Pushing Offshore Wind Energy Regions (POWER)

POWER Offshore Summer School 2006

Operation and Maintenance

Gerard van Bussel

TU Delft

The Netherlands

Pushing Offshore Wind Energy Regions (POWER)

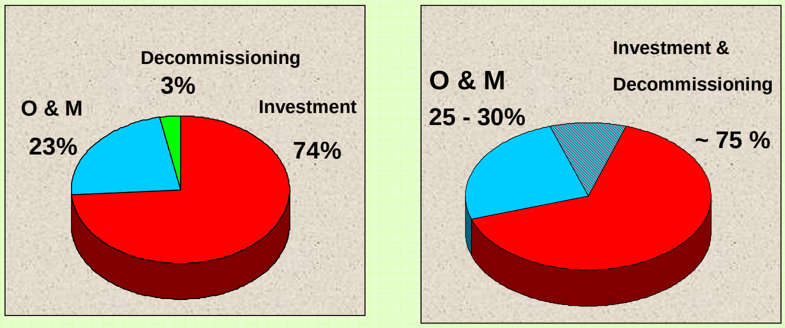
Contents

- Maintenance concepts
- RAMS definitions
- Access systems
- Maintenance strategies
- RAMS tools

TU Delft

Pushing Offshore Wind Energy Regions (POWER)

Typical contribution to energy cost

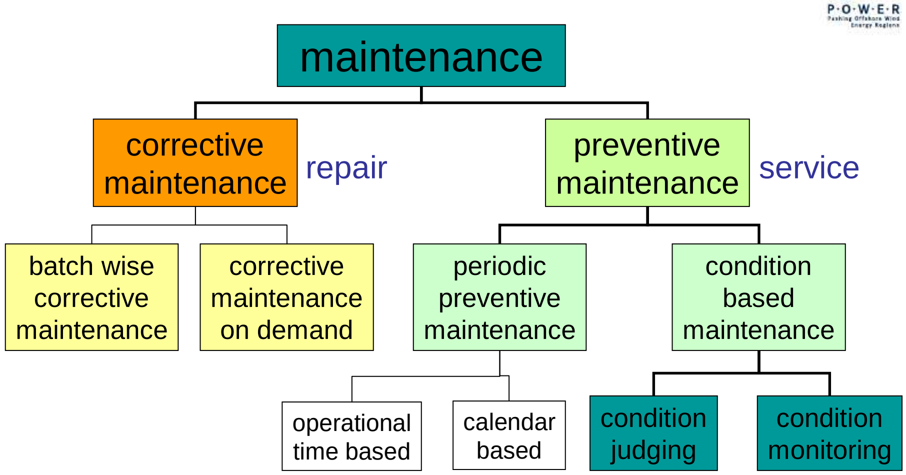


Opti-OWECS study (1998)

CA-OWEE (2001)

Pushing Offshore Wind Energy Regions (POWER)

Maintenance Concepts



Pushing Offshore Wind Energy Regions (POWER)

Failure frequencies 500kW class

	Tacke TW600	Enercon 40	Vestas V39/500
number of turbines	25	26	59
	events/year	events/year	events/year
Lightning	0	0.03	0
Blade	0.76	0.42	0.32
Rotor Brake	0	0	0
Pitch Mechanism	0	0.30	0.03
Brake	0.08	0	0
Shaft/Bearing	0.04	0.03	0
Gearbox	0.16	0	0.03
Generator	0	0.03	0.33
Hydraulic	0.32	0	0.27
Yaw System	0.32	0.23	0.08
Anemometry	0	0	0.01
Electronics	0.04	0.42	0.33
Electric	0.20	0.69	0.30
Inverter	0	0	0
Sensors	0.08	0.07	0.18
Other	0.20	0.38	0.37
Overall Total	**2.2**	**2.6**	**2.25**

Failure frequencies **2.2** **2.6** **2.25**

For larger machines (onshore) ● **2.2**

Delft

Pushing Offshore Wind Energy Regions (POWER)

Failure frequencies multi MW class

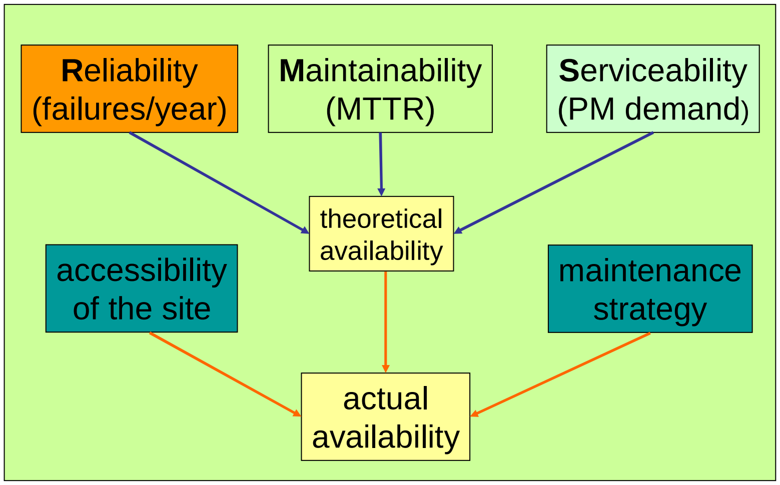
Total of all components **2.20 failures/year**

Component	Failure frequency (failures/year)
Shaft & Bearings	0.02
Brake	0.05
Generator	0.05
Parking Brake	0.05
Electric	0.14
Blade	0.16
Yaw System	0.23
Blade tips	0.28
Pitch Mechanism	0.28
Gearbox	0.30
Inverter	0.32
Control	0.34
Total	**2.20**

TUDelft

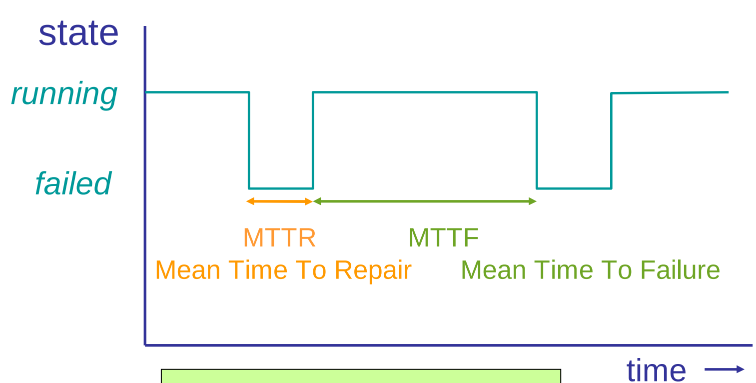
Pushing Offshore Wind Energy Regions (POWER)

Reliability, Availability, Maintainability, Serviceability



Pushing Offshore Wind Energy Regions (POWER)

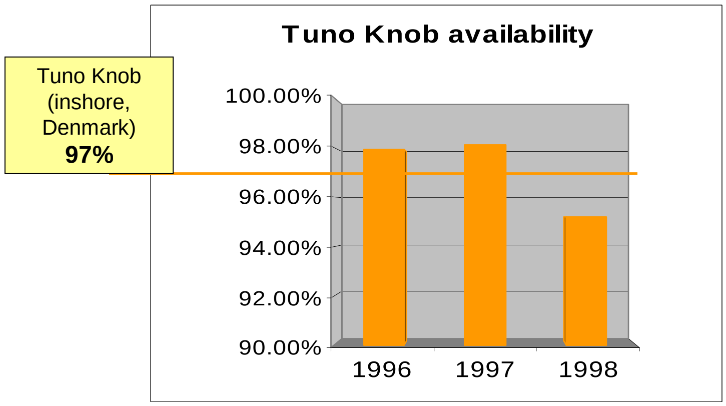
A measure for availability



$$\text{Availability} = \frac{\text{MTTF}}{\text{MTTR} + \text{MTTF}}$$

Pushing Offshore Wind Energy Regions (POWER)

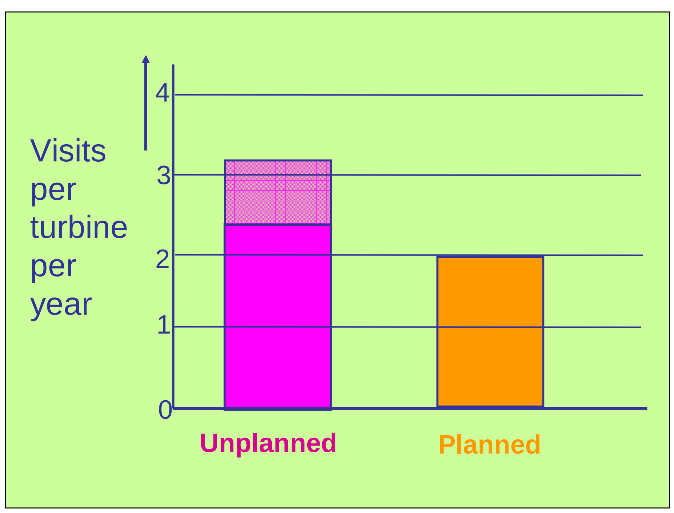
Experienced Availability



TU Delft

Pushing Offshore Wind Energy Regions (POWER)

Present maintenance demand

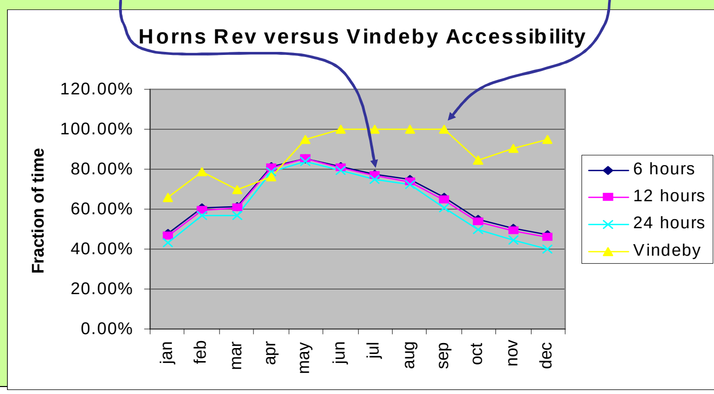


TU Delft

Accessibility of site (Vessel)

Horns Rev (near shore, North Sea)

Vindeby (inshore, Denmark)

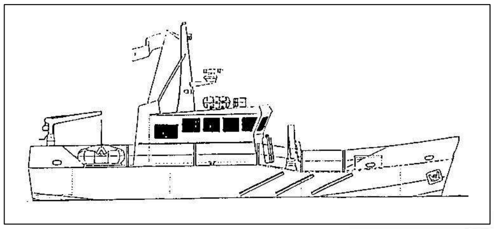


Means of crew transport

- Helicopter
  - fast
  - expensive
  - helipad
  - large operational window

- Tender vessel
  - fairly slow
  - cheap
  - boat landing
  - medium window

Means of crew transport and landing



Tender vessel
For crew transport

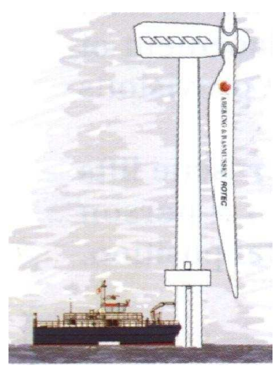
With a Zodiac
for landing

TUDelft

Pushing Offshore Wind Energy Regions (POWER)

Means of crew transport and landing

Catamaran landing vessel

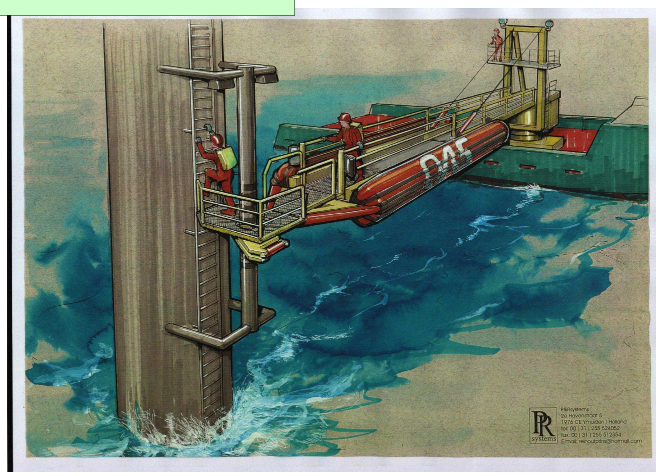


SWATH@A&R / Abeking &Rasmussen

TUDelft

Means of crew transport and landing

Flexible gangway



OAS: P&R systems / Reinout Prins

Pushing Offshore Wind Energy Regions (POWER)

Means of crew transport and landing

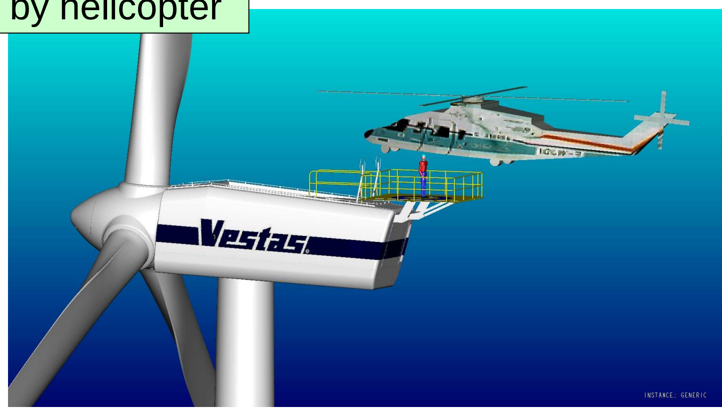
Ampelmann

TU Delft / Jan van der Tempel

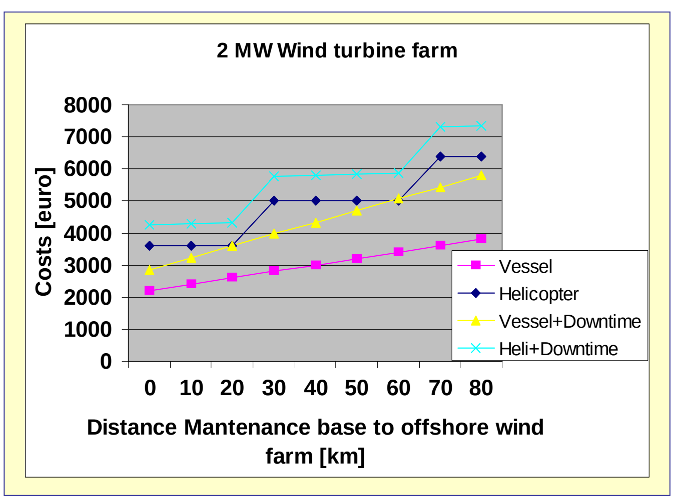
TU Delft

Means of crew transport and landing

Crew transport by helicopter



Cost comparison transport Vessel/Helicopter



Experiences in the real world

Maintaining Horns Rev:

- Access by boat: Winter 02/03: 5/7 days
  Winter 03/04: 1/7 days
- Helicopter: 6/7 days
- Vestas responsible for crew (60 people)
  Elsam for transport (6 people)
- 75.000 transfers in 1.5 years (2 x /day/turbine)

TU Delft

Pushing Offshore Wind Energy Regions (POWER)

Experiences in the real world

Maintaining Horns Rev

Reasons:

- Design not well adapted for offshore
- Strategy not optimal
- Onshore crews
- Sophisticated alarms, but what does it mean?

TU Delft

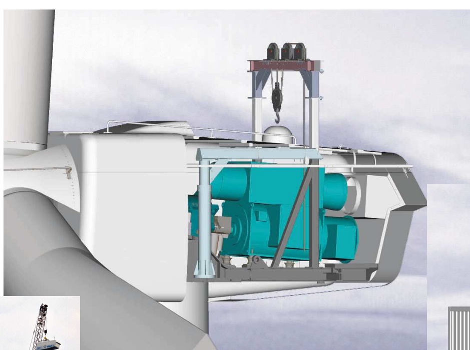
Lifting equipment (Installation and O&M)

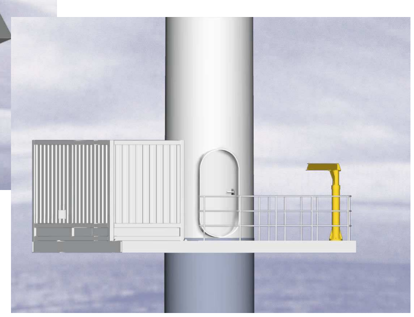
- Jack-up barge
- Crane vessels
- Jack up vessel (self propelled)
- Purpose built/ adapted
- Helicopter
- Built-in facilities (in wind turbine)

TU Delft

Pushing Offshore Wind Energy Regions (POWER)

O&M lifting facilities

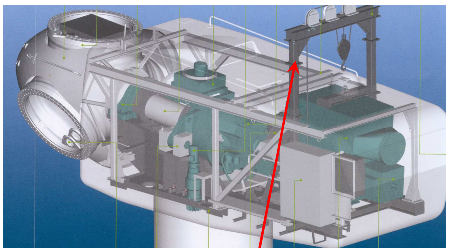




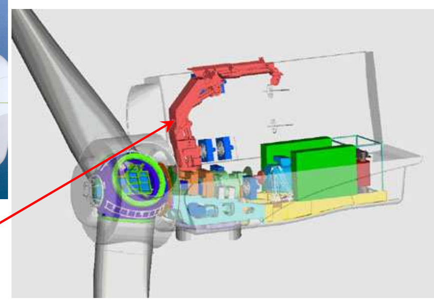
Utgrunden Wind farm, Sweden

TU Delft

O&M lifting facilities



GE Wind (Utgrunden, Sweden)



Nordex N80 Offshore

Internal cranes

TU Delft

Pushing Offshore Wind Energy Regions (POWER)

Maintenance strategies

- PM and CM on demand
  (onshore practice)
- Opportunity based maintenance
  (PM when CM is demanded)
- Condition based maintenance
  (PM and CM only when demanded)
- No maintenance/ batch maintenance

TU Delft

Maintenance strategies

- PM and CM on demand (onshore practice)
  (reduced PM demand, increased reliability)

Pushing Offshore Wind Energy Regions (POWER)

Maintenance strategies

- PM and CM on demand (onshore practice)
  (reduced PM demand, increased reliability)
- Opportunity based maintenance
  (flexible PM interval, increased reliability)

TU Delft

Pushing Offshore Wind Energy Regions (POWER)

Maintenance strategies

- PM and CM on demand (onshore practice)
  (reduced PM demand, increased reliability)
- Opportunity based maintenance
  (flexible PM interval, increased reliability)
- Condition based maintenance
  (extensive condition monitoring)

TU Delft

Pushing Offshore Wind Energy Regions (POWER)

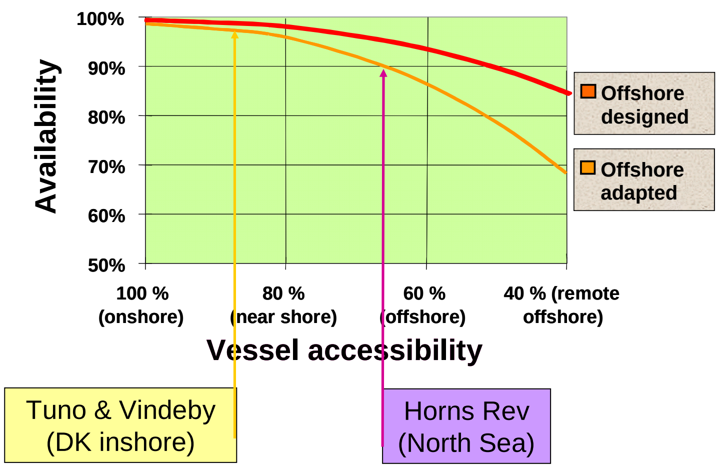
Maintenance strategies

- PM and CM on demand (onshore practice)
  (reduced PM demand, increased reliability)
- Opportunity based maintenance
  (flexible PM interval, increased reliability)
- Condition based maintenance
  (extensive condition monitoring)
- No maintenance/ batch maintenance
  (only feasible when failure freq. < 0.2 /year)

TU Delft

Pushing Offshore Wind Energy Regions (POWER)

Importance of (improved) Reliability



Pushing Offshore Wind Energy Regions (POWER)

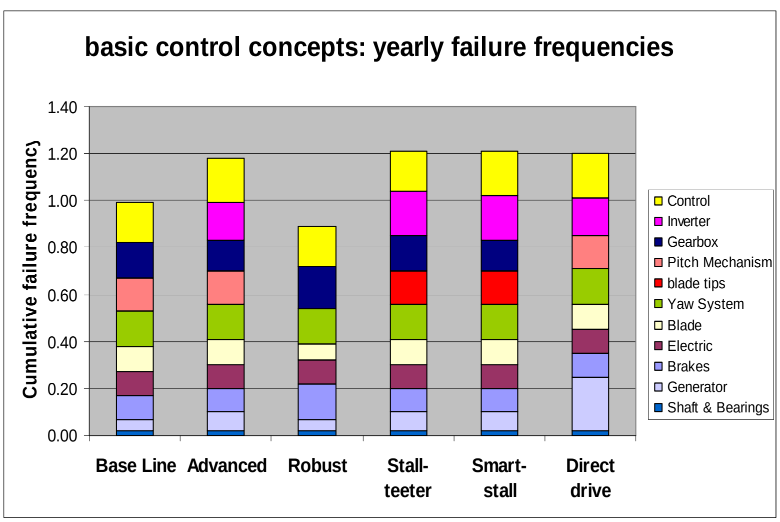
Reliability vs. turbine design

- Turbine design gets more complex:
  - Three bladed, variable speed pitch control
  - Doubly fed generators, Inverters
- **BUT**
- Offshore environment demands a robust, lean design:
  - Two blades !?
  - Stall control !??
  - Low speed or Direct drive generator !?

Wind turbine failures in past years

Pushing Offshore Wind Energy Regions (POWER)

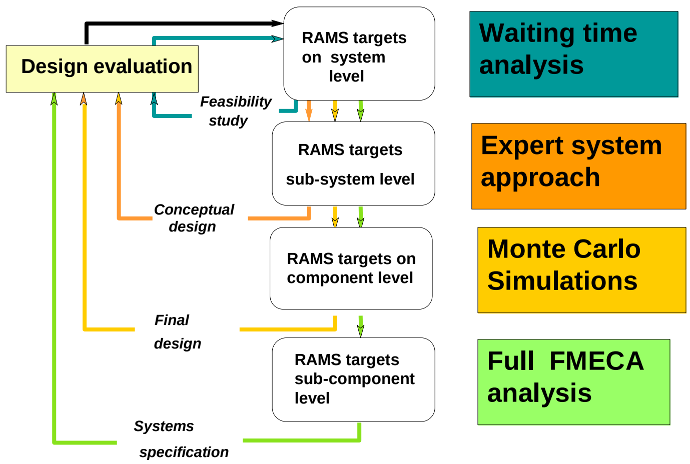
DOWEC concepts Reliability



TU Delft

Pushing Offshore Wind Energy Regions (POWER)

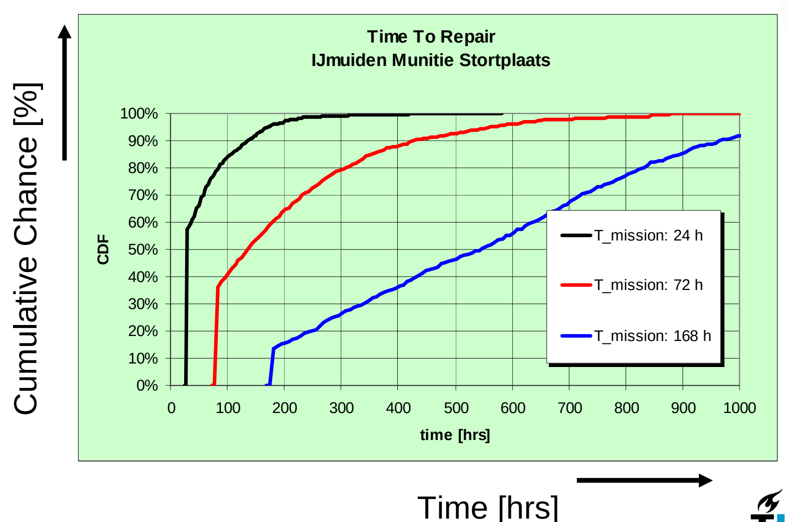
Assessing reliability, availability and O&M in the design process



TU Delft

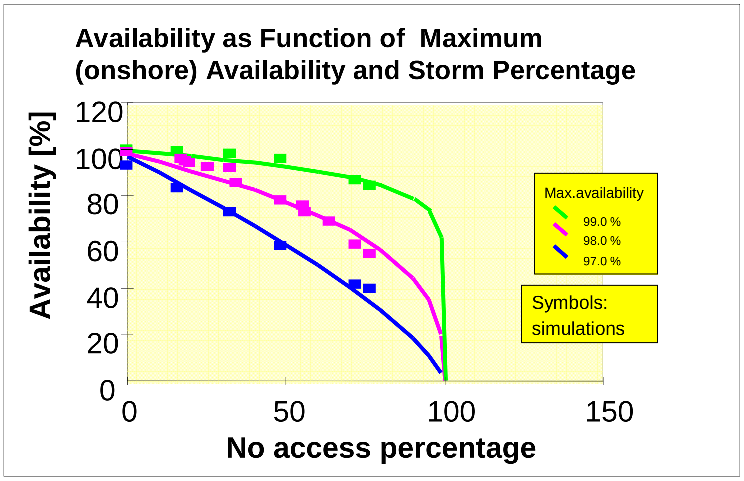
Pushing Offshore Wind Energy Regions (POWER)

Probabilistic Waiting time analysis



TU Delft

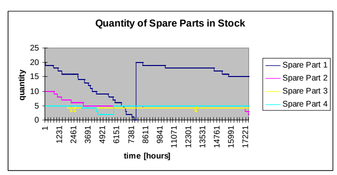
Trend lines in expert system

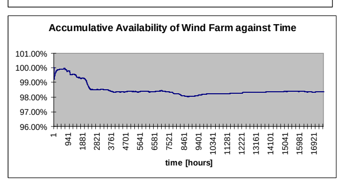


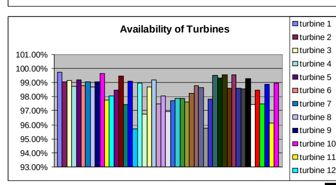
TUDelft

Numerical Monte Carlo Simulation

- Site conditions
  (wind and waves)
- Failures
  components of turbine,
  and wind farm
- Maintenance
  strategy
  - ships and crew
  - immediate/batch repair
  - overhaul
  - stock keeping







TUDelft

Pushing Offshore Wind Energy Regions (POWER)

FMECA: Failure Mode Effect and Criticality Analysis

- systematic brake down of:
  - functional components
  - hardware component
- analysis of:
  - effects of all kinds of failures upon functioning
  - criticality of failure (how does failure affect costs/environment)

TU Delft

Pushing Offshore Wind Energy Regions (POWER)

Conclusions

- Present reliability insufficient
- - Opportunity based maintenance (flexible PM intervals needed)
  - Condition based maintenance
- Crew transport by vessel
- Large (far) offshore scale wind farms need drastic design modifications

TU Delft