

Wind Energy Study Programs at Aalborg University

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Power Cluster WP 3

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1. Introduction

This report describes the main contents of the master programs related to wind energy at Aalborg University (AAU), Denmark. The following programs are included:

- MSc – Energy Technology: Wind Power Systems (WPS), section 2
- MSc - Mechanical Engineering: Design of Mechanical Systems, section 3
- MSc - Sustainable Energy Planning & Management Engineering, section 4
- MSc - Structural Engineering, section 5
- Continuing Education – WindMaster, section 6

Inaugurated in 1974 as the youngest of Denmark's five universities, Aalborg University (AAU) is currently Denmark's third largest university. It enrolls approximately 14,000 students in its Faculty of Humanities, Faculty of Social Sciences, Faculty of Medicine, and its Faculty of Engineering and Science. Aalborg University's emphasis on interdisciplinarity, problem-oriented and project-organized studies, and the interaction of theory and practices gives it a profile very different from the traditional university.

Both research and teaching at Aalborg University are based on inter-disciplinary and problem-oriented studies organised around group work. Furthermore project work generally accounts for 50% of the study time, while the other 50% are devoted to lectures and seminars. The projects take their starting points in real life problems and are often prepared in conjunction with local companies, authorities or organisations. Projects are normally prepared in groups of 3 to 5 students who work together throughout the entire semester under the supervision of one or more teachers.

The study plans are presently being updated implying that some of the courses are combined (to 5 ECTS courses), and the content slightly modified.

2. MSc – Energy Technology: Wind Power Systems (WPS)

The master programme in Wind Power Systems (WPS) at Department of Energy Technology focuses on the electrical aspects of wind power systems in subjects such as generators, power electronics, control engineering and power system technology related to wind power applications, see <http://www.et.aau.dk/education/> under WPS.



2.1 Programme Description

The MSc specialisation in WPS syllabus comprises the last three semesters of the Electrical Energy Engineering programme and may be commenced after the 7th semester of Electrical Energy Engineering or, for international students, by completing an Introductory 7th Semester. The themes for the three semesters are 'Interaction of wind generator and load', 'Optimization, Diagnosis and Control of Electrical Conditions in Wind Turbines and Wind Farms' providing an in-depth understanding of wind power systems, and the "Final project". A number of courses are offered only to WPS students. However, the majority of courses are common to the master programmes in Electrical Power Systems and High Voltage Engineering (EPSH), and Power Electronics and Drives (PED).

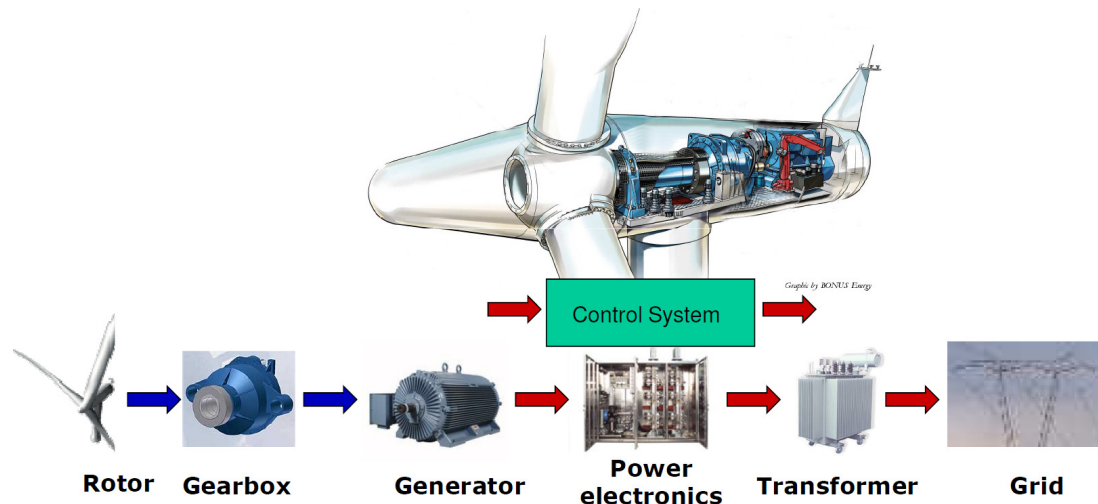
The main objectives of the syllabus may be summarized as follows:

- To provide students with experience of project work solving real problems associated with the Electrical Engineering of Wind Generation Technology.
- That students should understand the dynamics of wind power generation under normal and abnormal conditions of duty.
- To enable students to analyse the dynamic behaviour of wind turbine systems when they are connected to a power system with time varying loads.
- To enable students to analyse the load flow in a WPS, including reactive power flow and to analyse the stability in a WPS.
- To enable students to analyse the power quality of the system and to determine the need for power compensation.
- To enable students to synthesise control systems for different types of wind turbine systems.
- To enable students to analyse the power electronics interface between the wind turbines and the grid.
- To enable students to synthesise power electronic applications in power systems using wind turbines and to evaluate the performance during power system faults and during dynamic events.
- To enable students to evaluate the operation and control of wind power system to ensure acceptable power stability.

Through the M.Sc. specialisation in WPS, the students gain experience with project work in connection with problems in the areas of Electrical Engineering and Wind Generation Technology, and the students work with the dynamics of wind generators under normal and abnormal conditions of duty. The dynamic behavior of wind turbine systems when connecting them to a power system with time varying loads are analysed, and the stability in such a system is examined. Different types of wind turbines are analysed together with their control

principles and use of power electronics interface between the wind turbines and the grid. This specialisation enables the students to analyse the power electronic applications in power systems with wind turbines and to look at the performance during power system faults and dynamics. Based on this, the students should evaluate the operation and control of wind power system to realise good power stability.

The M.Sc. specialisation in WPS is taught in an innovative, dynamic and challenging environment through a combination of research-based courses and team-based project work. There is a high degree of interaction with the wind industry which takes an active part by providing project proposals for the problem-oriented project work and new laboratory set-ups.



2.2 1st Semester – Introduction to Wind Power Systems

The 1st MSc semester consists of four 5 ECTS teaching modules and a 10 ECTS project module.

Project example:

Improvements to the Domestic Energy Supply - Windenergy, Solar-energy, or UPS apparatus

Courses

- Dynamic models of electric machines and control systems - 5 ECTS
- High voltage engineering and design of switch mode converters - 5 ECTS
- Probability theory, statistics and English - 5 ECTS
- Problem-based learning, MATLAB and control theory - 5 ECTS

2.3 2nd Semester – Interaction of wind generator and load

Project theme: Interaction of wind generator and load

Students will complete a project in which a wind turbine system has to be controlled under time varying loads, either as a stand-alone system or coupled to a power network. The system should be modelled, simulated and evaluated with respect to power quality and system stability. It must be determined whether any power compensation units/systems are necessary.

Project examples:

- Grid connection of large off-shore wind turbine parks
- Operation Of Wind Turbines in Isolated Power Systems
- Power Quality of Grid Connected Wind Turbines.

Courses

- Advanced course in electrical power systems - 5 ECTS

- High power converters, devices and EMI/EMC – 5 ECTS
- Optimization theory and stochastic processes – 5 ECTS

2.4 3rd Semester – Control of wind generator systems

Project theme: Optimization, Diagnosis and Control of Electrical Conditions in Wind Turbines and Wind Farms.

The project should be based upon a wind turbine system or a wind farm to which an optimization, control- or diagnostic system is to be set up. First the system is to be modelled and different system identification methods can be applied to determine the parameters of the system. The system model is verified by simulations and data time series from either a real system or a laboratory set up. Based on the model, the optimization, control- or diagnostic system is set up to improve the performance of the system, either with regard to power output, energy efficiency, life time extraction, fault detections etc. and the system should be implemented and verified experimentally. To continue the development of scientific communication skills, the project result or parts of it are published in an article written in English to be presented at an internal seminar.

Project examples:

- Frequency control of wind farms
- Dynamic model of active stall wind turbines
- Control of Variable Pitch or Speed Wind Turbines with Doubly-Fed Induction Generators.

Courses:

10 ECTS of courses are to be chosen at this semester, and the courses offered can shift from year to year, depending on the number of students at the different specializations and the ongoing projects and research at the institute of Energy technology. Further, also courses from other universities might be used as electable courses. However, the following two courses are always offered:

- Neural Network and Fuzzy Logic / Neurale netværk og Fuzzy Logic - 5 ECTS
- System Identification and Diagnosis – 5 ECTS

2.5 4th Semester – Wind power systems

Project theme: Master's Thesis in Wind Power Systems

The Master's Thesis may study a known problem in the wind power system area. It may be an extension of project work from previous semesters or a completely new topic, possibly in collaboration with the wind industry, energy supply companies or the responsible power system utility. As courses are not normally offered on this semester, the entire semester is dedicated to the thesis work.

Examples of Master's Theses:

- Design of Power Electronic Grid Interface System for Large Scale Wind Turbines
- Optimisation of an Energy Conversion System in a Power System with Large Scale Wind Energy
- Performance of the synchronous generator as wind generator
- Assessment of the reliability of wind power systems.

3. MSc - Mechanical Engineering: Design of Mechanical Systems

Global competition has increased the demands for efficiency and functionality in industrial products. Therefore, the world needs engineers who can develop advanced mechanical systems, machines and products. The graduate programme Design of Mechanical Systems prepares you for meeting such challenges.

The Design of Mechanical Systems programme focuses on design and development of industrial products. Through both theory and practice, you learn how to combine technical and creative skills.

The programme gives you insight into a wide range of design tools; both classical engineering disciplines such as configuration of machine constructions and the use of advanced materials and handling of the latest computer-based design and calculation tools.

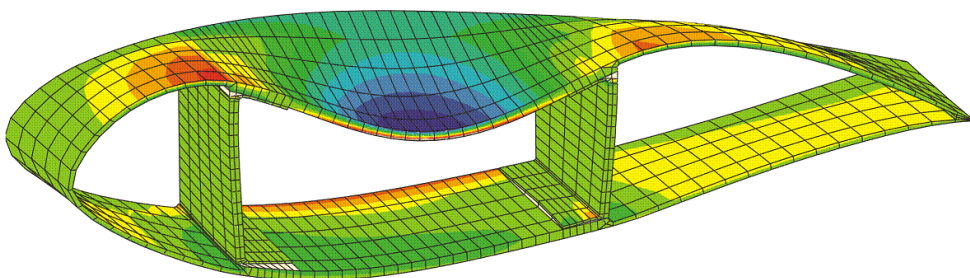
The programme offers courses within following fields, see <http://en.industri.aau.dk/education/design-of-mechanical-systems> :

- Stress and deformation analyses of load carrying structural elements
- Theory of elasticity
- Numerical and experimental methods
- Mathematics of vectors and tensors
- Linear elastic behaviour
- Viscoelastic behaviour
- Theory of plasticity
- Physical mechanisms of materials deformation
- Computational aspects

The project work is focused on putting theory into practice. You will do your project work in cooperation with a company; a great opportunity to try out your ideas and knowledge in a real life-situation.

Project examples:

- Defect analysis of a wind turbine blade
- Design of a wind turbine blade



4. MSc - Sustainable Energy Planning & Management Engineering



Sustainable Energy Planning and Management is an educational programme devised by a research unit called the Sustainable Energy Planning Group, see <http://www.energyplanning.aau.dk/>. The group resides at the Section of Technology, Environment and Society at the Department of Development and Planning at Aalborg University.

1st Semester: Projects, technologies, and corporations/companies

The first semester focuses on specific projects and energy technologies from a business-economic point of view. You will be introduced to theories, methods, and tools for evaluating energy projects in various corporate contexts.

2nd Semester: Systems, institutions, and society

The second semester focuses on entire energy systems, including institutional and societal perspectives. You will be introduced to theories, methods, and tools for evaluating energy systems and energy policies.

4.1 Courses

1st semester

Sustainable energy system analysis

The course Sustainable energy system analysis provides you with methods and models for the design and evaluation of technical, economic, and environmental consequences of different energy systems with emphasis on energy conservation, integrated distributed generation technologies, combined heat and power production, and renewable energy resources.

Energy and Environmental Tools and Project Evaluation

In the course Energy and Environmental Tools and Project Evaluation we focus on the environmental, political, economic, environmental and organisational assessment of energy projects and you will encounter a diverse field ranging from life-cycle assessment and environmental impact assessments to organisation theory and socio-economic feasibility studies.

Theories of Science and Research Designs

This course enables the student to reach an understanding of the main positions within the epistemology (theory of knowledge) of the social sciences and engineering, as well as the application of these to planning research and practice. The students will be trained in evaluating the adequacy of different perspectives on knowledge and science in relation to planning.

2nd semester*Technical Energy System Analysis and Policy Design*

The course Technical Energy System Analysis and Policy Design focuses both on the design of energy systems from a technical and economic point of view - though energy systems analyses - and the design of policies that facilitate the transition towards environmentally benign energy systems.

Energy and Environmental Policies

Energy and Environmental Policies introduce contemporary global energy and environmental policy as well as the decision processes and procedures applied in the policy making. The course also addresses issues such as technology transfer and the institutional framework within national and international energy policy.

Policy, Planning and Governance

This course introduces the concepts of power, politics and policy in relation to decision making processes. The course will provide the students with knowledge of discourses, institutions and actors, and an understanding of how these elements occur in planning processes. Furthermore the students will be able to critically reflect upon how the elements introduced through the course are being used and how to apply them in order to create an understanding of complex decision making processes.

3rd Semester: Traineeship or study abroad

During the 3rd semester, you do a three-month traineeship abroad or in Denmark. You are given a chance to apply your theoretical insights to a practical situation, in which you obtain not only practical experiences but also make contacts that may prove fruitful to you later. Hosts include utilities, consultancies, governmental organisations, and many others in Denmark and abroad. The actual choice depends on your personal preferences and your ability to secure a position. An alternative option is to enrol at another (Danish or foreign) university in order to undertake a one-semester study there.

4th Semester: Master's Thesis preparation

On the final semester, the main focus is on the writing of the Master's thesis. You work individually or in a small group with other students, and in co-operation with your supervisor. The Master's thesis, being the highest level of work undertaken, should aim at synthesising theories and methods in order to design a potential solution to real life sustainable energy planning and management problems.

The 4th semester may be combined with the 3rd semester to form an extended thesis. This is particularly relevant if, for instance, your research question demands more time for collecting data or conducting field studies. This option is not recommended for students without extensive experience in working on projects.

4.2 Projects

These are some of the projects which have been made by students at the Sustainable Energy Planning and Management programme:

1st Semester

Options for an old wind turbine business

With a decade-long history of erecting wind turbines on the best and most visible spots in Denmark, many turbines are now poorly located from a scenic point of view and replacement of the wind turbines is prohibited. This project analyses the very actual problems faced by many owners of small wind turbines: a) continuing its operation with potential rising operation and maintenance costs, b) selling the wind turbine, or c) using the placement right to erect a new wind turbine in another area.

2nd Semester

Institutional setting for wind power development

The project examines how a liberalised electric market can be regulated in order to facilitate the development of wind energy. The cases of Denmark and California are evaluated in relation to the promotion of wind energy and market liberalisation. Finally, the project proposes guidelines on appropriate regulatory forms.

3rd Semester (Traineeship)

Wind Power for the Transportation Sector

The project studies the possible overall system impacts of a hydrogen infrastructure that meets the energy needs for a high percentage of the transportation sector in Western Denmark. As part of the analysis, Genetic Algorithms are used for optimizing the operation of hydrogen fuelling stations.

4th Semester (Thesis)

5. MSc - Structural Engineering



Figure 5.1. Bucket foundation at Frederikshavn.

The overall objectives of the MSC program in civil and structural engineering are that the students obtain:

- Scientifically based knowledge about the structural behavior of civil engineering structures regarding the static as well as the dynamic response
- Understanding of geotechnical engineering and hydraulics as well as structure-soil and structure-fluid interaction based on scientific methods
- Understanding of analytical, numerical and experimental methods for analysis and design of engineering structures
- Knowledge about construction materials and soil regarding their mechanical behavior and modeling
- Knowledge about loads, especially environmental loads like wind and wave loads, and methods for their evaluation
- Knowledge about risk and reliability in engineering including uncertainties of loads, geometry, material properties, structural response and computational models
- Knowledge in one or more subject areas that is based on the highest international research within the fields of civil and structural engineering.

5.1 1st semester – Load-bearing structures

Project theme: Analysis and Design of Load-Bearing Structures – 15 ECTS

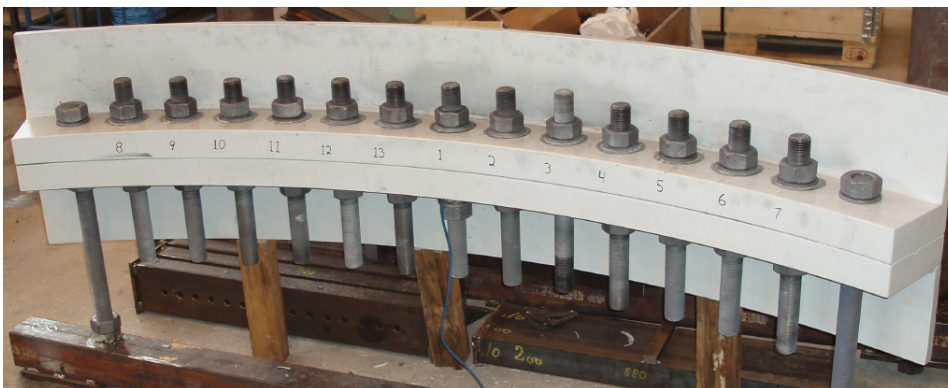


Figure 5.2. Lab test with bolted connection in wind turbine tower.

Project example:

- Analysis of bolted connection in wind turbine tower

Courses:**Structural Mechanics and Dynamics – 5 ECTS**

Kinematics of different structural elements; continuum mechanics; dynamic response; analysis of dynamic structural response; Finite Element Analysis of linear elastic dynamic problems; experimental work related to dynamic testing of structures.

Fluid and Water Wave Dynamics – 5 ECTS

Fluid kinematics; stresses in fluids, equation of motion, constitutive models and Navier-Stokes equations; ideal fluids and potential flows, including application of potential theory to simple problems for example circular cylinder and calculation of hydrodynamic mass; Reynolds averaging and turbulence models; turbulent and laminar boundary layers including understanding of momentum equation for boundary layers; wind generated waves; potential theory to linear surface waves on a horizontal bed, including description and linearisation of boundary conditions, solving Laplace equation and the dispersion equation; Kinematic and dynamic description of linear surface waves, including particle velocities and accelerations, pressure field, particle paths, wave energy, energy flux and group velocity; waves in shallow water, i.e. shoaling, refraction, diffraction and wave breaking; Statistical description of waves in time and frequency domain.

Material Modelling in Civil Engineering – 5 ECTS

Fundamental properties of construction materials in civil engineering with emphasis on their mechanical response; fundamental theories and methods for analysis of structural material behaviour, including elasticity and plasticity; implementation of material models into computational codes including the Finite Element Method; experimental work related to calibration of material models.

5.2 2nd semester – Excitation and foundation of offshore structures

Project theme: The Excitation and Foundation of Marine Structures – 15 ECTS

Project examples:

- Extension of the Horn's Rev Offshore Wind Farm, Denmark
- Suction bucket foundation of offshore wind turbine



Figure 5.3. Laboratory tests with scour protection and wave loads.

Courses:**Advanced Soil Mechanics – 5 ECTS**

Manipulation of three-dimensional stress and strain states; qualitatively describe the expected behavior of soil based on information about relative density or water content, stress level and OCR; Critical State Soil Mechanics (CSSM) for soil based on results from standard laboratory

tests; Must know CSSM model to interpret and predict stress and strain conditions for soil; triaxial compression tests on sand and/or clay; time and rate effects for soil using a viscoplastic framework; advanced 3D constitutive models for soil and calibrate the models to relevant laboratory tests.

Advanced Structural Engineering – 5 ECTS

Non-linear effects in structural response, i.e. influence of large displacements, plasticity or other non-linear material behavior and dynamic effects; advanced structural analysis and its applications in engineering; non-linear behavior of thin-walled structures i.e. buckling and postbuckling behavior and influence of geometric imperfections; modeling of joints in structures linear as well as non-linear; non-linear Finite Element analysis of thin-walled structures.

Risk and Reliability in Engineering – 5 ECTS

Risk, uncertainty, reliability and safety; statistical methods for modeling physical, model, statistical and measurement uncertainties; assessment of reliability of structural systems using probabilistic methods; systems reliability for non-structural components and its applications in engineering.

Coastal, Offshore and Port Engineering – 5 ECTS

Non-linear waves, including 2nd and 5th order and stream function theory; extreme climate analysis; currents and water level variations in the coastal zone; environmental loads on coastal, offshore and port structures including ice, wave, current and wind loads; sediment transport, scour and scour protection; port layout and design of breakwaters.

5.3 3rd semester – Advanced structural engineering problem

Project theme: Analysis and Solution of an Advanced Civil and/or Structural Engineering Problem – 15 ECTS

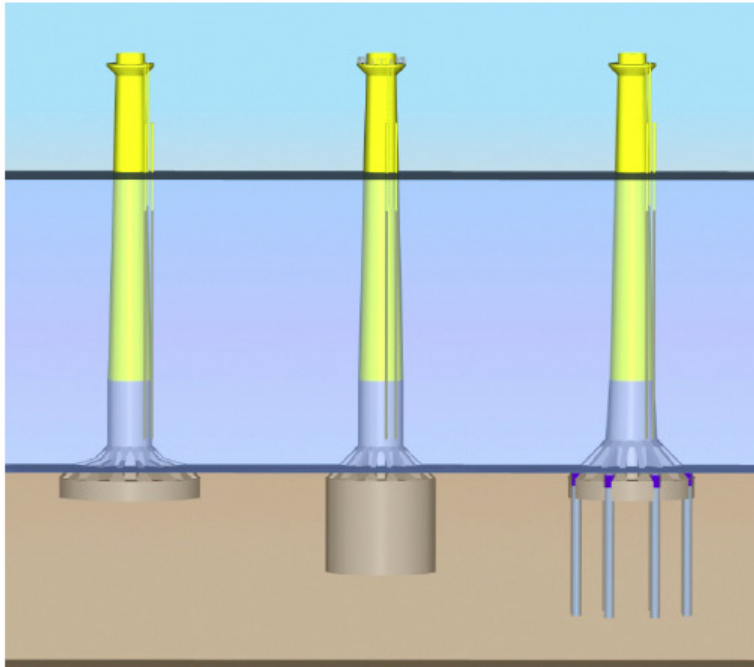


Figure 5.4. Foundation of offshore wind turbines.

Project examples:

- Load and turbulence modeling for wind turbines
- Experimental analysis of scour for monopile offshore wind turbine

Courses:**Renewable Energy Structures: Wind Turbines and Wave Energy Devices – 5 ECTS**

Wind turbines and wave energy devices; design of main structural components for wind turbines and wave energy devices; assess wave energy resources and wave loads on wave energy devices; assess load effects in structural elements in wave energy devices, and verification for ULS and fatigue limit states; correlation between wind wave and current, incl. weather windows; verification of sufficient reliability of wind turbines; basic aerodynamics, aeroelasticity and rotordynamics for wind turbines; wind energy resources; load effects in structural elements in wind turbines, and verification for ULS and fatigue during operation and stand-still.

Wind Loads on Structures – 5 ECTS

Nature of wind: wind profile, mean wind, extreme wind, turbulence, turbulence field – for applications for structures such as buildings, bridges and wind turbines; modeling and calculation of wind loads on civil engineering structures; stochastic processes, stochastic dynamics and wind actions on structures; stochastic dynamics and its applications in engineering, especially for wind actions.

Fracture Mechanics and Fatigue – 5 ECTS

Fracture mechanics analysis in order to establish criteria for crack initiation and crack growth; application of fracture mechanics in engineering applications; models for analysis of fatigue i.e. models for crack growth and influence of loading sequences; application of fatigue analysis in engineering applications.

5.4 4th semester

Final thesis:



Figure 5.5. Failure of wind turbine blade.

Project examples:

- Risk-based planning of operation and maintenance for offshore wind farm
- Calibration of dynamic stall model for wind turbine blade using CFD
- Characteristic behavior of bucket foundation in clay
- Wave loads on offshore wind turbines

6. Continuing Education – WindMaster

The master program WindMaster is a continuing education program aimed for people working in the wind energy industry. The work load corresponds to half the normal work load for a full-time student. At present the WindMaster program is not available, but is expected to be offered again soon.



6.1 Background

Wind turbine technology has become an important industry. Many new technologies have been applied to ensure that the global wind energy sector develops rapidly. The wind industry is very important in Denmark, internationally well known and widely respected. The technology used is very advanced. New developments must be made continuously to ensure that the wind industry can compete in future. A major challenge could be to halve the price per produced kWh by reducing the cost of wind turbine itself. Improving reliability is a key-issue for the future. Connection to the network grid is a new challenge, since more and more energy is supplied by dispersed generation. This demands new control functions to ensure a reliable and stable electric energy supply.

Target group

- Engineers with a Bachelor of Science in Engineering who wish to proceed to a master's degree
- Engineers with a Master of Science in Engineering who wish to supplement the degree with a specialization in another field of study, i.e. electrical engineers who wish to continue their education in the mechanical area or visa versa.

The programme

To ensure a supply of qualified engineers in the wind industry area an international master programme is offered for mechanical or electrical engineers working with wind turbines. Aalborg University, Denmark, offers a two-year part-time study programme that you can complete simultaneously with working in industry. The programme is modularized allowing courses and projects to be completed individually.

Purpose of the Study Programme

The purpose of the master programme in wind energy is to enable the student to:

- acquire research based competence in the wind energy area
- acquire knowledge of fundamental theories and methods used in the area
- attain theoretical and practical skills required for wind turbine planning and design
- develop technical skills relating to the design, analysis, specification and evaluation of complex wind turbine projects.

Two specializations

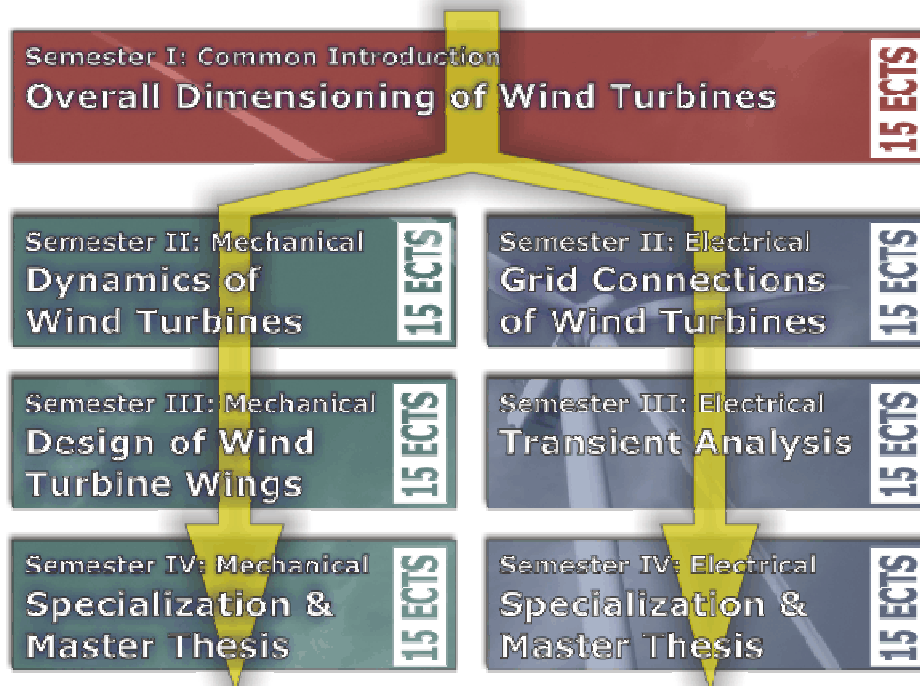


Figure 6.1. Structure of WindMaster programme.

Each semester of the part-time study corresponds to a workload of 15 ECTS. This includes six 2-3 day seminars, distance learning, self study, and project group work.

The programme has an electrical and a mechanical specialization and the structure of the programme is shown in figure 6.1.

The first semester of the programme introduces important problems arising in wind energy systems. Following this, you can choose either the Mechanical or the Electrical Specialization. The participants have to make this choice before study start. The technical content of the Mechanical Specialization is focused on the determination of aerodynamic loads on wind turbines, dynamic structural analysis and the optimization of wind turbine blades. This will enable participants to analyse and design wind turbine structures, taking into account structural dynamics, aerodynamics and material properties.

The technical content of the Electrical Specialization is focused on electrical and control aspects within the wind turbine technology. This includes the study of electrical machines, power electronics, control theory, and analysis of the effect of connecting of wind turbine generators to the power network. Stability and protection issues are also studied, enabling participants to analyse, design and evaluate the electrical components in a wind generator system and to predict the dynamic interaction of the wind turbine and the network grid. Some common core courses are shared by the two specializations, whereas others are individual to the two study programmes.

Work load

The Wind Energy programme has been planned in order to allow the participants to combine the study with a full time job. As a general guideline a half-time study will require approximately 15 – 20 hours per week throughout the duration of the programme.

Semester 1: Common Introduction

The intention of the common core courses in the first semester is to provide an introduction to important problems arising in wind energy engineering. The semester includes electrical, mechanical, structural and aerodynamic subjects.

Project:

'Overall design of wind turbines'

Goals:

The purpose is to enable the student to analyse:

- the aerodynamic load on a wind turbine
- structural strengths of tower and blades
- the drive train and generator.

Activities:

Wind turbine analysis will be based on an actual site where the wind conditions are known and where the power output from the wind turbine is defined. Knowing these parameters, the students will be required to specify and dimension the wind turbine. The aerodynamic loads on the blades and the needed strength of the wings and tower should be determined and the output power calculated. Based on these data and the selected control strategy (pitch or active stall) the generator and drive train should be designed.

Courses on the 1st semester:

- Aerodynamics I - 1 ECTS
- Strength of Materials - 1 ECTS
- Electricity, Magnetism, and Circuit Theory - 1 ECTS
- Control of Wind Turbines - 1 ECTS
- Planning of Wind Power Projects - 1 ECTS
- Generators I - 1 ECTS
- Load Modelling - 1 ECTS

6.2 Mechanical Specialization

Semester 2

The aim of the project unit is to provide the student with the knowledge needed to analyse the Structural behaviour of a wind turbine due to time varying loads caused by turbulence, the motion of the rotor in an inhomogeneous wind field, or load changes caused by yaw or pitch motions. Furthermore, to analyse aeroelastic load variations on the blade due to the influence of the elastic deformation of the blade on the surrounding air flow.

Project:

'Dynamic analysis of wind turbines'

Goals:

The student will at the end of the project unit have achieved the skill to:

- analyse and understand fundamental aerodynamic concepts as stall, dynamic stall, double stall
- aerodynamic damping, including aeroelastic vibrations caused by these phenomena
- perform, via profile theory, a global dynamic modeling of a wind turbine with coupling to time-varying aerodynamic and vibration control loads.

Activities:

Based on data for a given wind turbine the dynamic analysis of a substructure or the entire structure is performed, where the dynamic effect of turbulence or control forces are taken into consideration.

Courses on the 2nd semester:

- Finite Element Method I - 1 ECTS
- Rotor Dynamics I - 1 ECTS
- Aerodynamics II - 1 ECTS
- Rotor Dynamics II - 1 ECTS
- Aerodynamics III - 1 ECTS

- Generators II - 1 ECTS
- Turbulence Theory - 1 ECTS

Semester 3

The project unit should enable the student to apply principles for design and analysis of selected parts of a wind turbine rotor blade, including design aspects related to weight critical structures with maximum strength and stiffness.

Project:

'Analysis and design of wind turbine rotor blades'

Goals:

At the end of the project unit the student should be able to:

- perform analysis using mechanics of composite materials
- analyse the interplay between composite materials and adjacent structural elements
- design and analyse structures made of composite materials, including problems related to local effects
- apply standard design rules for wind turbine rotor blades
- apply advanced strength and stiffness analysis using finite element modelling of selected parts of a wind turbine rotor blade.

Activities:

The starting point is selected parts of an existing wind turbine blade and based on this the structural problem is stated and its solution is sought using systematic design work.

Courses on the 3rd semester:

- Composite Materials for Wind Turbine Rotor Blades - 2 ECTS
- Control Theory - 1 ECTS
- Optimization Methods - 1 ECTS
- Energy system Analysis and Societal Economy - 1 ECTS
- Power Electronics and Control - 1 ECTS

Semester 4

The aim of the project unit is to demonstrate that the student is capable of working out an unaided project at a high technical level, which encompasses advanced methods and theories from structural and control engineering with relevance to wind turbines.

Final Thesis:

The theme can be any specialization in the field of wind energy engineering. Typically, the final thesis will be a further elaboration of some of the work carried out in the previous semesters. However, it is also possible to work on an entirely different subject.

Goals:

The student will at the end of the project unit have achieved the skills to:

- evaluate the benefit of wind turbine technology within the mechanical and power electronic areas
- evaluate alternative control strategies and optimization methods
- use economical constraints in combination to code provisions in wind turbine design.

Activities:

The final project will be a natural continuation of the projects carried out at the previous semesters, usually the project work at the 3rd semester. Additionally, the project may be based on a project proposed by the wind turbine industry, or be a part of a larger ongoing research project at the university. If the project is carried out in cooperation with the industry, this partner will usually be willing to provide sufficient specification and equipment. Alternatively, the project may be based on completely new ideas suggested by the student or the supervisor, where relation to previous projects or courses is not as pronounced.

Courses on the 4th semester:

- Fatigue - 1 ECTS
- Finite Element Method II - 1 ECTS
- Reliability and Codes - 1 ECTS

6.3 Electrical Specialization**Semester 2**

The intention is to enable the student to analyse the conditions and problems when wind turbines are connected to the power supply network. The problem is partly due to the irregular dynamic behaviour of wind turbines, due to wind fluctuation. This semester focuses is on the quasi-steady-state operating conditions of the wind generator.

Project:

'Grid connections of wind turbines'

Goals:

The purpose of the semester is to enable the student to analyse:

- power flow in the power supply network
- power electronics in relation to wind generators
- aerodynamic loads on the rotor
- the wind turbine generator - dynamic interaction of the blades, tower and drive train on the delivered power from the wind turbine.

Activities:

The idea is to enable the student to calculate the power delivered to the power supply network from the wind generator, based on known wind conditions, and the mechanical and electrical construction of the wind generator and the power supply network.

Courses on the 2nd semester:

- Power Electronics - 2 ECTS
- Electrical Power Transmission - 1 ECTS
- Rotor Dynamics I - 1 ECTS
- Aerodynamics II - 1 ECTS
- Generators II - 1 ECTS
- Turbulence Theory - 1 ECTS

Semester 3

The intention of this semester is to enable the student to analyse the transient behaviour of the wind generators when they are connected to the power supply network. This includes analyses of wind generator behaviour when fault conditions arise in the power supply network, and how different control strategies can result in different transient behaviours for various transient occurrences on the power supply network (switching of components etc.) and at the wind turbine (for instance start and stop).

Project:

'Transient analysis'

Goals:

The purpose of the semester is to enable the student to analyse:

- diverse stability conditions on the power supply network
- the effect of applying different protection equipment
- the effect of applying diverse wind turbine control strategies
- optimization methods
- energy system analysis methods
- the economic aspects of wind turbine operation.

Activities:

The idea is to enable the student to make simulations of transient occurrences with wind turbines connected to the power supply network, at start and stop and under a number of fault conditions on the power supply network and the wind turbine. In the simulations the effect of applying various control strategies will be analysed, to find the best solution. The effect of applying different protection equipment on the stability of the system will be studied.

Courses on the 3rd semester:

- Network Stability and Protection - 2 ECTS
- Control Theory - 1 ECTS
- Optimization Methods - 1 ECTS
- Energy System Analysis and Societal Economy - 2 ECTS
- Power Electronics and Controllers - 1 ECTS

Semester 4

The aim of the project unit is to demonstrate that the student is capable of working out an unaided project at a high technical level, which encompasses advanced methods and theories from structural and control engineering with relevance to wind turbines.

Final Thesis:

The theme can be any specialization in the field of wind energy engineering. Typically, the final thesis will be a further elaboration of some of the work carried out in the previous semesters. However, it is also possible to work on an entirely different subject.

Goals:

The student will at the end of the project unit have achieved the skills to:

- evaluate the benefit of wind turbine technology within the mechanical and power electronic areas
- evaluate alternative control strategies and optimization methods
- use economical constraints in combination to code provisions in wind turbine design.

Activities:

The final project will be a natural continuation of the projects carried out at the previous semesters, usually the project work at the 3rd semester. Additionally, the project may be based on a project proposed by the wind turbine industry, or be a part of a larger ongoing research project at the university. If the project is carried out in cooperation with the industry, this partner will usually be willing to provide sufficient specification and equipment. Alternatively, the project may be based on completely new ideas suggested by the student or the supervisor, where relation to previous projects or courses is not so as pronounced.

Courses on the 4th semester:

- Advanced Generators and Controllers - 2 ECTS
- Reliability and Codes - 1 ECTS