Continuing Education and PhD Course on Reliability, Probabilistic Design and Risk Analysis of Wind Turbines

Organized by:

- Department of Civil Engineering, Aalborg University, Aalborg Denmark
- The Joint Committee on Structural Safety (JCSS)

Increased Interest In Risk and Reliability

Methods of reliability, risk and safety assessment are increasingly gaining importance as decision support tools in various fields of engineering. In order to utilize these methods and to exploit their potential in industrial applications, an understanding of the fundamental principles is necessary. The Advanced School aims at educating engineers and researchers to work more efficiently in supporting decision makers and clients for a sustainable societal development.

JCSS

The JCSS is a committee in the field of Structural related Risk and Reliability, acting on behalf of the Liaison Committee of the following six international professional associations:

- CIB International Council for Research and Innovation in Building and Construction
- ECCS European Convention for Constructional Steelwork
- fib International Federation for Structural Concrete
- IABSE International Association for Bridge and Structural Engineering
- RILEM Reunion internationale des Laboratoires et Experts des Materiaux
- IASS International Association for Shell and Spatial structures

The goals of the JCSS are:

- To improve the general knowledge and understanding within the fields of safety, risk, reliability and quality assurance, for all types of civil engineering and building structures, on the basis of sound scientific principles and with an open eye for the applications in practice.
- To take care that inter-associational pre-normative research in the field of Risk and Reliability is performed in an effective and adequate way.

Benefits

The participants benefit by becoming able to master the methods of reliability, risk and safety assessment in the application field of wind turbine engineering. Furthermore, based on the knowledge gained from the course, the participants can offer clients new services related reliability, risk and resilience informed decision support.

Who should attend?

The present course is targeted PhD students and professionals working in the field of wind turbine design, operations and management. However, the course is also of interest to engineers involved in probabilistic structural analysis, design and reliability assessment, as well as engineering supervisors and managers. Participants are expected to have basic knowledge on basic probability theory, statistics, linear algebra and elementary structural analysis (static/dynamic).

Information and course plan

Time and Place

Time: November 11-15, 2019.
Place: Aalborg University, Department of Civil Engineering, Thomas Manns Vej 23, 9220 Aalborg.

Learning Methods and Activities

Learning methods and activities comprise lectures, practical exercises and self-studies. Self-study assignments will typically consist of calculations that develop understanding of the materials presented in class. Participants will be made familiar with the state-of-the-art computational methods and software in this field.

Evaluation and Diploma

Course Diplomas are issued by the JCSS on the basis of active course participation and a positive evaluation of the provided material by the participant.

Lecturers

John D. Sørensen
Professor, Department of Civil Engineering
Aalborg University, Denmark

Jannie S. Nielsen
Associate Professor, Department of Civil Engineering
Aalborg University, Denmark

Michael H. Faber
Professor, Department of Civil Engineering
Aalborg University, Denmark

Costs and Registration

The course is free of charge for PhD students. For other participants the cost is DKK 10.000.
Registration at https://phd.moodle.aau.dk/course/index.php?categoryid=162

Contact

The course is organized by Professor John Dalsgaard Sørensen, Department of Civil Engineering, Aalborg University, from whom further information may be obtained.

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Course Plan

Lecture contents

Monday, November 11
• 9:00-12:00
  ○ Introduction
  ○ Uncertainty modelling (strength, loads, lifetimes, models, ...)
  ▪ Bayesian statistical methods
  ▪ Characteristic values
  ○ Example – STATREL + Matlab + Excel
  ○ Exercise 1 – statistical analysis for strength data
  ○ Exercise 2 – statistical analysis for wind and wave data
• 12:00-12.45 lunch
• 12.45-16.30
  ○ Estimation of failure probability by FORM
  ○ FERUM (Matlab) + STRUREL - examples
  ○ Exercise 3 – reliability index

Tuesday, November 12 • 9:00 – 12:00   ○ Estimation of failure probability by SORM and simulation

- Design Load cases in IEC 61400 – probabilistic modelling
- Exercise 4 – model uncertainty
- Classical reliability of mechanical and electrical components (failure rates)

- 12-12.45 lunch
- 12:45-16:30
  - Partial safety factor calibration + Target reliability
  - Calibration of partial safety factors in IEC 61400
  - Exercise 5 – calibration of partial safety factors
  - System modelling: Reliability of series and parallel systems
  - Example – SYSREL
  - Exercise 6 - system reliability

Wednesday, November 13

- 9:00 – 12:00
  - Time-variant reliability - Load combinations - Inverse FORM
  - Probabilistic design of wind turbines – extreme loads and fatigue
  - Exercise 7 - partial safety factor calibration for wind turbines
- 12-12.45 lunch
- 12:45-16:30
  - Site suitability analysis – probabilistic approach
  - Surrogate Models in Wind Turbine Reliability
  - Lifetime extension – probabilistic approach
  - Exercise 8 – Lifetime extension

Thursday, November 14

- 9:00 – 12:00
  - Operation & Maintenance planning for wind turbines
  - Accessibility
  - Maintenance optimization
  - Exercise 9 - OM
- 12-12.45 lunch
- 12:45-16:30
  - Reliability- and risk-based planning of Operation & Maintenance
  - Bayesian networks for maintenance planning
  - Exercise 9 - OM *continued*

Friday, November 15

- 9:00 – 12:00
  - Decision analysis
  - Probabilistic systems risk modelling and analysis
  - Risk, robustness and resilience of systems
  - Exercise 10 – Decision analysis
- 12-12.45 lunch
- 12:45-16:30
  - Value of Information in Assets Integrity Management
  - Resilience informed integrity management for wind turbine parks
  - Exercise 11 – Systems

Lecture Material

The following notes and papers form the basis for the lectures. Additional material may be provided.

1. Sørensen, J.D.: Notes in 'Structural Reliability Theory - and Risk Analysis'. Aalborg University, 2004.
2. Ditlevsen, O. & H.O. Madsen: Structural Reliability Methods. Wiley, 1996. (supplementary)
3. Sørensen, J.D.: Framework for risk-based planning of operation and maintenance for offshore wind turbines. Wind Energy, Vol. 12, 2009, pp. 493-506.
4. Sørensen, J.D. and Henrik S. Toft: Probabilistic design of wind turbines. Energies, Vol. 3, 2010, pp. 241-257.
5. Toft, H.S., J.D. Sørensen & D. Veldkamp: Assessment of Load Extrapolation Methods for Wind Turbines. Journal of Solar Energy Engineering, Vol. 133, No. 2, 2011, pp. 1-8.
6. Toft, H.S., K. Branner, P. Berring & J.D. Sørensen: Defect Distribution and Reliability Assessment of Wind Turbine Blades. Engineering Structures, Vol. 33, 2011, pp. 171-180.
7. Nielsen, J.J. & J.D. Sørensen: On Risk-Based Operation and Maintenance of Offshore Wind Turbine Components. Journal for Reliability Engineering & System Safety, Vol.96, No. 1, 2011, pp. 218-229.
8. Nielsen, J.S. & J.D. Sørensen: Methods for Risk-Based Planning of O&M of Wind Turbines. Energies, Vol. 7, 2014, pp. 6645-664.
9. Ragan,P. & L. Manuel: Statistical extrapolation methods for estimating wind turbine extreme loads. Journal of Solar Engineering, Vol. 130, No. 1, 2008.
10. Sørensen, J.D.: Reliability-based calibration of fatigue safety factors for offshore wind turbines. International Journal of Offshore and Polar Engineering. Vol. 22, No. 3, 2012, pp. 234–241.
11. Winterstein, S.R., Ude, T.C., Cornell, C.A., Bjerager, P., and Haver, S. 1993. Environmental parameters for extreme response: inverse FORM with omission factors. Proceedings, ICOSSAR93, Innsbruck, Austria.
12. Christensen, C.F. and Arnbjerg-Nielsen, T.: Return Period for Environmental Loads – Combination of Wind and Wave Loads for Offshore Wind Turbines. Rambøll, 2000.
13. Sørensen, J.D., I.B. Kroon and M.H. Faber: Optimal Reliability-Based Code Calibration. "Structural Safety", Vol. 15, 1994, pp. 197-208.
14. Sørensen, J.D. & N.J. Tarp-Johansen: Reliability-based optimization and optimal reliability level of offshore wind turbines. International Journal of Offshore and Polar Engineering (IJOPE), Vol. 15, No. 2, June 2005, pp. 1-6.
15. Sørensen, J.D., S. Frandsen and N.J. Tarp-Johansen: Effective Turbulence Models and Fatigue Reliability in Wind Farms. Probabilistic Engineering Mechanics, Vol. 23, 2008, pp. 531-538.
16. Tarp-Johansen, N.J., P.H. Madsen and Sten Frandsen: Partial safety factors for extreme load effects. Risø report R-1319, 2002.
17. JCSS (2008) Joint Committee on Structural Safety: Risk Assessment in Engineering Principles, System Representation & Risk Criteria. JCSS Publication, http://www.jcss.ethz.ch/.
18. Sørensen, J.D. and H.S. Toft: Safety Factors – IEC 61400-1 ed. 4 - background document. 2015.
19. Toft, H.S., L. Svenningsen, J.D. Sørensen, W. Moser & M.L. Thøgersen: Uncertainty in Wind Climate Parameters and their Influence on Wind Turbine Fatigue Loads. Renewable Energy, Vol. 90, 2016, pp. 352-361.

20. Sørensen, J.D.: Reliability assessment of turbines. Proc. ICASP12, Vancouver, July 2015.
21. Nielsen, L., Tølbøll, S. G., Qin, J. and Faber M. H. (2019) Faith and fakes – dealing with critical information in decision analysis, Civil Engineering and Environmental Systems, 36:1, 32-54, DOI: 10.1080/10286608.2019.1615476
22. Qin, J.; Faber, M.H. Resilience Informed Integrity Management of Wind Turbine Parks. Energies 2019, 12, 2729.
23. Faber, M. H., Qin, J., Miraglia, S., & Thöns, S. (2017). On the Probabilistic Characterization of Robustness and Resilience. Procedia Engineering, 198, 1070-1083. https://doi.org/10.1016/j.proeng.2017.07.151.
24. Thöns, S., Faber, M. H., & Val, D. (2017). On the Value of Structural Health Monitoring Information for the Operation of Wind Parks. In 12th International Conference on Structural Safety and Reliability (pp. 3008-3017). IASSAR.

Notes:

1. Characteristic values
2. Model uncertainty
3. Maximum Likelihood

Additional material:

- Madsen, H.O. & S. Krenk & N.C. Lind: Methods of Structural Safety. Prentice-Hall, 1986.
- Faber, M. H. (2012) Statistics and Probability Theory: In Pursuit of Engineering Decision Support. / Springer Publishing Company, 2012. 206 p. (Topics in Safety, Risk, Reliability and Quality, Vol. 18).
- Faber, M. H. (2009) Risk and Safety in Civil Engineering, Lecture Notes, http://civil.aut.ac.ir/Binary/UploadedFiles/2009-08-30/znsnztiikk_Risk%20and%20Safty%20in%20Civil%20Engineering.pdf.