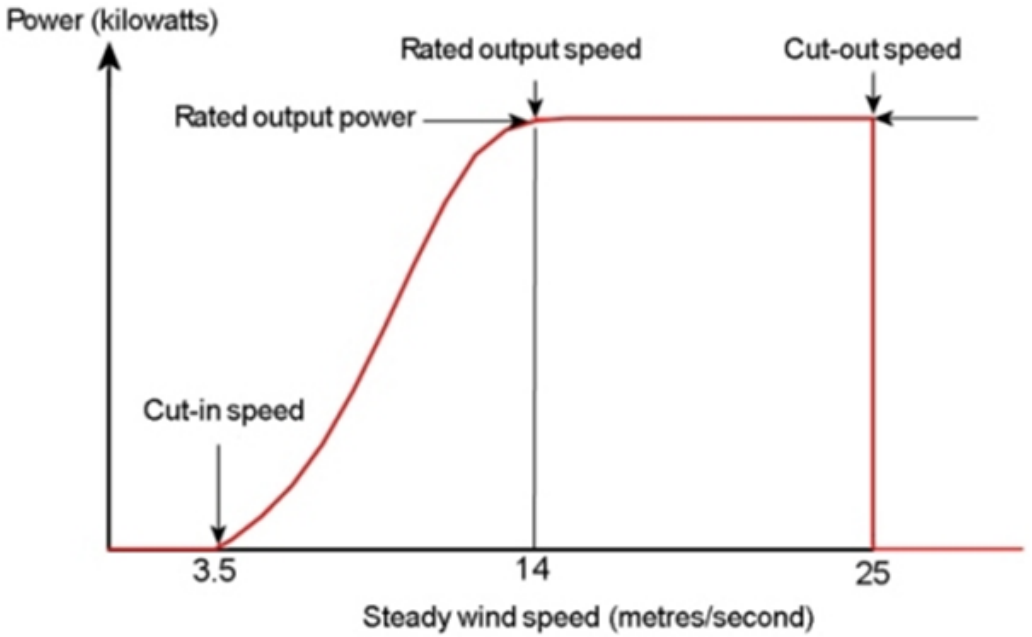
- Offshore
- Larger turbines
- Grid support
- Power Plant

How to Control a Wind Turbine?

- **Low wind speed**
  - Extract as much power as possible – optimal pitch setting
- **High wind speed**
  - Extract as much as the possible without harming the turbine (both mechanical structure and electrical components) – Control by changing the pitch.

Goal:

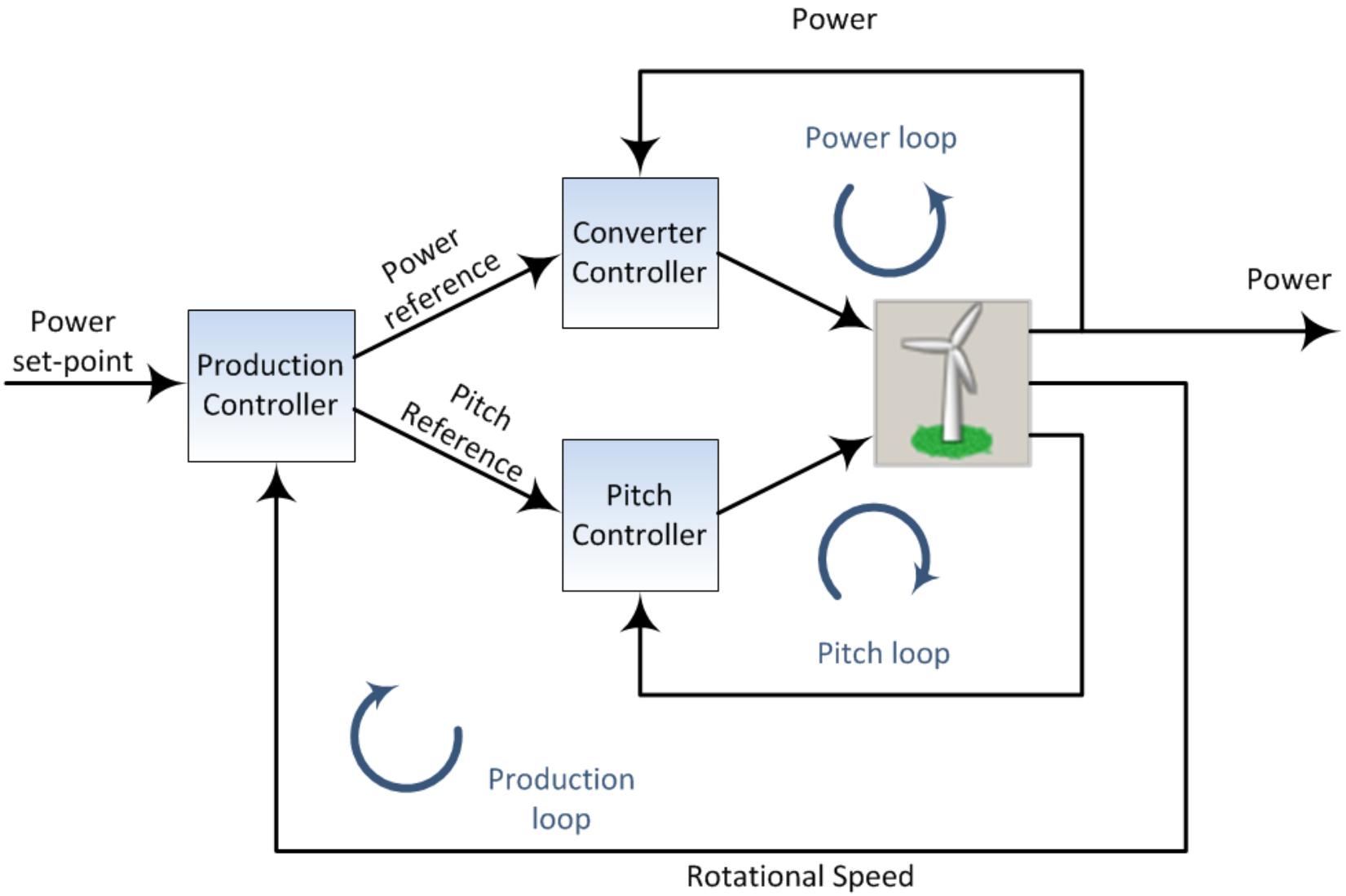
- Optimize power production of wind turbine
- Ensure structural loads are under control
- Start/stop/emergency procedures
- Grid requirements (FRT, ramp rates, …)



Typical wind turbine power output with steady wind speed.

Wind Turbine Control

Local Turbine Control



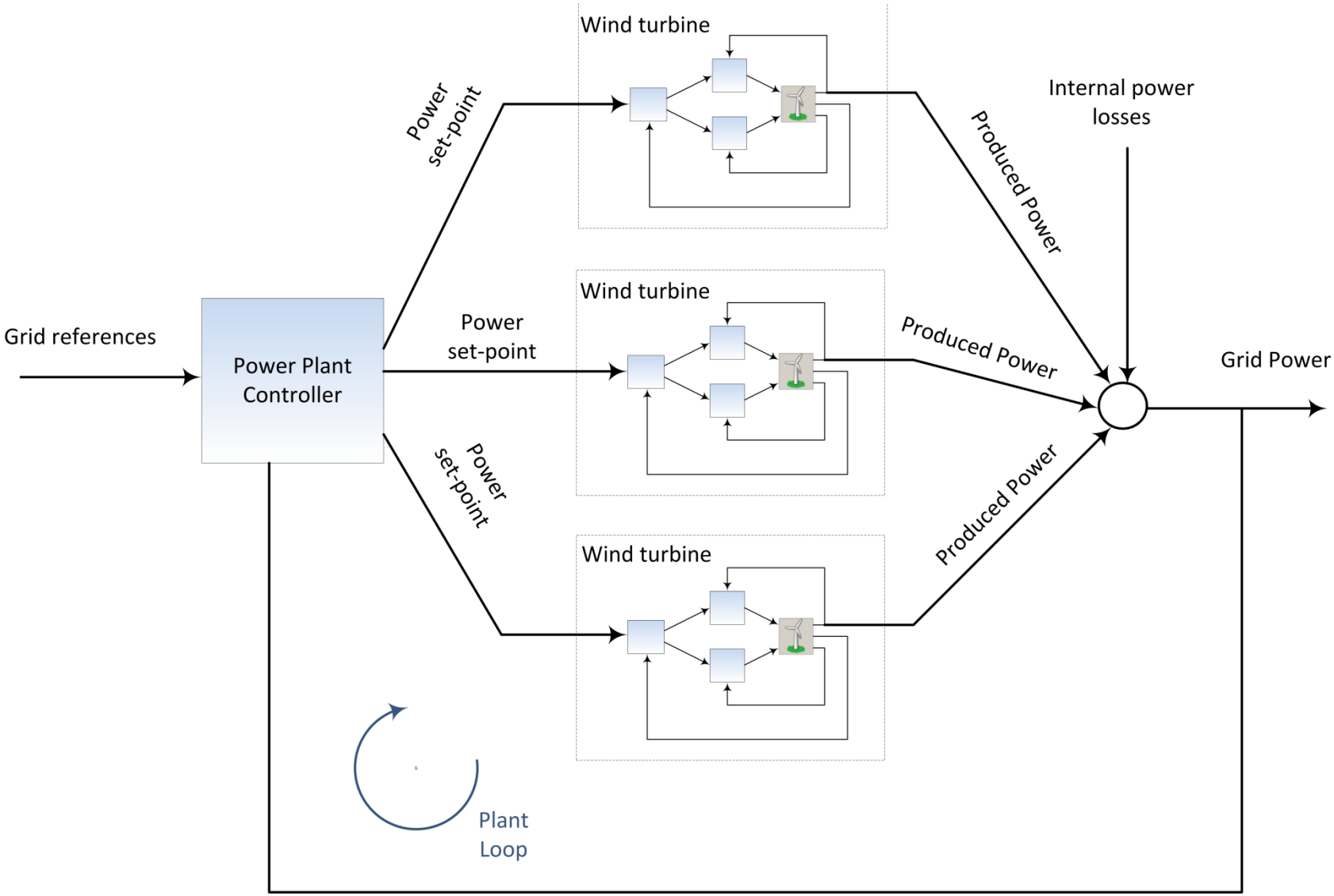
What is a Wind Farm?

A number of turbines at the same location
One common grid connection point
One common reporting and control unit

Can often support the grid
Easy control of many turbines

Wind Turbine Control

Plant Control



Turbine Control
Control Methodology

Classical control Methodology:

- Feed-forward
- Feed-back
- Cascaded control
- PID control
- Gain scheduling
- Switch logics
- Integrator anti-windup
- Static nonlinearity compensation

Why do we still use classical control methodology?

- Control engineers know them and thrust them (proven technology)!
- Robust towards unmodeled dynamics (which are never well represented by parameter variations)
- Relative modular. That is, you can add or remove specific functionalities without having to retune the entire system.

Turbine Control & Operation

What is in the future?

Academic popular areas:

- Modeling
  - System identification (track resonance frequencies, changes, …)
  - Probabilistic predictions of worst case
- Large interest in MPC
  - Many interesting results
  - No really mature yet (maybe industry lacks experience)
- LIDAR technology
  - Expected to improve performance significantly
  - Modeling issues (more on next slide)?
  - VERY expensive.
- Farm Optimization (more on coming slides)
  - Answer the question: Can turbines be operated better if their interaction (through the wind) is taken into consideration?
  - Many models and solutions presented
  - Extremely hard to test in real life (unpredictable wind, high noise levels, experiments cannot be reproduced)

LIDAR

What happens between points of measurement and the rotor?

- High frequency turbulernce?
- Extreme events?
- Wind shear?

Wind Farm Control

Wake effects

Seen from a down-wind turbine, upwind turbines disturb the wind field

- Decreased wind speed
- Increased turbulence

Greedy turbine (Industry) – All turbines maximize their OWN production
Team players (Academic) – Coordinate turbines to ensure that TOTAL power is maximized

Wind Farm Control

Challenges

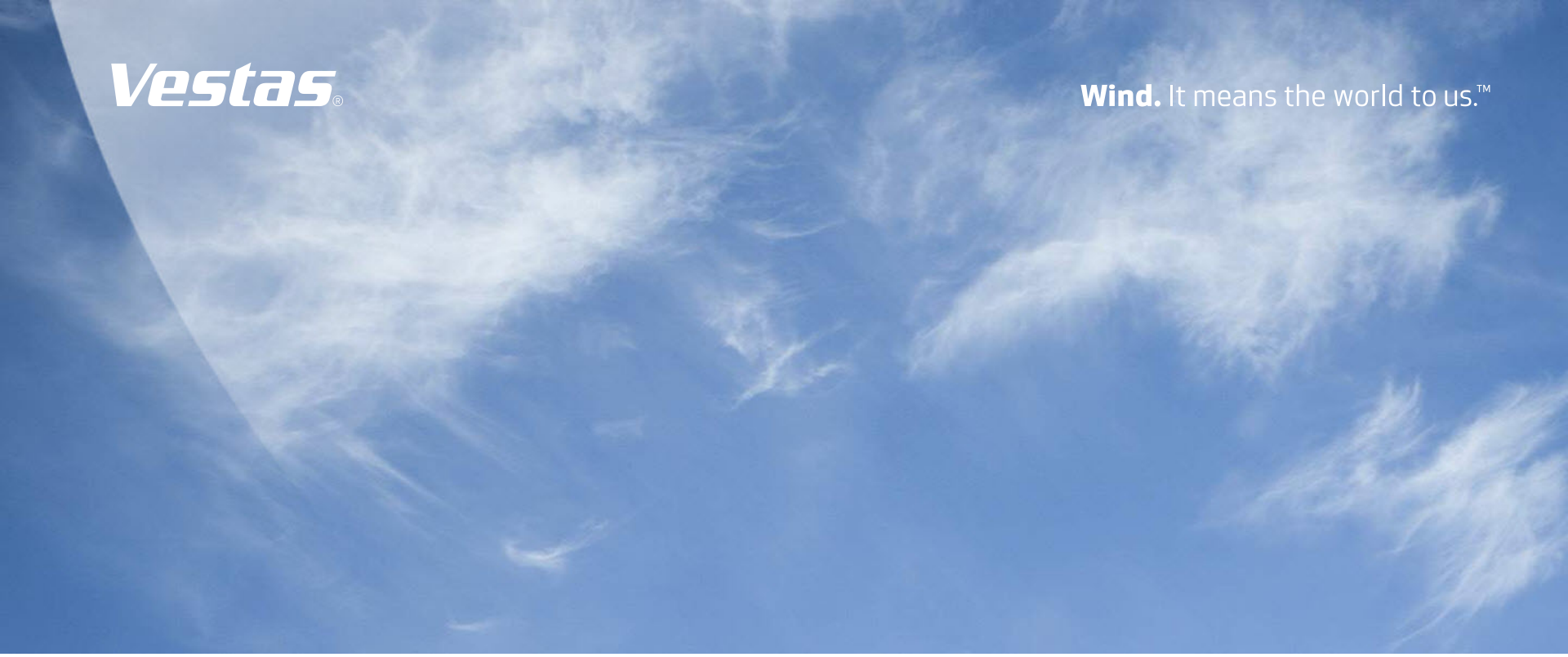
Modeling: Extremely hard to test in real life

Communication infrastructure

- Long communication lines (imagine 10x10 turbines with 500 m spacing ~ 50 km excl. land connection) in
- Harsh environments offshore

Expected benefits:

- Additional production (chip tuning)
- And/or less structural loads, allowing the producer a simpler (cheaper) construction



Thank you for your attention