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

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> 230 staff members
MISSION
DTU will develop and create value using the natural sciences and the technical sciences to benefit society.
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

![Diagram showing frequency and voltage tolerance](image)
Tolerance of frequency & voltage deviations

Abnormal Operation

Diagram showing the tolerance limits for frequency and voltage deviations with shaded areas indicating different zones of 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 due to fast and large changes in wind speed
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

• 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

Vestas
Siemens Wind Power
DONG Energy
Vattenfall
ABB
Siemens
DTU
Aalborg University
Wind Farm Performance Requirements

Wind Farm TSO Interface. Grid code requirements apply HERE
Contract structures...

Wind

Set-points

MV ARRAY CABLES

SUBSTATION MV SG

SUBSTATION TRANSFORMER

SUBSTATION HV SG

Grid Code

HV GRID

COMP CON

OLTC CON

WTG CONTROL

SS CONTROL

SCADA

VATTENFALL
Wind Farm Test - scope

Legend:
- Physical Hardware
- Grid Emulation
- Real Time Simulation

14 June 2013
Overall schematic

Test Centre switchgear allows turbines to be connected to the grid either directly or through the Test Facility.

The Test Facility grid emulation equipment allows tests to be performed without disturbing the main public grid.

The Test Facility short circuit equipment can also be coupled in and out to individual turbines.

GRID EMULATOR

SHORT CIRCUIT TEST UNIT

TEST FACILITY

TEST CENTRE
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’

Courtesy of Siemens Wind Power