KTH Electrical Engineering

# EG2340 Wind Power Systems
# Course Syllabus 2016

The latest news related to the course is announced on the course webpage
https://www.kth.se/social/course/EG2340/.

You can also contact the course staff at the department for Electric Power Systems, Teknikringen 33:


Lennart Söder (examiner, lecturer)
Phone 08-790 8906
lsod@kth.se

Lars Herre (coordinator, assistant)
lherre@kth.se

Ilias Dimoulkas (assistant)
iliasd@kth.se

Stefan Stancovic (lecturer, assistant)
stanko@kth.se

Yalin Huang (assistant)
yalin@kth.se

David Risberg (assistant)
dri@kth.se


External Experts:

| | |
|---|---|
| Thomas Ackermann | Energynautics GmbH |
| Hans Bergström | Department of Earth Sciences, Uppsala University |
| Karl Bolin | Department of Aeronautical and Vehicle Engineering, KTH |
| Katherine Elkington | Svenska Kraftnät |
| Staffan Engström | Ägir konsult |
| Kjell Grip | Vindval, which is financed by Naturvårdsverket |
| Sara Nilsson | Vattenfall AB |
| Richard Ogiewa | Enercon GmbH |
| Sven Ruin | TEROC AB |
| Antonio Segalini | Department of Mechanics, KTH |
| Mattias Wärn | Svea Vind Offshore |

## Course schedule

The detailed course schedule can be found on KTH Social, or directly accessed through
https://www.kth.se/social/course/EG2340/calendar/

## Objectives

The course Wind Power Systems aims at providing knowledge about the wide area of technology that is needed for persons working in the wind energy industry or related industry, such as generation or network companies.

At the end of the course you should be able to:

- give some basic definitions (power curve, overall efficiency, Betz limit, stall and pitch regulation, etc.),
- understand basic concepts, such as power in the wind, vertical distribution of wind speeds, power production and efficiency of a wind turbine, energy yield of a wind turbine from a site,
- calculate energy yield of a wind turbine using actual wind speed measurements or approximate data,
- describe the main wind turbine design concepts, main differences, advantages, disadvantages,
- understand basic concepts from grid integration of wind turbines (voltage at the connection point, active, reactive power, strength of the grid, power quality of a wind turbine),
- describe some effects that wind power has on power system operation and grid investments,
- describe operation of hybrid systems (wind/diesel, wind/battery/diesel),
- describe effects that wind power has on environment,
- describe different economical support schemes for wind power.

In order to receive a higher grade (A-D), you will also need to show that you are able to

- derive the important formulas studied during the course (power in the wind, Betz limit, etc.),
- analyse and compare characteristics of different wind turbines,
- present some control possibilities of wind turbines,
- analyse wind conditions, and wind farm layout possibilities of the particular site,
- perform basic calculations and analysis for grid connection of a wind turbine,
- describe main aspects treated in the Grid Codes for connection of wind turbines and explain why those aspects are important.

## Prerequisites

60 HP (basic mechanics, basic physics, complex numbers, numerical methods), and documented proficiency in English B or equivalent. Basic knowledge in Matlab programming is recommended.

## Course Registration

You must register for this course through KTH's web registration system. You must also register here se page: (https://www.kth.se/social/course/EG2340/page/course-information-course-syllabus/) for internal usage.

## Course Structure

The course includes 24 lectures, 5 exercise sessions and a five-hour examination. It is taught in English. Reading suggestions related to each lecture are given in the schedule on KTH Social and at the end of this document. During the course assistance hours, the teaching assistant will be available to assist the students with the assignments and/or project work, and review the completed home assignments.

## Student Office

STEX – Studerandeexpeditionen
Osquldas väg 10
Phone 08-790 9086/7

## Course Literature

The following book is highly recommanded for this course: J.F. Manwell, J.G. McGowan, A.L. Rogers, *Wind Energy Explained: Theory, Design and Application, Second edition*. It can be bought from STEX for 500 SEK. In addition, overhead and online material can be found on the course webpage.

## Home Assignments

You can work on five facultative assignments that should give you a better understanding. All assignments will be marked, but only the best four can give up to 2.5 bonus points each for the exam (for a maximum of 10 extra points in total). The bonus points are valid for the exam in May and the re-exam in August this year.

The assignments should be completed individually and a written report has to be submitted thru the WEB system: https://www.kth.se/social/course/EG2340/page/course-information-course-syllabus/ If Matlab is used for completing the assignments the code should be included with the report. Solutions to the assignments must be well motivated and explained in detail. All equations used must be written clearly and all variables clarified. Figures and tables must be properly scaled and have labels and captions. Write your name and personal number on the front page of the assignments.

The assignments will be uploaded on KTH Social. The teaching assistant (see table below) will be available to answer questions during the scheduled course assistance hours.

| Assignment | Due date | Teaching assistant |
|---|---|---|
| 1. Wind Data Analysis | Monday 19 September, 09.00 | Ilias Dimoulkas |
| 2. Power Generation Technology | Monday 10 October, 09.00 | Stefan Stankovic |
| 3. Grid Integration of Wind Power Systems | Thursday 20 October, 09.00 | Stefan Stankovic |
| 4. Wind Turbine Design Concepts | Thursday 1 December, 09.00 | Yalin Huang |
| 5. Small Scale Wind Power Systems | Thursday 15 December, 09.00 | Lars Herre |

## Project

There is also a course project, where a group of 3 or 4 students makes a technical and economical pre-feasibility study for an imaginary wind farm project given real wind data, location, electrical network topology etc.

The project description and data will be uploaded on KTH Social.

Each project group will also receive a project report from another group to read. They should then act as an opponent by preparing some questions to ask about the report.

Upon completing of the project, the students are rewarded 1.5 hp (ECTS credits).

The reports summarizing the results of the project should be submitted has to be submitted thru the WEB system: https://www.kth.se/social/course/EG2340/page/course-information-course-syllabus/ The project assistants are Daniel Risberg and Yalin Huang.

All presentations will be on Tuesday December 13, 10-12 in the rooms: B2, B3 and E2. The presentations should be around 15 minute long.

## Examination

Rules regulating written examinations at the Royal Institute of Technology (KTH) can be found on KTH Intranet.

The examination is a single-part examination. Upon completing the course work and passing the final exam, which is given twice a year, the students are awarded 6 hp (ECTS credits). The regular exam is on Saturday 14 January and a re-examination will take place in spring 2017 (details to be announced).

At KTH **it is compulsory to register for examinations**. In order to be eligible for a seat during the exam, the examinee must file this registration in advance. Bookings must be made in advance through https://www.kth.se/student/minasidor/.

The final grade of the course is given according to the table below.

| Total score: Exam (max 100 points) +Assignments (max 10 points) | Grade |
|---|---|
| 0–57 | F |
| 58–60 | FX* |
| 61–68 | E |
| 69–76 | D |
| 77–84 | C |
| 85–92 | B |
| 93–110 | A |

FX*: conditional fail.

## Study Trip

We plan to organize a 2-day study trip involving a visit to a wind farm and a visit to a company, e.g. a wind turbine manufacturer or a system operator. For the study trip in 2015 we went to Germany.

Participation in the study trip is not compulsory. Costs for the study trip are shared between the students and the department. Typically the costs for each student are around 500–700 SEK = mainly cost for flight ticket.

The study trip will preliminary take place on Monday–Tuesday, 21-22 November, Germany, and will be discussed during the initial lectures. Information about registration will be given during the lectures.

## Course Evaluation

Your feedback is important for continuously improving of the course. Any feedback you have during the course can be sent to Lennart or Lars and evaluation forms will be available at the middle and the end of the course.

# LIST OF LECTURES AND ASSOCIATED READING SUGGESTIONS

**Lennart Söder: Intro – Thursday 160901 13-14, E3**

**Thomas Ackermann: Crash course I and II – Friday 160902 13-17, B1**
Chapter 1.
Chapter 11: 11.1, 11.2, 11.3.3.1, 11.3.3.3, 11.3.4, 11.4, 11.5.1 – 11.5.3, 11.5.4.3, 11.5.4.4, 11.7.

**Lennart Söder: Wind measurement – Tuesday 160906 13-15, B1**
Chapter 2: 2.2.1, 2.2.3, 2.3.4, 2.3.5, 2.4 – 2.6, 2.8.
Chapter 9: 9.3, 9.4.1 – 9.4.2.5.
Chapter 11: 11.5.2.2.

**Hans Bergström: Meteorology – Tuesday 160913 13-15, K1**
Chapter 2: 2.1, 2.2, 2.3 (skip 2.3.3), 2.4.3, 2.4.4, 2.6.
Chapter 9: 9.1, 9.2.

**Stefan Stankovic: Power generation technology I and II – Thu 160915 13-15, Q2 + Tue 160920 13-15, B1**
Chapter 5: 5.1 – 5.7.

**Antonio Segalini: Aerodynamics I and II – Thu 160922 13-15, Q2 + Fri 160923 13-15, B2**
Chapter 2: 2.2.3, 2.3.5.
Chapter 3: 3.1, 3.2, 3.3, 3.4.1 – 3.4.6, 3.6.3, 3.7, 3.9, 3.10, 3.12.

**Lennart Söder: Electric power systems I and II – Tue 160927 13-15, B1 + Thu 160929 13-15, D3**
Chapter 5: 5.1 – 5.3.
Chapter 9: 9.5.1.

**Staffan Engström: Design of a wind turbine – Tuesday 161004 13-15, B3**
Chapter 3: 3.14.1.
Chapter 6: 6.3.2, 6.3.3 (skip 6.3.3.5).
Chapter 7: 7.1 – 7.4.

**Katherine Elkington: Planning for wind power at Svenska Kraftnät – 161006 13-15, Q2**

**Richard Ogiewa: Enercon: Wind farm control – Tuesday 161011 13-15, B1**
Chapter 3: 3.1, 3.2, 3.3, 3.4.1 – 3.4.6, 3.5, 3.6, 3.7, 3.8, 3.9, 3.10, 3.12, 3.14.1.
Chapter 4: 4.1, 4.2.
Chapter 5: 5.6.
Chapter 6: 6.5.2, 6.5.4, 6.5.5.
Chapter 7: 7.3.1, 7.7. Chapter 8: 8.1 – 8.3.

**Sven Ruin: Stand-alone and hybrid systems – Monday 161103, 13-15, K1**
Chapter 10: 10.1 – 10.3 (skip 10.3.4).

**Lennart Söder: Electric network integration and balancing – Fri 161104 13-15, Q2 + Tue 161108 14-16, Q2**
Chapter 9: 9.5.4, 9.5.5.
Chapter 11: 11.5.

**Mattias Wärn: Project development – 161110 14-16, B1**

**Karl Bolin: Wind Turbine Noise – Wednesday 161111, 13-15, B3**
Chapter 12: 12.4.1 – 12.4.3, 12.4.5, 12.4.6, 12.7.

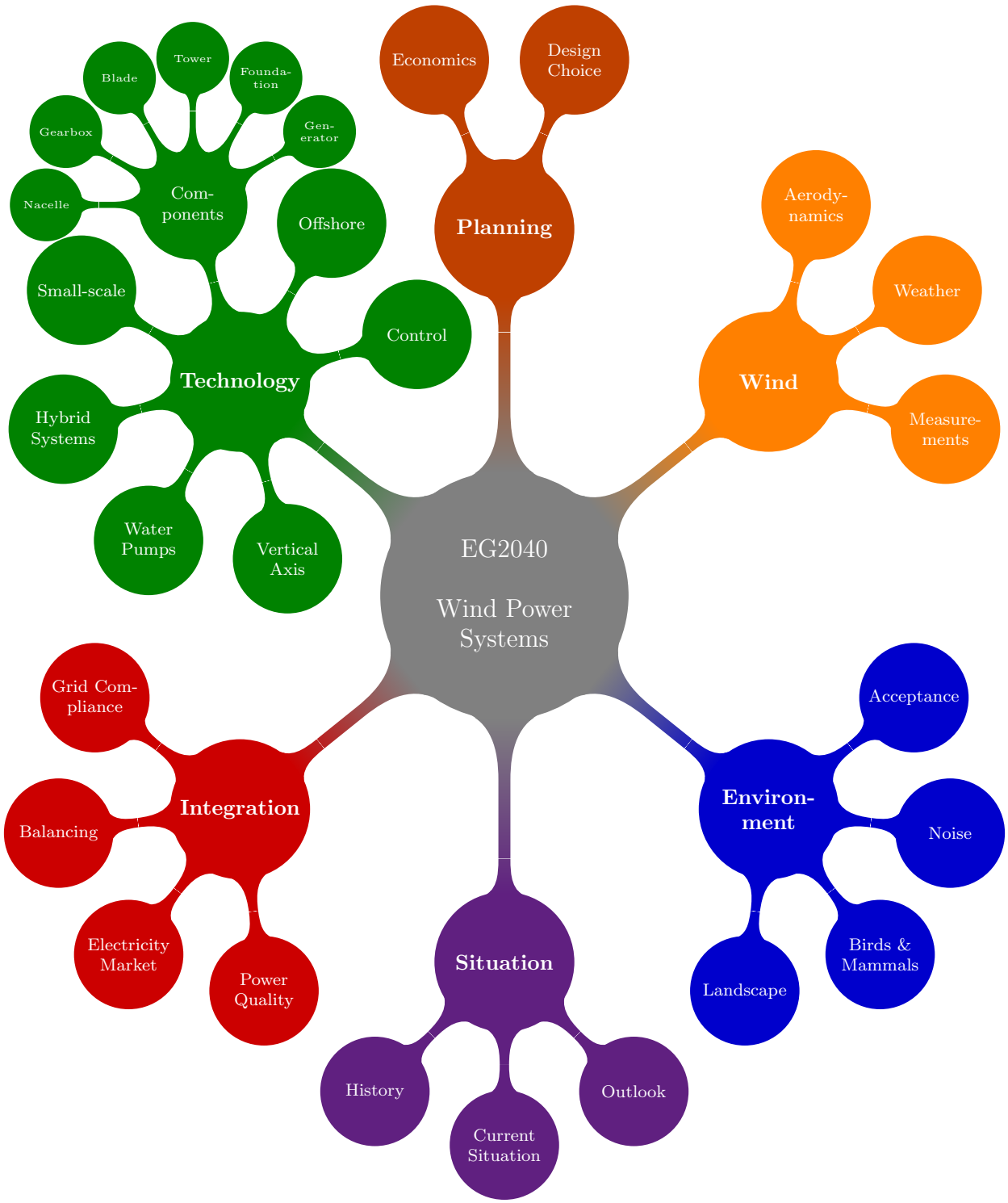
**Thomas Ackermann: European integration studies – 161124 13-15, B3**

**Thomas Ackermann: Offshore wind power – Tuesday 161129 13-15, V3**
Chapter 1: 1.2.5.
Chapter 3: 3.14.1.
Chapter 7: 7.3.1.
Chapter 10: 10.4 (skip 10.4.4).
Chapter 12: 12.1.

**Thomas Ackermann: Wind pumps and small turbines – Wednesday 161201 13-15, B1**
Chapter 10: 10.1 – 10.3, 10.6.1.

**Kjell Grip: Wind power and the environment – 161206 13-15, B2**
Chapter 12: 12.1, 12.2 (skip 12.2.4), 12.3.1, 12.3.2, 12.4.1, 12.5.1, 12.7.2.

**Sara Nilsson: Life Cycle analysis – Wednesday 161208 13-15, Q2**


EG2040
Wind Power Systems
Planning
Economics
Design Choice
Technology
Components
Blade
Tower
Foundation
Generator
Gearbox
Nacelle
Offshore
Small-scale
Control
Hybrid Systems
Water Pumps
Vertical Axis
Wind
Aerodynamics
Weather
Measurements
Integration
Grid Compliance
Balancing
Electricity Market
Power Quality
Situation
History
Current Situation
Outlook
Environment
Acceptance
Noise
Birds & Mammals
Landscape