



Curriculum for the Master of Science Programme in Sustainable Energy Engineering

Aalborg University
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Preface

Pursuant to Act 367 of March 18, 2015 on Universities (the University Act) with subsequent changes, the following curriculum for the Master of Science programme in Sustainable Energy Engineering is stipulated. The programme also follows the Joint Programme Regulations and the Examination Policies and Procedures for the Faculty of Engineering and Science.

The Master of Science programme in Sustainable Energy Engineering is a two-year education which contains in total two specialisations in the areas of thermal and offshore engineering

- Process Engineering and Combustion Technology
- Offshore Energy Systems

The programme gives a possibility to obtain advanced skills within areas as for instance efficient use of energy, renewables, control engineering and energy production and distribution technology.

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1. Legal Basis of the Curriculum

1.1 Basis in Ministerial Orders

The Master of Science programme in Sustainable Energy Engineering is organised in accordance with the Ministry of Higher Education and Science's Order no. 1328 of November 15, 2016 on Bachelor's and Master's Programmes at Universities (the Ministerial Order of the Study Programmes) and Ministerial Order no. 1062 of June 30, 2016 on University Examinations (the Examination Order). Further reference is made to Ministerial Order no. 258 of March 18, 2015 (the Admission Order) and Ministerial Order no. 114 of February 3, 2015 (the Grading Scale Order) with subsequent changes.

1.2 Faculty Affiliation

The Master of Science programme falls under the Faculty of Engineering and Science, Aalborg University.

1.3 Board of Studies Affiliation

The Master of Science programme falls under the Study Board of Energy in the School of Engineering and Science

1.4 External Evaluator Corps

The programme falls under the external evaluator corps: Ingeniøruddannelsernes landsdækkende censorkorps – Electrical or Mechanical depending on the specialisation.

2. Admission, Degree Designation, Programme Duration and Competence Profile

2.1 Admission

Applicants with a legal claim to admission:

Applicants with the following degree are entitled to admission to the Master of Science programme in Sustainable Energy Engineering:

- Bachelor of Science (BSc) in Energy Engineering, Aalborg University
- Bachelor of Engineering (BE) in Sustainable Energy, Aalborg University

Applicants without legal claim to admission:

Students with another Bachelor's degree may, upon application to the Study Board of Energy, be admitted after a specific academic assessment if the applicant is considered having comparable educational prerequisites. The University can stipulate requirements concerning conducting additional exams prior to the start of study.

2.2 Degree Designation in Danish and English

The Master of Science programme entitles the graduate to the designation of one of the following titles:

- Civilingeniør, cand.polyt. (candidatus/candidata polytechnics) i bæredygtig energiteknik med specialisering i proces- og forbrændingsteknik. The English designation is: Master of Science (MSc) in Engineering (Sustainable Energy Engineering with specialisation in Process Engineering and Combustion Technology)
- Civilingeniør, cand.polyt. (candidatus/candidata polytechnics) i bæredygtig energiteknik med specialisering i offshore energisystemer. The English designation is: Master of Science (MSc) in Engineering (Sustainable Energy Engineering with specialisation in Offshore Energy Systems)

2.3 The Programme's Specification in ECTS Credits

The Master of Science programme is a 2-year, research-based, full-time study programme taught in English. The programme is set to 120 ECTS credits.

2.4 Competence Profile on the Diploma

The following competence profile will appear on the diploma:

A graduate of the Master of Science programme has competences acquired through an educational programme that has taken place in a research environment.

The graduate of the Master of Science programme can perform highly qualified functions on the labour market on the basis of the educational programme. Moreover, the graduate has prerequisites for research (a PhD programme). Compared to the Bachelor's degree, the graduate of the Master of Science programme has developed her/his academic knowledge and independence, so that the graduate can independently apply scientific theory and method in both an academic and occupational/professional environment.

2.5 Competence Profile of the Programme

The graduate of the Master of Science programme has the following qualifications:

Knowledge

- Knowledge about the state of the art of research within their field of specialisation
- Have knowledge on a scientific basis to reflect over subject areas related to sustainable energy engineering and identify scientific problems within that area
- Knowledge and insight into publication ethics in research
- Knowledge about the ethics related to the social, economic and environmental impact of research
- Have knowledge and comprehension within innovation and entrepreneurship in relation to project work and courses
- Have advanced skills in probability theory and statistics, control theory and simulation technique

In addition, students have the following knowledge:

- The specialisation in Process Engineering and Combustion Technology:
 - Advanced knowledge and comprehension within process and combustion systems including conversion, consumption and transport of energy and advanced thermal and fluid systems
 - Understanding of the design, modelling and optimisation of process and combustion systems used in various energy conversion applications
 - Understanding of the detailed operation, functionality and interactions between the various components of key thermal energy conversion technologies
 - Have detailed insight in system integration with respect to both system efficiency and control aspects of energy systems
- The specialisation in Offshore Energy Systems:
 - Advanced knowledge and comprehension within offshore systems
 - Understanding of the design, analyses, modelling and diagnosis of offshore energy systems used in various energy production applications
 - Comprehension of the detailed operation, functionality and

interaction between the various components used in offshore systems, including knowledge about fluid mechanics and flow systems, water wave dynamics, electrical machines and mechanics

- Have detailed insight in system integration with respect to both system efficiency and control engineering aspects of offshore energy systems

Skills

- Be proficient in the scientific methods, tools and general skills related to employment within the subjects of sustainable energy engineering
- Be able to obtain advanced skills in simulation techniques and mathematical methods
- Be able to evaluate and select among the scientific theories, methods, tools and general skills of the subject area(s) and, on a scientific basis, develop new analyses and solutions
- Be able to communicate research-based knowledge and discuss professional and scientific problems with both peers and non-specialists
- Be able to obtain skills which are related to his/her field within sustainable energy engineering
- Be able to use advanced laboratory test set-ups and data collection methods

In addition, the different specialisations have the following skills:

- The specialisation in Process Engineering and Combustion Technology:
 - The ability to develop, construct and understand the operation of thermal energy conversion systems in the laboratory and in real applications
- The specialisation in Offshore Energy Systems:
 - The ability to construct and understand the operation of offshore systems in the laboratory and in real applications

Competences

- Be able to demonstrate an understanding of research work and be able to become a part of the research environment
- Be able to manage work and development in situations that are complex, unpredictable and require new solutions within the area of energy engineering
- Be able to independently initiate and implement discipline-specific and interdisciplinary cooperation and assume professional responsibility
- Be able to independently take responsibility for own professional development and specialisation and be able to collaborate in groups according to the PBL Model
- Upon completion of the MSc programme the student has achieved advanced professional competences in production, distribution and the usage of electrical, thermal and/or mechanical energy together with design and control of energy or mechatronic systems
- The competences should advance the student's ability to perform in functions within planning, development, consulting and research in Danish as well as international industries or public institutions.

Examples could be research and development departments or managing positions in energy supply companies, the wind, machine, or process industry together with electro-technical- and consultancy companies, etc.

3. Content and Organisation of the Programme

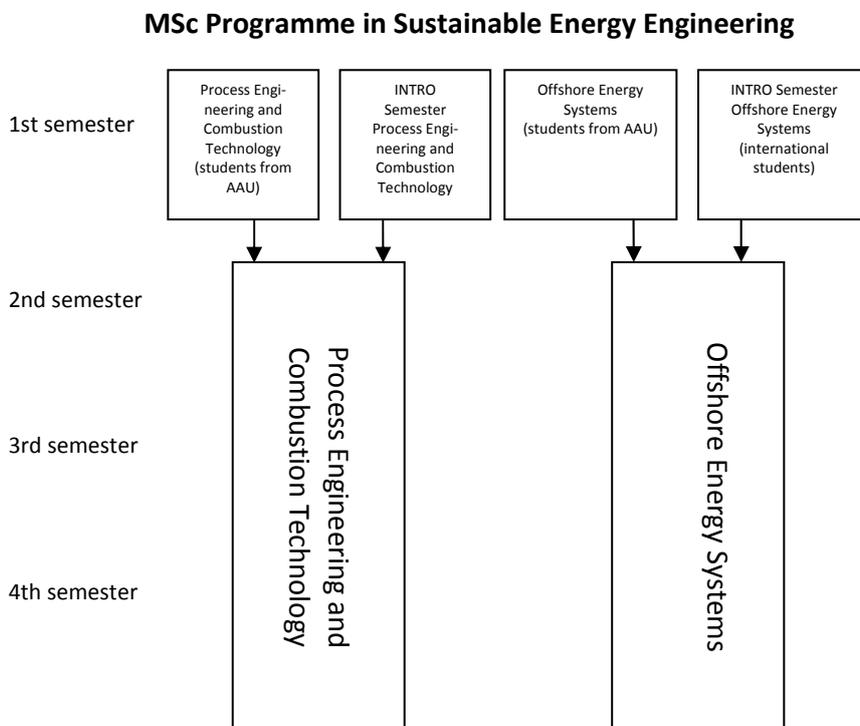
The programme is structured in modules and organised as a problem based study. A module is a programme element or a group of programme elements, which aim(s) to give students a set of professional skills within a fixed time frame specified in ECTS credits, and concluded with one or more examinations within the specific exam periods. Examination formats are defined in the curriculum.

The programme is based on a combination of academic, problem oriented and interdisciplinary approaches and organised on the following types of instruction that combine skills and reflection:

- Lectures
- project work
- workshop
- exercises (individually and in groups)
- teacher feedback
- reflection
- portfolio work study circle
- self-study

1st to 4th semesters of the programmes are taught in English and projects are to be written in English.

The structure of the Master of Science study programme is shown in the following figure



Overview of the Programme

All modules are assessed through individual grading according to the 7-point grading scale or Passed/Not passed grade. All modules are assessed by the supervisor together with an external adjudicator (external assessment) or an internal adjudicator (internal assessment) or by assessment by the supervisor or lecturer only.

MSc in Process Engineering and Combustion Technology					
Semester	Code	Module	ECTS	Assessment	Exam
1st	M1-1/ ME1-4*	Fluid Mechanical Analysis Methods Problem Based Project Organised Learning in Combustion Technology*	15 (10*)	7-point grading scale	Internal
	M1-7	Computational Fluid Dynamics (CFD) and Multiphase Flow	5	7-point grading scale	Internal
	M1-8	Fluid Mechanics and Compressible Flow	5	7-point grading scale	Internal
	M1-12	Probability Theory, Stochastic Processes and Applied Statistics	5	7-point grading scale	Internal
	M1-13*	Control Theory and MATLAB*	5*	7-point grading scale	Internal
2nd	ME2-1	Combustion and/or Process Systems	15	7-point grading scale	External
	ME2-3	Process Simulation	5	Passed/Not passed	Internal
	ME2-4	Combustion Technology and Chemical Reac- tors	5	7-point grading scale	Internal
	M2-13	Optimisation Theory and Reliability	5	7-point grading scale	Internal
3rd	ME3-1**	Advanced Combustion and Process Sys- tems**	20**	7-point grading scale	Internal
	M3-7***	Voluntary traineeship***	30***	7-point grading scale	Internal
		Elective courses	10	7-point grading scale	Internal
4th	ME4-1	Master's Thesis (possibly 50 ECTS taking both 3rd and 4th semester projects)	30, 50	7-point grading scale	External
Total			120		

* For international students

** The student may follow a relevant study as a guest student (30 ECTS) at another university in Denmark or abroad, see details in Moodle. **However the student's special preferences for the semester must be approved by the Study Board in advance.**

*** Instead of doing the project work and the elective courses, the student can do project work in a company as an individual or as a part of a group. See details in Moodle. **However the student's special preferences for the semester must be approved by the Study Board in advance.**

MSc in Offshore Energy Systems					
Semester	Code	Module	ECTS	Assessment	Exam
1st	ME1-2/ ME1-5*	Modelling and Identification of Offshore Systems Problem Based Project Organised Learning in Modelling and Identification of Offshore Systems*	15 (10*)	7-point grading scale	Internal
	ME1-3	System Identification and Diagnosis	5	7-point grading scale	Internal
	ME1-6	Fluid and Water Wave Dynamics	5	7-point grading scale	Internal
	M1-12	Probability Theory, Stochastic Processes and Applied Statistics	5	7-point grading scale	Internal
	M1-13*	Control Theory and MATLAB*	5*	7-point grading scale	Internal
	2nd	ME2-2	Dynamic Control of Offshore Electrical Sys- tems	15	7-point grading scale
ME2-5		Offshore Energy System Technology	5	7-point grading scale	Internal
ME2-6		Control and Surveillance of Processes and Systems	5	7-point grading scale	Internal
ME2-7		Dynamic Modelling of Electrical Machines	5	7-point grading scale	Internal

		and Control Systems			
3rd	ME3-2**	Advanced Control of Offshore Energy Systems**	20**	7-point grading scale	Internal
	M3-7***	Voluntary traineeship***	30***	7-point grading scale	Internal
		Elective courses	10	7-point grading scale	Internal
4th	ME4-2	Master's Thesis (possibly 50 ECTS taking both 3rd and 4th semester projects)	30, 50	7-point grading scale	External
Total			120		

* For international students

** The student may follow a relevant study as a guest student (30 ECTS) at another university in Denmark or abroad, see details in Moodle. **However the student's special preferences for the semester must be approved by the Study Board in advance.**

*** Instead of doing the project work and the elective courses, the student can do project work in a company as an individual or as a part of a group. See details in Moodle. **However the student's special preferences for the semester must be approved by the Study Board in advance.**

Elective courses on 3rd semester MSc

In addition to the project work, the students should choose 10 ECTS courses on the 3rd semester MSc. The Study Board of Energy offers a portfolio of various, elective courses covering the technical aspects for the thermal, electrical, mechatronic and offshore specialisations with reference to well-defined research programmes which reflect the current research focus of the Department of Energy Technology. Each year the Study Board of Energy selects a number of the courses below to be announced as the year's elective courses (6 to 10). Based on the number of students assigned to each of these courses, 2 to 6 courses will be taught covering broadly all specialisations.

The elective courses approved by the Study Board of Energy are given in the following overview

Elective courses					
Semester	Code	Module	ECTS	Assessment	Exam
3rd	M3-8	Advanced Analysis of Thermal Machines	5	7-point grading scale	Internal
	M3-9	Advanced Modelling and Control of Voltage Source Converters	5	7-point grading scale	Internal
	M3-10	Analysis of Advanced Thermal Process Systems	5	7-point grading scale	Internal
	M3-11	Battery Energy Storage Systems	5	7-point grading scale	Internal
	M3-12	Biomass Conversion and Biofuels	5	7-point grading scale	Internal
	M3-13	Biomass Gasification, Combustion and their Advanced Modelling	5	7-point grading scale	Internal
	M3-14	Control of Grid Connected Photovoltaic and Wind Turbine Systems	5	7-point grading scale	Internal
	M3-15	Electrochemical Modelling of Fuel Cells, Electrolysers and Batteries	5	7-point grading scale	Internal
	M3-16	Energy Conversion and Storage in Future Energy Systems	5	7-point grading scale	Internal
	M3-17	Fault Tolerant Control	5	7-point grading scale	Internal
	M3-18	Future Power Systems in Denmark	5	7-point grading scale	Internal
	M3-19	Modern Electrical Drives	5	7-point grading scale	Internal
	M3-20	Modern Power Electronic devices and their Models	5	7-point grading scale	Internal
	M1-11	Non-linear Control and Multi-body Systems	5	7-point grading scale	Internal
	ME1-3	System Identification and Diagnosis ***	5	7-point grading scale	Internal
	M3-21	Test and Validation	5	Passed/Not passed	Internal
	M3-22	Wind Power System and Renewable Energy Grid Integration	5	7-point grading scale	Internal

*** This course is not offered to the students at the Offshore Energy Systems specialisation since they have already had this course.

Courses from other specialisations at Aalborg University or from other universities might be relevant too. Nevertheless, the courses must be approved by the Study Board of Energy in advance.

3.1 Module Descriptions of 1st Semester

Background

The objective of the 1st semester at the Master of Science study programme in Sustainable Energy Engineering is to prepare the students to follow one of the two specialisations offered:

- Process Engineering and Combustion Technology
- Offshore Energy Systems

To qualify for the 1st semester of the Master of Science study programme in Sustainable Energy Engineering, 4 routes are approved for students who have followed the Bachelor's study programme in Energy Engineering at Aalborg University:

- Thermal Processes (Esbjerg Campus)
- Dynamic Systems (Esbjerg Campus)
- Thermal Energy Engineering (Aalborg Campus)
- Mechatronics (Aalborg Campus)

For students with a bachelor's degree from another university an introductory 1st semester is mandatory (called INTRO semester), in which a basic course is taught to familiarize the students with Problem Based Learning, besides the engineering courses belonging to the specialisation. Furthermore, an extra course in Control Theory and Matlab is held for the intro semester students.

Content

For all students

1st semester contains engineering subjects (courses and project work) in the area of the chosen specialisation.

For students with a Bachelor's Degree from Aalborg University

The students are required to acquire knowledge about scientific English, and the project work will be documented by a scientific paper, a summary report, a poster and a presentation at a conference, all in English.

For Students with a Bachelor's Degree from another university (INTRO semester)

Here the focus is on the problem based, project organised learning method used at Aalborg University. The students will write a project report documenting their project work. The students must attend "Project Based Learning and Project Management" to gain knowledge about the problem based teaching method used at Aalborg University.

3.1.a Course in Problem Based Learning and Project Management (INTRO and guest students)

Title

Problem Based Learning and Project Management/Projektbaseret læring og projektledelse

Objective

The objective is to prepare newly started Master's students from another university than AAU to enter the Problem Based Learning environment at AAU and manage study projects in close collaboration with peers.

Students who complete the module should:

Day 1

- Describe and discuss the Aalborg PBL Model based on the three key words: Group work, project work, problem orientation
- Identify an initial individual challenge when using a PBL approach

Day 2

- Develop and practice peer feedback skills
- Practice collaborative learning in a group
- Design a plan of action to deal with an initial individual PBL challenge or curiosity

Day 3

- Practice presentation skills
- Practice critical skills when giving feedback to peers
- Reflect on own and peer skills in relation to PBL practice

Type of instruction

Three-half-day workshops centred on the individual student working with an individual challenge or curiosity in relation to using a PBL approach. Peer learning is also a hallmark, since the students will discuss and reflect on their individual challenges or curiosities in a peer learning group.

Form of examination

Internal assessment during the course/class participation according to the rules in the Examination Policies and Procedures, Addendum to the Joint Programme Regulations of Faculty of Engineering and Science, Aalborg University. In this case the assessment is primarily based on the oral performance during the course, this means that the student has to be active during the course time and participate in discussions. The course is an integrated part of the project for those not acquainted to the Aalborg PBL Model, and is a condition for participation in the project examination. In this way there will be no diploma for the course and it will not be visible on the academic transcripts.

Evaluation criteria

As stated in the Joint Programme Regulations.

3.1.b Project on 1st Semester Process Engineering and Combustion Technology

Title

M1-1 Fluid Mechanical Analysis Methods/Fluidmekaniske analysemetoder

Objective

After completion of the project the student should:

Knowledge

- Have knowledge and comprehension within analytical, numerical and experimental analysis methodology for fluid flow
- Have knowledge and comprehension within the flow around or within simplified components

Skills

- Be able to verify analytical and numerical approaches by means of simple laboratory experiments
- Be able to use methods for documenting the project work as a scientific paper and poster

Competences

- Be able to control the working and development process within the project theme, and be able to develop new solutions within fluid-mechanical analysis methods
- Be able to define and analyse, in an independent manner, scientific problems within the area of fluid mechanical methods, and based on that make and state the reasons for decisions made

Type of instruction

Problem based project oriented project work in groups.

The project should be based upon a simple fluid flow problem. The problem should be investigated using analytical, numerical and experimental methods. The problem can be a process or a typical engineering component which involves single phase fluid flow of a stationary or a transient nature.

The project should involve the Computational Fluid Dynamics (CFD) simulation of the simple fluid flow problem. The simulation should be verified by laboratory experiments and the validity of any assumptions made should be checked. The purpose of the project may be to analyse the performance of an engineering component, to investigate the validity of empirical expressions or to conduct parameter variations on a design, or similar.

The project must be documented as described in “Guidance for the Project of 1st semester of Master of Science in Sustainable Energy Engineering” (sec. 3.1.d).

Examination format

Oral examination with internal adjudicator in accordance with the rules in the Examination Policies and Procedures. The exam will be based on the documentation submitted and the rules in “Guidance for the Project of 1st Semester of Master of Science in Sustainable Energy Engineering” (sec. 3.1.d).

Assessment criteria

As stated in the Joint Programme Regulations.

3.1.c Project on 1st Semester Offshore Energy Systems

Title

ME1-2 Modelling and Identification of Offshore Systems/Modellering og identifikation af offshore systemer

Objective

After completion of the project the student should:

Knowledge

- Have knowledge and comprehension within the design, analysis and modelling of offshore energy systems or subsystems with complex dynamics and elements with linear and non-linear behaviour
- Have knowledge and comprehension within test design and iterate the modelling and identification of components used in offshore energy systems
- Have knowledge and comprehension within modelling of offshore energy systems based on physics as well as data in the form of stochastic systems or processes

Skills

- Be able to judge the usefulness of the used different scientific methods for the analysis, modelling, and verification of offshore energy systems and/or components
- Be able to verify the analytical and numerical approaches by means of simple laboratory experiments
- Be able to communicate scientific results by means of papers, posters and oral presentations

Competences

- Be able to control the working and development process within the project theme and be able to develop new solutions within offshore energy systems
- Independently be able to define and analyse scientific problems for offshore energy systems and subsystems, and based on this be able to make and state the reasons for decisions made, for instance with respect to their influences on the environment
- Independently be able to continue own development in competence and specialisation

Type of instruction

Problem based project oriented project work in groups.

The project should be based on a mechanical, electrical, process system, etc. used in the offshore energy area.

The set up system should be analysed, and models and simulations of the system are to be made. Different methods are to be applied to find the parameters of the system.

The set-up models should be verified by experimental test either directly on a real offshore system or on a model or parts of the scaled systems set up in the laboratory.

The project must be documented as described in “Guidance for the Project of 1st semester of Master of Science in Sustainable Energy Engineering” (sec. 3.1.d).

Examination format

Oral examination with internal adjudicator in accordance with the rules in the Examination Policies and Procedures. The exam will be based on the documentation submitted and the rules in “Guidance for the Project of 1st Semester of Master of Science in Sustainable Energy Engineering” (sec. 3.1.d).

Assessment criteria

As stated in the Joint Programme Regulations.

3.1.d Guidance for the Project of 1st Semester Master of Science in Sustainable Energy Engineering

(For students with a Bachelor’s degree from Aalborg University) (not INTRO)

Vejledning for projektet på 1. semester af kandidatuddannelsen i bæredygtig energiteknik

(For studerende med en bachelor fra Aalborg Universitet) (ikke INTRO)

1. Demands to the project documentation

The project should fulfil the objectives of the 1st semester project theme and should be documented to an acceptable technical and scientific level. The documentation shall include a scientific paper and a poster, which shall fulfil the standard for an international conference, e.g. the IEEE specifications. Moreover, the documentation shall include a project summary report - see below.

2. Project documentation

The following material must be uploaded to the system “Digital Exam” on the date given for the submission:

- Scientific paper, max. 10 pages, which presents the primary content and results of the project work
- Project summary report (see below)
- Project poster

3. Conference participation

The paper must be presented, by one or more group members at a conference arranged within the Department of Energy Technology. The conference will be run in the same manner as an international confer-

ence. The project poster must also be presented at this conference. All group members must attend the conference and the poster session to be allowed to participate in the project examination.

4. Project summary report

The project summary report should elaborate the project details and conclusions. **The maximum length of the summary report (report without appendices) is 50 pages**, and in addition the summary report should follow the rules as laid down by the Study Board of Energy in "Procedure for Project Work", i.e. the total number of pages must not exceed $30 + 15 \times$ number of students in the project group.

5. Project exam

The project evaluation will take place at a later date than the conference.

At the project examination the project group shall present its project work in accordance to the Examination Policies and Procedures, Addendum to the Joint Programme Regulations

The presentation and assessment of the project is conducted in English.

3.1.e Project on 1st INTRO Semester of Process Engineering and Combustion Technology

Title

ME1-4 Problem Based Project organised Learning in Combustion Technology/Problembaseret projektorganiseret læring i forbrændingsteknik

Prerequisites

It is a pre-condition for students who have not studied the Aalborg PBL Model at Aalborg University that they have passed the course in "Project Based Learning and Project Management" (see section 3.1.a) prior to the project examination.

Objective

After completion of the project the student should:

Knowledge

- Have knowledge and comprehension within the Problem Based Learning methods, as it is applied at Aalborg University
- Have knowledge and comprehension within analytical, numerical and experimental analysis methodology for fluid flow
- Have knowledge and comprehension within the flow around or within simplified components

Skills

- Be able to verify the analytical and numerical approaches by means of simple laboratory experiments
- Be able to communicate scientific results by means of a project report and an oral presentation in English
- Be able to structure and plan PBL based project work and writing

Competences

- Be able to control the working and development process within the project theme, and be able to develop new solutions within fluid-mechanical analysis methods
- Be able to define and analyse, in an independent manner, scientific problems within the area of fluid mechanical methods, and based on that make and state the reasons for decisions made
- Be able to continue, in an independent manner, their own development in competence and specialisation

Type of instruction

Problem based project oriented project work in groups.

During the project period you should be able to plan and structure the project work, work in groups and solve conflicts, use consensus versus fight/voting and see differences among group members as a strength. You should also work with the structure of a project report and prepare a problem formulation, set up project limitation and time schedule.

The project should contain a detailed analysis of a simple flow situation or combustion process. The analysis should include a numerical analysis which can be compared to relevant flow or combustion theory.

The calculations should be verified by laboratory experiments. The validity of any assumptions made should be checked.

The project should be based upon a problem which has its origins in thermal energy engineering. The problem should typically include a thermal energy conversion process and/or a fluid flow component.

Examination format

Oral examination with internal adjudicator in accordance with the rules in the Examination Policies and Procedures, Addendum to the Joint Programme Regulations.

Assessment criteria

As stated in the Joint Programme Regulations.

3.1.f Project on 1st INTRO Semester of Offshore Energy Systems**Title**

ME1-5 Problem Based Project Organised Learning in Modelling and Identification of Offshore Systems/
Problembaseret projektorganiseret læring i modellering og identificering af offshore systemer

Prerequisites

It is a pre-condition for students who have not studied the Aalborg PBL Model at Aalborg University that they have passed the course in "Project Based Learning and Project Management" (see section 3.1.a) prior to the project examination.

Objective

After completion of the project the student should:

Knowledge

- Have knowledge and comprehension of the Problem Based Learning methods, as it is applied at Aalborg University
- Have knowledge and comprehension within the design, analysis and modelling of offshore energy systems or subsystems with complex dynamics and elements with linear and non-linear behaviour
- Have knowledge and comprehension within test design, modelling and identification of components used in offshore energy systems
- Have knowledge and comprehension within modelling of offshore energy systems based on physics as well as data in the form of stochastic systems or processes

Skills

- Be able to judge the usefulness of the used different scientific methods for the analysis, modelling, and verification of offshore energy systems and/or components
- Be able to verify the analytical and numerical approaches by means of simple laboratory experiments

- Be able to communicate scientific results by means of a project report and an oral presentation in English.

Competences

- Be able to control the working and development process within the project theme, and be able to develop new solutions within modelling and identification of offshore systems
- Independently be able to define and analyse scientific problems for modelling and identification of offshore systems, and based on this be able to make and state the reasons for decisions made for instance with respect to their influences on the environment
- Independently be able to continue own development in competence and specialisation

Type of instruction

Problem based project oriented project work in groups.

During the project period you should be able to plan and structure the project work, work in groups and solve conflicts, use consensus versus fight/voting and see differences among group members as a strength. You should also work with the structure of a project report and prepare a problem formulation, set up project limitation and time schedule.

The project should be based on modelling and identification of a simple offshore system.

The set-up system should be analysed, and models and simulations of the offshore system are to be made. Different system identification methods are to be applied to find the parameters of the system.

The set-up models should be verified by experimental tests, either directly on a real offshore system or on a model, or parts of the systems, set up in the laboratory.

Examination format

Oral examination with internal adjudicator in accordance with the rules in the Examination Policies and Procedures, Addendum to the Joint Programme Regulations.

Assessment criteria

As stated in the Joint Programme Regulations.

3.1.h Course Module on 1st Semester: Computational Fluid Dynamics (CFD) and Multiphase Flow

Title

M1-7 Computational Fluid Dynamics (CFD) and Multiphase Flow/Numerisk strømningslære (CFD) og flerfasestrømning

Objective

Students who complete the module should:

Knowledge

- Have knowledge about the methods behind Computational Fluid Dynamics (CFD)
- Have knowledge about various spatial and temporal discretisation schemes
- Have knowledge about the pressure-velocity coupling method for solving the Navier-Stokes equations numerically
- Have knowledge about meshing strategies and boundary conditions
- Have knowledge about the fundamentals of turbulence, the energy cascade and Kolmogorov hypotheses

- Have knowledge and understanding within Reynolds-Averaged Navier-Stokes (RANS) and turbulence modelling
- Have knowledge about the fundamentals of multiphase flow
- Have knowledge about different modelling approaches for multiphase flow and multiphase models in the context of CFD
- Have knowledge about turbulence-particle interaction in multiphase flow

Skills and Competences

- Be able to use the finite volume method to numerically solve simple problems
- Be able to perform a mesh independency study in CFD analyses
- Be able to perform CFD analyses of a turbulent flow with regards to selection of turbulence model and near wall modelling/meshing strategy
- Be able to perform CFD analyses for non-reacting multiphase flow, for both the Euler-Euler and Euler-Lagrange approaches
- Be able to apply proper terminology in oral, written and graphical communication and documentation within CFD, turbulence and multiphase flows

Type of instruction

Lectures supplemented by workshops, exercises, hands-on and self-studies.

Examination format

Oral examination which can be based on a mini-project in accordance with the rules in the Examination Policies and Procedures, Addendum to the Joint Programme Regulations of the Faculty of Engineering and Science, Aalborg University.

Assessment criteria

As stated in the Joint Programme Regulations.

3.1.i Course Module on 1st Semester: Fluid Mechanics and Compressible Flow

Title

M1-8 Fluid Mechanics and Compressible Flow/Fluidmekanik og kompressible strømninger

Objective

Students who complete the module should:

Knowledge

- Have knowledge about fluid kinematics
- Have knowledge about stresses in fluids, equation of motion, constitutive models and Navier-Stokes equations
- Have knowledge about ideal fluids and potential flows, including application of potential theory to simple problems
- Have knowledge and comprehension within the fundamentals of gas dynamics and compressible flow
- Have knowledge about steady and unsteady shock wave phenomena in compressible flow
- Have knowledge about aerofoil performance in compressible flows

Skills and Competences

- Be able to describe assumptions and limitations of mathematical models for different types of flows
- Be able to apply appropriate analytical and semi-empirical models for mathematical description of fluid dynamic problems

- Be able to describe turbulent and laminar boundary layers including understanding of the momentum integral equation for boundary layers
- Be able to apply appropriate analytical and numerical method techniques to gas dynamics and compressible flows
- Be able to apply proper terminology in oral, written and graphical communication and documentation within fluid dynamics
- Be able to apply the topic of the module in multi-disciplinary contexts

Type of instruction

Lectures supplemented by workshops, exercises, self-studies and study groups.

Examination format

Oral examination in accordance with the rules in the Examination Policies and Procedures, Addendum to the Joint Programme Regulations of the Faculty of Engineering and Science, Aalborg University.

Assessment criteria

As stated in the Joint Programme Regulations.

3.1.j Course Module on 1st INTRO Semester: Control Theory and MATLAB

Common for students with a Bachelor's degree from another university than Aalborg University

Title

M1-13 Control Theory and MATLAB (INTRO only)/Reguleringsteknik og MATLAB (kun for INTRO)

Objective

Students who complete the module should:

Knowledge

- Be able to comprehend time-domain analysis of continuous-time systems
- Be able to comprehend frequency response analysis of continuous-time systems
- Be able to apply the basic rules in discrete control theory including having knowledge about sampling systems, zero-order-hold and the influence of time delays
- Have knowledge and comprehension within the basic features of MATLAB as a programming language

Skills

- Be able to analyse and to design time-invariant linear continuous-time control systems using classical methods
- Be able to analyse different design and compensation methods in control engineering
- Be able to apply discrete equivalents for continuous transfer functions
- Be able to analyse, design and implement digital control systems
- Be able to use commercial simulation software as a control system design tool
- Be able to use the simple plotting facilities in MATLAB
- Be able to use data analysis routines in MATLAB

Competences

- Independently be able to define and analyse scientific problems

Type of instruction

The course will be taught by a mixture of lectures, workshops, exercises, mini-projects and self-study.

Examination format

Written examination in accordance with the rules in the Examination Policies and Procedures, Addendum to the Joint Programme Regulations of the Faculty of Engineering and Science, Aalborg University.

Assessment criteria

As given in the Joint Programme Regulations.

3.1.k Course Module on 1st Semester: System Identification and Diagnosis**Title**

ME1-3 System Identification and Diagnosis/Systemidentifikation og diagnosticering

Objective

Students who complete the module should:

Knowledge

- Have comprehension of the fundamental principles of typical methods of system identification
- Have comprehension of the fundamental concepts, terms and methodologies of abnormal diagnosis
- Have comprehension of some typical model-based and signal-based diagnosis

Skills

- Be able to apply the learned knowledge to handle some simple system identification problems under assistance of a commercial software
- Be able to apply and analyse different diagnosis methods

Competences

- Independently be able to define and analyse scientific problems within the area of system identification and diagnosis
- Independently be able to be a part of professional and interdisciplinary development work within the area of system identification and diagnosis

Type of instruction

The course is taught by a mixture of lectures, workshops, exercises, mini projects or self-studies.

Examination format

Oral examination in accordance with the rules in the Examination Policies and Procedures, Addendum to the Joint Programme Regulations of the Faculty of Engineering and Science, Aalborg University.

Evaluation criteria

As stated in the Joint Programme Regulations.

3.1.l Course Module on 1st Semester: Fluid and Water Wave Dynamics**Title**

ME1-6 Fluid and Water Wave Dynamics/Strømningslære og bølgehydraulik

Objective

Students who complete the module should:

Knowledge

- Have knowledge about fluid kinematics

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

Skills

- Be able to describe assumptions and limitations of mathematical models for different types of flows
- Be able to apply analytical and semi-empirical methods for mathematical description of fluid dynamic problems
- Be able to calculate kinematics and dynamics of regular linear waves on deep and shallow water
- Be able to analyse irregular waves in time and frequency domain

Competences

- Be able to apply proper terminology in oral, written and graphical communication and documentation within fluid and water wave dynamics

Type of instruction

Lectures, etc. supplemented with project work, workshops, presentation seminars, lab tests.

Examination format

Oral or written exam in accordance with the rules in the Examination Policies and Procedures, Addendum to the Joint Programme Regulations of the Faculty of Engineering and Science, Aalborg University.

Assessment criteria

As stated in the Joint Programme Regulations.

3.1.m Course Module on 1st Semester: Probability Theory, Stochastic Processes and Applied Statistics

Title

M1-12 Probability Theory, Stochastic Processes and Applied Statistics/Sandsynlighedsregning, stokastiske processer og anvendt statistik

Objective

To introduce the student to concepts and ideas within statistics and how statistics can be applied to problems relevant to electrical engineering.

Students who complete the course module should:

Knowledge

- Have knowledge about fundamental concepts in probability, including conditional probability and independence
- Have knowledge about discrete and continuous random variables and relevant properties of these
- Have knowledge about various examples of descriptive statistics and graphics, e.g. histograms, box-plots, scatterplots, lag plots and auto covariance plots
- Have knowledge about statistical inference, including estimation, confidence intervals and hypothesis testing
- Have knowledge about basic concepts related to stochastic processes such as stationarity, correlation function and spectral density
- Have elementary knowledge about Wiener processes, white noise and linear stochastic differential equations
- Have comprehension of a concrete example of a model for a simple stochastic process

Skills

- Be able, given specific data, to specify a relevant statistical model and account for the assumptions and limitations of the chosen model
- Be able to use relevant software for carrying out the statistical analysis of given data and be able to interpret the results of the analysis
- Be able to use statistical models, like linear regression (simple and multiple) and analysis of variance

Competences

- Be able to judge the applicability of statistics within own area
- Be capable of performing a critical evaluation of the results of a statistical analysis
- Be capable of communicating the results of a statistical analysis to people with no or little background within statistics.

Type of instruction

Lectures in combination with practical exercises and self-study or similar.

Examination format

Oral or written examination in accordance with the rules in the Examination Policies and Procedures, Addendum to the Joint Programme Regulations of the Faculty of Engineering and Science, Aalborg University.

Assessment criteria

As stated in the Joint Programme Regulations.

3.2 Module Descriptions of 2nd Semester

3.2.a Project on 2nd Semester Process Engineering and Combustion Technology

Title

ME2-1 Combustion and/or Process Systems/Forbrændings- og/eller processystemer

Prerequisites

The module is based on knowledge achieved when studying the 1st semester on the Master of Science in Sustainable Energy Engineering with specialisation in Process Engineering and Combustion Technology or similar.

It is a pre-condition for students who have not studied the Aalborg PBL Model at Aalborg University that they have passed the course in "Project Based Learning and Project Management" (see section 3.1.a) prior to the project examination.

Objective

After completion of the project the student should:

Knowledge

- Have knowledge and understanding within process and/or combustion systems, their components and the interaction between these
- Have knowledge about the design, modelling and optimisation of the individual components comprising process and/or combustion systems
- Have knowledge and comprehension within the multiphase and chemical reaction aspects involved in process and/or combustion systems

Skills and competences

- Be able to judge the usefulness of different scientific methods used for the analysis, modelling and simulation of process and/or combustion systems
- Be able to verify the analytical and numerical approaches by means of experimental data
- Be able to manage the problem based work and development process within the project theme
- Be able to independently define and analyse scientific problems within the topic of process and/or combustion and to propose and develop solutions for the present problem
- Be able to independently continue own development in competence and specialisation

Type of instruction

Problem based project oriented project work in groups.

The project should be based on a combustion or process system which involves aspects of either multiphase flow and/or chemical reactions.

The project should involve simulation of a combustion or process system or part thereof. Tools such as numerical optimisation, Computational Fluid Dynamics, process simulation or similar should be applied. The project could be based on a steady state process, operational variations or transient problems arising from start-up and shut down of combustion and/or process facilities.

The results obtained from analysis, modelling or simulations should be attempted to be verified by laboratory experiments or existing process data from a plant.

Examination format

Oral examination with external adjudicator in accordance with the rules in the Examination Policies and Procedures, Addendum to the Joint Programme Regulations.

Assessment criteria

As stated in the Joint Programme Regulations.

3.2.b Project on 2nd semester Offshore Energy Systems

Title

ME2-2 Dynamic Control of Offshore Electrical Systems/Dynamisk styring af elektriske offshore systemer

Prerequisites

The module is based on knowledge achieved when studying the 1st semester on the Master of Science in Sustainable Energy Engineering with specialisation in Offshore Energy Systems or similar.

It is a pre-condition for students who have not studied the Aalborg PBL Model at Aalborg University that they have passed the course in "Project Based Learning and Project Management" (see section 3.1.a) prior to the project examination.

Objective

After completion of the project the student should:

Knowledge

- Have knowledge and comprehension within how to design, analyse and model offshore energy systems and the relationship between the used components
- Have knowledge and comprehension within electrical machines and/or power converters used for offshore energy systems
- Have knowledge and comprehension within control of electrical machines, compressors, pumps, thermal, or hydraulic machines, etc., used for offshore energy systems

Skills

- Be able to judge the usefulness of the different scientific methods for analysis and modelling of the offshore energy systems
- Be able to design advanced control systems to improve the performance and the energy efficiency of the different offshore energy systems
- Be able to verify the analytical and numerical approaches by means of laboratory experiments

Competences

- Be able to control the working and development process within the project theme, and be able to develop new solutions within offshore energy systems
- Independently be able to define and analyse scientific problems in the area of offshore energy systems, and based on that make and state the reasons for decisions made
- Independently be able to continue own development in competence and specialisation

Type of instruction

Problem based project-oriented project work in groups.

The project should be based on an offshore energy system which includes fluid power, electrical, mechanical and/or thermal etc. components to be modelled, analysed and controlled. This could e.g. be a wave energy system, offshore oil & gas, offshore wind turbines, or their subsystems, etc.

The systems should be analysed and a mathematical simulation model should be developed for the system. Based on the model, the system is analysed with regard to efficiency, technology choices and technology interaction. The analysis is the basis for setting up a control system and making a design or redesign of the system, or selected parts hereof. The design may take its basis in the existing system (optimised redesign) or may include new solutions or designs and control methods. In both cases emphasis is placed on the fact that the system is improved with regard to efficiency and system performance.

The developed design and control method, or the essential parts hereof, may be experimentally verified, either in model scale or on the real system, if possible.

Examination format

Oral examination with external adjudicator in accordance with the rules in the Examination Policies and Procedures, Addendum to the Joint Programme Regulations.

Assessment criteria

As stated in the Joint Programme Regulations.

3.2.c Course Module on 2nd Semester: Process Simulation

Title

ME2-3 Process Simulation/Processimulering

Objectives

Students who complete the module should:

Knowledge

- Have knowledge about the principles of process simulation
- Have knowledge about process optimisation using process simulation
- Have knowledge about computational aspects of phase equilibria
- Have knowledge about instrumentation and PFD & PID's
- Have knowledge about commercial process simulators

Skills

- Be able to illustrate an actual process in a PFD
- Be able to convert a PFD into a working process simulation
- Be able to perform both steady-state and dynamic simulations

Competences

- Be able to investigate a given case using simulation tools
- Be able to select an appropriate thermodynamic model for a given case

Type of instruction

Mainly via lectures, supplemented by workshops, exercises, hands-on and self-study.

Examination format

Oral examination based on a mini project in accordance with the rules in the Examination Policies and Procedures, Addendum to the Joint Programme Regulations of the Faculty of Engineering and Science, Aalborg University.

Assessment criteria

As stated in the Joint Programme Regulations.

3.2.d Course Module on 2nd Semester: Optimisation Theory and Reliability

Title

M2-13 Optimisation Theory and Reliability/Optimeringsteori og pålidelighed

Prerequisites

The module is based on knowledge achieved in Probability Theory, Stochastic Processes and Applied Statistics on 1st semester of Master of Science study programme in Sustainable Energy Engineering or similar.

Objective

Students who complete the module should:

Knowledge

- Have comprehension of the fundamental concepts, terms and methods used within optimisation
- Have comprehension of the fundamental concepts, terms and typical methods used within numerical optimisation of linear and non-linear optimisation problems

- Have gained an in-depth understanding of important concepts and methods of optimisation for efficient solution of optimisation problems within different areas of engineering
- Have comprehension of how to apply reliability and robust design approach during product development
- Understand statistics that support robustness and reliability
- Have knowledge about cost of poor quality in a product life-time
- Be able to establish mission profile for different applications and use it into the useful reliability context
- Understand difference between preventive scheduled maintenance or by degradation
- Have comprehension of stressor components like temperature, humidity, vibration and their impact
- Be able to model and determine life-time of components
- Understand physics of failure approach and also failure mechanism – both in normal operations and beyond
- Have knowledge about qualitative and quantitative test methods for reliability assessment
- Have knowledge about prognostic methods and real-time monitoring in power electronic systems

Skills

- Be able to use optimisation concepts and topics
- Be able to use numerical methods of unconstrained optimisation
- Be able to use numerical (mathematical programming) methods for optimisation of multidimensional functions with constraints
- Be able to solve multi-objective optimisation problems
- Be able understand how designs fits into the robustness validation concept
- Be able to set up simple methods for reliability targets and field analysis
- Be able to set up lifetime requirement at function level or component level
- Have knowledge of how to use test methods for reliability and robustness assessment

Competences

- Be able to account for the considerations involved in the process of formulating and solving engineering optimisation problems, choosing an advantageous method of solution, and implementing it in practice
- Be able to build a system reliability model
- Set up design limits in respect to reliability
- Be able to specify test procedures for new product development

Type of instruction

The form(s) of teaching will be determined and described in connection with the planning of the semester. The description will account for the form(s) of teaching and may be accompanied by an elaboration of the roles of the participants (see chapter 3).

Examination format

Written examination in accordance with the rules in the Examination Policies and Procedures, Addendum to the Joint Programme Regulations of the Faculty of Engineering and Science, Aalborg University.

Assessment criteria

As stated in the Joint Programme Regulations.

3.2.e Course Module on 2nd Semester: Combustion Technology and Chemical Reactors

Title

ME2-4 Combustion Technology and Chemical Reactors/Forbrændingsteknik og kemiske reaktorer

Objective

Students who complete the module should:

Knowledge

- Have knowledge about the technologies used within emission control and how chemical kinetics influences combustion processes
- Understand the analytical methods used in the analysis of combustion flames
- Understand the analytical methods used in processes involving simultaneous heat and mass transfer
- Understand the terminologies and notations used in fundamental chemical reactor analysis.
- Understand how mixing affects the conversion in actual chemical reactors
- Understand how catalysts are practically arranged and supported in various types of chemical reactors and understand how this affects the overall performance parameters

Skills and Competences

- Be able to use software used in combustion analysis
- Be able to calculate chemical compositions arising from kinetically controlled chemical reactions considering chemical mechanisms and the Arrhenius equation
- Understand the analytical methods used in the analysis of combustion flames
- Be able to design fundamental emission control systems
- Be able to design and model the fundamental classes of chemical reactors, i.e. plug flow reactors, constantly stirred reactors and batch reactors with one and multiply simultaneous reactions considering chemical kinetics in one and multiple dimensions, isothermally or non-isothermally as well as in steady and unsteady operation
- Be able to calculate mass convection and diffusion and perform fundamental analysis on processes involving combined heat and mass transfer processes
- Be able to estimate the mass transport in porous materials
- Have the ability to apply and integrate the topics in an interdisciplinary correspondence with other related disciplines
- Be able to understand the assumptions of the fundamental design of chemical reactors and combined heat and mass transfer

Type of instruction

Mainly via lectures, supplemented by workshops, exercises, hands-on and self-study.

Examination format

Oral examination in accordance with the rules in the Examination Policies and Procedures, Addendum to the Joint Programme Regulations of the Faculty of Engineering and Science, Aalborg University.

Assessment criteria

As stated in the Joint Programme Regulations.

3.2.f Course Module on 2nd Semester: Offshore Energy System Technology

Title

ME2-5 Offshore Energy System Technology/Offshore energisystemer

Objective

Students who complete the module should:

Knowledge

- Have knowledge about offshore wind/wave energy systems, modelling and simulation tools for offshore wind turbine and wind farm design
- Have comprehension of drilling technology, reservoir theory, extraction principles for oil and gasses and enhanced oil recovery methods

Skills

- Independently be able to define and analyse scientific problems involving offshore energy systems/subsystems
- Be able to analyse methods for design and control of offshore wind farms and power plants
- Be able to judge the usefulness of the set up methods for the drilling technology, the reservoir theory and different extraction principles
- Be able to relate the methods to applications in industry

Competences

- Independently be able to be a part of professional and interdisciplinary development work within offshore energy systems

Type of instruction

The course is taught by a mixture of lectures, workshops, exercises, mini projects or self-studies.

Examination format

Oral examination in accordance with the rules in the Examination Policies and Procedures, Addendum to the Joint Programme Regulations of the Faculty of Engineering and Science, Aalborg University.

Assessment criteria

As stated in the Joint Programme Regulations.

3.2.g Course Module on 2nd Semester: Control and Surveillance of Processes and Systems

Title

ME2-6 Control and Surveillance of Processes and Systems/Regulerings- og overvågningsprocesser og – systemer

Prerequisites

The module is based on knowledge achieved in control theory and digital microprocessors.

Objective

Students who complete the module should:

Knowledge

- Have comprehension of some typical industrial automation processes or systems including PLC systems and SCADA systems
- Have comprehension of fundamental concepts and terms of non-linear systems and non-linear control theory
- Have comprehension of Lyapunov's methods for stability analysis and non-linear control theory

Skills

- Be able to use basic mathematical tools for analysing the response and stability of non-linear systems
- Be able to apply the acquired knowledge to handle some small-sized industrial automation systems
- Be able to apply selected methods for non-linear control design
- Be able to judge the usefulness of the applied methods
- Be able to relate the methods to applications in industry

Competences

- Independently be able to define and analyse scientific problems within the area of control and surveillance systems
- Independently be able to be a part of professional and interdisciplinary development work within the area of control and surveillance systems

Type of instruction

The course is taught by a mixture of lectures, workshops, exercises, mini-projects or self-studies.

Examination format

Oral examination in accordance with the rules in the Examination Policies and Procedures, Addendum to the Joint Programme Regulations of the Faculty of Engineering and Science, Aalborg University.

Evaluation criteria

As stated in the Joint Programme Regulations.

3.2.h Course Module on 2nd Semester: Dynamic Modelling of Electrical Machines and Control Systems

Title

ME2-7 Offshore Energy Systems/Dynamiske modeller for elektriske maskiner og regulering

Objective

Students who complete the module should:

Knowledge

- Be able to comprehend dynamic models of the transformer, DC Motor, the synchronous machine and the induction machine
- Have knowledge about the limitations for a dynamic model of an electrical machine
- Control principles of DC motors
- Have knowledge about AC machines and space vectors
- Comprehension of techniques for scalar variable-speed control of induction machines
- Knowledge about implementation of different controllers for variable-speed AC-drives
- Knowledge about basic non-linear control theory and its application of electrical machine drives

Skill and Competences

- Independently be able to define and analyse scientific problems involving a dynamic model of an electrical machine
- Be able to analyse and design scalar and vector controllers for electrical drives
- Be able to apply selected linear and non-linear control methods for electrical drives

Type of instruction

The course will be taught by a mixture of lectures, workshops, exercises, mini-projects and self-study.

Examination format

Written examination in accordance with the rules in the Examination Policies and Procedures, Addendum to the Joint Programme Regulations of the Faculty of Engineering and Science, Aalborg University.

Evaluation criteria:

As stated in the Joint Programme Regulations.

3.3 Module Descriptions of 3rd Semester

3.3.a Project on 3rd Semester: Process Engineering and Combustion Technology

Title

ME3-1 Advanced Combustion and Process Systems/Avancerede forbrændings- og processystemer

Prerequisites

The module is based on knowledge achieved when studying the 2nd semester at the Master of Science in Sustainable Energy Engineering with specialisation in Process Engineering and Combustion Technology or similar

It is a pre-condition for students who have not studied the Aalborg PBL Model at Aalborg University that they have passed the course in "Project Based Learning and Project Management" (see section 3.1.a) prior to the project examination.

Objective

After completion of the project the student should:

Knowledge

- Knowledge and understanding within advanced aspects of process and combustion systems
- Knowledge about advanced models, tools and methods applied for process and combustion systems

Skills and competences

- Be able to select the most suitable scientific method to solve the problem from the range of different methods which can be used for the analysis, modelling and simulation of process and combustion systems
- Be able to manage the problem based work and development process within the project theme and to communicate scientific results in a professional manner
- Be able to independently define and analyse scientific problems within the topic of process and combustion, to propose and develop solutions for the present problem and to evaluate these solutions
- Be able to independently continue own development in competence and specialisation
- Be able to follow more sophisticated literature, or state-of-the-art, on CFD, turbulent flow and multi-phase flow

Type of instruction

Problem based project oriented project work in groups.

The project work must be documented by a scientific paper (max. 8 pages). If judged necessary, this paper may be accompanied by a project summary report. The project summary report should elaborate the project details and conclusions. **The maximum length of the summary report (report without appendices) is 50 pages**, and in addition the summary report should follow the rules as laid down by the Study Board of Energy in "Procedure for Project Work", i.e. the total number of pages must not exceed $30 + 15 \times$ number of students in the project group.

The project should be based on a combustion or process system, or parts thereof, which involve the use of advanced analysis, simulation or experimental methods.

The project should encompass a state-of-the-art analysis of the present system or process and be focused towards finding new insight into the topic.

The project can be fully based on experimental work, fully on simulation models or both. The project should be based on an on-going research project at the department or at a commercial cooperation partner.

Due to special technical or scientific documentation requirements, the student documents the project work in a project report, which can be prepared individually or in a group within the project theme; **however the student's special preferences for the semester must be approved by the Study Board in advance.**

Examination format

The project group should orally present the project work and scientific paper as specified in the Examination Policies and Procedures, Addendum to the Joint Programme Regulations. The project group members will undergo an individual, oral examination, with internal adjudicator, based on the scientific paper and the project summary report.

It is a pre-condition that the student has submitted a scientific article and presented the scientific article at the CES conference prior to the project examination. All group members must be present at the conference.

Assessment criteria

As stated in the Joint Programme Regulations.

3.3.b Project on 3rd Semester: Offshore Energy Systems

Title

ME3-2 Advanced Control of Offshore Energy Systems/Avanceret regulering af offshore energisystemer

Prerequisites

The module is based on knowledge achieved when studying the 2nd semester at the Master of Science in Sustainable Energy Engineering with specialisation in Offshore Energy Systems or similar.

It is a pre-condition for students who have not studied the Aalborg PBL Model at Aalborg University that they have passed the course in "Project Based Learning and Project Management" (see section 3.1.a) prior to the project examination.

Objective

After completion of the project the student should:

Knowledge

- Have knowledge and comprehension within how to design control, diagnostic and/or surveillance systems for offshore energy systems
- Have knowledge and comprehension within different advanced control methods

Skills

- Be able to judge the usefulness of the different scientific methods for the design of control, diagnostic and/or surveillance systems for offshore energy systems
- Be able to verify the different scientific analysis and methods by laboratory experiments

Competences

- Be able to control the working and development process within the project theme, and be able to develop new solutions within control, diagnostic and/or surveillance of offshore energy systems

- Be able to show entrepreneurship to define and analyse scientific problems in the area of control, diagnostic and/or surveillance of offshore energy systems, and based on that make and state the reasons for decisions made
- Be able to set up innovative ideas within the area of control, diagnostic and/or surveillance of offshore energy systems
- Independently be able to continue own development in competence and specialisation
- Be able to follow more sophisticated literature, or state-of-the-art, within control, diagnostic and/or surveillance of offshore energy systems

Type of instruction

Problem based project-oriented project work in groups.

The project work must be documented by a scientific paper (max. 8 pages). If judged necessary, this paper may be accompanied by a project summary report. The project summary report should elaborate the project details and conclusions. **The maximum length of the summary report (report without appendices) is 50 pages**, and in addition the summary report should follow the rules as laid down by the Study Board in "Procedure for Project Work", i.e. the total number of pages must not exceed $30 + 15 \times \text{number of students}$ in the project group.

The project work will consider advanced control, optimisation or diagnostic or surveillance systems for offshore energy systems. Based on a model, the advanced control-, diagnostic or surveillance 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. The system should be implemented and verified experimentally.

Due to special technical or scientific documentation requirements, the student documents the project work in a project report, which can be prepared individually or in a group within the project theme; ***however the student's special preferences for the semester must be approved by the Study Board in advance.***

Examination format

The project group should orally present the project work and scientific paper as specified in the Examination Policies and Procedures, Addendum to the Joint Programme Regulations. The project group members will undergo an oral examination, with internal adjudicator, based on the scientific paper and the project summary report.

It is a pre-condition that the student has submitted a scientific article and presented the scientific article at the CES conference prior to the project examination. All group members must be present at the conference.

Assessment criteria

As stated in the Joint Programme Regulations.

3.3.c Module on 3rd Semester: Voluntary Traineeship in a Company

Title

M3-7 Voluntary Traineeship in a Company/Projektorienteret forløb i en virksomhed (virksomhedsophold)

Prerequisites

The module is based on knowledge achieved when studying the previous semesters on the Master of Science in Energy Engineering or similar.

Objective

Students who complete the module should

Knowledge

- have knowledge about analytical, numerical and/or experimental methods for analysis of advanced tasks within the field of the external organisation
- understand the connection between theory and practice
- have knowledge about the organisational structure and the work of an organisation seen from an engineering/managerial perspective

Skills

- be able to apply analytical, numerical and/or experimental methods for analysis and solving of advanced tasks within the field of the external organisation
- be able to compare and evaluate assumptions, limitations and uncertainties related to the methods applied in connection to finding solutions of advanced challenges within the field of the external organisation

Competences

- be able to handle development-oriented situations in connection to either studying or working
- be able to use the correct terminology in oral, written or graphical communication and documentation of challenges and solutions within the field of the external organisation
- be able to analyse the academic, professional and social benefits of the traineeship
- be able to communicate these results in a project report and/or a case-based project report
- be able to evaluate the learning result of the traineeship

Type of instruction

The student works in a company providing experience in solving advanced and relevant engineering tasks on a level corresponding to the study programme's 3rd semester and with a progression in the degree of difficulty of the tasks during the period. The type of work must allow for an academic report to be made.

The student writes either a project report or a case-based project report within the theme of the 3rd semester of the specialisation, cf. "Guidelines for Project Work in an External Organisation (Voluntary Traineeship)" laid down by the School of Engineering and Science.

Examination format

An oral and individual examination based on either the project report or the case-based project report will be held in accordance with the rules in the Examination Policies and Procedures, Addendum to the Joint Programme Regulations of Faculty of Engineering and Science, Aalborg University.

Assessment criteria

As stated in the Joint Programme Regulations.

3.3.d Course Module on 3rd Semester: Advanced Analysis of Thermal Machines

Title

M3-8 Advanced Analysis of Thermal Machines/Avanceret analyse af termiske maskiner

Prerequisites

2nd semester on the Master of Science in Energy Engineering with a thermal specialisation, Master of Science in Sustainable Energy Engineering with specialisation in Process Engineering and Combustion Technology or similar.

Objective

Students who complete the module should have:

Knowledge within

- Conversion between different forms of energy
- Design of thermal machines
- Performance characteristics of thermal machines
- Behaviour of in- and outflow conditions for thermal machines
- Advanced analytical, numerical and/or experimental analysis of thermal machines
- Energy, momentum and heat exchange in thermal machines
- Phase change and multi-phase characteristics of thermal machines

Skills

- Be able to select and apply appropriate methods for performance analysis of thermal machines
- Be able to apply multi physics modelling in the analysis of thermal machines and components
- Be able to select and apply appropriate equipment for monitoring and performance measurements on thermal machines

Competences

- Independently be able to simulate thermal machines in design and off-design operation
- Independently be able to evaluate the performance of thermal machines in a given application or system
- Independently be able to evaluate the effect of design changes in thermal machines
- Independently be able to continue the development of own competences in the field of thermal machines

Type of instruction

The course is taught by a mixture of lectures, lab exercises, and self-studies.

Examination format

Oral examination based on a handed-in mini-project/test report (individual or in groups) and will be held in accordance with the rules in the Examination Policies and Procedures, Addendum to the Joint Programme Regulations of the Faculty of Engineering and Science, Aalborg University.

Assessment criteria

As stated in the Joint Programme Regulations.

3.3.e Course Module on 3rd Semester: Advanced Modelling and Control of Voltage Source Converters

Title

M3-9 Advanced Modelling and Control of Voltage Source Converters/Avancerede modellering af regulerende af effektelektroniske konvertere

Prerequisites

The module adds to the knowledge obtained in the 2nd semester on the Master of Science in Energy Engineering with an electrical specialisation or the Master of Science in Sustainable Energy Engineering with specialisation in Offshore Energy Systems or similar.

Objective

Students who complete the module should:

Knowledge

- Have knowledge about average and small-signal models for voltage Source Converter (VSC) circuits including pulse-width modulators and different output filters
- Understand impedance-based approach to get an insightful yet easy-to-implement way for controller design and stability assessment of VSCs
- Understand impedance-based stability analysis of grid synchronisation and outer DC link voltage control loops
- Understand equivalence and differences between models represented by single-input single-output complex transfer functions and multi-input multi-output transfer matrices
- Have knowledge about passivity-based stability analysis and control for robustly stable VSCs with different grid conditions
- Have knowledge about virtual-impedance-based control for active stabilisation and harmonic compensation of VSCs

Skills

- Be able to develop small-signal models for the closed-loop-controlled VSC with closed correlations with time-domain simulations
- Be able to design current controller, phase-locked loop, and DC link voltage controllers under given dynamic specifications
- Be able to identify the causes of the different instability phenomena of grid-connected VSCs
- Be able to design and implement different active damping controllers for stabilizing VSCs

Competences

- Be able to deal with the instability problems in the emerging VSCs-based power systems, which are nowadays commonly found in renewable power plants, electric transportation systems, and flexible ac/dc transmission/distribution systems

Type of instruction

The course is taught by a mixture of lectures, workshops, exercises in simulations (PLECS) and experiments (dSPACE 1007). Guest lectures relevant to the course will also be involved.

Examination format

Students should do a mini project and submit the report in groups, and then an oral examination will be held in accordance with the rules in the Examination Policies and Procedures, Addendum to the Joint Programme Regulations of the Faculty of Engineering and Science, Aalborg University.

Assessment criteria

As stated in the Joint Programme Regulations.

3.3.f Course Module on 3rd Semester: Analysis of Advanced Thermal Process Systems

Title

M3-10 Analysis of Advanced Thermal Process Systems/Analyse af avancerede termiske processer

Prerequisites

The module adds to the knowledge obtained in the 2nd semester on the Master of Science in Energy Engineering with a thermal specialisation or the Master of Science in Sustainable Energy Engineering with a specialisation in Process Engineering and Combustion Technology or similar.

Objective

Students who complete the module should:

Knowledge

- Have comprehension of the aspects of integration and analysis of advanced thermal processes regarding, for example:
 - Analysis and optimisation of thermal systems using techniques such as pinch analysis and heat exchanger network synthesis using mathematical programming techniques
 - Case: Modelling of part-load conditions in thermal systems including practical control aspects
 - Case: Modelling and integration of advanced fuel cell systems
- Have knowledge about advanced fluid dynamical topics and system analysis of such systems related, for example:
 - Techniques involved in the design of heat/mass exchangers – shell-and-tube, plate, extended surface, evaporators, condensers, humidifiers, etc. Flow induced vibrations
 - Two-phase fluid flow, models, boiling, condensation and instabilities
 - Equations of State. Thermodynamic functions/properties. Maxwell's relations. Residual properties. Phase equilibrium and phase change
 - Heat transfer by radiation. Modelling methods (e.g. Discrete Ordinate, Discrete Transfer, Monte-Carlo, etc). Gaseous radiative properties. CFD modelling of radiative heat transfer

Skills

- Be able to identify the elements related to the control aspects of thermal systems
- Be able to apply the knowledge gained to set up experiments on advanced fluid dynamical systems
- Be able to apply the knowledge on advanced fluid dynamical systems related to the above topics

Competences

- Independently be able to define and analyse scientific problems within the area of advanced thermal process systems and advanced fluid dynamical systems
- Independently be able to be a part of professional and interdisciplinary development work within the area of thermal process systems and advanced fluid dynamical systems

Type of instruction

The course is taught by a mixture of lectures, workshops, exercises, mini-projects and self-study.

Examination format

Oral examination which will be held in accordance with the rules in the Examination Policies and Procedures, Addendum to the Joint Programme Regulations of the Faculty of Engineering and Science, Aalborg University.

Assessment criteria

As stated in the Joint Programme Regulations.

3.3.g Course Module on 3rd Semester: Battery Energy Storage Systems

Title

M3-11 Battery Energy Storage Systems/Energilagringssystemer til batteri

Prerequisites

The module adds to the knowledge obtained in the 2nd semester on the Master of Science in Energy Engineering with an electrical or thermal specialisation or the Master of Science in Sustainable Energy Engineering with specialisation in Offshore Energy Systems or similar.

Objective

Students who complete the module should:

Knowledge

- Have knowledge about different battery energy storage technologies (e.g. lithium-ion, lead acid etc.) and understand their operation principles
- Understand the operation/role of energy storage devices and their suitability for different applications (e.g., grid services, electrical vehicles etc.)
- Have good knowledge about the performance (static and dynamic) behaviour of batteries and its dependence on the operating conditions (temperature, load current etc.). Gain experience about different performance and thermal modelling approaches and model parameterization techniques.
- Understand the degradation process of lithium-ion and lead-acid batteries from a macroscopic perspective. Gain knowledge about different methods for lifetime estimation of batteries.
- Gain practical knowledge about testing of lead-acid and lithium-ion batteries in laboratory

Skills

- Be able to evaluate the suitability of different energy storage technologies for various applications
- Be able to test different battery technologies in laboratory and to measure their most important electrical and thermal parameters
- Be able to derive various battery parameters from laboratory measurements.

Competences

- Be able to develop performance models for different battery technologies based on various requirements
- Independently be able to develop procedures for laboratory testing of batteries

Type of instruction

The course will be planned and organised in close interaction with on-going research and development activities at the Department of Energy Technology and its collaborators. All modules include exercises focusing on the presented material; some exercises will be performed using MATLAB and Simulink. Moreover, some exercises will be carried out on programmable battery test stations.

Examination format

Each student should submit all the laboratory exercises in the form of a report. The oral examination will be based on the submitted report and will be held in accordance with the rules in the Examination Policies and Procedures, Addendum to the Joint Programme Regulations of the Faculty of Engineering and Science, Aalborg University.

Assessment criteria

As stated in the Joint Programme Regulations.

3.3.h Course Module on 3rd Semester: Biomass Conversion and Biofuels

Title

M3-12 Biomass Conversion and Biofuels/Avancerede biobrændstoffer

Prerequisites

The module adds to the knowledge obtained in the 2nd semester on the Master of Science in Energy Engineering with a thermal specialisation or the Master of Science in Sustainable Energy Engineering with specialisation in Process Engineering and Combustion Technology or similar.

Objective

Students who complete the module should:

Knowledge

- Biomass resource quantification
- Thermo-chemical and bio-chemical conversion pathways
- Biorefinery concepts

Skills

- Be able to assess suitable conversion routes for specific biomasses
- Be able to carry out chemical analysis of fuels to assess their properties
- Be able to analyse and evaluate processes of biomass conversion to fuel or energy
- Be able to evaluate the sustainability of biofuels from different biomass resources using a life cycle perspective with focus on greenhouse gas emissions
- Be able to apply process modelling methods to biorefinery concepts

Competences

- Independently be able to assess biomass resources dedicated for bioenergy production and to design systems of biomass conversion, i.e. biorefineries
- Independently be able to design and analyse production processes for converting biomass resource into biofuel

Type of instruction

The course is taught by a mixture of lectures, lab exercises and self-studies.

Examination format

Oral examination based on a delivered mini-project/test report (individual or made in groups with maximum 2 persons) and will be held in accordance with the rules in the Examination Policies and Procedures, Addendum to the Joint Programme Regulations of the Faculty of Engineering and Science, Aalborg University.

Assessment criteria

As stated in the Joint Programme Regulations.

3.3.i Course Module on 3rd Semester: Biomass Gasification, Combustion and their Advanced Modelling

Title

M3-13 Biomass Gasification, Combustion and Their Advanced Modelling/Forgasning af biogas, forbrænding og avanceret modellering

Prerequisites

The module adds to the knowledge obtained in Heat transfer; Fundamentals of CFD; Combustion theory; Fluid mechanics.

Objective

Students who complete the module should:

Knowledge

- Understand solid biomass feedstock: Fuel characterisation, thermochemical conversion and the various sub-processes, heat and mass transfer in biomass thermochemical conversion
- Understand radiation heat transfer without participating medium: Fundamentals, view factors, surface resistance and space resistance, network method
- Understand radiation heat transfer with participating medium: Radiative properties of gas mixture, radiative transfer equation, modelling of radiative heat transfer

- Have knowledge about biomass gasification and combustion on particle scale: Time scale analysis, ignition mechanisms, reactions of gasification, regimes of char reactions, modelling of biomass particle conversion
- Have knowledge about biomass gasification on reactor scale: Principles, key factors, types of gasifiers and their key characteristics, gasifier design, success stories of biomass gasification
- Have knowledge about suspension-firing of biomass: NO_x control by combustion, different arrangements of suspension-firing, modelling of suspension-firing – overview and specific issues, case studies
- Have knowledge about grate-firing of biomass: Key components in grate boilers, breakthrough, potential problems and solutions, modelling of grate-firing – general strategy and examples

Skills

- Be able to identify the appropriate utilisation technology for a given biomass based on its properties
- Understand thermal radiation heat transfer, various applications, and advanced modelling of radiation heat transfer without and with participating medium
- Understand the mechanisms and the key issues in biomass gasification and the modelling
- Understand the key sub-processes in biomass combustion and various key biomass combustion technologies (their advantages and disadvantages, and modelling strategies)
- Be able to developing key sub-models for biomass conversion and implementing them into commercial CFD

Competences

- Have in-depth understanding of all the important issues in biomass gasification and combustion, including combustion physics (e.g., radiative heat transfer, turbulent flow) and combustion chemistry (e.g., pyrolysis, homogeneous and heterogeneous reactions)
- Be able to develop sub-models and codes for the key, special processes in biomass gasification and combustion process and ability to perform a reliable CFD of biomass gasifier and combustor

Type of instruction

Lectures in combination with tutorials, assignments and hands-on.

Examination format

Oral examination in accordance with the rules in the Examination Policies and Procedures, Addendum to the Joint Programme Regulations of the Faculty of Engineering and Science, Aalborg University.

Assessment criteria

As stated in the Joint Programme Regulations.

3.3.j Course Module on 3rd Semester: Control of Grid Connected Photovoltaic and Wind Turbine Systems

Title

M3-14 Control of Grid Connected Photovoltaic and Wind Turbine Systems/Regulering af nettilsluttede solcelle-og vindmøllesystemer

Prerequisites

The module adds to the knowledge obtained in the 2nd semester on the Master of Science in Energy Engineering with an electrical specialisation or the Master of Science in Sustainable Energy Engineering with specialisation in Offshore Energy Systems or similar.

Objective

Students who complete the module should:

Knowledge

- Understand the operation principle of most common PV and WT systems
- Have knowledge about the most important single- and three-phase inverter topologies, used in renewable energy systems
- Have knowledge about the various pulse width modulation (PWM) techniques used with different inverter topologies
- Understand maximum power point trackers
- Have knowledge about different phase-lock loop (PLL) and control methods, current, voltage and power loops used in control schemes of grid connected inverters
- Have knowledge about grid requirements, standards describing anti-islanding methods, THD limits, etc. that grid connected inverters must comply with

Skills

- Be able to implement different PWM strategies for single- and three-phase converters
- Be able to verify different PLL methods based on laboratory experiments
- Be able to design/tune a control scheme for a grid connected converter

Competences

- Be able to create mathematical models for PV cells, panels and arrays
- Be able to develop simulation models for different PV and WT converter
- Be able to implement a grid connected converter control
- Understand the purpose and methods for grid support by renewable systems

Type of instruction

The course will be planned and organised in close interaction with on-going research and development activities at the Department of Energy Technology and its collaborators. Project topics are accounted for when determining the course content. Guest lecturers will also be involved if this is relevant to the course aims.

All lectures include exercises focusing on the presented material. Some of the exercises will be done using MATLAB and Simulink. Several exercises will be performed in the PV-lab (PON109-1.135) using experimental set-ups, like current control for a grid connected converter using dSPACE 1103. This way the participants will get a hands-on experience with real-life systems.

Examination format

Each student should submit all the laboratory exercises in the form of a report. The oral examination will be based on the submitted report and the presented material in accordance with the rules in the Examination Policies and Procedures, Addendum to the Joint Programme Regulations of the Faculty of Engineering and Science, Aalborg University.

Assessment criteria

As stated in the Joint Programme Regulations.

3.3.k Course Module on 3rd Semester: Electrochemical Modelling of Fuel Cells, Electrolysers and Batteries

Title

M3-15 Electrochemical Modelling of Fuel Cells, Electrolysers and Batteries/Elektrokemisk modellering af brændselsceller, batterier og elektrolyse

Prerequisites

The module adds to the knowledge obtained in the 2nd semester on the Master of Science in Energy Engineering, Sustainable Energy Engineering or similar.

Objective

Students who complete the module should:

Knowledge

- Have knowledge about the components that make up an electrochemical cell
- Understand the thermodynamics of fuel cells, electrolysers and batteries
- Understand the relations governing the kinetics of electrochemical reactions
- Understand the mechanisms governing charge, mass and energy transport within electrodes and electrolytes
- Have knowledge about how to model catalyst poisoning
- Understand how the individual processes are coupled

Skills

- Be able to develop models for different types of electrodes
- Be able to combine electrode models with other sub models to create a full electrochemical cell model
- Be able to apply appropriate simplifications depending on the application

Competences

- Independently be able to analyse and model real electrochemical cells
- Independently be able to identify the validity or limitations of an electrochemical model
- Independently be able to simplify an electrochemical model so it is applicable in modelling of thermal or electrical systems

Type of instruction

The course is taught by a mixture of lectures, workshops, exercises and self-studies.

Examination format

Oral examination which will be held in accordance with the rules in the Examination Policies and Procedures, Addendum to the Joint Programme Regulations of the Faculty of Engineering and Science, Aalborg University.

Assessment criteria

As stated in the Joint Programme Regulations.

3.3.1 Course Module on 3rd Semester: Energy Conversion and Storage in Future Energy Systems

Title

M3-16 Energy Conversion and Storage in Future Energy Systems/Konvertering og lagring af fremtidige energisystemer

Prerequisites

MATLAB familiarity.

Objective

Students who complete the module should:

Knowledge

- Have knowledge about the basic principles of electrochemical energy conversion

- Have knowledge about the different types of electrolysers, fuel cells and battery energy storage technologies
- Understand the operation/role of energy storage devices and their suitability for different applications (e.g., grid services, V2G, renewables' grid integration etc.)
- Have good knowledge about the performance (static and dynamic) behaviour of fuel cells, electrolysers and batteries and their dependence on the operating conditions (temperature, load current, etc.). Gain experience about different performance and thermal modelling approaches and model parameterization techniques
- Gain knowledge about the testing of fuel cells, electrolysers and batteries in the laboratory

Skills

- Be able to develop a simple model of an electrochemical cell or system
- Be able to test an electrolyser or fuel cell or battery
- Be able to evaluate the suitability of different energy storage technologies for various applications
- Be able to derive various parameters from laboratory measurements

Competences

- Be able to develop performance models for different battery technologies based on various requirements
- Independently be able to identify the validity or limitations of an electrochemical model
- Be able to analyse data from the fuel cell, electrolyser and battery tests

Type of instruction

The course will be planned and organised in close interaction with on-going research and development activities at the Department of Energy Technology and its collaborators. All lectures include exercises focusing on the presented material; some exercises will be performed using MATLAB and Simulink. Moreover, some exercises will be carried out on programmable battery test stations.

Examination format

Oral examination based on a delivered mini-project/test report (individual or made in groups) and will be held in accordance with the rules in the Examination Policies and Procedures, Addendum to the Joint Programme Regulations of the Faculty of Engineering and Science, Aalborg University.

Assessment criteria

As stated in the Joint Programme Regulations.

3.3.m Course Module on 3rd Semester: Fault Tolerant Control

Title

M3-17 Fault Tolerant Control/Fejltolerant regulering

Prerequisites

The module adds to the knowledge obtained in courses on non-linear control theory and multi-variable control.

Objective

Students who complete the module should:

Knowledge

- Have comprehension of the fundamental concepts, terms and methods used within fault tolerant control
- Have comprehension of failure mode and effect analysis (FMEA)
- Have comprehension of modelling faults in dynamic systems and closed loop control systems
- Have comprehension of analytical redundancy
- Have knowledge about statistical fault detection including cumulative sum and generalised likelihood tests
- Have comprehension of residual generation for detection and isolation and decision ruling
- Have comprehension of fault detection using both observers and parity methods

Skills

- Be able to use analyse fault development and mitigation approaches
- Be able to list considered faults, how they propagate through the system and assess their severity and occurrence likelihood
- Be able to design fault detection observers
- Be able to design fault detection with parity equations
- Be able to design a FDI observer for unknown inputs
- Be able to develop fault tolerant strategies for ensuring the continuation of the system in the presence of faults
- Be able to design both passive and active fault tolerant controller for continuous systems

Competences

- Be able to account for the considerations involved in the process of formulating and solving fault tolerant control problems, choosing suited approaches and implementing it in practice
- Be able to develop fault detection and isolation (FDI) algorithms

Type of instruction

The form(s) of teaching will be determined and described in connection with the planning of the semester. The description will account for the form(s) of teaching and may be accompanied by an elaboration of the roles of the participants (see chapter 3).

Examination format

Internal written examination in accordance with the rules in the Examination Policies and Procedures, Addendum to the Joint Programme Regulations of the Faculty of Engineering and Science, Aalborg University.

Assessment criteria

As stated in the Joint programme Regulations.

3.3.n Course Module on 3rd Semester: Future Power System in Denmark/Fremtidens el-forsyning i Danmark

Title

M3-18 Future Power System in Denmark/Fremtidens el-forsyning i Danmark

Prerequisites

The module adds to the knowledge obtained in the 2nd semester on the Master of Science in Energy Engineering with an electrical specialisation or similar.

Objective

Students who complete the module should:

Knowledge

- Have knowledge and understanding within the technique of the grid and system challenges that the electricity power system in Denmark is expected to face in the future in terms of design and system operation.

Skills and Competences

- Be able to explain the grid technique and systemic challenges of electricity supply in Denmark in the future facing, both design and / or terms of system operation
- Be able to analyse and assess the structure, composition, interaction and mutual influence between the relevant parts of the electricity grid and power system in one or more of the fields distribution, transmission, production and consumption
- Be able to use and through that become familiar with earlier learned electrical power system theory
- Be able to identify, evaluate, and argue for changes in existing power system facilities taking into consideration high personal security, high continuity of supply and finance

Type of instruction

The course will include lectures; guest-lectures; team work; web-conferences/question time; and conference. With starting point in Denmark's existing electrical power system, and known political objectives and decisions for Denmark (at regional or national level), students must analyse their way through to a concrete solution for the future electricity supply in Denmark, based on the course's theme and within a more defined, self-elected project focus.

Examination format

Oral examination based on a delivered mini-project/test report (individual or made in groups) and will be held in accordance with the rules in the Examination Policies and Procedures, Addendum to the Joint Programme Regulations of the Faculty of Engineering and Science, Aalborg University.

Assessment criteria

As stated in the Joint Programme Regulations.

3.3.o Course Module on 3rd Semester: Modern Electrical Drives

Title

M3-19 Modern Electrical Drives/Moderne elektriske drivsystemer

Prerequisites

The module adds to the knowledge obtained in the 2nd semester on the Master of Science in Energy Engineering with an electrical specialisation or the Master of Science in Sustainable Energy Engineering with specialisation in Offshore Energy Systems or similar.

Objective

Students who complete the module should:

Knowledge

- Have a solid knowledge about the electromagnetic field behaviour for various types of electrical machines. This gives a firm base for understanding of the advantages and disadvantages of different types of electrical machines. It consequently leads to a good understanding of new types of machines invented in recent years, e.g. the modern drive unit in electric vehicles or wind turbines, and magnetic gears.
- Have a detailed knowledge of the small DC link drive system and the corresponding active damping control methods. This has become a hot topic in recent years.
- Gain good experience about design of various controllers to meet different requirements, e.g. very low speed stable operation, low-cost controller design, drive stability issues, etc.

Skills

- Be able to understand and evaluate new types of high performance electrical machines that may occur in the future
- Be able to identify the pros and cons of existing sensorless control methods and design the most proper controller for selected applications
- Be aware of important practical implementation issues when designing the controller
- Be able to test, measure and characterize the performance of different electrical drive systems

Competences

- Independently be able to contribute to a professional team dealing with design of modern electrical drives, including new high performance electrical machines and advanced control technologies

Type of instruction

The course is taught by a mixture of lectures, workshops, exercises, mini-projects and self-studies. Instead of using complicated mathematical equations and electromagnetic theory, particularly-made Finite Element Models visualizing the electromagnetic field behaviour inside a machine will be used to give an easy but deep access to many difficult topics involved in the electrical machine theory. Various advanced sensorless control technologies developed in recent years will be discussed for permanent magnet machine and synchronous reluctance machine (which has received great interests in recent years). Achievements obtained from recent PhD projects carried out at the department will be presented.

Examination format

Oral examination based on a delivered mini-project/test report (individual or made in groups) and will be held in accordance with the rules in the Examination Policies and Procedures, Addendum to the Joint Programme Regulations of the Faculty of Engineering and Science, Aalborg University.

Assessment criteria

As stated in the Joint Programme Regulations.

3.3.p Course Module on 3rd Semester: Modern Power Electronic Devices and their Models

Title

M3-20 Modern Power Electronic Devices and their Models/Moderne effektelektronikkomponenter og deres modeller

Prerequisites

The module adds to the knowledge obtained in the 2nd semester on the Master of Science in Energy Engineering with an electrical specialisation or the Master of Science in Sustainable Energy Engineering with specialisation in Offshore Energy Systems or similar.

Objective

Students who complete the module should:

Knowledge

- Have a basic knowledge about figure of merit of present and future wide-bandgap semiconductor materials (SiC, GaN, GaO, diamond, etc.)
- Have a solid knowledge about operating principles and founding equations of modern power electronic devices: SCRs, MOSFETs, IGBTs, rectifiers, FR diodes, Schottky diodes, HEMTs, etc.
- Have a solid knowledge about operating range basing on real-life application, like LVDO, POL, power supplies, welding machines, solar inverters, wind turbines, HVDC, etc.
- Have a basic knowledge about power electronic device design principles, constraints and trade-offs

- Have a good understanding of simulation tools, both at device level and circuit level (PSpice, LTSpice, etc.)
- Understanding of the interaction between the external circuit, including driving circuit, and the power electronic device
- Have a good knowledge about abnormal conditions and instabilities
- Have a hands-on experience on real problems related to power electronic devices, as driver selection, heatsink thermal design, losses and efficiency estimation and measurement

Skills

- Be able to recognise and classify traditional and modern power semiconductor devices
- Be able to test and characterize real power devices, both statically and dynamically
- Be able to simulate with good accuracy electrical behaviour of power electronic devices, including power losses and junction temperature estimation
- Be able to select an appropriate power devices for a given real application, e.g. DC/DC or DC/AC converters
- Experience gained from practical tasks will let you be aware of important implementation issues when designing power electronic circuits, e.g. thermal design, safe operating area, etc.

Competences

- Be able to contribute to a professional team in design of power electronic circuits with skills on part number selection, driving design and simulation of traditional and modern power electronic components

Type of instruction

The course is taught by a mixture of lectures, workshops, exercises, mini-projects and self-studies.

Examination format

Oral examination based on a delivered mini-project/test report (individual or made in groups) and will be held in accordance with the rules in the Examination Policies and Procedures, Addendum to the Joint Programme Regulations of the Faculty of Engineering and Science, Aalborg University.

Assessment criteria

As stated in the Joint Programme Regulations.

3.3.q Course Module on 1st Semester: Non-linear Control and Multi-body Systems

Title

M1-11 Non-linear Control and Multi-body Systems/Ikke-lineær regulering og flerlegeme systemer

Objective

Students who complete the module should:

Knowledge

- Be able to carry out kinematic analysis of multi-body systems
- Be able to model multi-body dynamical systems using selected methods
- Be able to develop complete system models that include actuators and possible hard non-linearities
- Be able to analyse systems using linearization-, Lyapunov- and phase plane methods
- Be able to design non-linear controllers for considered systems in the presence on uncertain and possibly varying system parameters

Skills

- Be able to establish various types models for non-linear system, including multi-body and actuator models
- Be able to judge the usefulness of the different analyses and design methods
- Be able to apply the learned knowledge to analyse and study non-linear dynamical systems
- Be able to design selected types of non-linear controllers
- Be able to implement selected types of non-linear controllers

Competences

- Independently be able to describe and analyse non-linear systems
- Independently be able to design considered non-linear controllers
- Independently be able to continue own development within the field of non-linear systems analysis and control

Type of instruction

The form(s) of teaching will be determined and described in connection with the planning of the semester. The description will account for the form(s) of teaching and may be accompanied by an elaboration of the roles of the participants (see chapter 3).

Examination format

Internal, written/oral examination in accordance with the rules in the Examination Policies and Procedures, Addendum to the Joint Programme Regulations of the Faculty of Engineering and Science, Aalborg University

Assessment criteria

As stated in the Joint Programme Regulations.

3.3.r Course Module on 3rd Semester: System Identification and Diagnosis

Please refer to 3.1.k Course Module on 1st Semester.

3.3.s Course Module on 3rd Semester: Test and Validation/Test og validering

Title

M3-21 Test and Validation/Test og validering

Prerequisites

The module builds upon knowledge obtained in the modules Applied Statistics and Probability Theory or similar.

Objective

Students who complete the module should:

Knowledge

- Understand methodology for design of experiments and test series and for reduction of ambiguity of experimental results, and for comparability with model predictions
- Explain elementary and advanced quantification tools, and their application to validation between model and experiment data
- Account for common contemporary methods and relevant specific industry standards
- Understand processing methods for analog and digital data (continuous vs. discrete)

Skills

- Scrutinize a non-trivial physical systems for appropriate experimental study
- Isolate principal measurable parameters

- Design an experiment matrix for systematic variation of parameters
- Perform a probabilistic study of the experimental data in order to quantify the influence of individual parameters
- Scrutinize a model (analytical or numerical) for comparison with an appropriate experimental study
- Isolate principal input parameters and their known or assumed statistical variations
- Perform a probabilistic study of the model in order to quantify the level of confidence
- Account for the level of coherence between test results and model predictions
- Identify invalid data (outliers)
- Account for common errors and limitations in the processing of model data or experimentally obtained data

Competences

- Undertake experiment planning and execution for refinement and validation (or rejection) of model-based predictions of phenomena within their principal line of study

Type of instruction

The course is taught by a mixture of lectures, workshops, exercises, mini-projects and self-studies.

Examination format

Oral examination based on submitted written assignment.

Assessment criteria

As stated in the Joint Programme Regulations.

3.3.t Course Module on 3rd Semester: Wind Power System and Renewable Energy Grid Integration

Title

M3-22 Wind Power System and Renewable Energy Grid Integration/Nettilslutning af vindmøller og bæredygtige energiforsyninger

Prerequisites

The module adds to the knowledge obtained in the 2nd semester on the Master of Science in Energy Engineering with an electrical specialisation or the Master of Science in Sustainable Energy Engineering with specialisation in Offshore Energy Systems or similar.

Objective

Students who complete the module should:

Knowledge

- Have knowledge and comprehension within electrical system overview of wind energy conversion systems
- Have knowledge and comprehension within wind power generators
- Have knowledge and comprehension within the power electronics converters in wind power conversion system
- Have knowledge and comprehension within the wind turbine systems
- Have knowledge and comprehension within optimisation theory and its application on offshore wind farms and electrical systems
- Have knowledge and comprehension within operation and control of wind turbines and wind farms
- Have knowledge and comprehension within renewable energy sources in transmission power systems
- Have knowledge and comprehension within renewable energy sources in distribution power systems

Skills

- Be able to apply theories to analyse wind turbine systems
- Be able to apply power flow analysis of large renewable energy systems
- Be able to implement optimisation in an offshore wind farm and design its electrical systems
- Be able to simulate the different grid-connected wind turbine systems, including Double Fed Induction Generator (DFIG) based wind turbines and Permanent Magnet Synchronous Generator (PMSG) based wind turbines
- Be able to analyse the impact of renewable energy sources on the power system

Competences

- Be able to understand the state-of-art knowledge within the area of renewable energy
- Independently be able to define and analyse scientific problems within the area of wind power systems
- Independently be able to communicate results from advanced wind power technology
- Independently be able to be a part of professional and interdisciplinary development work in renewable energy technology

Type of instruction

Lectures, exercises, simulations and group discussions.

Examination format

Each student should submit an exercise report. The oral examination will be based on the submitted report and will be held in accordance with the rules in the Examination Policies and Procedures, Addendum to the Joint Programme Regulations of the Faculty of Engineering and Science, Aalborg University.

Assessment criteria

As stated in the Joint Programme Regulations.

3.4 Module Descriptions of 4th Semester

3.4.a Master's Thesis on 4th Semester in Process Engineering and Combustion Technology

Title

ME4-1 Master's Thesis in Process Engineering and Combustion Technology/Kandidatspeciale i proces- og forbrændingsteknik

Prerequisites

The module is based on knowledge achieved when studying the 3rd semester on the Master of Science in Sustainable Energy Engineering with specialisation in Process Engineering and Combustion Technology or similar.

It is a pre-condition for students who have not studied the Aalborg PBL Model at Aalborg University that they have passed the course in "Project Based Learning and Project Management" (see section 3.1.a) prior to the project examination.

Objective

After completion of the project the student should:

Knowledge

- Have knowledge and comprehension within the area of process engineering and combustion technology at the highest international level
- Be able to critically judge knowledge and identify new scientific problems within the area of process engineering and combustion technology
- Have comprehension of the implications within the research work (research ethics)

Skills

- Be able to judge the usefulness of different scientific methods and tools for analysis and problem solving within the field of process engineering and combustion technology
- Be able to use advanced laboratory set-ups, data analysis methods and analysis and modelling methods within the field of process engineering and combustion technology
- Be able to communicate scientific problems both to specialists and the public
- Have obtained skills related to the industrial area within process engineering and combustion technology

Competences

- Be able to control complex or unexpected working and development situations within process engineering and combustion technology, and be able to develop new solutions
- Independently be able to define and analyse scientific problems, and based on that, make and state the reasons for decisions made
- Independently be able to continue own development in competence and specialisation
- Independently be able to be the head of professional and interdisciplinary development work and be able to undertake the professional responsibility

Type of instruction

Problem based project oriented project work.

The final project may study new subjects or be an extension of the project work from previous semesters. The subject matter will remain in the area of process engineering and combustion technology. The project may be of theoretical or experimental nature, and will often be in collaboration with an industrial company or other research institution performing research in the area of process engineering and combustion technology.

The Master's Thesis can be conducted as a long Master's Thesis using both the 3rd and 4th semesters. If choosing to do a long Master's Thesis, it must include experimental work and must be approved by the Study Board in advance. The amount of experimental work must reflect the allotted ECTS.

Examination format

Oral examination with external adjudicator as given in the Examination Policies and Procedures, Addendum to the Joint Programme Regulations.

Assessment criteria

As stated in the Joint Programme Regulations.

3.4.b Master's Thesis on 4th Semester in Offshore Energy Systems

Title

ME4-2 Master's Thesis in Offshore Energy Systems/Kandidatspeciale i offshore energisystemer

Prerequisites

The module is based on knowledge achieved when studying the 3rd semester on the Master of Science in Sustainable Energy Engineering with specialisation in Offshore Energy Systems or similar.

It is a pre-condition for students who have not studied the Aalborg PBL Model at Aalborg University that they have passed the course in "Project Based Learning and Project Management" (see section 3.1.a) prior to the project examination.

Objective

After completion of the project the student should:

Knowledge

- Have knowledge and comprehension within the area of offshore energy systems at the highest international level
- Be able to critically judge knowledge and identify new scientific problems within the area of offshore energy systems
- Have comprehension of the implications within the research work (research ethics)

Skills

- Be able to judge the usefulness of different scientific methods and tools for analysis and problem solving within the field of offshore energy systems
- Be able to use advanced laboratory set-ups, data analysis methods and analysis and modelling methods within the field of offshore energy systems
- Be able to communicate scientific problems both to specialists and the public
- Have obtained skills related to the industrial area within offshore energy systems

Competences

- Be able to control complex or unexpected working and development situations within offshore energy systems, and be able to develop new solutions
- Independently be able to define and analyse scientific problems, and based on that make and state the reasons for decisions made
- Independently be able to continue own development in competence and specialisation
- Independently be able to be the head of professional and interdisciplinary development work and be able to undertake the professional responsibility

Type of instruction

Problem based project oriented project work.

The final project may study new subjects or be an extension of the project work from previous semesters. The subject matter will remain in the area of offshore energy systems. The project may be of theoretical or experimental nature and will often be in collaboration with an industrial company or other research institution performing research in the area of offshore energy systems.

The Master's Thesis can be conducted as a long Master's Thesis using both the 3rd and 4th semesters. If choosing to do a long Master's Thesis, it must include experimental work and must be approved by the Study Board in advance. The amount of experimental work must reflect the allotted ECTS.

Examination format

Oral examination with external adjudicator as given in the Examination Policies and Procedures, Addendum to the Joint Programme Regulations.

Assessment criteria

As stated in the Joint Programme Regulations.

4. Entry into Force, Interim Provisions and Revision

The curriculum is approved by the Dean of the Faculty of Engineering and Science and enters into force as of September 2017.

Students who wish to complete their studies under the previous curriculum from 2012 must conclude their education by the summer examination period 2018 at the latest, since examinations under the previous curriculum are not offered after that date.

5. Other Provisions

5.1 Rules concerning Written Work, including the Master of Science Thesis

In the assessment of all written work, regardless of the language it is written in, weight is also given to the student's spelling and formulation ability, in addition to the academic content. Orthographic and grammatical correctness as well as stylistic proficiency are taken as a basis for the evaluation of language performance. Language performance must always be included as an independent dimension of the total evaluation. However, no examination can be assessed as 'Pass' on the basis of language performance alone; similarly, an examination cannot be assessed as 'Fail' on the basis of poor language performance alone.

The Study Board can grant exemption from this in special cases (e.g., dyslexia or a native language other than Danish).

The Master's thesis must be written in English and include a summary. The summary is included in the evaluation of the project as a whole. The summary should be in English or Danish (Swedish and Norwegian)¹ and it must be at least 1 page and not more than 2 pages.

5.2 Rules concerning Credit Transfer (Merit), including the Possibility for Choice of Modules that are part of Another Programme at a University in Denmark or Abroad

In the individual case, the Study Board can approve successfully completed (passed) program elements from other Master's programmes in lieu of program elements in this programme (credit transfer). The Study Board can also approve successfully completed (passed) program elements from another Danish program or a program outside of Denmark at the same level in lieu of program elements within this curriculum. Decisions on credit transfer are made by the Study Board based on an academic assessment. See the Joint Programme Regulations for the rules on credit transfer.

5.3 Rules for Examinations

The rules for examinations are stated in the Examination Policies and Procedures published by the Faculties of Engineering, Science and Medicine on their website.

5.4 Exemption

In exceptional circumstances, the Study Board can grant exemption from those parts of the curriculum that are not stipulated by law or ministerial order. Exemption regarding an examination applies to the immediate examination.

5.5 Additional Information

The current version of the curriculum is published on the Study Board of Energy's website, including more detailed information about the programme, including exams.

¹ The Study Board can grant exemption from this.

5.6 Rules and requirements concerning the reading of texts in foreign languages

It is assumed that the student can read academic texts in modern English and use reference works, etc., in other European languages.