Uncertainty propagation in wind turbine and support structure design

11 October 2017

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  - Introduction to probabilistic design methods in DNVGL
- Part 2: Laurent van den Bos, CWI / TUDelft
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DNVGL

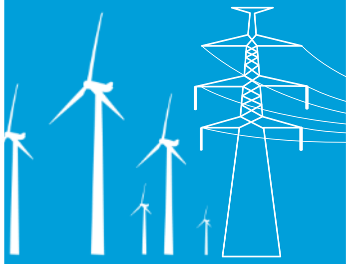
150	350	100	15,000
years	offices	countries	employees

business areas

MARITIME

OIL & GAS

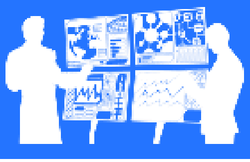
ENERGY



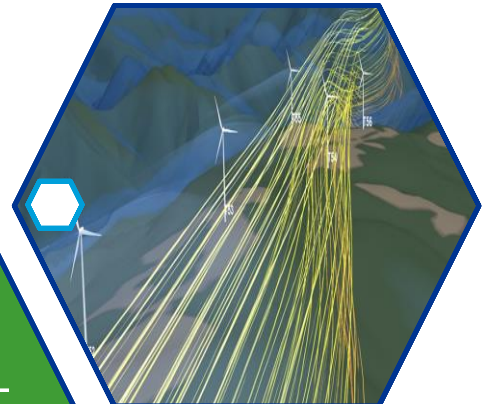
BUSINESS ASSURANCE

SOFTWARE

RESEARCH & INNOVATION



Energy - Renewables Advisory supporting offshore development

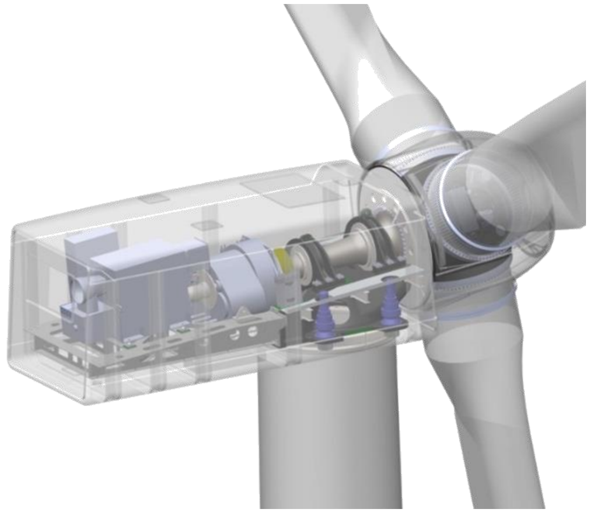


Project Development & Engineering

Turbine Engineering

Offshore Projects

DNVGL Turbine Engineering Support



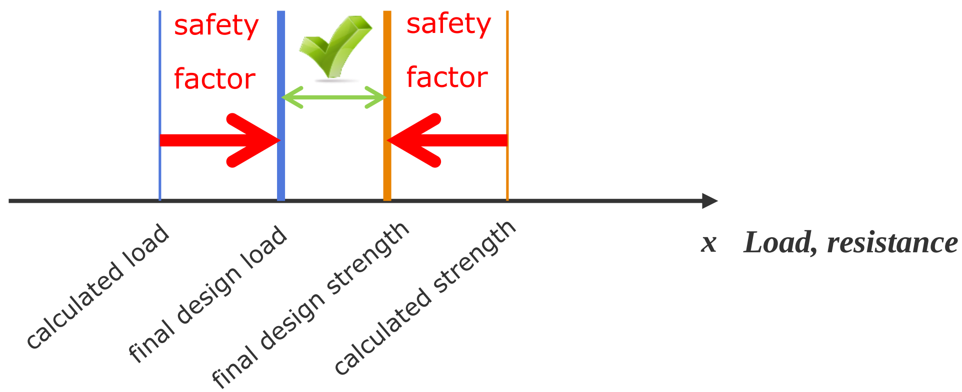
- Providing advisory services to manufacturers of wind turbines, farm developers & wind farm operators
- ~40 staff, based predominantly in Bristol UK, Groningen NL and Beijing CN
- Global business unit with equal split of customers in Asia and Europe
- Sections; loads analysis, control design, structural & mechanical design
- R&D topic: probabilistic design

"The world is noisy and messy.
You need to deal with the uncertainty"

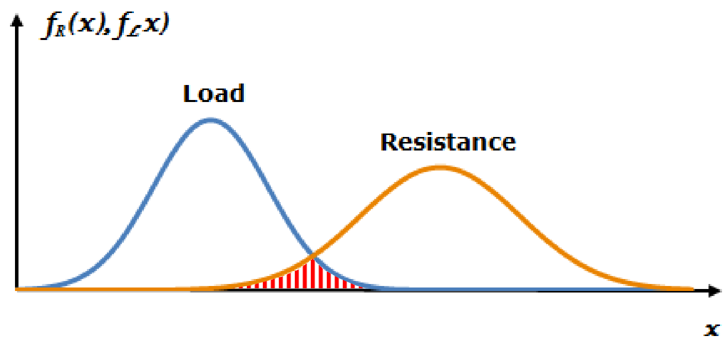
- Daphne Koller

What is probabilistic design? – the technical concept

deterministic approach



probabilistic approach

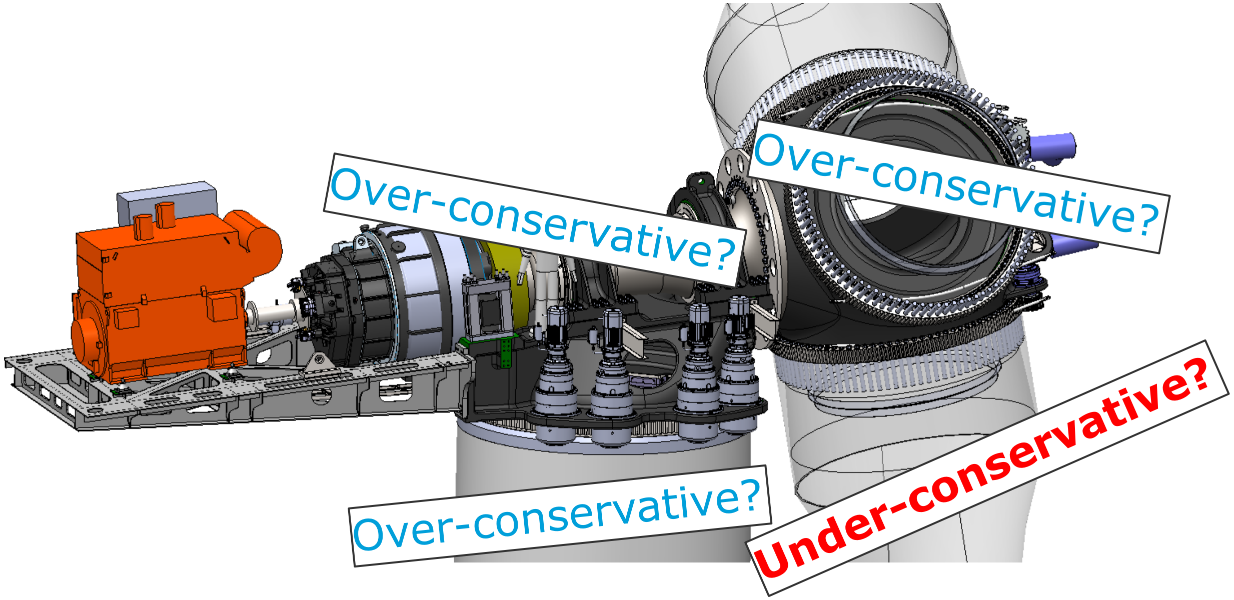


Aim: Annual probability of failure **(P_f) < ~5e-4**

Why probabilistic design?

Current deterministic approach...

- **PSF=1.35** calibrated for application across a broad range of technologies - ***generic***

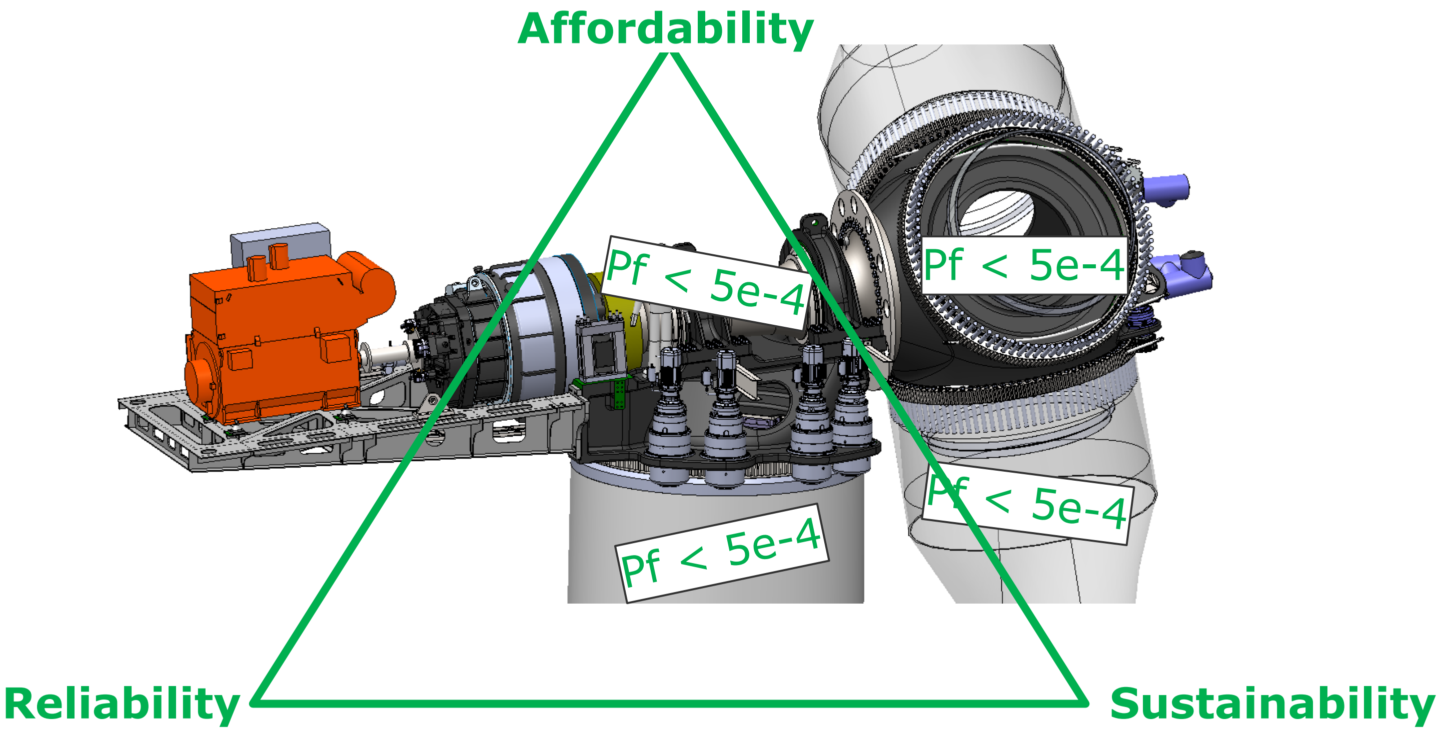


Current safety-factor based design methods are a "blunt instrument": **potentially over-conservative** (or under-conservative!)

Why probabilistic design?

With probabilistic design approach…

- ***Specific*** probabilities of failure (Pf) are well understood by year, component and failure mode
- Treatment of uncertainty in a more rigorous manner



Use probabilistic design approach in order to rationally balance **reliability** and **costs**

probabilistic design – how?

For Structural Reliability Analysis (SRA), we define our model as a:

Limit state function:

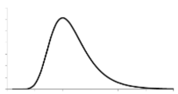
$G(X,Y) = S(X) - L(Y)$, $G < 0$: failure

L: load model
S: strength model
X,Y: stochastic parameters

Probability of failure = P[G<0] → ***calculated using numerical uncertainty propagation methods*** *(FORM, SORM, Montecarlo, …)*

Example: SRA applied to 7MW turbine fatigue

Example limit state – fatigue in tower can of offshore 7MW turbine

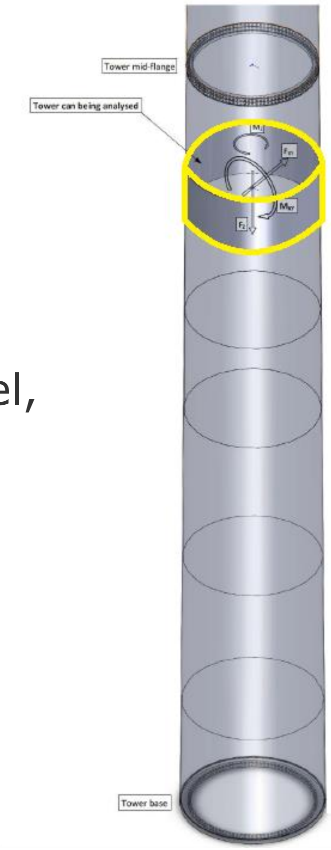


Uncertainties in **loads**:

- Input uncertainties: turbulence, air density , airfoil characteristics,..
- Model uncertainties: structural dynamics model, aerodynamic model

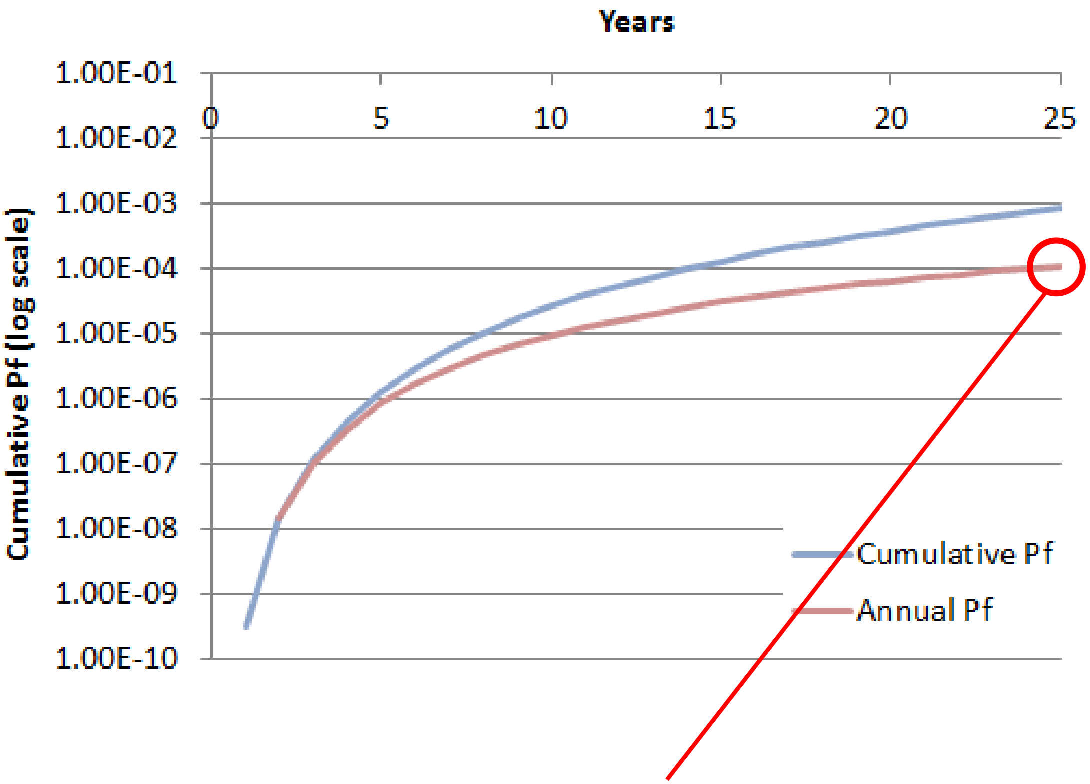
Uncertainties in **resistance**:

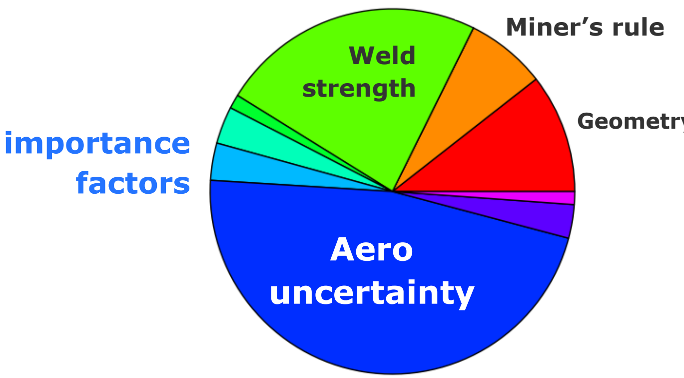
- Input uncertainties: geometric tolerance, weld fatigue strength,..
- Model uncertainties: Miner's rule,..



Example: SRA applied to 7MW turbine fatigue

- Limit state for tower can with lowest safety margin from original design (10-15%)

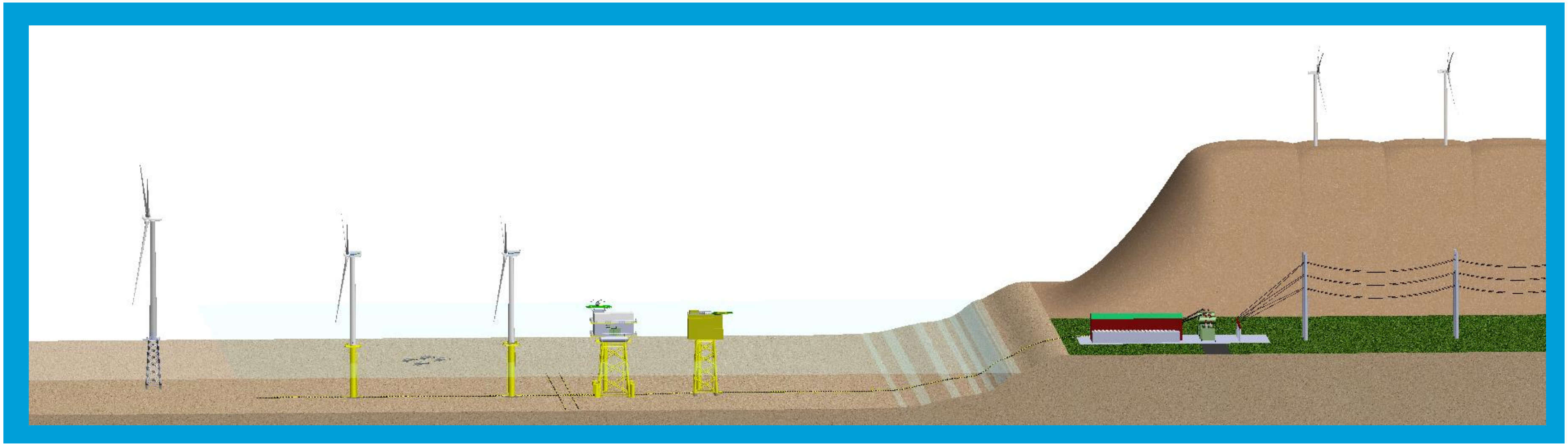




Annual P_f at year 25: **1.13e-4** ~ Pf_target (5e-4)

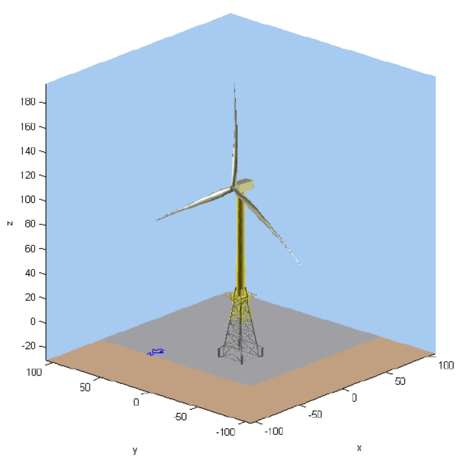
Other applications of uncertainty propagation methods

- Quantification of uncertainty & risk in:
  - Energy yield
  - Offshore LCOE
  - Turbine site suitability

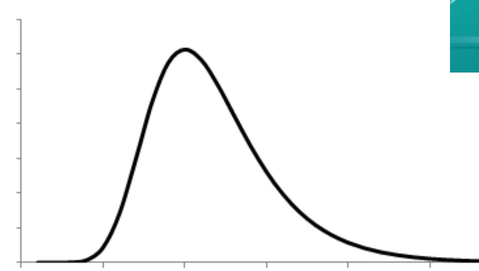


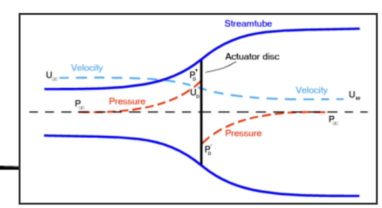
Future work

- Loads important source of uncertainty in design
- Existing uncertainty propagation methods have limitations:
  - FORM method: inaccuracies introduced by linearization
  - Monte-Carlo method: computationally expensive
- Need better uncertainty propagation methods
- In addition, need to quantify uncertainty in loads model itself.



Aerodynamic model





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