Wind turbine design drivers

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ONE PARTNER. WORLDWIDE SUPPORT.

LOC Group
Marine and Engineering Consultants
Established 1979
400 staff
30 offices

Skillset

- Naval Architects
- Master Mariners
- Civil & Structural Engineers
- Marine Engineers
- Mechanical Engineers
- Geotechnical Engineers
- Metocean Engineers
- Hydrodynamicists
- Subsea, Cable & Pipeline Engineers
Technical Services Overview

Planning & Permitting

Wind Resource Assessment

Turbine Review, Selection & Procurement

Design engineering

Transport & Installation

Operational Services
Outline

- Wind turbine scale
- Design drivers:
  - Fatigue loading
  - Extreme loading
- Design standards
- Drivers for SHM & NDT
Wind turbine scale
GE Haliade-X 12MW

- 12 MW capacity
- 220-meter rotor
- 107-meter long blades
- 260 meters high
- 67 GWh gross AEP
- 63% capacity factor
- 38,000 m² swept area

Wind Class IEC: IB

Compared to other structures:

- Flat Iron Building: 285 ft (87 m)
- Statue of Liberty: 305 ft (93 m)
- Washington Monument: 555 ft (169 m)
- Chrysler Building: 1046 ft (319 m)
- Empire State Building: 1454 ft (445 m)
- Haliade-X 12 MW: 853 ft (260 m)
- Eiffel Tower: 1063 ft (324 m)
- London Eye: 443 ft (135 m)
- Big Ben: 315 ft (96 m)
- Tower of Pisa: 186 ft (57 m)
- Arc de Triomphe: 162 ft (49.5 m)
GE Haliade-X 12MW

A380: 80m wingspan

Blade length 107m
GE Haliade-X 12MW

Rotor area: 38,000m²

5.3 football pitches
Mass flow rate through rotor disk at rated wind speed: 373 tonnes/s

50 Routemaster buses
Design drivers
External Conditions + Design Situation = Design Load Case

Normal External Conditions + Normal Operation = Design Load Case
Fatigue loading

- Wind turbines are fatigue machines!
- Flexible / dynamic structures – multiple modes of vibration
- Stochastic aerodynamic & hydrodynamic loads
- Drives design of:
  - Hub
  - Mainframe
  - Tower welds
  - Grouted joints
  - Support structure joints
  - Rolling elements (gears & bearings)
Dynamically active structure

• Campbell diagram reveals complex interaction between excitation frequencies & modal frequencies of the structure.
• Drives design of:
  • Support structure stiffness
  • Blade mass / stiffness
  • Control system
Design Situation

External Conditions + Design Situation = Design Load Case

Normal External Conditions + Normal Operation

Extreme External Conditions + Normal Operation
Extreme loads – extreme environmental conditions

• Design standards specify the combination of 50-year return environmental conditions with a normally operating / idling turbine.

Damage caused by typhoon Maemi in 2003 (Ishihara et al, 2005)

• Blade / tower clearance, tower buckling & foundation design (& others) are driven by extreme loads
Extreme loads – extreme environmental conditions

Blyth V66 monopile subjected to 8m waves

• Extreme waves drive air-gap requirements & (possibly) foundation strength
Design Situation

External Conditions + Design Situation = Design Load Case

Normal External Conditions + Normal Operation = Design Load Case

Extreme External Conditions + Normal Operation = Design Load Case

Annual External Conditions + Fault States = Design Load Case
Extreme loads – fault conditions

- Consequences of sensor & actuator faults are analysed in combination with 1-year return environmental conditions

Nordex N80/2500 at Screggagh wind farm
Some other design drivers

Corrosion

Scour

Lightning strike

Leading edge erosion
Design standards
Design standards for wind turbines

- IEC 61400-1 “Wind turbines – part 1: Design requirements”
- IEC 61400-3-1 “Wind turbines – part 3-1: Design requirements for offshore wind turbines”
- DNVGL-ST-0437 “Loads and site conditions for wind turbines”
- DNVGL-ST-0126 “Support structures for wind turbines”
- DNVGL-ST-0361 “Machinery for wind turbines”
- Deutsche Institut für Bautechnik (DIBt) “Guidelines for loads on wind turbine towers and foundations.”
- DS472 “Load and Safety for Wind Turbine Structures”
- NEN6096 “Safety Requirements for Wind Generators”
- ABS “Guide for Building and Classing Offshore Wind Turbine Installations”
- & others…
Drivers for SHM & NDT
Drivers for SHM & NDT

- Owners need to understand the residual life of their turbines as they prepare for:
  - Lifetime extension
  - Adaptions
  - Decommissioning / repowering

- SHM should begin well before year 20 (!) but best practice is not well defined in the wind industry.
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