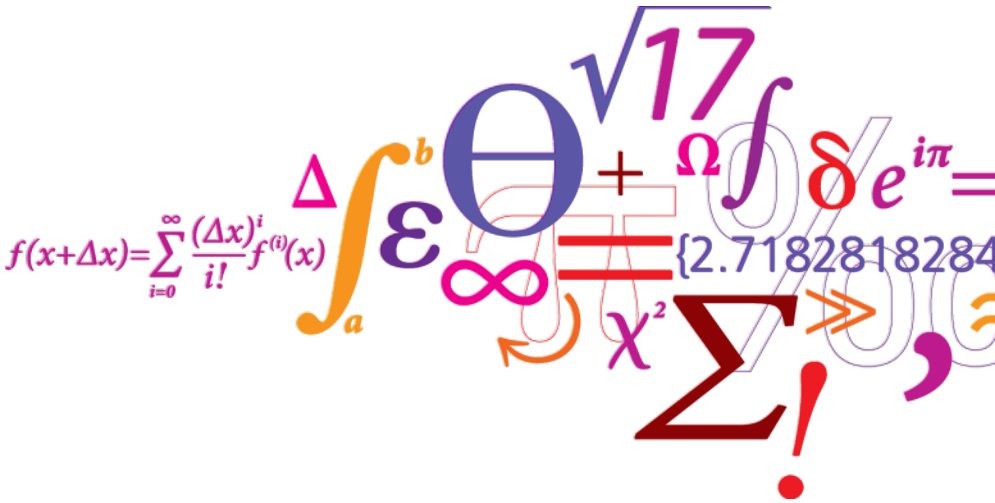
An Overview of Grid Requirements in Denmark and the DTU Advanced Grid Test Facility at Østerild

Tom Cronin
DTU Wind Energy
Technical University of Denmark



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Composite Mechanics

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> 230 staff members

- Composites and Materials Mechanics
- Materials Science and Characterisation
- Fluid Mechanics
- Test and Measurements
- Wind Turbines Structures
- Aerolastic Design
- Meteorology
- Wind Energy Systems

DTU Wind Energy

DTU – Excellence since 1829

Østerild test station

MISSION
DTU will develop and create value using the natural sciences and the technical sciences to benefit society

Main campus

Høvsøre test station

Risø campus

Overview of this presentation

- DTU Wind Energy
- What's the reason for me being at this workshop?
- The Danish grid requirements
  - Who, what and how?
- The DTU Advanced Grid Test Facility
  - Why, what, where and when?

Danish grid codes

- ”Technical regulation 3.2.5 for wind power plants with power output greater than 11kW”
- Issued by the Transmission System Operator: Energinet.dk
- Website: www.energinet.dk
- Due to history of Danish wind power, the Danish grid codes have been at the forefront
- Comprehensive grid codes are needed if have high penetration
- Occasions in Western Denmark when wind power exceeds consumption
- National annual average around 25%
- Average wind production to increase to meet the goal of 50% by 2025.
- Grid codes need to keep in front of this development.

The Danish Grid Codes - structure

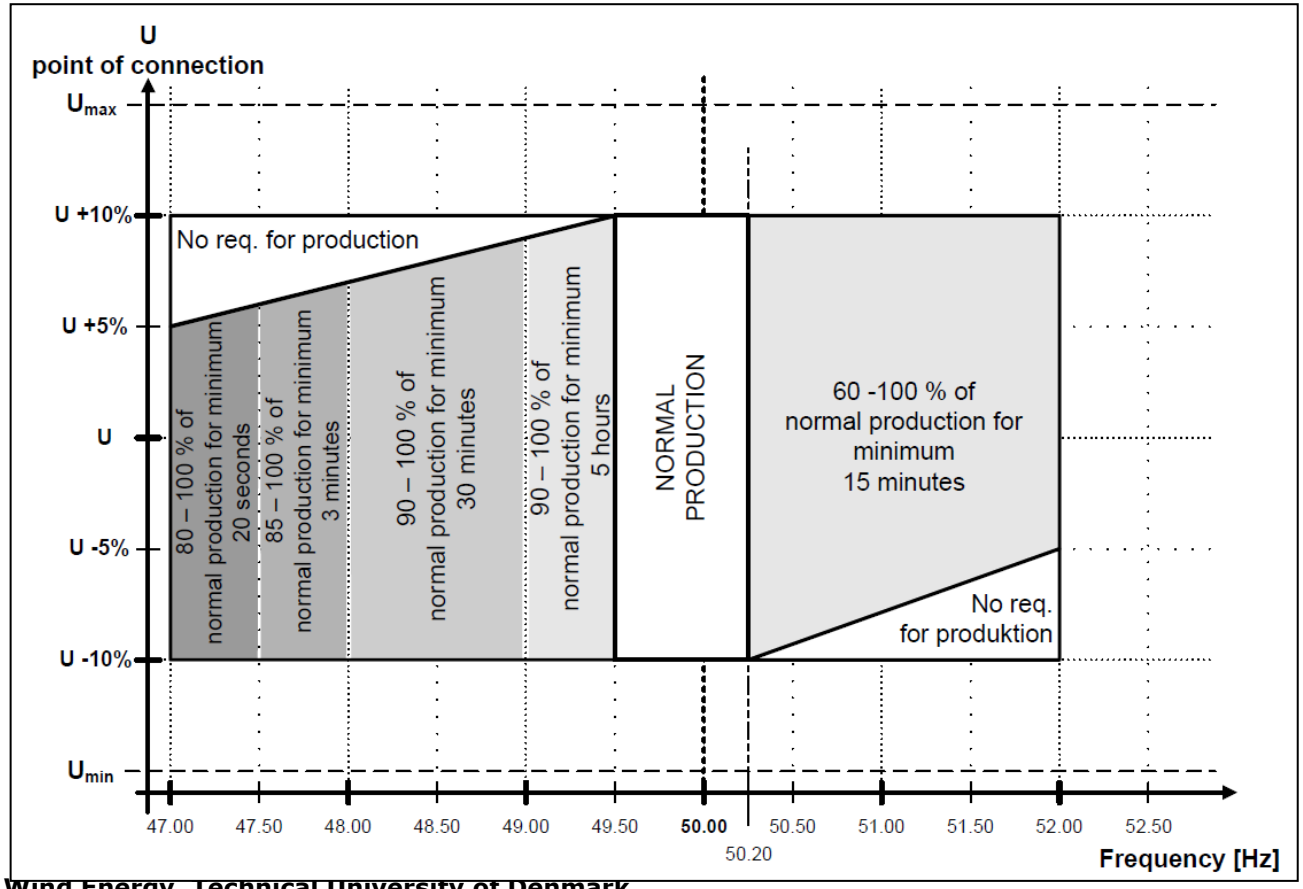
- Tolerance of voltage and frequency deviations
  - Normal operation
  - Abnormal operation
- Electricity quality
- Control and monitoring
- Protection
- Data communication and exchange of signals

All diagrams courtesy of Energinet.dk

Tolerance of frequency & voltage deviations

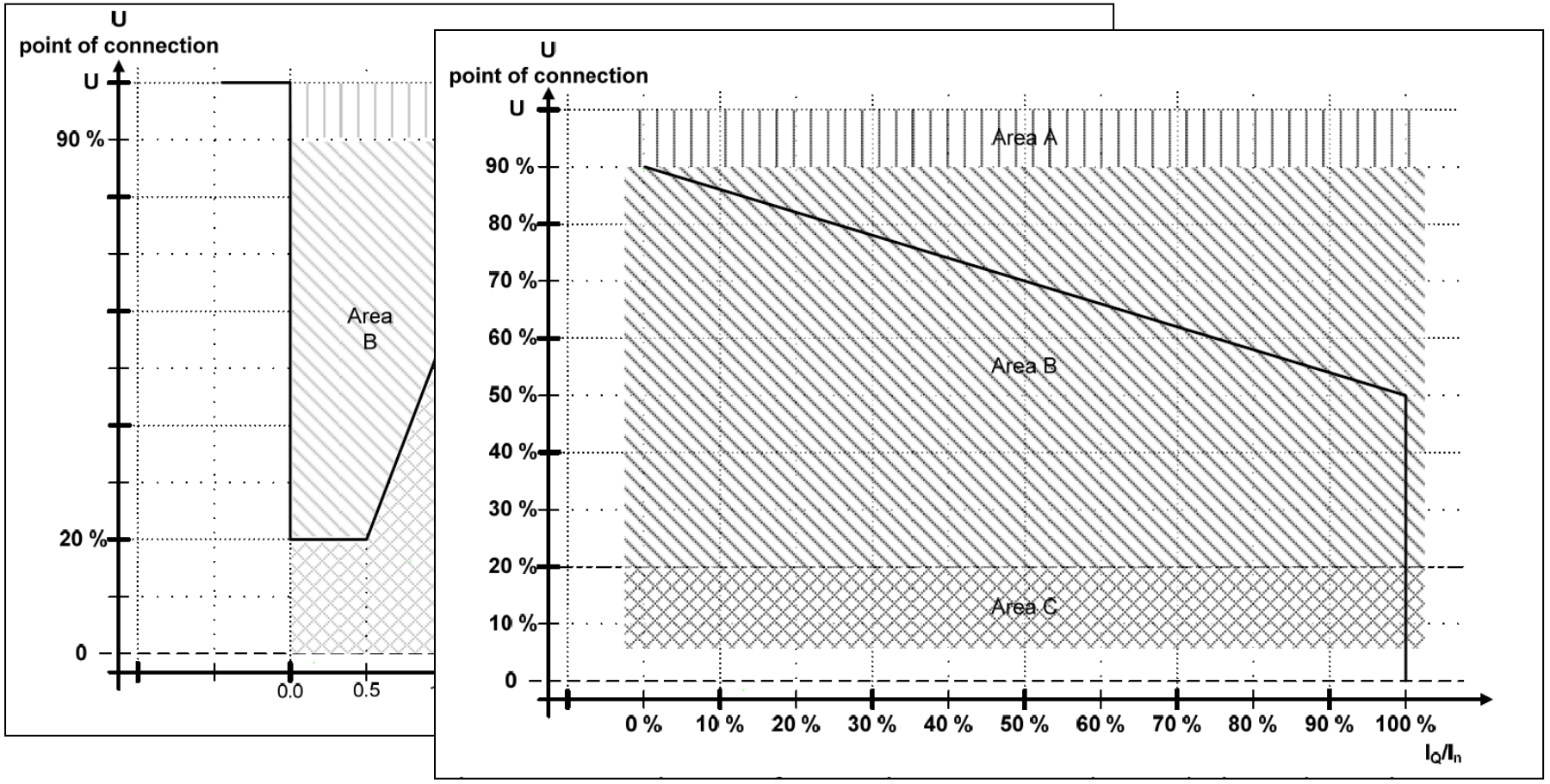
"A *wind power plant* must be able to withstand frequency and voltage deviations in the *point of connection* under normal and abnormal operating conditions while reducing the active power as little as possible."

Normal Operation



Tolerance of frequency & voltage deviations

Abnormal Operation



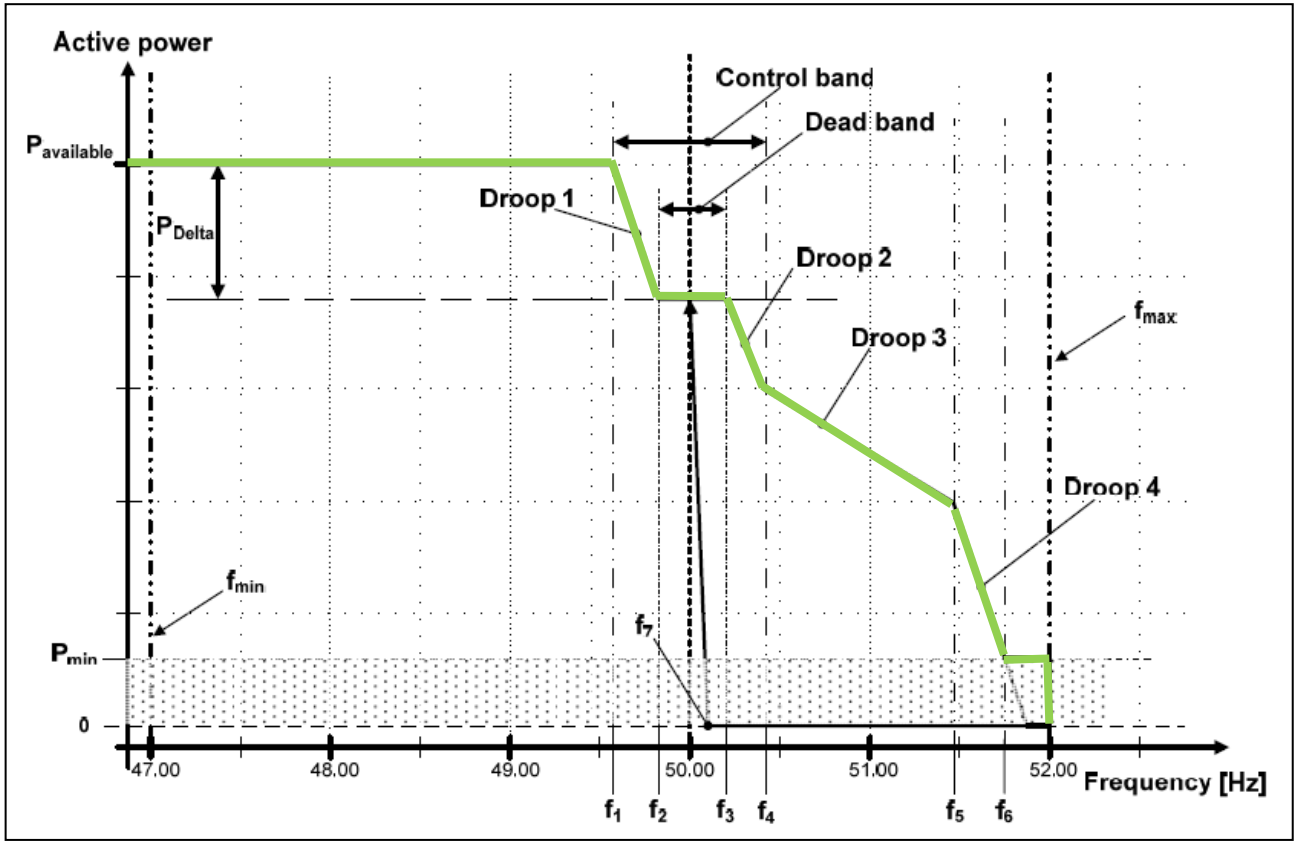
Electricity quality

The grid codes consider:

- Voltage fluctuations
  - Rapid voltage changes
  - Flicker (continuous and switching)
- High frequency currents and voltages
  - Harmonics
  - Inter-harmonics
  - Disturbances greater than 2 kHz

Control & Monitoring: Active power control

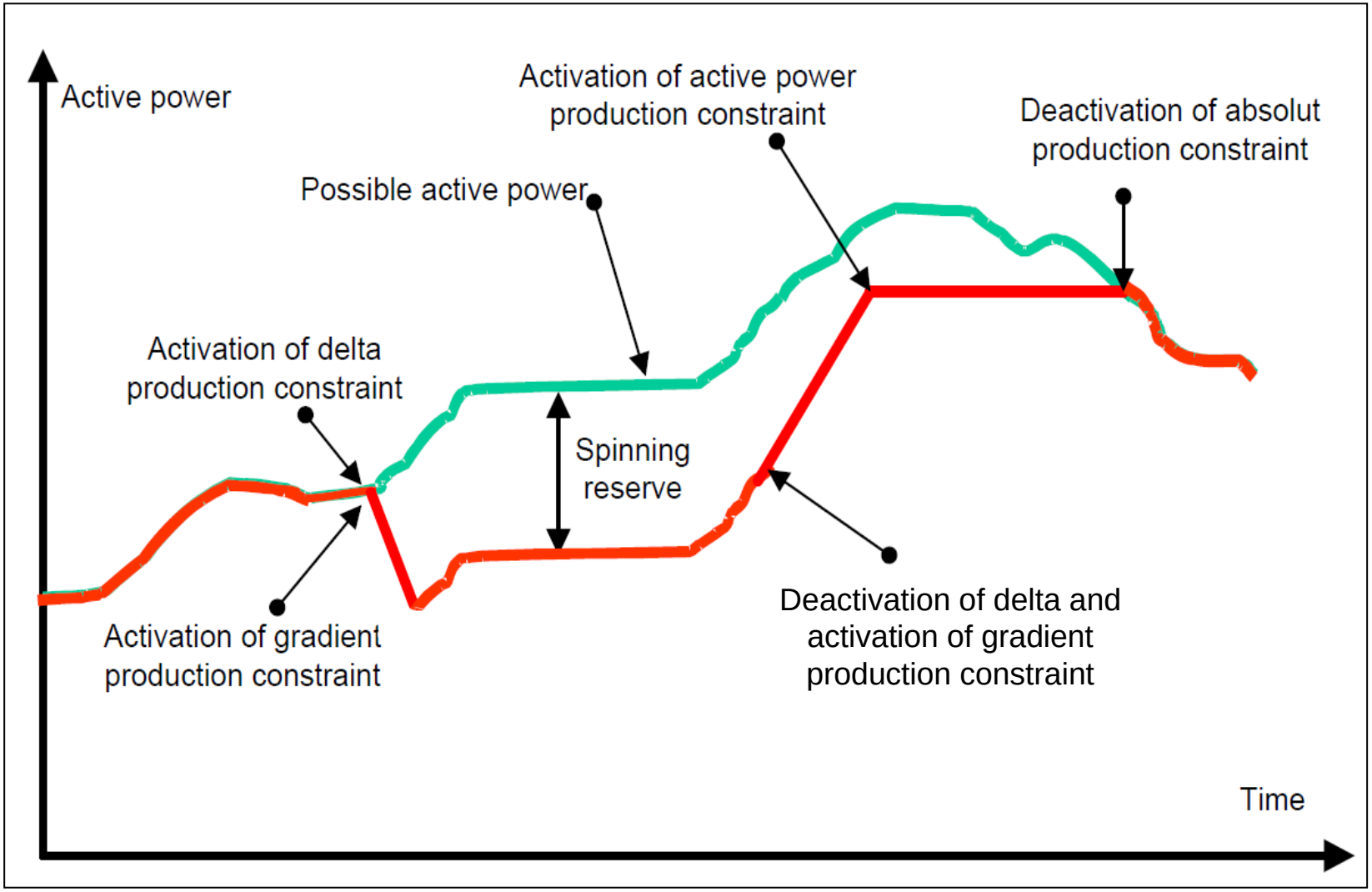
- Frequency control
  - Remotely set droop curves dictate active power vs. frequency



Control & Monitoring: Active power control

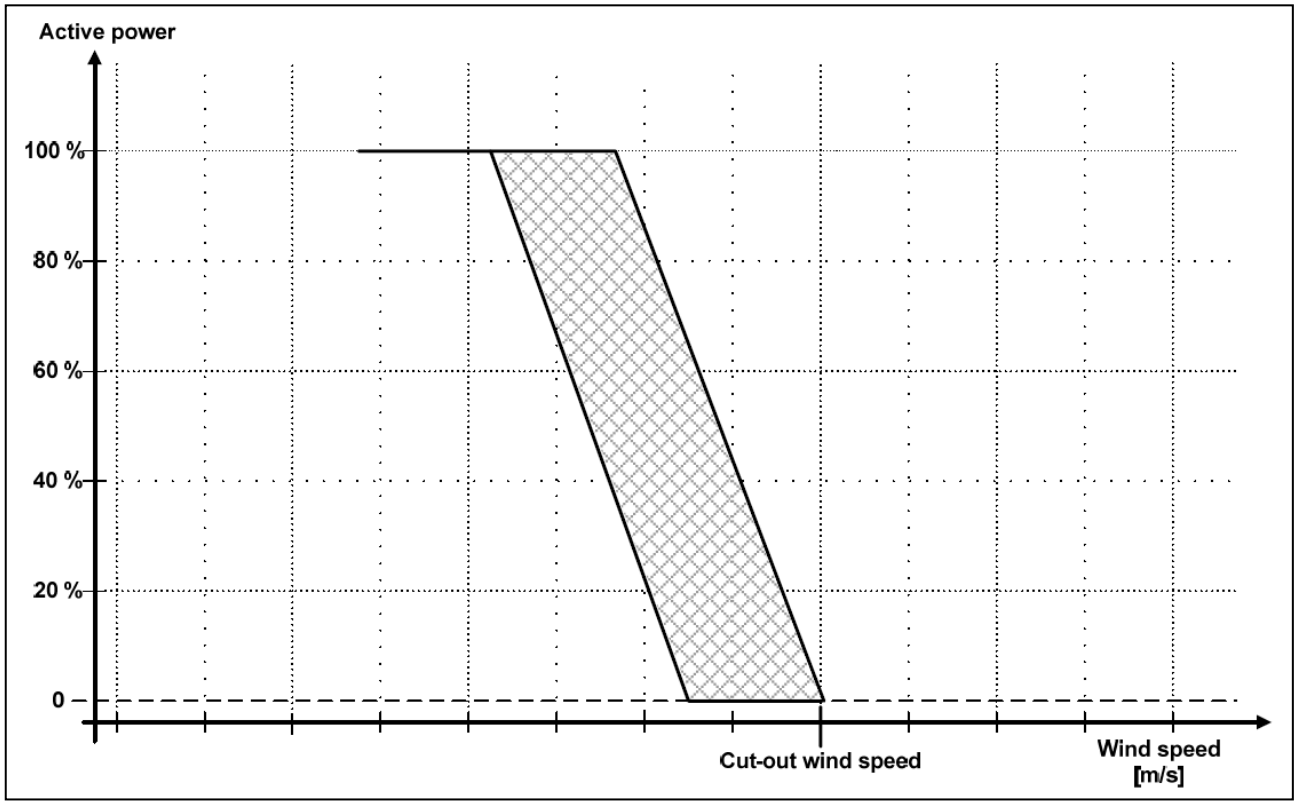
- Absolute production constraint
  - Used to prevent overload of system/power lines
- Delta production constraint (spinning reserve)
  - To create a reserve in preparation of frequency control
- Power gradient constraint
  - To prevent system instability dues to fast and large changes in wind speed

Active power control: example



Active power control limits

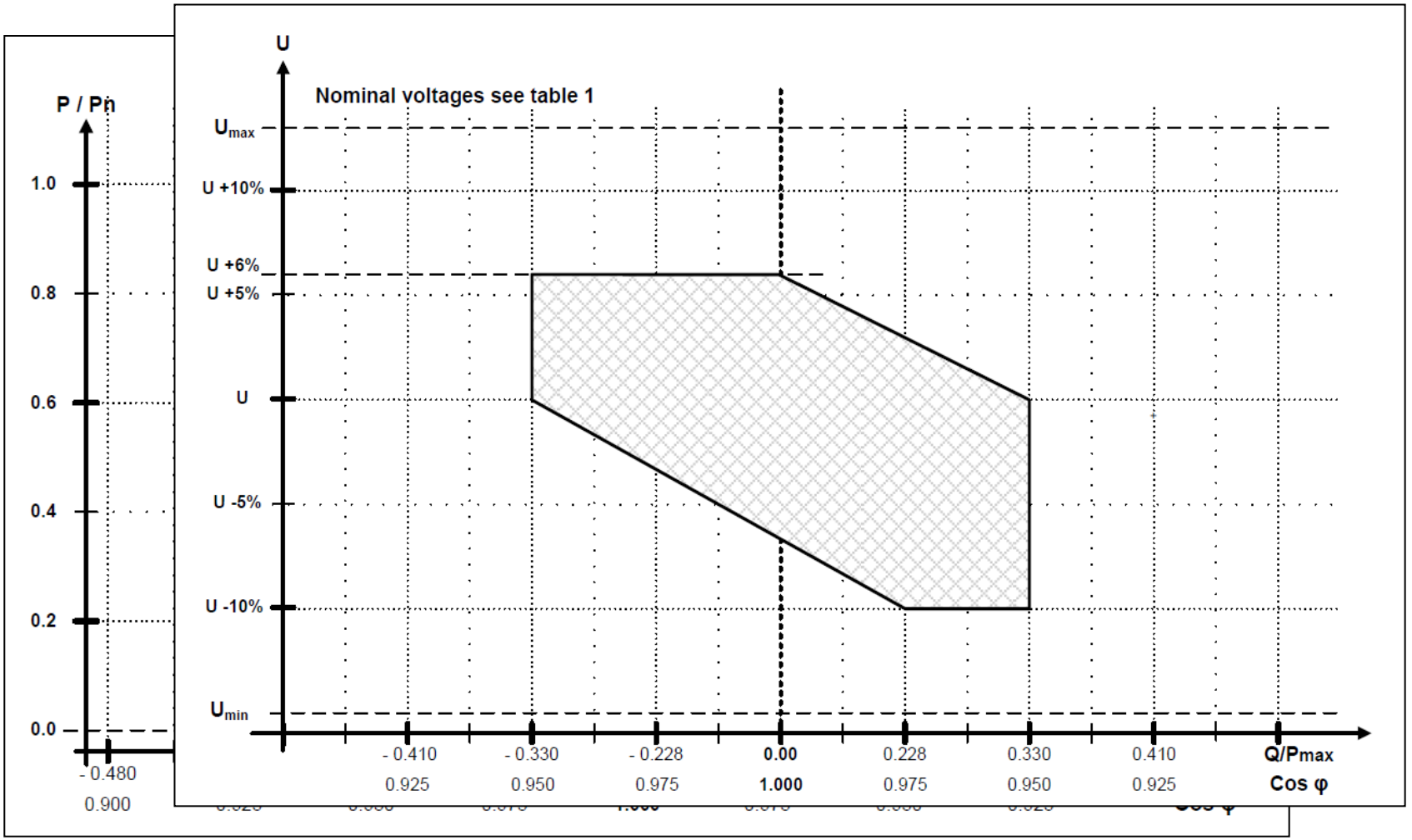
- Must be able to down-regulate from 100% to 20% of power plant capacity
- Near cut-out wind speed: additional control



Control & Monitoring: Reactive power control

- Q control
  - Reactive power is independent of active power
- Power factor control
  - Reactive power is proportional to active power
- Voltage control
  - Controls the voltage at the voltage reference point , wrt reactive power output

Reactive power control limits



Grid codes and the DTU Grid Test Facility

- **In 2011, our feasibility study looked at**
  - Global grid codes
  - Manufacturers' requirements
  - Developers' needs
  - Research areas
  - Equipment alternatives

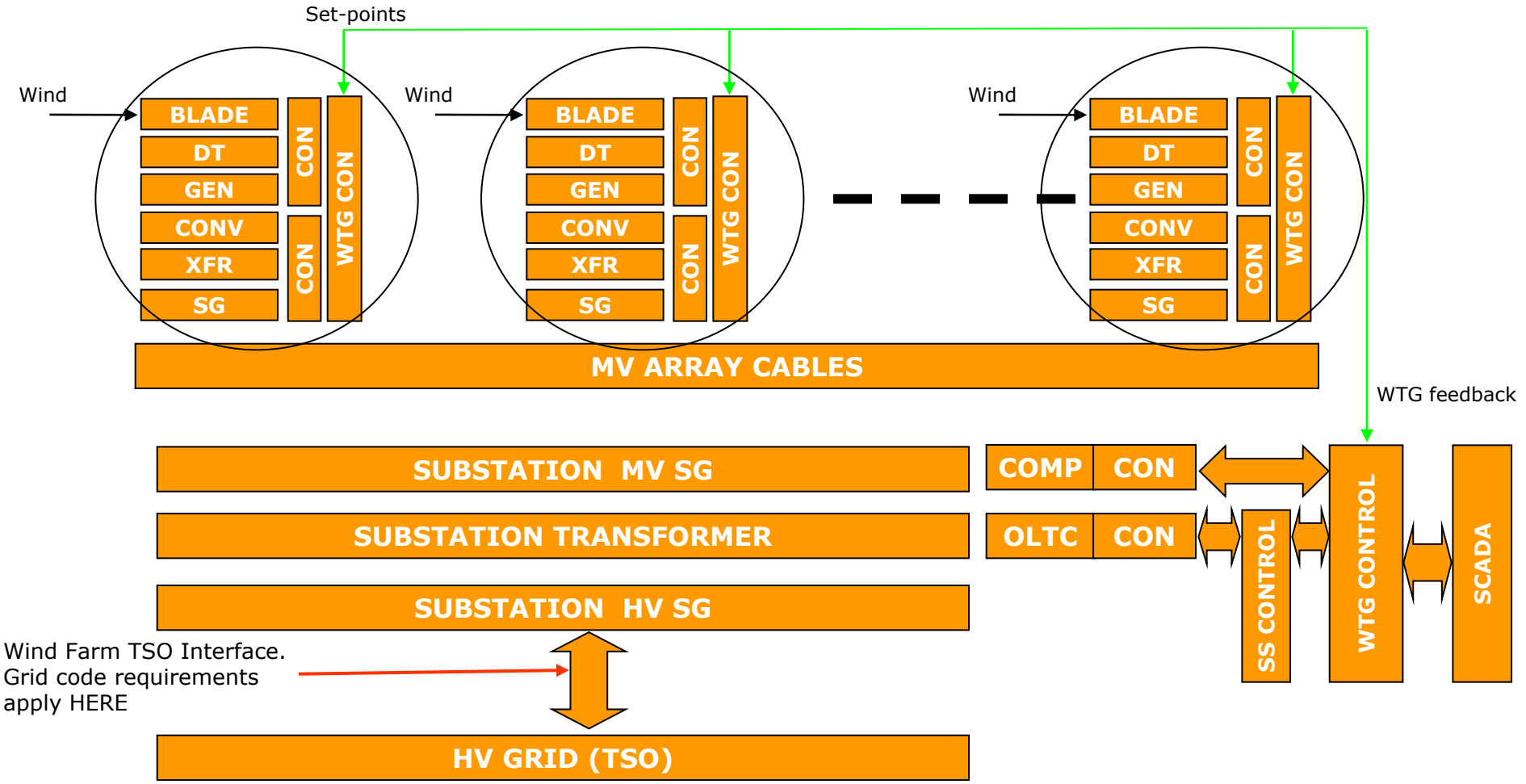
Vestas
Siemens Wind Power
DONG Energy
Vattenfall
ABB
Siemens
DTU
Aalborg University

- **Conclusion**

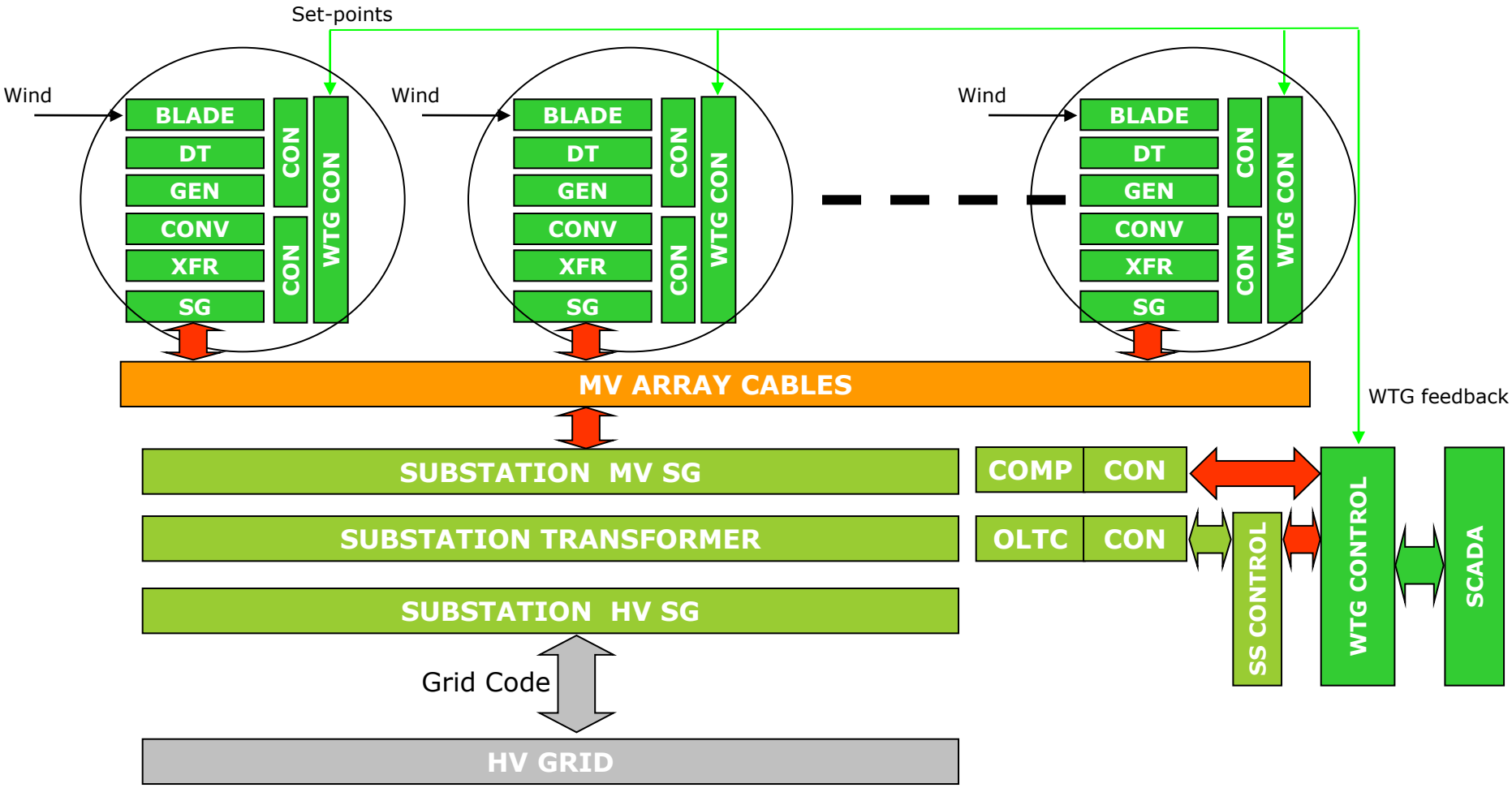
  Optimum facility combines a converter-based unit and an impedance-based unit

- **The DTU Advanced Grid Test Facility**
  - 10MW, upgradable to 16MW
  - Grid codes – verification of compliance esp. frequency control
  - Wind turbine testing/development/proving
  - Development of future standards and grid codes
  - Simulation models – validation
  - Wind farm testing

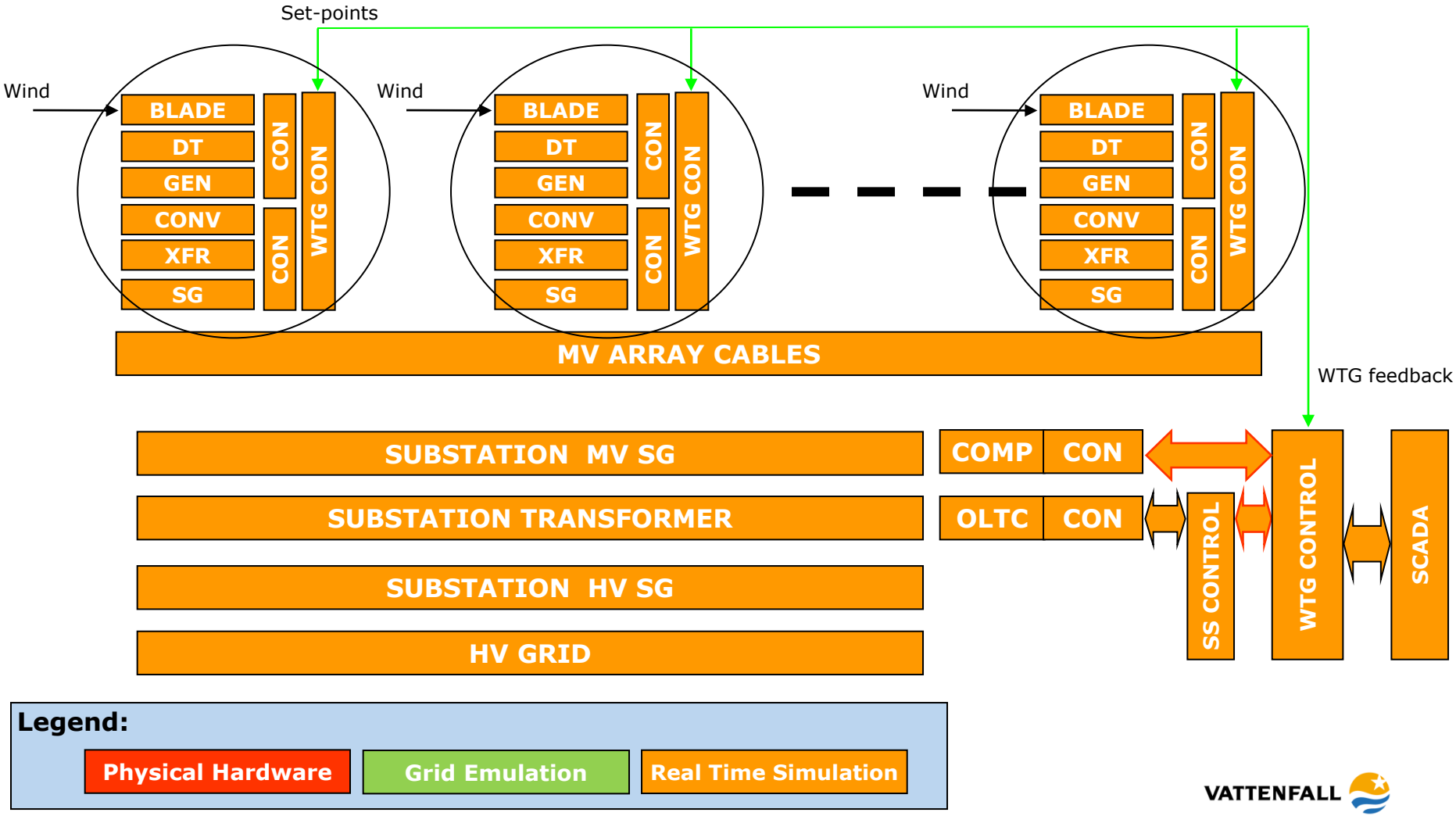
Wind Farm Performance Requirements



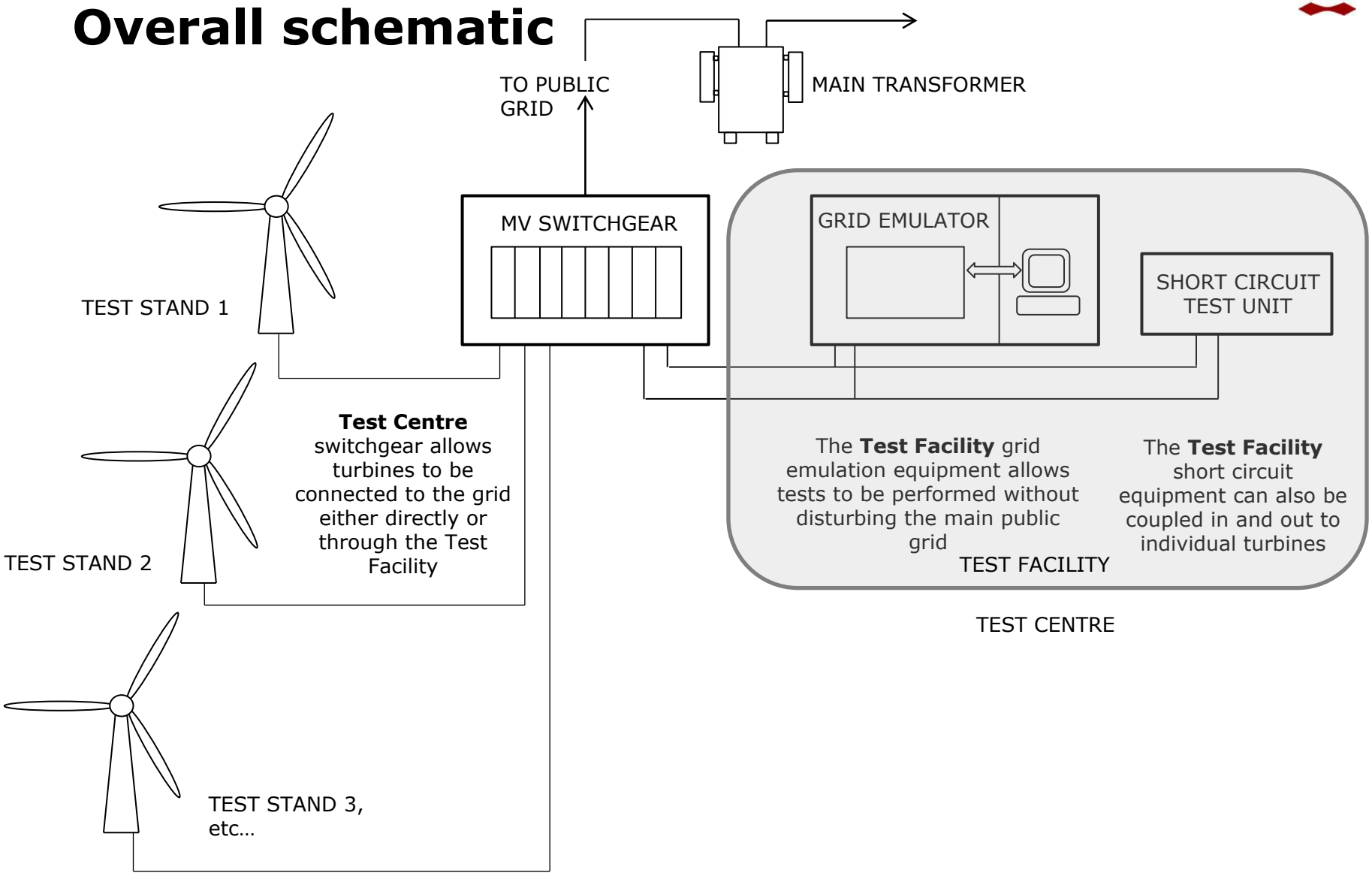
Contract structures…



Wind Farm Test - scope



Overall schematic



To be located at the Danish National Test Centre for Large Wind Turbines, Østerild

Test Centre:
- Opened Oct 2012
- For turbines up to 250m height
- Up to 16MW

Grid Facility:
- €4M secured
- Further funding negotiations
- Transportable
- Ready 'mid 2015'

GREEN LABS DK

Courtesy of Siemens Wind Power