



# Decision Making as the Wind Blows

- A Perspective on Wind Energy Control

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

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*Control and coordination of wind turbines*

# What I will Cover

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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?

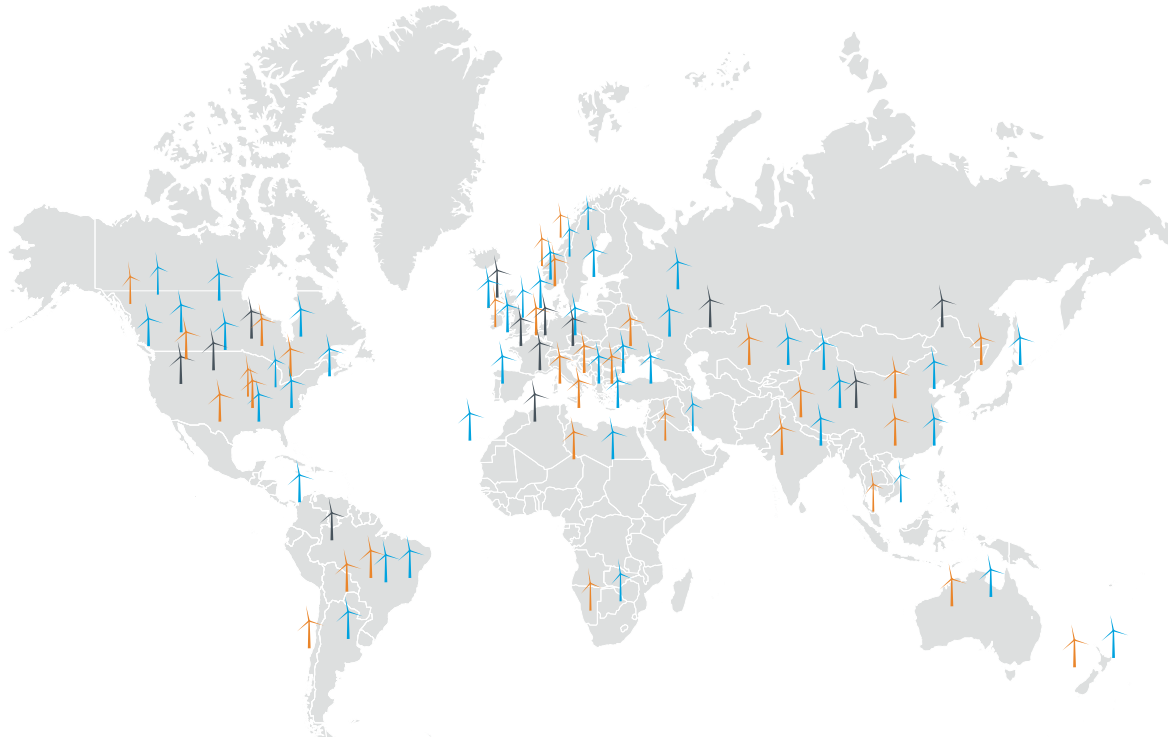
# About Vestas

## Vestas at a glance

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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.



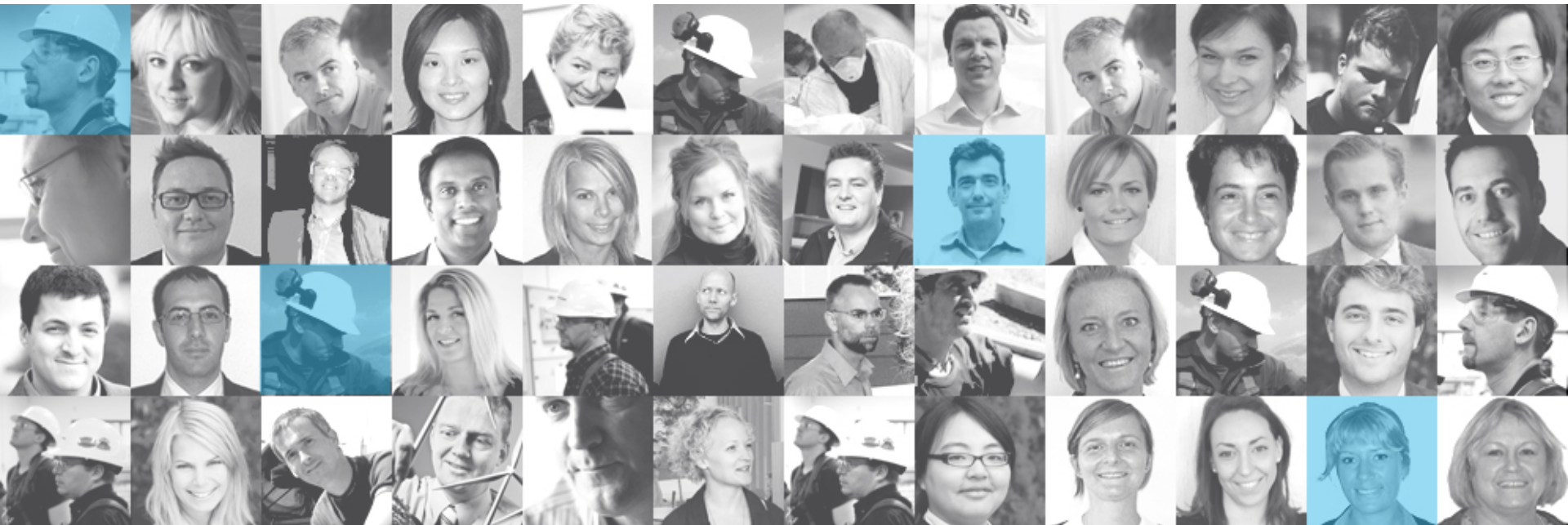
# About Vestas

## Vestas people

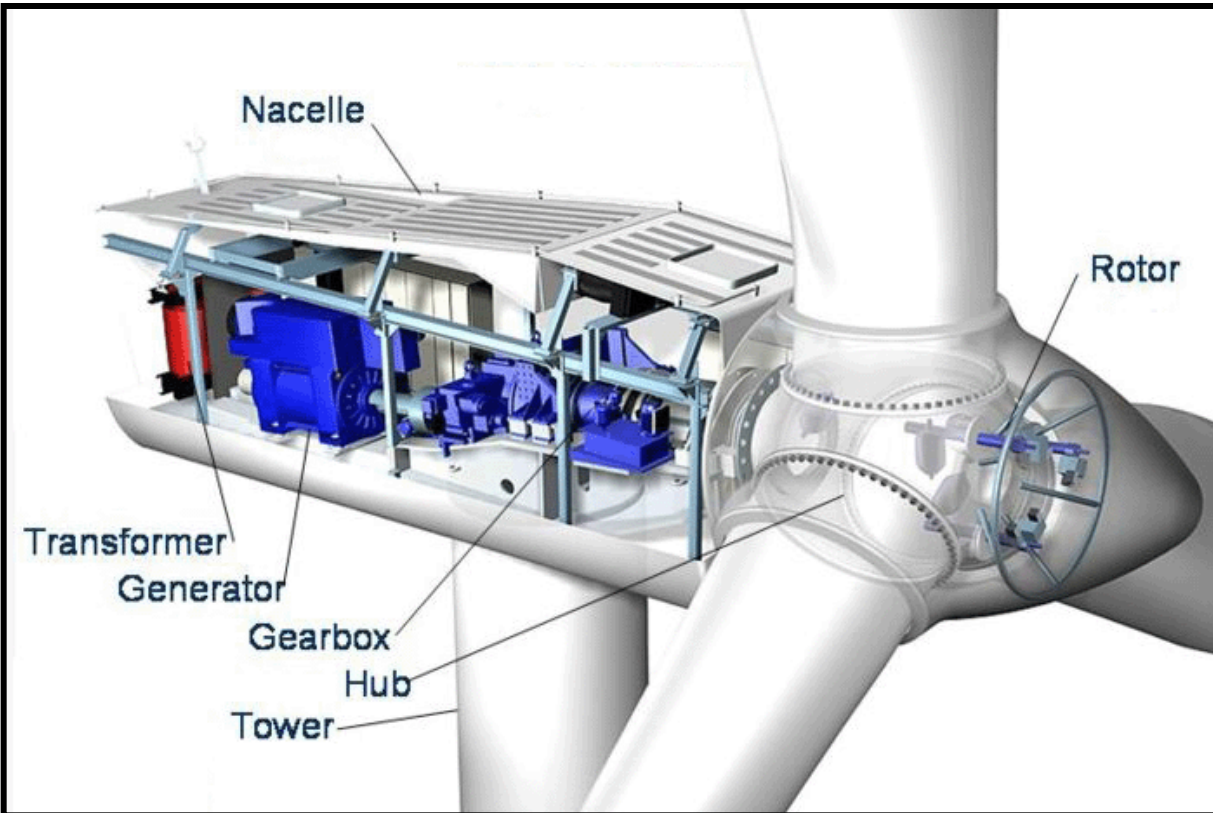
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More than **20,000 people** committed to wind,  
representing more than **85 nationalities**.

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



# What is a Wind Turbine Generator?



# Trends in the Wind Area

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- Offshore
- Larger turbines
- Grid support
- Power Plant

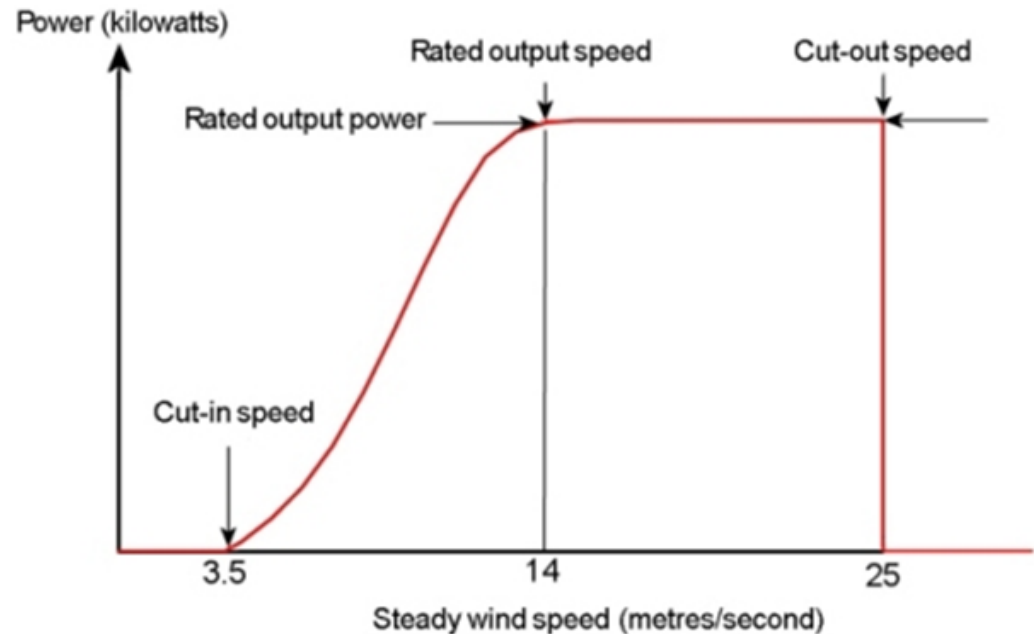


# How to Control a Wind Turbine?

- **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, ...)

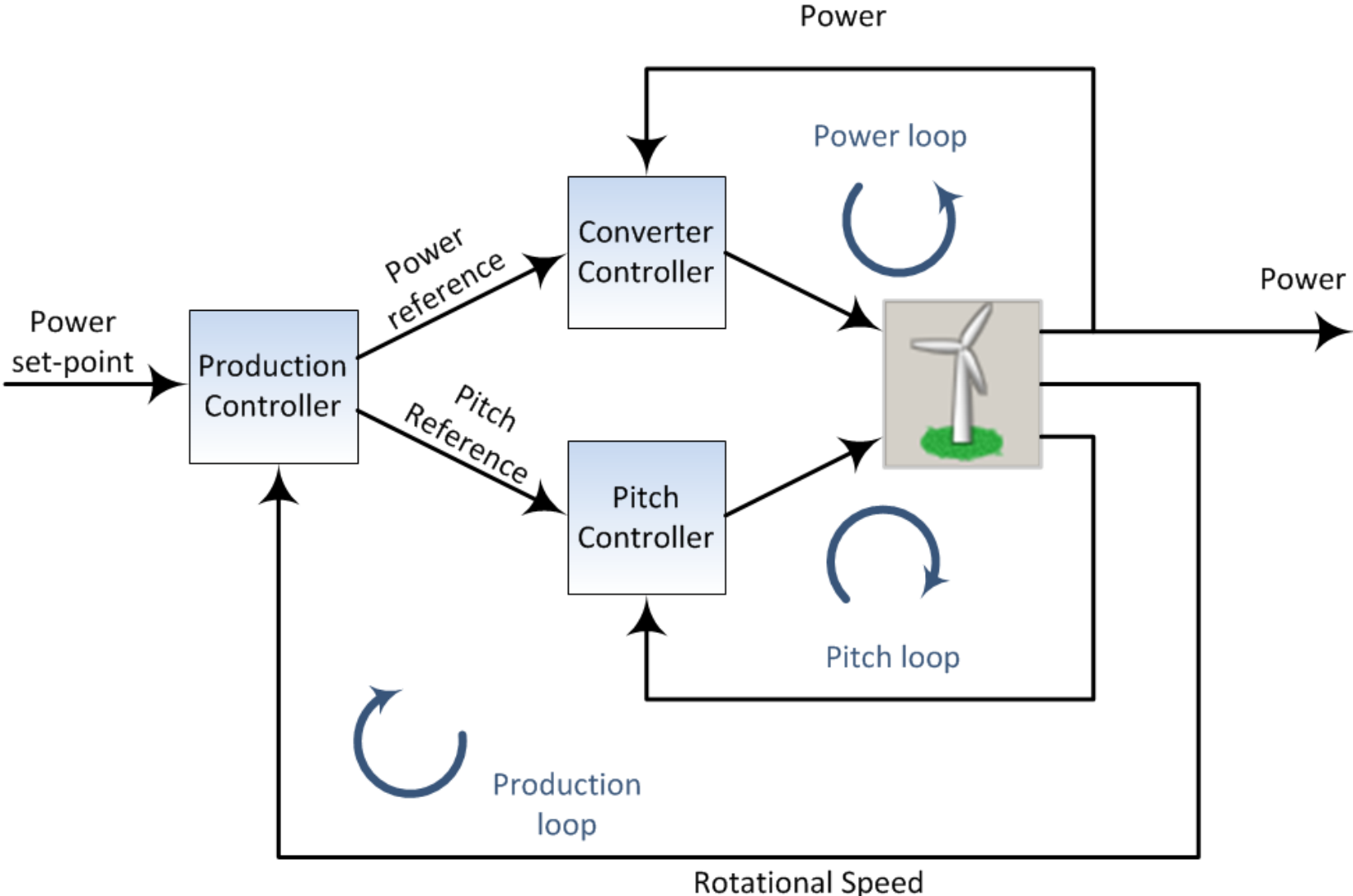


Typical wind turbine power output with steady wind speed.



# Wind Turbine Control

## Local Turbine Control



# What is a Wind Farm?

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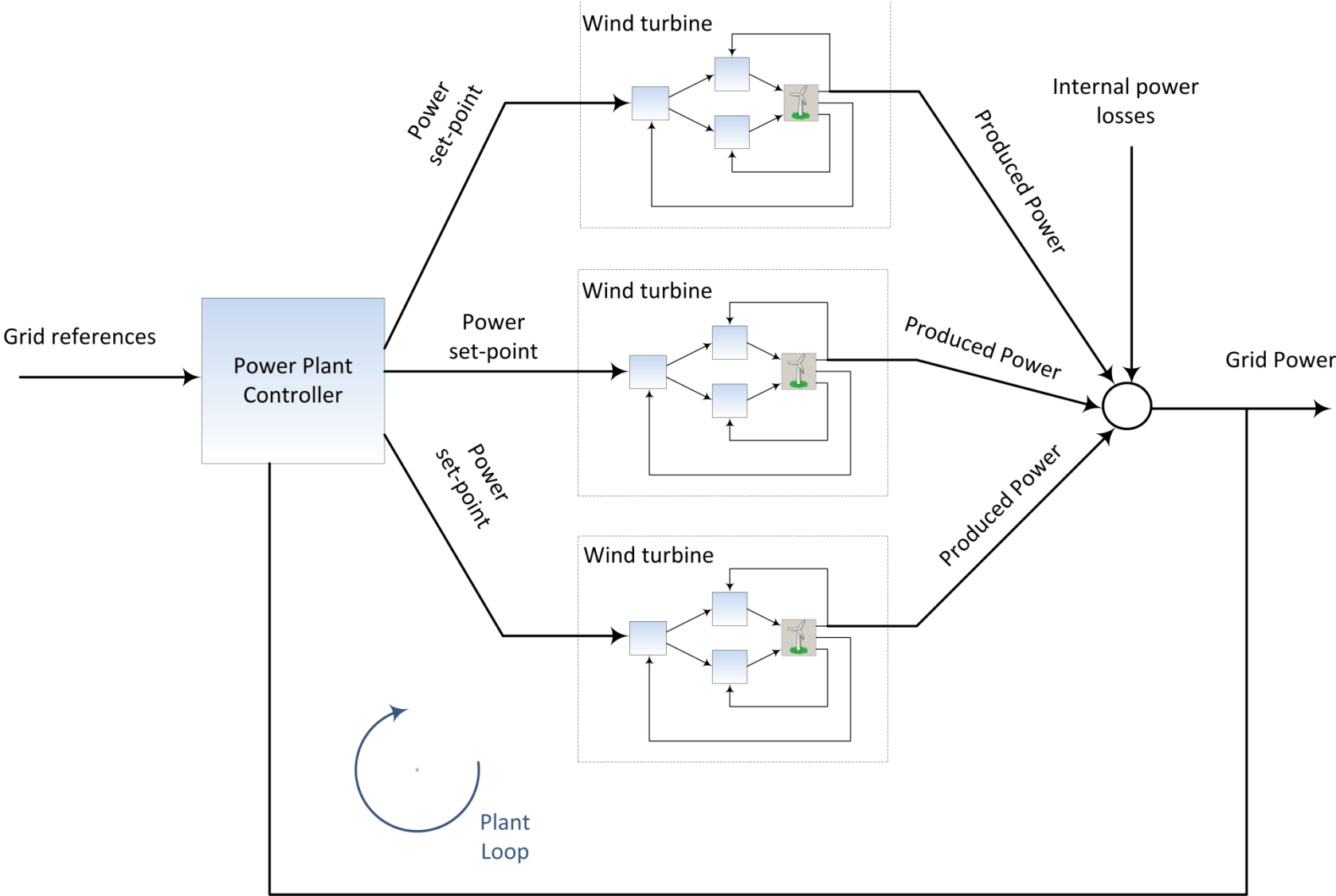
A number of turbines at the same location  
One common grid connection point  
One common reporting and control unit



Can often support the grid  
Easy control of many turbines

# Wind Turbine Control

## Plant Control



# Turbine Control

## Control Methodology

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### 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?

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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?

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- High frequency turbulence?
- 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

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





The Vestas logo is displayed in a white, italicized, sans-serif font. It is positioned in the upper left corner of the slide, which features a background of a bright blue sky with wispy white clouds. A semi-transparent blue curved shape is visible in the top left corner, partially overlapping the logo.

**Vestas**<sup>®</sup>

**Wind.** It means the world to us.<sup>™</sup>

# Thank you for your attention

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