Summer PhD School

in

Uncertainty Quantification and Reliability Assessment of Offshore Wind Turbines

LEARNING OBJECTIVES

1) Understand the wind turbine design assessment process and be familiar with the major standards and the prescriptions (load cases, limit states) defined in them
2) Know the building elements and the modelling chain required to set up a reliability assessment for offshore wind turbines (e.g. limit states, system variables, environmental variables and uncertainties)
3) Identify key variables and describe them through probability distributions
4) Select appropriate sampling strategies depending on the problem at hand (space-filling vs. for numerical integration)
5) Assess model uncertainty through comparing models of different fidelity
6) Carry out uncertainty propagation and numerical integration to compute reliability indexes
7) Train several types of surrogate models and carry out global sensitivity analysis
8) Know how to implement reliability and UQ problems in Python using existing frameworks

PRACTICAL DETAILS:

Time: 28-31 August 2023 (4 days with physical presence)

Location: DTU Wind Energy campus, Frederiksborgvej 399, 4000 Roskilde, Denmark

Price: free for participants among project partners.

Included with registration: lunches, coffee and refreshments

Day 1: Monday 28-08-2023

Time	Title	Presenter	Notes
09:00 – 09:15	Welcome and intro	N. Dimitrov	
09:15 – 09:45	Introduction to probabilistic design	N. Dimitrov, Mark Kelly (DTU)	Introduction to the main elements of Prob. Design – potential applications, benefits over classical design. Illustrative examples from wind energy.
09:45 – 10:30	Uncertainty quantification basics – part 1	S. Marelli (ETHZ)	Different ways of dealing with uncertainty: - Uncertainty propagation - Reliability analysis - Sensitivity analysis
10:30 – 10:45	Coffee break		
10:45 – 11:30	Uncertainty quantification basics – part 2	S. Marelli (ETHZ)	Different ways of dealing with uncertainty – continued. Concept of surrogate models. Practical example with UQLab
11:30 – 12:15	Uncertainties inherent for the wind turbine design process (modelling chain)	Alexis Cousin (IFPEN) (online)	Discuss the types of uncertainty, how they affect the design and how they could potentially be estimated
12:15 – 13:15	Lunch		
13:15 – 14:00	Uncertainties inherent in atmospheric modelling and their effect on loads and reliability	Mostafa Paskyabi (UiB) (online)	Discuss the types of uncertainty affecting the atmospheric models (e.g. multi-scale models) and how they propagate to wind turbine loads.
14:00 – 14:45	Introduction to popular UQ frameworks	Vincent Chabridon, Elias Fekhari (EDF)	Introduction to OpenTURNs - on-screen examples
14:45 – 15:15	Coffee break		
15:15 – 17:00	Introduction to the study cases and programming environments. Form groups, initialize group work. Group work, initialize and test the study case, data loading and visualization.	Group work supported by teachers	Intro to study cases. Help with programming environments and running test scripts.

Day 2: Tuesday 29-08-2023

Time	Title	Presenter	Notes
09:00 – 09:45	Introduction to probabilistic design guidelines and the IEC standards system	J.D.Sørensen (AAU)	Guest lecturer. IEC Standard design basis, meaning of safety factors.
09:45 – 10:30	Distribution fitting – part 1	Erik Vanem (DNV)	Joint distribution fits, copulas, isoprobabilistic transformations (Rosenblatt, Nataf)
10:30 – 10:45	Coffee break		
10:45 – 11:30	Distribution fitting – part 2	Erik Vanem (DNV)	Extreme distributions, environmental contours
11:30 – 12:15	Model uncertainties characterization using Gaussian models	Christian Agrell (DNV)	Introduction to Gaussian processes and how to use that to create emulators and surrogate models
12:30 – 13:30	Lunch		
13:30 – 15:00	Group exercise: fitting of environmental distributions	Group work supported by teachers	
15:00 – 15:30	Coffee break		
15:30 – 17:30	Group exercise: limit state formulation, choice of variable distributions	Group work supported by teachers	

Day 3: Wednesday 30-08-2023

Time	Title	Presenter	Notes
09:00 – 10:15	Inspiration with advanced UQ topics – part 1	Vincent Chabridon, Elias Fekhari (EDF)	Advanced sensitivity analysis (Vincent Chabridon) Advanced sampling with Kernel herding (Elias Fekhari)
10:15 – 11:00	Common reliability assessment methods	Nikolay Dimitrov (DTU)	Overview of common reliability methods
11:00 – 11:15	Coffee break		
09:45 – 11:00	Exercise – simple MC-FORM-IS analysis	Emmanuel Ardillon (EDF)	Includes a description of advanced FORM-IS analysis
12:30 – 13:30	Lunch		
13:30 – 14:15	Inspiration with advanced UQ topics – part 2	Nikolay Dimitrov (DTU)	The Hiperwind project: learnings and inspiration for practical UQ and reliability assessment
14:15 – 14:30	Closing and wrap-up of the lecture-based part of the course		
14:30 – 15:00	Coffee break		
15:00 – 17:30	Group exercise: fitting an uncertainty model between a data-driven surrogate model and aeroelastic load simulation data		Group work supported by teachers

Day 4: Thursday 31-08-2023

Time	Topic
09:00 – 15:00	Main theme: course work, programming Main goal: complete reliability assessment in ULS – Finalize the limit state definition – Populate the uncertainty models – Choose appropriate reliability assessment methods and run analysis