HORIZON 2020

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Structural probabilistic assessment of Offshore Wind Turbine operation fatigue based on Kriging interpolation

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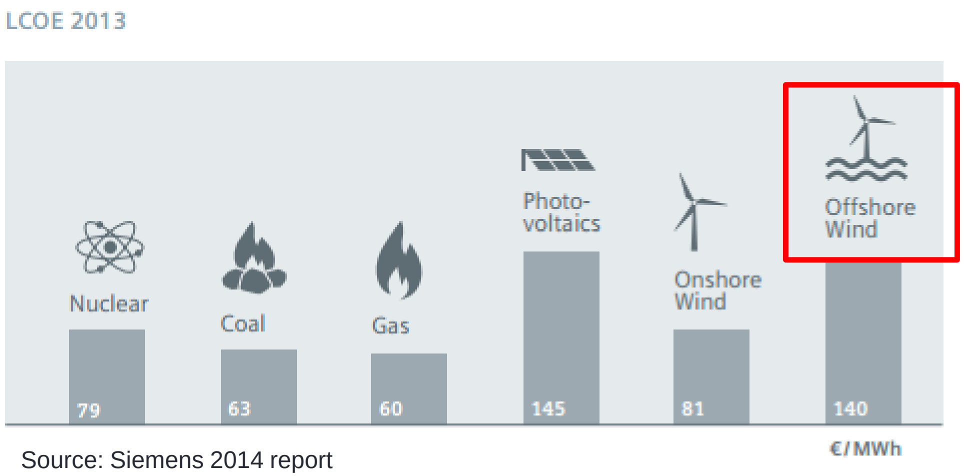
Outline

- Introduction
- Offshore wind turbine fatigue design methodology
- Structural probabilistic assessment of Offshore Wind Turbine operation fatigue based on Kriging interpolation
- Conclusions
- Further developments

Why is **Offshore Wind Turbines** development important?

- Global warming is a scientific fact.
- Renewable energy needs to be “pulled” forward.
  - EU targets of 20% of Renewable Energy in total energy consumption by 2020 and 27% by 2030 (EU Commission).
  - Projections of >2°C increase in global temperature by 2100 compared with pre-industrial levels (Paris Agreement).

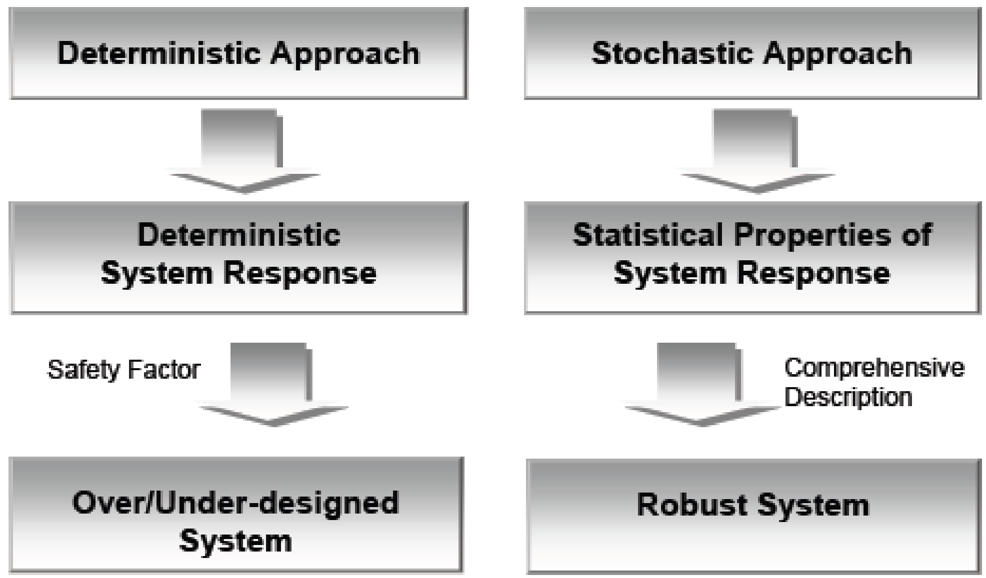


Source: Siemens 2014 report

Introduction

- Probabilistic analysis of the design of **Offshore Wind Turbine (OWT)** towers

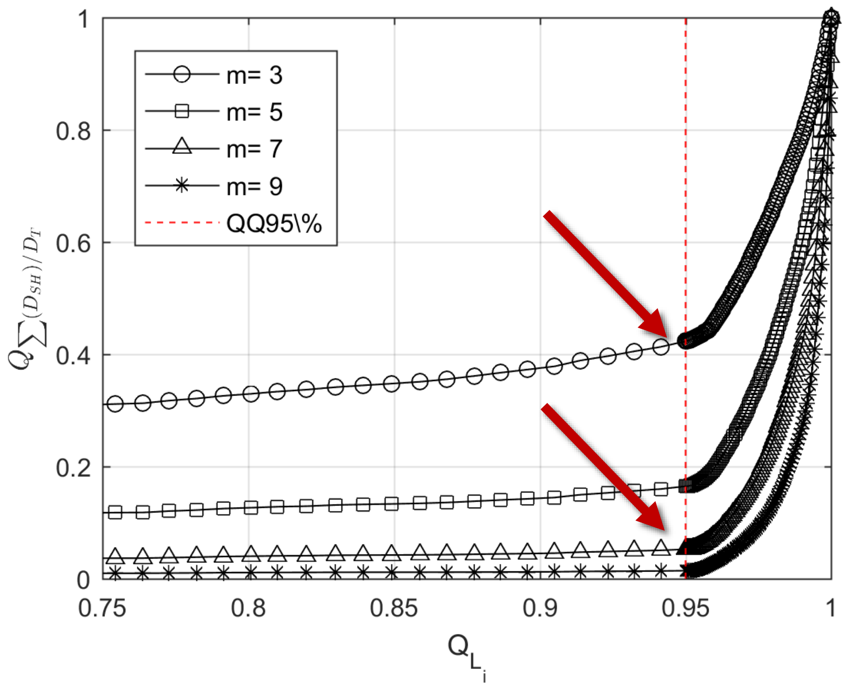
- OWT are highly complex systems that are affected by **multiple sources of uncertainty**. Demand a strong reliability design basis.



- **OWT Towers fatigue life**

Why?

Offshore wind turbine fatigue design methodology



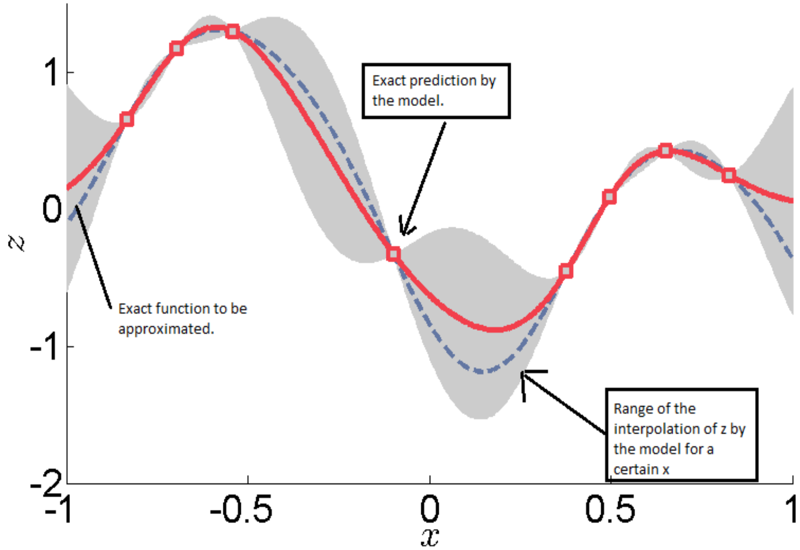
- Computationally **demanding task.**
- Current methodology involves the extrapolation of load cycles using a **Peak-Over-threshold** approach. **Below the threshold** level **loads** are accounted **deterministically** (IEC 61400-3).

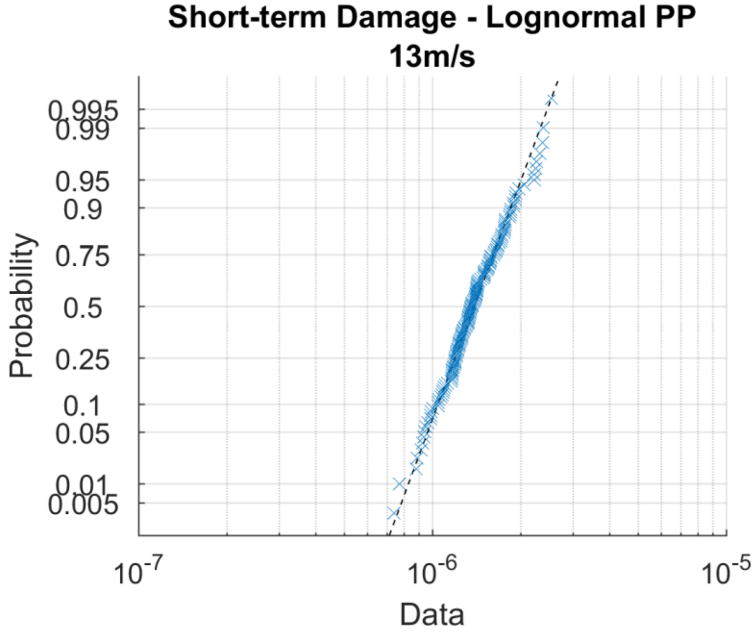
$$D_T = \sum_{i=1}^{N_T} D_{SH\,i}$$

- Still they may account for substantial damage for low SN slope (m) materials. High damage generated by small amplitude loads.
  - **Ok** for e.g. **blades**.
  - **Not ok** for e.g. **tower**.

Probabilistic optimization of the design of OWT towers

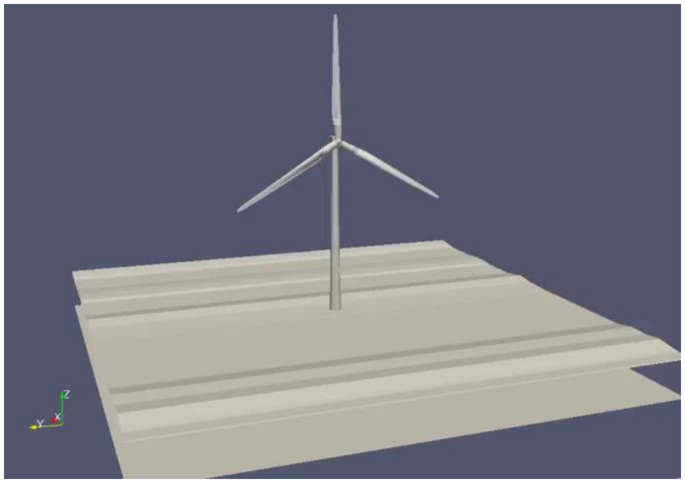
- Using Kriging surrogate models to design towers to fatigue
  - Short term damage follows a **Lognormal distribution.**
  - **Kriging** is an **interpolation model** that considers **Gaussian uncertainty** in the interpolation.





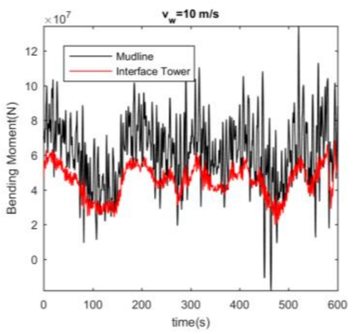
- Applied to **decrease computational cost**.
- **Potential** of application for reliability is **very high**.

Probabilistic optimization of the design of OWT towers



NREL FAST Monopile OWT

Loads tower sections.



Rainflow counting, damage summation and statistical characterization of short-term damage.

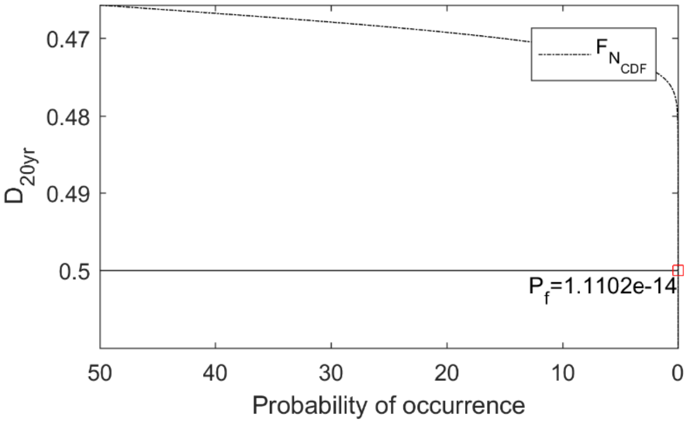
Kriging surrogate model.

Statistically accurate?

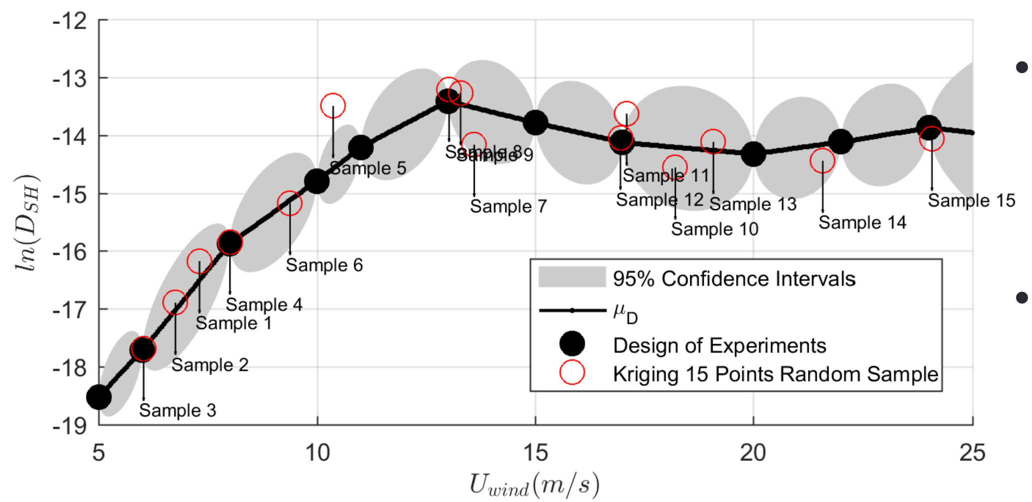
No

Yes

Long term fatigue damage distribution.

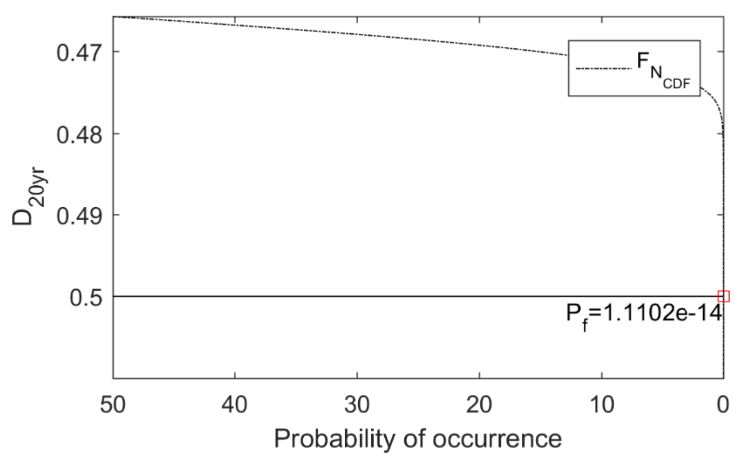


Results - Structural probabilistic assessment of Offshore Wind Turbine operation fatigue based on Kriging interpolation



- Variations of short term damage with the wind are very high.
- 72 evaluations to create the model + 60 evaluations to correct it. Validated with m-life.

- 100 evaluations of 20 years damage (time demanding).
- Very low probability of failure NREL 5MW monopile OWT.



Conclusions

- A **new approach** was implemented to design OWT to fatigue design. It is a "**non-intrusive**" methodology.

- The **Gaussian properties** of the Kriging surface **are adequate for simulating short term damage** on the OWT tower.

- Using the Kriging to approximate the damage surface of the model can **cut computational** time from the design analysis.
  - OWT fatigue design is a very computer resource consuming task.

- **Using the estimation** of **error** in some points of the DoE to **correct** the prediction **is valid** option but that needs more research.
  - It demands many additional simulations to converge the statistical distributions.

Further Developments:

- **Stochastic sensitivity** of the Design of Experiments (DoE).
  - No additional complexity should be considered in the model if the variable does not account for important information in regard of OWT tower damage.

- **Adaptive Design of Experiments** when creating the surrogate model.
  - Allows to optimize the ratio cost/accuracy when creating the surrogate model.

- **Study the influence of deterministic prediction in DoE** when creating the surrogate model.

- **Nevertheless, interesting potential** to design and optimize the design of OWT towers to operational fatigue.

Thank you!

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