LORC Nacelle Testing

Realistic indoor nacelle testing using grid emulation

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Wind Power in Denmark

- Population 5.6 mio.
- Installed Wind Capacity (2014)
  - 4.891 MW
- Large Offshore Parks in DK
  - Anholt 400 MW
    - 111 x 3.6 MW SWP (2013)
  - Horns reef II 209 MW
    - 91 x 2.3 MW SWP (2009)
  - Horns reef I 160 MW
    - 80 x 2 MW Vestas (2002)
  - Rødsand II 207 MW
    - 90 x 2.3 MW SWP (2010)
  - Nysted (Rødsand I) 166 MW
    - 70 x 2.3 MW SWP (2003)
Wind Power share of load in DK

- In January 2015, wind produced 61.7% of Denmark’s electricity.
- [www.energinet.dk](http://www.energinet.dk) for actual consumption/production.

Source: Stiesdal presentation Wind Energy Denmark 2015
One week overview electricity DK (w34, 2015)

Source: Stiesdal presentation Wind Energy Denmark 2015

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Danish offshore wind companies and LORC

- LORC founded in 2009 by former Prime Minister Poul Nyrup Rasmussen:

- LORC board:
  - Manufacturers
  - Developer
  - TSO (> 100kV)
  - Tech. consult
  - Former site owner
  - Universities
  - Observer

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Lindoe site and offshore wind activities

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Infrastructure in the industrial park

- Nacelle testing facility located under the 1000T gantry crane (video)
LORC nacelle function test rig

Prime mover motor (12MW@10RPM)

Misalignment / safe set coupling

Hub adaptor

Concrete foundation

Base adaptor

Tower adaptor

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Prime Mover Direct Drive Motor

- Permanent magnet medium voltage direct drive (GE)
  - Tandem motor design
    - 1 rotor drum
    - 2 stators
- Weight app. 300,000 kg
- Rated voltage 3.200V
- Speed range 0.1 – 22 RPM
- Rated torque 12 MNm
  - Peak (60s) 15.5 MNm
- Full load tested on site

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Misalignment/Safety Coupling

- Link-arm coupling (± 50mm X,Y,Z)
- Rated torque 8.6 MNm
  - Max torque 12.1 MNm
- Overload safety system (24 elements)
  - Configurable trip settings (3 – 6 – 9 – 12… elements)
  - System tested on the bench
    - Locked nacelle rotor
    - Reactivating using rubber hammer (BIG ONE)

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Picture V112 on the bench

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Controlling the test rig

Mode 3: Torque ctrl. mode
**Grid Supply**

- 63 / 33 kV
- 16 MVA
- OLTC: (+/- 14%)
- 2% steps

**Transformers**

- T1: 33/3kV; 16 MVA
- T2: 3/33kV 11 MVA

**MV Inverters**

- GE MV7315 3kV
- 6 x 15MVA (DC/AC)

**MV Inverters**

- 36 kV
- (40,5 kV)

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Power Flow

Option 1:
Public Grid
33 kV; 50 Hz
- Fixed frequency (50Hz)
- OLTC to control voltage level
- 14 steps of 2% (Max 36kV)
- Low Harmonics (PQ measurements)

Option 2:
Grid Emulation
~5 – 40 kV; 45 – 65 Hz
- Variable frequency (45-65Hz)
- SW controlled voltage regulation
- Low Voltage Ride Through (LVRT)
- High Voltage Ride Through (40kV)
Grid Emulator Performance

- THD$_{50}$ $\sim$ 0.7 % (up to 2.5kHz)
- THD$_{\text{total}}$ $\sim$ 2 %
Grid Emulator LVRT

- Low Voltage ride through 0.25pu; 300ms
Grid Emulator LVRT

- Low Voltage ride through 0,5pu; 1500ms (inside profile) 1900ms (outside profile)

- Accuracy in ms (dip detected fx. 202ms)
- Voltage ramp max 80pu/s -> 2,6MV/s (tested up to 500pu/s)
Grid emulator LVRT (db. dips)

- 0.5pu; 500ms -> 1pu; 500ms -> 0.5pu; 500ms
Grid Emulator LVRT

- Adjustable recovery voltage
Grid emulator HVRT

- High Voltage ride through 1,22pu (40kV); 200ms
- Additional OV capability by including tap changer
Unbalanced voltage faults

- L1&L3 0.7pu; 500ms
Frequency variations

- 50 -> 46.5Hz in 500ms; 46.5 -> 53.5Hz in 1000ms; 53.5 -> 50Hz in 500ms