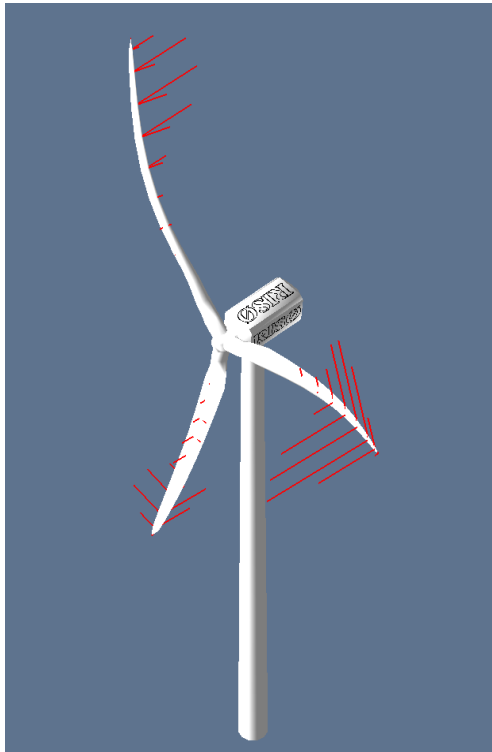


# Wind Turbine Dynamics and Aeroelasticity

Ph.D. / Advanced eng. course



Risø DTU National Laboratory for  
Sustainable Energy  
Technical University of Denmark,  
Wind Energy Division

August 23-28, 2010 at Risø DTU

## Background

Modal frequencies, damping and shapes of the vibration modes of operating wind turbines can be computed with and without the influence of the aerodynamic forces from the surrounding flow. The vibration modes of the unforced turbine (excluding the aerodynamic forces) constitute a dynamic fingerprint that defines its modal dynamics; these structural modes form the basis of the aeroelastic response of wind turbines due to the aerodynamic forces. The vibration modes of the turbine including the aerodynamic forces determine its aeroelastic stability properties through the damping of these aeroelastic modes. Stall-induced vibrations and classical flutter are the two main mechanisms that may lead to aeroelastic instabilities of three-bladed turbines with negative damping of an aeroelastic mode.

## Learning objectives

After the course the participants should be able to:

- Explain the methods of computing the modal frequencies, damping and shapes of the structural and aeroelastic modes of operating wind turbines, and apply these methods for turbine analysis.
- Analyze and optimize modal dynamics of three-bladed wind turbines, and to explain these structural modes in the aeroelastic response of operating wind turbines.
- Explain the mechanisms of the aeroelastic instabilities called stall-induced vibrations and classical flutter, and analyze the risk of these instabilities for a given wind turbine.
- Present and disseminate the important issues of wind turbine modal dynamics and aeroelastic stability to colleagues and fellow students.
- Perform further state-of-the-art research within dynamics and aeroelastic stability of wind turbines.

The teaching will consist of a combination of dialog-based lectures and group work with illustrative example assignments, where the introduced methods are applied.

## Participants

This course is aimed at graduate students interested in wind energy research and engineers in the wind turbine industry with the purpose to learn how to describe, analyze and optimize the modal dynamics and aeroelastic stability of wind turbines based on the commercial three-bladed concept. The participants must have pre-knowledge of vibration analysis and linear dynamics of mechanical systems. No particular knowledge of wind turbines is needed; however, a general knowledge of structural dynamics and/or aerodynamics is required.

## Program outline

### Monday: Introduction

08.00-09.00	Registration + Breakfast
09.00-09.30	Welcome and Introduction
09.30-12.00	Repetition of linear vibration analysis and introduction of turbine terminology
12.00-13.00	Lunch
13.00-17.00	Group work with modal dynamics of three-bladed turbines

### Tuesday: Modal Dynamics

09.00-10.00	Presentations of the results of yesterday's exercise
10.00-12.00	Methods for vibration analysis of wind turbines and their structural modal dynamics
12.00-13.00	Lunch
13.00-17.00	Group work with modal dynamics of wind turbines

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*Wednesday: Aeroelastic stability*

09.00-10.00	Presentations of the results of yesterday's exercise
10.00-12.00	Aeroelastic modelling and stability analysis of wind turbines
12.00-13.00	Lunch
13.00-17.00	Group work with aeroelastic stability analysis of wind turbines

*Thursday: Aeroelastic stability*

09.00-10.00	Presentations of the results of yesterday's exercise
10.00-12.00	Aeroelastic instabilities for wind turbines: Stall-induced vibrations and classical flutter
12.00-13.00	Lunch
13.00-17.00	Group work with aeroelastic stability analysis of wind turbines
19:00-	Workshop Dinner

*Friday: State of the art & Exam*

09.00-09.30	Breakfast together with the Aeroelastic Design group
09.30-10.30	Presentations of the results of yesterday's exercise
10.30-12.00	Presentation of current research in aeroelasticity of wind turbines, course evaluation and discussion of future work
12.00-13.00	Lunch
13.00-14.00	Written exam based on a case study.
14.00-15.00	Visit to the old Test Station for Small Turbines

**Working Load**

Approximately 40 hours in total, including work sessions during the course period at Risø-DTU (lectures, discussions and assignments) as well as preparatory required reading before course start.

**Study Material**

Lecture notes covering the course will be distributed by e-mail to the participants shortly after registration.

**Language**

All lectures will be given in English.

**Evaluation and Diplomas**

To pass the course, a sufficient score on the written exam and active participation and work with assignments are required. ETCS points: 2.5

**Organizer**

Senior Scientist Morten Hartvig Hansen, Wind Energy Division.

**Registration**

For registration please contact Susann Berner, Risø DTU, Wind Energy Division, Building 118, Frederiksborgvej 399, DK-4000 Roskilde, Denmark. tel.: (+45) 4677 5030, fax: (+45) 4677 5960, e-mail: sber@risoe.dtu.dk.

**Registration fee**

The registration fee for students is 100 Euro enrolled at universities and public research institutions covering hand-outs, coffee and social events. For researchers employed at universities and public research institutions the registration fee is 300 Euro. For all other participants the registration fee is 1,500 Euro.

**Deadline**

Applicants should submit a request for registration to be at the hands of the course secretariat no later than August 1st, 2010. Final enrolment will be confirmed within a week after this date.

**Housing**

Accommodation can be arranged either at the Risø DTU's Guest House for the cost of 260 DKK per night, please notice that there is a limited amount of rooms available there. The participants can also arrange to stay in hotels or hostels, e.g. Hotel Prindsen in central Roskilde [www.hotelprindsen.dk](http://www.hotelprindsen.dk) or Roskilde Hostel [www.rova.dk](http://www.rova.dk).



Participants from the course in 2008