The Faculty of Engineering and Science
The Study Board of Energy

AALBORG UNIVERSITY
DENMARK

Curriculum for the Master of Science Programme in Energy Engineering

Aalborg University
September 2017

Campus: Aalborg

Preface

Pursuant to Act 261 of March 18, 2015 on Universities (the University Act) with subsequent changes, the following curriculum for the Master of Science programme in Energy Engineering is stipulated. The programme also follows the Joint Programme Regulations and the Examination Policies and Procedures for Faculty of Engineering and Science.

The Master of Science programme in Energy Engineering is a two-year education which contains in total 6 specialisations within the areas of thermal, electrical and mechatronic control engineering.

- Thermal Energy and Process Engineering
- Fuel Cells and Hydrogen Technology
- Wind Power Systems
- Power Electronics and Drives
- Electrical Power Systems and High Voltage Engineering
- Mechatronic Control Engineering

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

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1. Legal Basis of the Curriculum

1.1 Basis in Ministerial Orders
The Master of Science programme in 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, 2015 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's programme falls under the Faculty of Engineering and Science, Aalborg University.

1.3 Board of Studies Affiliation
The Master's 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 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, 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 polytechnices) i energiteknik med specialisering i termisk energi og procesteknik. The English designation is: Master of Science (MSc) in Engineering (Energy Engineering with specialisation in Thermal Energy and Process Engineering)
- Civilingeniør, cand.polyt. (candidatus/candidata polytechnices) i energiteknik med specialisering i brændselsceller og brintteknologi. The English designation is: Master of Science (MSc) in Engineering (Energy Engineering with specialisation in Fuel Cells and Hydrogen Technology)
- Civilingeniør, cand.polyt. (candidatus/candidata polytechnices) i energiteknik med specialisering i vindmølleteknologi. The English designation is: Master of Science (MSc) in Engineering (Energy Engineering with specialisation in Wind Power Systems)
- Civilingeniør, cand.polyt. (candidatus/candidata polytechnices) i energiteknik med specialisering i effektelektronik og elektriske drivsystemer. The English designation is: Master of Science (MSc) in Engineering (Energy Engineering with specialisation in Power Electronics and Drives)
- Civilingeniør, cand.polyt. (candidatus/candidata polytechnices) i energiteknik med specialisering i elektriske anlæg og højspændingsteknik. The English designation is: Master of Science (MSc) in En-

gineering (Energy Engineering with specialisation in Electrical Power Systems and High Voltage Engineering)

- Civilingeniør, cand.polyt. (candidatus/candidata polytechnices) i energiteknik med specialisering i mekatronisk reguleringsteknik. The English designation is: Master of Science (MSc) in Engineering (Energy Engineering with specialisation in Mechatronic Control Engineering)

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 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, simulation techniques and optimisation

In addition, students from the different specialisations have the following knowledge:

- The specialisation in Thermal Energy and Process Engineering:
  - Advanced knowledge about and comprehension of the conversion and transport processes within advanced thermal and fluid systems
  - Knowledge about the design, modelling and optimisation of energy systems used in various energy conversion applications
  - Knowledge about the detailed operation, functionality and interactions between the various components of key thermal energy conversion technologies
  - Detailed knowledge regarding system integration with re-

    - spect to both system efficiency and control aspects of energy systems

- The specialisation in Fuel Cells and Hydrogen Technology:
    - Advanced knowledge about and comprehension of the conversion and transport processes within fuel cells and hydrogen systems
    - Understanding of the design, modelling and optimisation of energy systems used in various energy conversion applications involving fuel cell and hydrogen production technology
    - Knowledge about the detailed operation, functionality and interaction between the various components used in fuel cell and hydrogen production systems
    - Have detailed knowledge about system integration with respect to both system efficiency and control aspects of fuel cell and hydrogen production systems
- The specialisation in Wind Power Systems:
    - Advanced knowledge about and comprehension of the electrical area of wind turbine technology i.e. generators, converters, connection of wind turbines to the network grid and analysis of the systems under stationary and contingency situations
    - Knowledge about how to apply test methods and systems for high voltage components (non-destructive) according to applicable standards. This includes testing for electromagnetic compatibility
    - Knowledge and comprehension within operation and control of wind turbines and wind farms
    - Knowledge and comprehension within optimisation theory and its application on wind farms and electrical systems
- The specialisation in Power Electronics and Drives:
    - Advanced knowledge and comprehension within efficient usage of electrical energy, intelligent energy conversion using power electronic systems and electrical machines
    - Understanding of the operation, function and interaction between various components and sub-systems used in power electronic converters, electric machines and adjustable-speed drives
    - Knowledge enabling the design, modelling, simulation and synthesis of power converter-based systems used for conversion of electric energy
- The specialisation in Electrical Power Systems and High Voltage Engineering:
    - Advanced knowledge and comprehension within production, transmission, distribution and consumption of electric energy both under stationary and contingency situations using the newest technologies in the power system field
    - Knowledge about how to apply test methods and systems for high voltage components (non-destructive) according to applicable standards. This includes testing for electromagnetic compatibility
- The specialisation in Mechatronic Control Engineering:
    - Knowledge and comprehension within advanced control

engineering and understanding of the synergistic aspects in combining mechanical, thermal, electric and control technologies in the design process when designing mechatronic systems
  - Understanding of the importance of physical and mathematical modelling in mechatronic system design
  - Understanding of more advanced control techniques, e.g. multi-variable control, sliding mode control, adaptive control, feedback linearization, etc.

Skills

- Be proficient in the scientific methods, tools and general skills related to employment within the subjects of 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 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 Thermal Energy and Process Engineering:
  - The ability to develop, construct and understand the operation of thermal energy conversion systems in the laboratory and in real applications
- The specialisation in Fuel Cells and Hydrogen technology:
  - The ability to construct and understand the operation of fuel cell based systems in the laboratory and in real applications
  - Analytical skills in system integration with respect to system efficiency and control aspects of fuel cell energy systems
- The specialisation in Wind Power Systems:
  - The ability to analyse the dynamic behaviour of wind turbine systems when they are connected to a power system with varying loads
  - The ability to analyse the load flow in wind power systems, including reactive power flow and the ability to analyse the stability in wind power systems
  - The ability to analyse the power quality of the system and to determine the need for power compensation
  - The ability to synthesise control systems for different types of wind turbine systems and to analyse the power electronic interface between wind turbines and grids
  - The ability to implement optimisation in a wind farm and design its electrical system
- The specialisation in Power Electronics and Drives:
  - Experience in the design of controllers for power electronic drive systems using classical and modern control theory
  - Experience with the practical implementation of controllers

- using for example digital signal processors
  - The ability to develop, construct, operate and test power electronic converters and drives in the laboratory
  - Experience in relation to renewable energy and grid connected converters
- The specialisation in Electrical Power Systems and High Voltage Engineering:
  - The ability to apply different methods of analysis and synthesis for design and simulation of various electrical power systems both in stationary and in contingency situations
  - The ability to apply different control and surveillance systems for control of the network grid. This will include power system protection and the application of power electronic compensation units
- The specialisation in Mechatronic Control Engineering:
  - The ability to include the controller design as an integrated part of the mechatronic design process
  - The ability to apply different methods of analysis and synthesis for design and simulation of various mechatronic systems

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 competence in production, distribution and the usage of electrical, thermal and /or mechanical energy together with design, control and optimisation of energy or mechatronic systems
- The competences should advance the students 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

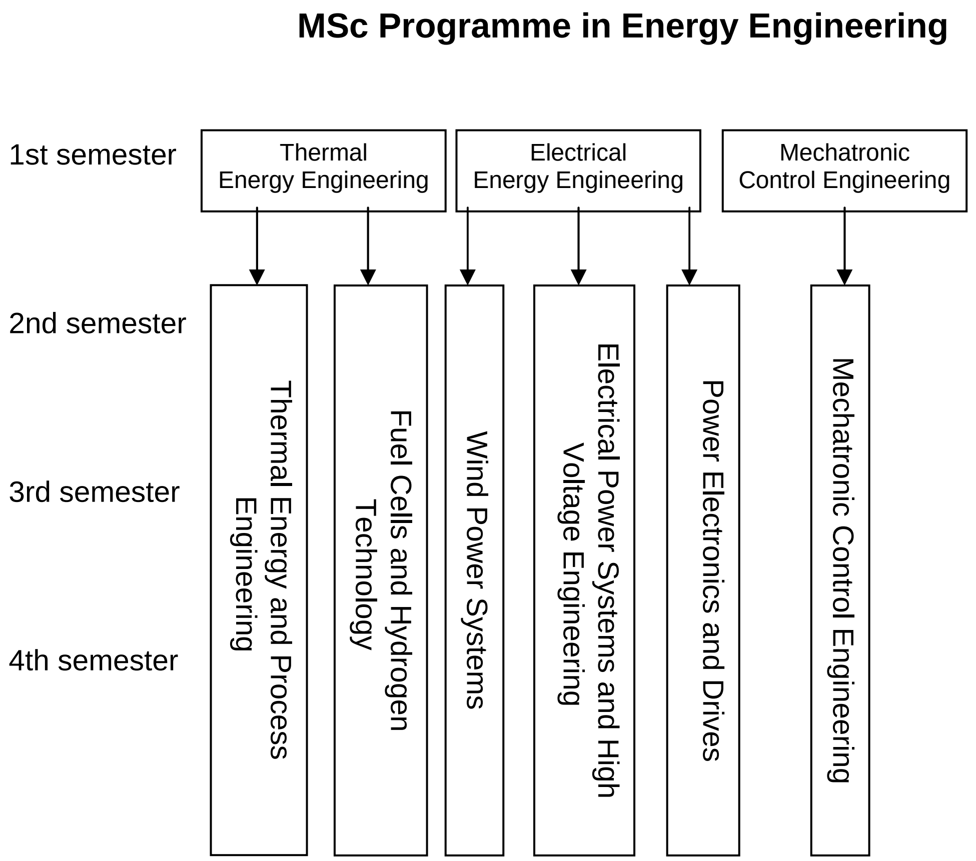
The programme is structured in modules and organised as a problem based study. A module is a programme element or a group of programme elements which aims to give students a set of professional skills within a fixed time frame specified in ECTS credits and concluding with one or more examinations within 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 organized based on the following types of instruction that combine skills and reflection:

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

1st to 4th semesters of the programme 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. All modules are assessed by the supervisor/lecturer together with an external adjudicator (external assessment) or an internal adjudicator (internal assessment) or by assessment by the supervisor or lecturer only.

MSc in Thermal Energy and Process Engineering					
Semester	Code	Module	ECTS	Assessment	Exam
1st	M1-1/ M1-4*	Fluid-Mechanical Analysis Methods Problem Based Project Organised Learning in Thermo-Mechanical Analysis Methods*	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	M2-1	Modelling and Optimisation of Energy Systems	15	7-point grading scale	External
	M2-7	Fuel Conversion and Production	5	7-point grading scale	Internal
	M2-8	Chemical Reactors and Process Systems	5	7-point grading scale	Internal
	M2-13	Optimisation Theory and Reliability	5	7-point grading scale	Internal
3rd	M3-1**	Optimisation, Analysis and Control of Thermal Energy and Processing 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	M4-1	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 Fuel Cells and Hydrogen Technology					
Semester	Code	Module	ECTS	Assessment	Exam
1st	M1-1/ M1-4*	Fluid-Mechanical Analysis Methods Problem Based Project Organised Learning in Thermo-Mechanical Analysis Methods*	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	M2-2	Modelling and Optimisation of Fuel Cell Systems	15	7-point grading scale	External
	M2-7	Fuel Conversion and Production	5	7-point grading scale	Internal
	M2-8	Chemical Reactors and Process Systems	5	7-point grading scale	Internal
	M2-13	Optimisation Theory and Reliability	5	7-point grading scale	Internal
3rd	M3-2**	Optimisation, Analysis and Control of Fuel Cell and Hydrogen Technology 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	M4-2	Master's Thesis (possibly 50 ECTS taking both 3rd and 4th semester projects))	30, 50	7-point grading scale	External
Total			120		

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MSc in Wind Power Systems					
Semester	Code	Module	ECTS	Assessment	Exam
1st	M1-2/ M1-5*	Dynamics in Electrical Energy Engineering Problem Based Project Organised Learning in Dynamics in Electrical Energy Engineering*	15 (10*)	7-point grading scale	Internal
	M1-9	Dynamic Modelling of Electrical Machines and Control Systems	5	7-point grading scale	Internal
	M1-10	High Voltage Engineering and EMI/EMC	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	M2-3	Interaction between Wind Power Generation Units and Electrical Loads or Power System	15	7-point grading scale	External
	M2-9	Advanced Course in Electrical Power Systems	5	7-point grading scale	Internal
	M2-12	**Advanced power electronics and applica-tions**	5	7-point grading scale	Internal
	M2-13	Optimisation Theory and Reliability	5	7-point grading scale	Internal
3rd	M3-3**	Advanced project in Wind Power 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	M4-3	Master's Thesis (possibly 50 ECTS taking both 3rd and 4th semester projects))	30, 50	7-point grading scale	External
Total			120		

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*** 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 Power Electronics and Drives					
Semester	Code	Module	ECTS	Assessment	Exam
1st	M1-2/ M1-5*	Dynamics in Electrical Energy Engineering Problem Based Project Organised Learning in Dynamics in Electrical Energy Engineering*	15 (10*)	7-point grading scale	Internal
	M1-9	Dynamic Modelling of Electrical Machines and Control Systems	5	7-point grading scale	Internal
	M1-10	High Voltage Engineering and EMI/EMC	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	M2-4	Control of Power Electronic Systems	15	7-point grading scale	External
	M2-10	**Control of Electrical Drive Systems and**	5	7-point grading scale	Internal

		Converters			
	M2-12	Advanced Power Electronics and Applications	5	7-point grading scale	Internal
	M2-13	Optimisation Theory and Reliability	5	7-point grading scale	Internal
3rd	M3-4**	Advanced project in Power Electronic and Drives**	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	M4-4	Master's Thesis (possibly 50 ECTS taking both 3rd and 4th semester projects))	30, 50	7-point grading scale	External
Total			120		

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*** 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 Electrical Power Systems and High Voltage Engineering					
Semester	Code	Module	ECTS	Assessment	Exam
1st	M1-2/ M1-5*	Dynamics in Electrical Energy Engineering Problem Based Project Organised Learning in Dynamics in Electrical Energy Engineering*	15 (10*)	7-point grading scale	Internal
	M1-9	Dynamic Modelling of Electrical Machines and Control Systems	5	7-point grading scale	Internal
	M1-10	High Voltage Engineering and EMI/EMC	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	M2-5	Modern Electrical Power Systems Analysis	15	7-point grading scale	External
	M2-9	Advanced Course in Electrical Power Systems	5	7-point grading scale	Internal
	M2-12	Advanced Power Electronics and Applications	5	7-point grading scale	Internal
	M2-13	Optimisation Theory and Reliability	5	7-point grading scale	Internal
3rd	M3-5**	Advanced project in Electrical Power Systems and High Voltage 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	M4-5	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 Mechatronic Control Engineering					
Semester	Code	Module	ECTS	Assessment	Exam
1st	M1-3/ M1-6*	Control of a Hydraulic Actuated Mechanical Structure Problem Based Project Organised Learning in Control of a Hydraulically Actuated Mechanical Structure *	15 (10*)	7-point grading scale	Internal
	M1-9	Dynamic Modelling of Electrical Machines and Control Systems	5	7-point grading scale	Internal

	M1-11	Non-linear Control and Multi-body Systems	5	7-point grading scale	Internal
	M1-12	Probability Theory, Stochastic Processes and Advanced Statistics	5	7-point grading scale	Internal
	M1-13*	Control Theory and MATLAB*	5*	7-point grading scale	Internal
2nd	M2-6	Advanced Control of Electrical Machines	15	7-point grading scale	External
	M2-10	Control of Electrical Drive Systems and Con-verters	5	7-point grading scale	Internal
	M2-11	Multi Variable Control	5	7-point grading scale	Internal
	M2-13	Optimisation Theory and Reliability	5	7-point grading scale	Internal
3rd	M3-6**	Mechatronic 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	M4-6	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 on the Mechatronic Control Engineering 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 on the Master of Science programme in Energy Engineering is to prepare the students to follow one of the six specialisations offered:

- Thermal Energy and Process Engineering
- Fuel Cells and Hydrogen Technology
- Wind Power Systems
- Power Electronics and Drives
- Electrical Power Systems and High Voltage Engineering
- Mechatronic Control Engineering

To qualify for the 1st semester of the Master of Science programme in Energy Engineering, 5 routes are approved for students who have followed the Bachelor's study programme in Energy at Aalborg University:

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

Prerequisites
None

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 Thermal Energy Engineering Specialisations
Common for students with a Bachelor's degree from Aalborg University heading for specialisations in Thermal Energy and Process Engineering and Fuel Cells and Hydrogen 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 document 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 Energy Engineering" (sec. 3.1.e).

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 Energy Engineering" (sec. 3.1.e).

Assessment criteria
As stated in the Joint Programme Regulations.

3.1.c Project on 1st Semester Electrical Energy Engineering specialisations
Common for students with a Bachelor's degree from Aalborg University heading for the specialisations in Electrical Power Systems and High Voltage Engineering (EPSH), Power Electronics and Drives (PED) and Wind Power Systems (WPS)

Title
M1-2 Dynamics in Electrical Energy Engineering/Dynamik i elektriske energisystemer

Objective
After completion of the project the student should:

Knowledge

- Have knowledge and comprehension within dynamics in electrical energy engineering systems or apparatus
- Have knowledge and comprehension within modelling and simulation technologies required in accomplishing dynamic analysis

Skills

- Be able to analyse the dynamic behaviour of electrical energy systems or apparatus within the area of electrical power systems, electrical drive systems or in wind power systems

- Be able to make models and simulate such dynamic systems
- Be able to use methods for documenting the project work as a scientific paper and poster
- Be able to verify the models and the simulations by measurement in the laboratory or from existing data

Competences

- Be able to control the working and development process within the project theme, and be able to develop new solutions within the area of dynamics in electrical energy engineering
- Independently be able to define and analyse scientific problems within the area of dynamics in electrical energy engineering, 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 is based on a problem where the dynamics of an electrical energy system or an electrical apparatus has to be analysed. The problem can be in the area of:

- Electrical power systems
- Electrical drive systems
- Wind power systems

where for instance short circuits, starting procedures, control issues etc. demands that the dynamics of the systems have to be taken into account.

The system or apparatus is analysed and modelled and has to be simulated in an appropriate simulation tool.

Verification of the models and the simulations are done by measurement in the laboratory or from existing data.

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

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 Energy Engineering" (sec. 3.1.e).

Assessment criteria

As stated in the Joint Programme Regulations.

3.1.d Project on 1st Semester Mechatronic Control Engineering

For students with a Bachelor´s degree from Aalborg University heading for the specialisation in Mechatronic Control Engineering

Title

M1-3 Control of a Hydraulically Actuated Mechanical Structure/Regulering af et hydraulisk aktueret mekanisk system

Objective

After completion of the project the student should:

Knowledge

- Have knowledge about mechanical structures with complex dynamics and elements with non-linear behaviour.

Skills

- Be able to apply identification methods for determining system dynamics, when system information is not available
- Be able to apply the fundamental aspects of non-linear control theory and enable him/her to utilise the available system information to apply selected non-linear control methods on the considered system
- Be able to use methods for documenting the project work as a scientific paper and poster
- Be able to verify the models and the simulations by measurement in the laboratory or from existing data

Competences

- Be able to control the working and development process within the project theme, and be able to develop new solutions within the area of control of hydraulic actuated mechanical structures
- Independently be able to define and analyse scientific problems within the area of control of hydraulic actuated mechanical structures, 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 takes its base in a hydraulically actuated mechanical system, which is to be controlled as a feedback system.

Models of both the mechanical structure and the actuation system are made and system identification methods should be used for critical parts where no component/system information is available. The models or critical parts hereof should be experimentally verified to show the validity of the models.

Based on the developed models one or more selected non-linear control methods should be used to develop a control algorithm for the system, which should be implemented and verified experimentally and the results should be compared to what may be obtained with standard linear controllers.

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

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 Energy Engineering” (sec. 3.1.e).

Assessment criteria
As stated in the Joint Programme Regulations.

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

(For students with a Bachelor’s degree from Aalborg University) (not INTRO)
Vejledning for projektet på 1. semester af Kandidatuddannelsen i Energiteknik
(For studerende med en bacheloruddannelse 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 conference. 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. **<u>The maximum length of the summary report (report without appendices) is 50 pages</u>**, 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 × 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.f Project on 1st INTRO Semester of Thermal Energy Engineering Specialisations
Common for students with a Bachelor's degree from another university than Aalborg University heading for the specialisations in Thermal Energy and Process Engineering and Fuel Cells and Hydrogen Technology

Title
M1-4 Problem Based Project Organised Learning in Thermo-Mechanical Analysis Methods/
Problembaseret projektorganiseret læring i termo-mekaniske analysemetoder

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 the basis for both the analytical and especially the numerical analysis methodology for fluid flow and heat transmission, around or within simplified

components or thermal process systems. These components or systems can be considered as integral parts of energy machinery or energy conversion systems

Skills

- Be able to verify, where relevant, the analytical and numerical approaches by means of simple laboratory experiments
- Be able to structure and plan PBL based project work and report writing
- 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 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.

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.g Project on 1st INTRO Semester of Electrical Energy Engineering Specialisations

Common for students with a Bachelor’s degree from another university than Aalborg University heading for the specialisations in Electrical Power Systems and High Voltage Engineering (EPSH), Power Electronics and Drives (PED) and Wind Power Systems (WPS)

Title

M1-5 Problem Based Project Organised Learning in Dynamics in Electrical Energy Engineering/
Problembaseret projektorganiseret læring i dynamik i elektriske energisystemer

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 analytical skills within project work in connection with problems in the areas of electrical energy engineering.
- Have knowledge and comprehension within dynamics in electrical energy engineering systems or apparatus

Skills

- Be able to analyse the dynamic behaviour of electrical energy systems or apparatus within the area of electrical power systems, electrical drive systems or in wind power systems
- Be able to make models and simulate such dynamic systems
- Be able to verify the models and the simulations by measurement in the laboratory or from existing data

Competences

- Be able to control the working and development process within the project theme, and be able to develop new solutions within the area of dynamics in electrical energy engineering
- Independently be able to define and analyse scientific problems within the area of dynamics in electrical energy engineering, 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.

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 is based on a problem where the dynamics of an electrical energy system or an electrical apparatus has to be analysed. The problem can be within the area of:

- Electrical power systems
- Electrical drive systems
- Wind power systems

where, for instance, short circuits, starting procedures, control issues etc. demand that the dynamics of the systems have to be taken into account.

The system or apparatus is analysed and modelled and has to be simulated in an appropriate simulation tool.

Verification of the models and the simulations are done by measurement in the laboratory or from existing data.

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 Project on 1st INTRO Semester of Mechatronic Control Engineering
Common for students with a Bachelor's degree from another university than Aalborg University heading for the specialisation in Mechatronic Control Engineering

Title
M1-6 Problem Based Problem Organised Learning in Control of a Hydraulically Actuated Mechanical Structure/Problembaseret projektorganiseret læring i styring og regulering af et hydraulisk aktueret mekanisk system

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 analytical skills within project work in connection with problems in the areas of mechatronic control engineering
- Have knowledge about mechanical structures with complex dynamics and elements with non-linear behaviour

Skills
- Be able to apply identification methods for determining system dynamics, when system information is not available
- Be able to apply the fundamental aspects of non-linear control theory and enable him/her to utilise the available system information to apply selected non-linear control methods on the considered system
- Be able to verify the models and the simulations by measurement in the laboratory or from existing data

Competences
- Be able to control the working and development process within the project theme, and be able to develop new solutions within the area of control of hydraulic actuated mechanical structures
- Independently be able to define and analyse scientific problems within the area of control of hydraulic actuated mechanical structures, 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.

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 takes its base in a hydraulically actuated mechanical system, which is to be controlled as a feedback system.

Models of both the mechanical structure and the actuation system are made and system identification methods should be used for critical parts where no component/system information is available. The models or critical parts hereof should be experimentally verified to show the validity of the models.

Based on the developed models one or more selected non-linear control methods should be used to develop a control algorithm for the system, which should be implemented and verified experimentally and the results should be compared to what may be obtained with standard linear controllers.

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.i 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 Faculty of Engineering and Science, Aalborg University.

Assessment criteria
As stated in the Joint Programme Regulations.

3.1.j 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 Faculty of Engineering and Science, Aalborg University.

Assessment criteria
As stated in the Joint Programme Regulations.

3.1.k Course Module on 1st Semester: Dynamic Modelling of Electrical Machines and Control Systems

Title
M1-9 Dynamic Modelling of Electrical Machines and Control 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, the synchronous machine and the induction machine
- Have knowledge about the limitations for a dynamic model of an electrical machine
- Comprehend techniques for scalar variable-speed control of induction machines
- Have knowledge about implementation of controllers for variable-speed AC-drives
- Have knowledge about basic Finite Element Method for parameter estimation of dynamic systems

Skills and Competences
- Independently be able to define and analyse scientific problems involving a dynamic model of an electrical machine
- Be able to construct dynamic models for different electrical machines and implement them in simulation software
- Be able to analyse and design scalar controllers for electrical drives
- Be able to apply the Finite Element Method for determination of parameters used in dynamic models

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 Faculty of Engineering and Science, Aalborg University.

Assessment criteria
As stated in the Joint Programme Regulations.

3.1.l Course Module on 1st Semester: High Voltage Engineering and EMI/EMC

Title
M1-10 High Voltage Engineering and EMI/EMC/Højspændingsteori og EMI/EMC

Objective
Students who complete the module should:

Knowledge
- Have knowledge and comprehension within the following areas:

- Fundamentals of high voltage engineering
- Generation and measurement of High AC, DC and impulse voltages
- Non-destructive test methods in high voltage engineering
- Fundamental electrostatic field stress and dielectric breakdown
- Gaseous discharges
- Fundamentals of EMI/EMC
- EMI/EMC problems in power electronic converters
- Proper layout, layout guide
- EMI/EMC models and solutions
- EMI/EMC filters
- EMI/EMC standards

Skills

- Be able to apply theories and laboratory experiments to describe generation and measurement of high AC, DC and impulse voltages for testing high voltage equipment
- Be able to apply theories and laboratory experiments to describe non-destructive test methods for evaluating the quality and lifetime of dielectrics
- Be able to apply theories and laboratory experiments to describe electric field stresses and gaseous discharges
- Be able to identify sources of EMI/EMC problems
- Be able to estimate and/or measure the EMI of a converter
- Be able to design filters

Competences

- Independently be able to define and analyse scientific problems within the area of power system high voltage engineering and EMI/EMC
- Independently be able communicate results from power system high voltage engineering and EMI/EMC
- Independently be able to be a part of professional and interdisciplinary development work within the field of power system high voltage engineering and EMI/EMC

Type of instruction

Lectures and laboratory experiments.

Examination format

Written examination with questions in both high voltage and EMI/EMC 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.

3.1.m 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

*Competence*s
- 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 Faculty of Engineering and Science, Aalborg University

Assessment criteria
As stated in the Joint Programme Regulations.

3.1.n 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 Faculty of Engineering and Science, Aalborg University.

Assessment criteria
As stated in the Joint Programme Regulations.

3.1.o 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)/Reguleringsteori 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

*Competence*s
- 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 Faculty of Engineering and Science, Aalborg University.

Assessment criteria
As given in the Joint Programme Regulations.

3.2 Module Descriptions of 2nd Semester

3.2.a Project on 2nd Semester Thermal Energy and Process Engineering

Title
M2-1 Modelling and Optimisation of Energy Systems/Modellering og optimering af energisystemer

Prerequisites
The module is based on knowledge achieved when studying the 1st semester on the Master of Science in Energy Engineering on one of the Thermal Energy Engineering specialisations 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 have:

Knowledge
- Knowledge and comprehension and skills within synthesis of thermodynamic systems, their components and the interactions between these
- Knowledge about the design, modelling and optimisation of systems involving thermal equipment such as engines, gas-turbines, steam turbines in stand-alone or combined cycle configurations
- Knowledge about the conversion of plant-based biomass feedstocks and biological waste products to liquid fuels and the economic and strategic impact of the technologies involved
- Knowledge and comprehension within the thermodynamic aspects of processes involved in thermal and fuel conversion plants which involve phase change and both sub- and supercritical operation
- Knowledge and comprehension within the multiphase and chemical reaction based aspects involved in combustion processes and chemical process reactors

Skills
- Be able to judge the usefulness of the used different scientific methods for analysis and modelling of the energy systems
- Be able to verify the analytical and numerical approaches by means of experimental data
- Be able to select an appropriate optimisation procedure used for the energy systems and evaluate the optimisation results

Competences

- Be able to control the working and development process within the project theme, and be able to develop new solutions within energy systems
- Be able to independently define and analyse scientific problems in the area of modelling and optimisation of energy systems

Type of instruction

Problem based project oriented project work in groups.

The project should be based upon a thermal power plant or upon a fuel conversion process plant. The thermal plant could be a combined heat and power plant, a de-centralised power plant or a cooling plant. The plants should be simulated to achieve an optimum plant design in terms of overall plant economy. In the design of the plant analytical tools are to be applied, such as numerical optimisation, non-linear dynamical modelling or process integration.

In addition the plant designed should be evaluated in relation to operational variations and/or the problems arising from start-up.

Examination format

Oral examination with external adjudicator 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.

3.2.b Project on 2nd Semester Fuel Cells and Hydrogen Technology

Title

M2-2 Modelling and Optimisation of Fuel Cell Systems/Modellering og optimering af brændselscellesystemer

Prerequisites

The module is based on knowledge achieved when studying the 1st semester on the Master of Science in Energy Engineering on one of the Thermal Energy Engineering specialisations 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 about the design, modelling and optimisation of energy systems used in various energy production applications involving fuel cell technology
- Have knowledge about and comprehension of the detailed operation, functionality and interaction between the various components used in fuel cell- and hydrogen production systems
- Have knowledge needed to construct and operate fuel cell based technologies in the laboratory and in real applications

Skills

- Be able to have analytical skills in system integration with respect to system efficiency and control aspects of fuel cell energy systems
- Be able to judge the usefulness of the used different scientific methods for analysis and modelling of fuel cell and hydrogen systems
- Be able to verify the analytical and numerical approaches by means of laboratory experiments
- Be able to evaluate the optimisation procedures used for fuel cell and hydrogen systems

Competences

- Be able to control the working and development process within the project theme, and be able to develop new solutions within fuel cell and hydrogen systems
- Be able to independently define and analyse scientific problems in the area of fuel cells and hydrogen systems

Type of instruction
Problem based project oriented project work in groups.

The semester focuses on modelling and optimisation of a physical fuel cell or hydrogen based system. The semester project serves to give the students an advanced comprehension of systems based upon fuel cells and hydrogen technology. The fundamental competence within thermodynamics and control engineering within these systems are established.

The students must develop a non-linear dynamical model of a system – for instance using block diagrams as in Simulink. Simultaneously, a data acquisition and control system is developed in for instance the Labview real time system through which basic analogical data acquisition and control is interconnected.

Examination format
Oral examination with external adjudicator 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.

3.2.c Project on 2nd Semester Wind Power Systems

Title
M2-3 Interaction between Wind Power Generation Units and Electrical Loads or Power System/
Interaktion mellem vindmøllegeneration og laster eller el-nettet

Prerequisites
The module is based on knowledge achieved when studying the 1st semester on the Master of Science in Energy Engineering on one of the Electrical Energy Engineering specialisations 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 set up demands/specifications for the interaction between wind power generator units and electrical loads or power system

Skills

- Be able to analyse the steady-state control and operation of wind power generation units connected to a system with time varying loads
- Be able to analyse the load flow in a system with wind generation
- Be able to analyse power system stability in a grid with high wind power penetration
- Be able to analyse the power quality aspects and identify the need and requirements for compensation units
- Be able to identify and develop appropriate models for wind power generation units including subsystems suitable for specific power systems studies
- Be able to assess wind power systems by means of simulation tools and/or laboratory experiments

Competences

- Be able to control the working and development process within the project theme
- Be able to identify specific technical requirements at system and subsystem level within the project theme
- Be able to independently identify and analyse technical and scientific problems related to the integration of wind power generation units in the electrical grid
- Be able to propose and select feasible solutions for solving specific challenges related to the grid integration of wind power
- Be able to independently continue own development in competence and specialisation

Type of instruction
Problem based project oriented project work in groups.

The background of the project is a wind turbine system either a stand-alone or grid connected which has to be controlled under time varying loads and wind speed. Possible power quality and stability challenges are identified and formulated. The main components of the system are described and its requirements and specifications are given.

The system is modelled and implemented using a simulation tool. The system is analysed with respect to power quality and stability. Methods, algorithms, devices for improving the power quality and stability of the entire system are proposed, developed and tested.

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.d Project on 2nd semester Power Electronics and Drives

Title
M2-4 Control of Power Electronic Systems/Styring af effektelektroniske systemer

Prerequisites
The module is based on knowledge achieved when studying the 1st semester on the Master of Science in Energy Engineering on one of the Electrical Energy Engineering specialisations 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 have:

Knowledge

- Knowledge about modelling, analysing and simulating a system that must include a power electronic converter, a power source and an application typically an AC electric machine or an AC grid
- Comprehension of the practical implementation and test of the designed digital controller for the selected system

Skills

- Be able to apply a systematical design procedure for selection of a digital controller for the analysed system in order to meet certain performance requirements
- Be able to verify the analysis and models by means of laboratory experiments or by using real measured data series

Competences

- Be able to control the working and development process within the project theme, and be able to develop new solutions within control in power electronic systems
- Independently be able to define and analyse scientific problems in the area of control of power electronic systems, and based on that make and state the reasons for decisions made for instance with respect to their influences on the total system
- Independently be able to continue own development in competence and specialisation

Type of instruction
Problem based project oriented project work in groups.

The project must include a power electronic converter, a power source and an application, typically an AC electric machine or an AC grid.

The operating principles for the system must be described and a control problem is formulated including key specifications.

A dynamic simulation model is made taking the relevant dynamics into account. Different digital control methods are designed, analysed and evaluated by means of the simulation model. At least one method is selected for practical implementation in a real system incorporating a power electronic converter, a power source and a load, and a real-time digital control system based on a digital signal processor or a micro controller. The whole system is tested and the developed control strategies are evaluated.

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.e Project on 2nd semester Electrical Power Systems and High Voltage Engineering

Title
M2-5 Modern Electrical Power Systems Analysis/Analyse af moderne elektriske fordelingsanlæg

Prerequisites
The module is based on knowledge achieved when studying the 1st semester on the Master of Science in Energy Engineering on one of the Electrical Energy Engineering specialisations 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 have:

Knowledge
- Knowledge about implementation and test of methodologies and techniques in modern power system analysis

Skills
- Be able to apply methods for synthesizing the design and simulation of control and active grid management of modern electrical power systems
- Be able to apply load flow and harmonic flow calculations in distribution and transmission systems
- Be able to conduct short circuit studies and analyse relay protection systems for modern power systems
- Be able to perform electromagnetic transient analysis of different phenomena in modern power systems
- Be able to understand and analyse the grid impact of distributed energy resources and other techno-economic system challenges in the design, control and management of modern electrical power systems
- Be able to apply the basics of load estimation, power system economics, demand side management techniques for operation and control of modern power systems
- Be able to verify the analysis and models by means of laboratory experiments or by using real measured data series

Competences
- Be able to control the working and development process within the project theme, and be able to develop new solutions within modern electrical power system analysis with adequate focus on economic and environmental-friendly technologies
- Independently be able to define and analyse scientific problems in the area of control and active network management of modern power systems, and based on that make and state the reasons for decisions made for instance with respect to their influences on the total system
- Independently be able to continue own development in competence and specialisation

Type of instruction
Problem based project oriented project work in groups.

The background of the project is an electrical power system which has to be controlled and/or supervised (digital simulators and instrumentation systems). The system is to be described and a specification is to be made. The system should be modelled and implemented in a simulation program. Different control and/or active network management methods are to be simulated, analysed and evaluated with the purpose of selecting a solution.

A complete system (or parts) should be designed and implemented as a real-time system in the laboratory or real time data should be achieved from an existing system. The implemented system and the designed control and/or active network management strategies should be tested, verified and evaluated based on the set-up in the laboratory or by real life data.

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.f Project on 2nd semester Mechatronic Control Engineering

Title
M2-6 Advanced Control of Electrical Machines/Avanceret styring af elektriske maskiner

Prerequisites
The module is based on knowledge achieved when studying the 1st semester on the Master of Science in Energy Engineering on the Mechatronic Control Engineering specialisation 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 have:

Knowledge

- Have knowledge about and understanding of the operating principles of an energy transmission system comprising a power electronic converter feeding an electric actuator
- Be able to analyse such a system and be able to set up dynamic system models
- Have comprehensive knowledge about practical application of feedback control theory for such a system

Skills

- Be able to apply appropriate methods and tools for analysis of power electronic converters
- Be able to design modulators for power electronic converters and be able to design control systems for an electrical actuator fed from a power electronic converter
- Be able to verify the analysis, models and the design by means of laboratory experiments

Competences

- Be able to control the working and development process within the project theme, and be able to analyse and develop a control system for an electric actuator fed by a power electronics converter
- Independently be able to define and analyse scientific problems in the said area
- Independently be able to continue own development in competence and specialisation

Type of instruction
Problem based project oriented project work in groups.

The project takes its base in an electric actuator that is used to drive a mechanical load. The actuator may be a poly-phase AC machine or another kind of electro-mechanical device. The actuator must be fed from a hard or soft-switched power electronic converter and closed-loop control principles must be adopted.

The whole power transmission system must be analysed. Selected parts of the system may be developed and realized in the project. This may also include development of a power electronic converter, a digital control system or interfacing circuitry.

Requirements to control strategies for the converter and the actuator must be formulated. Suitable modulation methods and controllers must be analysed, designed, simulated and evaluated.

Laboratory implementation and tests of the whole system or selected parts of it must be conducted and evaluated.

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.g Course Module on 2nd Semester: Fuel Conversion and Production

Title
M2-7 Fuel Conversion and Production/Brændstofkonvertering og –produktion

Prerequisites
The module is based on knowledge achieved in thermal and fluid dynamic systems or similar.

Objective
Students who complete the course module should:

Knowledge
- Have knowledge about combustion technology
- Have an understanding of the kinetics involved in combustion processes
- Understand the topology of important catalytic conversion technologies
- Understand technologies involved in the production and processing of biomass and biofuels
- Have knowledge about chemical storage technologies

Skills
- Be able to perform calculations related to chemical combustion including kinetics
- Be able to design typical chemical conversion systems
- Be able to design systems involved in the production of biomass and biofuels
- Be able to design and evaluate chemical storage technologies

Competences
- 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 process and storage systems.

Type of instruction
Lectures supplied with independent studies and possibly guest lectures.

Examination format
Oral examination. The exam can be based on mini projects and assignments solved during the course.

Assessment criteria
As stated in the Joint Programme Regulations.

3.2.h Course Module on 2nd Semester: Chemical Reactors and Process Systems

Title
M2-8 Chemical Reactors and Process Systems/Kemiske reaktorer og processystemer

Prerequisites
The module is based on knowledge achieved in thermal and fluid dynamic systems or similar.

Objective
Students who complete the course module should:

Knowledge

- Be able to understand components and system configurations used in electrochemical and chemical conversion processes
- Understand the terminologies and notations used in fundamental electrochemical and chemical reactor analysis
- Have knowledge about applications of mass transfer used in relation to electrochemical and chemical reactors as well as processing systems
- Have knowledge about dynamic modelling of process systems

Skills

- Be able to design and model the fundamental classes of chemical reactors with one or multiple simultaneous reactions including heat transfer in steady and unsteady operation
- Be able to calculate chemical compositions arising from kinetically controlled electrochemical and chemical reactions
- Be able to calculate mass convection and diffusion and perform analysis on processes involving combined heat and mass transfer as well as mass transfer in porous materials and multicomponent mixtures
- Be able to develop fundamental dynamic models of the used components and overall process systems

Competences

- 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 chemical reactors and combined heat and mass transfer

Type of instruction
Lectures supplied with independent studies and possibly guest lectures.

Examination format
Oral examination. The exam can be based on mini projects and assignments solved during the course.

Assessment criteria
As stated in the Joint Programme Regulations.

3.2.i Course Module on 2nd Semester: Advanced Course in Electrical Power Systems

Title
M2-9 Advanced Course in Electrical Power Systems/Avanceret kursus i elektriske anlæg

Prerequisites

The module is based on knowledge achieved in power systems and power electronics or similar.

Objective
Students who complete the module will have knowledge about and ability to analyse more advanced topics within the area of power systems taking a starting point from today's state-of-the-art.

Students who complete the module should:

Knowledge
- Have knowledge about and comprehension of overvoltage protection and insulation coordination in power systems
- Have knowledge about and comprehension of power system protection
- Have comprehension of the mathematical tools and theories for harmonic distorted signals
- Have knowledge about the international standards for harmonics
- Have comprehension of large power system behaviour with respect to real and reactive power control
- Have comprehension of physical and mathematical modelling of large power systems for power system stability analysis
- Have comprehension of the types and methods for power system stability analysis and means of improving system stability
- Have knowledge about the need for reactive compensation at the distribution and transmission level
- Have knowledge about different reactive compensation methods
- Have knowledge about power system transients including switching transients and the parameter determination for the components involved in the three phase power system
- Have comprehension for the design and testing of external insulation

Skills
- Must be able to apply theories and laboratory experiments to analyse the above mentioned areas of modern power systems. The level of knowledge will meet today's state-of-the-art
- Must be able to analyse overvoltage protection systems and perform insulation coordination. This includes insulation strength and its characteristics, phase-ground switching overvoltages, the lightning flash and shielding of transmission lines
- Must be able to apply theories, models and simulation tools to analyse power system control and stability concepts
- Must be able to design power system protection using distance and differential protection
- Be able to analyse sources and effects of harmonic distortion
- Be able to analyse power system harmonic phenomena
- Be able to evaluate results by using measurements and instruments used for harmonic analysis
- Be able to apply numerical simulation tools for analysing power system transients

Competences
- Independently be able to define and analyse scientific problems within the area of advanced power system technology
- Independently be able to communicate results from advanced power system technology
- Independently be able to be a part of professional and interdisciplinary development work in advanced power system technology

Type of instruction
Lectures, exercises and laboratory experiments.

Examination format
Written examination 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.

3.2.j Course Module on 2nd Semester: Control of Electrical Drive Systems and Converters

Title
M2-10 Control of Electrical Drive Systems and Converters/Regulering af elektriske drivsystemer og konvertere

Prerequisites
The module is based on knowledge achieved in Dynamic Modelling of Electrical Machines and Control Systems; Electrical Apparatus and Power Electronics; 1st semester project: Dynamics in Electrical Energy Engineering, or similar.

Objective
Students who complete the module should:

Knowledge
- Have knowledge about basic topologies for electrical drive systems
- Have knowledge about soft switching PWM-based circuits and resonant-based circuits in power electronic converters
- Have knowledge about how to control the basic topologies of converters for electrical drive systems
- Have comprehension of different control methods for electrical machines
- Have comprehension of advanced techniques for control of AC machines in high performance applications
- Have comprehension of different sensorless control methods

Skills
- Be capable of working with grid connected and autonomous electrical drive systems
- Be able to apply a suitable circuit topology for a given application
- Be capable of implementing different control methods for AC machines such as field oriented control and sensorless control

Competences
- Independently be able to define and analyse scientific problems within the area of control of electrical drive systems and converters
- Independently be able to communicate results from the area of control of electrical drive systems and converters
- Independently be able to be a part of professional and interdisciplinary development work in the area of control of electrical drive systems and converters

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 Faculty of Engineering and Science, Aalborg University.

Assessment criteria
As stated in the Joint Programme Regulations.

3.2.k Course module on 2nd semester: Multi Variable Control

Title
M2-11 Multi Variable Control/Multivariabel regulering

Prerequisites
The module is based on knowledge achieved in classical control theory and state space control.

Objective
Students who complete the module should:

Knowledge

- Have gained an in-depth understanding of basic aspects of multivariable control design, the approaches, the key quantities to consider and the fundamental limitations inherent in the design
- Be able to, on a scientific basis, to understand and apply advanced model based control design tools
- Be able to document understanding of multivariable systems (multiple inputs and multiple outputs MIMO)

Skills

- Be able to understand the fundamental performance limitations of single input and single output (SISO) systems
- Be able to represent linear systems in different ways: Transfer functions matrices, input-output equations, state space form, etc.
- Be able to understand what disturbances are, and to describe their character in a suitable way
- Be able to set up design specifications for MIMO systems
- Be able to understand basic limitations in control design
- Be able to set up the configuration of multivariable controllers
- Be able to design linear multivariable controllers

Competences

- Be able to undertake analysis, design and implementation of advanced multivariable control systems where experience and intuition play a very important role

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 or oral examination 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.

3.2.l Course Module on 2nd Semester: Advanced Power Electronics and Applications

Title
M2-12 Advanced Power Electronics and Applications/Avanceret effektelektronik og anvendelser

Prerequisites
The module is based on knowledge achieved in three phase inverters, control, machines and power systems or similar.

Objective
Students who complete the module should:

Knowledge

- Have knowledge and comprehension within the following areas
    - Magnetics scalability toward high power
        - High power three phase transformers
        - High power inductors
        - Material properties
    - High power devices
        - IGCT, GTO, Thyristor (Press-pack)
        - IGB T (package)
        - Emerging devices
        - Package properties
    - High-power converters
        - Graetz bridge, Two level and three level (NPC)
        - Overview of other multilevel converter topology and basic control and applications.
        - Modular multilevel converters
        - High Voltage DC transmission and STATCOM
    - High Power DC-DC converters
        - Soft switching, resonant
        - Converter topologies
            - Practical aspects of design

Skills

- Be able to compute the overall size and then system level ratings of the high power converters for different applications in power and renewable energy systems
- Be able to analyse the main components and requirements of high power converters
- Be able to evaluate the converter characteristics and design its high level controller
- Be able to analyse and evaluate the high power converter systems and evaluate their pros and cons for the given application
- Be able to evaluate the limitations and hence create the necessary design modifications (at system level) in high power converters

Competences

- Independently be able to define and analyse high power converter topologies and their specifications for the specific application in power and renewable energy systems
- Independently simulate the high power converter systems and communicate the results for system engineering
- Independently participate in the professional and interdisciplinary development work related with the application of high power converters in power and renewable energy systems

Type of instruction
Lecture followed by numerical and simulation exercises.

Examination format
Oral examination 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.

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

Title
M2-13 Optimisation Theory and Reliability/Optimeringsteori og pålidelighedsteori

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 Energy 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 fit 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 Faculty of Engineering and Science, Aalborg University.

Assessment criteria
As stated in the Joint Programme Regulations**.**

3.3 Module Descriptions of 3rd Semester

3.3.a Project on 3rd Semester Thermal Energy and Process Engineering

Title
M3-1 Optimisation, Analysis and Control of Thermal Energy and Processing Systems/Optimering, analyse og regulering af termiske energi- og processystemer

Prerequisites
The module is based on knowledge achieved when studying the 2nd semester on the Master of Science in Energy Engineering specialisation in Thermal Energy and Process Engineering 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, optimise, control and analyse thermal energy and process engineering systems
- Have knowledge and comprehension within first principle analysis methods

Skills

- Be able to judge the usefulness of the used different scientific methods for the design, optimisation and control of thermal energy and process engineering systems
- Be able to establish and verify scientific hypotheses
- Be able to apply first principle analysis methods to complex thermo- or fluid-dynamical as well as chemical processing systems

Competences

- Be able to control the working and development process within the project theme, and be able to develop new solutions within optimisation, control, and analysis of thermal energy and process engineering systems
- Be able to show entrepreneurship to define and analyse scientific problems in the area of optimisation, control, and diagnostic analysis of thermal energy and process engineering systems, and based on that make and state the reasons for decisions made
- Be able to materialise innovative ideas within the area of optimisation, control, and analysis of thermal energy and process engineering systems
- Be able to independently continue own development in competence and specialisation

- Be able to follow more sophisticated literature, or state-of-the-art, within CFD, turbulent flow, thermal system optimisation and multiphase 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) 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 × number of students in the project group.

The scientific paper will be presented at a conference arranged within the Department of Energy Technology prior to the project examination.

The project work should be based upon a thermal energy and process engineering system to which an optimisation, control or diagnostic system is to be set up.

First, the system is to be modelled and different system identification methods can be applied to determine the parameters of the system. The system model is verified by simulations and data time series from either a real system or a laboratory set-up.

Based on the model, the optimisation, control or diagnostic system is set up to improve the performance of the system, either with regard to power output, energy efficiency, life time extraction, fault detections etc. and the system should be implemented and verified experimentally.

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.b Project on 3rd Semester Fuel Cells and Hydrogen Technology

Title
M3-2 Optimisation, Analysis and Control of Fuel Cell and Hydrogen Technology Systems/Optimering, analyse og regulering af brændselscelle- og brintsystemer

Prerequisites
The module is based on knowledge achieved when studying the 2nd semester on the Master of Science in Energy Engineering with specialisation in Fuel Cells and Hydrogen 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 how to design, optimise, control and analyse fuel cells and hydrogen systems
- Have knowledge and comprehension within first principle analysis methods

Skills
- Be able to judge the usefulness of the used different scientific methods for the design, optimisation and control systems for fuel cell and hydrogen systems
- Be able to verify the different scientific analysis and methods by means of laboratory experiments.
- Be able to apply first principle analysis methods to complex thermo- or fluid-dynamical as well as chemical processing systems

Competences
- Be able to control the working and development process within the project theme, and be able to develop new solutions within optimisation, control, and analysis of fuel cell and hydrogen systems
- Be able to show entrepreneurship to define and analyse scientific problems in the area of optimisation, control, and diagnostic analysis of fuel cell and hydrogen systems, and based on that make and state the reasons for decisions made
- Be able to materialise innovative ideas within the area of optimisation, control, and analysis of fuel cell and hydrogen systems
- Be able to independently continue own development in competence and specialisation
- Be able to follow more sophisticated literature, or state-of-the-art, within fuel cell and hydrogen 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) 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 × number of students in the project group.

The scientific paper will be presented at a conference arranged within the Department of Energy Technology prior to the project examination.

The project should be based upon a fuel cell and hydrogen technology system to which an optimisation, control or diagnostic system is to be set up.

First, the system is to be modelled and different system identification methods can be applied to determine the parameters of the system. The system model is verified by simulations and data time series from either a real system or a laboratory set up.

Based on the model, the optimisation, control- or diagnostic system is set up to improve the performance of the system, either with regard to power output, energy efficiency, life time extraction, fault detections etc. and the system should be implemented and verified experimentally.

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 Project on 3rd Semester Wind Power Systems

Title
M3- 3 Advanced Project in Wind Power Systems/Avanceret project i vindmølleteknologi

Prerequisites
The module is based on knowledge achieved when studying the 2nd semester on the Master of Science in Energy Engineering with specialisation in Wind Power 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 of how to design optimisation, control and/or diagnostic systems for wind turbines or wind power plants
- Have knowledge and comprehension within different advanced control methods
- Have knowledge and comprehension within different system identification and/or diagnostic methods

Skills

- Be able to judge the usefulness of the used different scientific methods for the design of optimisation, control, and/or diagnostic systems for wind turbines or wind farms
- Be able to verify the different scientific analysis and methods by means of laboratory experiments

Competences

- Be able to control the working and development process within the project theme, and be able to develop feasible solutions within optimisation, control, and/or diagnostic of wind power systems
- Be able to show entrepreneurship to define and analyse scientific problems in the area of optimisation, control, and/or diagnostic of wind power systems, and based on that make and state the reasons for decisions made
- Be able to set up innovative ideas within the area of optimisation, control, and/or diagnostic of wind power 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 wind power systems or wind power plants

Type of instruction
Problem based project oriented project work in groups.

The project work must be documented by a scientific paper (max. 8 pages) 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 × number of students in the project group.

The scientific paper will be presented at a conference arranged within the Department of Energy Technology, prior to the project examination.

The project should be based upon a wind turbine system or a wind power plant to which an optimisation, control and/or diagnostic system is to be set up.

First, the system is to be modelled and different system identification methods can be applied to determine the parameters of the system. The system model is verified by simulations and data time series from either a real system or a laboratory set-up.

Based on the model, the optimisation, control and/or diagnostic system is set up to improve the performance of the system, either with regard to power output, energy efficiency, life time extraction, fault detections etc. and the system should be implemented and verified.

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.d Project on 3rd Semester Power Electronics and Drives

Title
M3-4 Advanced Project in Power Electronics and Drives/Avanceret project i effektelektronik og elektriske drivsystemer

Prerequisites
The module is based on knowledge achieved when studying the 2nd semester on the Master of Science in Energy Engineering with specialisation in Power Electronics and Drives 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 optimisation, control and/or diagnostic systems for power electronics drives or converters
- Have knowledge and comprehension within different advanced control methods and/or have knowledge and comprehension within different system identification and diagnostic methods

Skills
- Be able to judge the usefulness of the used different scientific methods for the design of optimisation, control and/or diagnostic systems for power electronic drives or converters
- Be able to verify the different scientific analysis and methods 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 optimisation, control and/or diagnostic of power electronic drives or converters
- Be able to show entrepreneurship to define and analyse scientific problems in the area of optimisation, control and/or diagnostic of power electronics drives or converters, and based on that make and state the reasons for decisions made
- Be able to set up innovative ideas within the area of optimisation, control and/or diagnostic of power electronic drives or converters
- Independently be able to continue own development in competence and specialisation
- Be able to follow more sophisticated literature, or state-of-the-art, within power electronics drives and converters

Type of instruction
Problem based problem oriented project work in groups.

The project work must be documented by a scientific paper (max. 8 pages) accompanied by a project summary report. The project summary report should elaborate the project details and conclusions. **<u>The maximum length of the summary report (report without appendices) is 50 pages</u>**, 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 × number of students in the project group.

The scientific paper will be presented at a conference arranged within the Department of Energy Technology, prior to the project examination.

The project should be based upon a power electronic drive or converter to which an optimisation, control and/or diagnostic system is to be set up.

First the system is to be modelled and different system identification methods can be applied to determine the parameters of the system. The system model is verified by simulations and data time series from either a real system or a laboratory set-up.

Based on the model, the optimisation, control and/or diagnostic system is set up to improve the performance of the system, either with regard to power output, energy efficiency, life time extraction, fault detections etc. and the system should be implemented and verified experimentally.

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.e Project on 3rd Semester Electrical Power Systems and High Voltage Engineering

Title
M3-5 Advanced Project in Electrical Power Systems and High Voltage Systems/Avanceret projekt i elektriske anlæg og højspændingssystemer

Prerequisites
The module is based on knowledge achieved when studying the 2nd semester on the Master of Science in Energy Engineering with specialisation in Electrical Power Systems and High Voltage Engineering 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 about and comprehension of how to design, optimise, operate and/or diagnose electrical power systems or high voltage systems
- Have knowledge and comprehension within different advanced optimisation methods and apply the mathematical concepts to electrical power systems or high voltage systems and/or have knowledge and comprehension within different system identification and diagnostic methods and their application
- Have knowledge and comprehension of how electric power systems are operated in different scenarios (steady-state, alert and/or emergency operation, during transients)

Skills

- Be able to judge the usefulness of the used different scientific methods for the design, optimisation, optimisation control and/or diagnostic of electric power systems or high voltage systems
- Be able to verify the different scientific analysis and methods by means of laboratory experiments and/or advance computer simulations

Competences

- Be able to control the working and development process within the project theme, and be able to develop new solutions within design, optimisation, operation and/or diagnostic of electrical power systems or high voltage systems
- Be able to show entrepreneurship to define and analyse scientific problems in the area of design, optimisation, operation and/or diagnostic of electrical power systems or high voltage systems, and based on that make and state the reasons for decisions made
- Be able to set up innovative ideas within the area of design, optimisation, operation and/or diagnostic of electrical power systems or high voltage 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 electrical power systems and high voltage 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) 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 × number of students in the project group.

The scientific paper will be presented at a conference arranged within the Department of Energy Technology, prior to the project examination.

The project should be based upon an electrical power system or a high voltage system to which an optimisation, control and/or diagnostic system is to be set up.

First, the system is to be modelled and different system identification methods can be applied to determine the parameters of the system. The system model is verified by simulations and data time series from either a real system or a laboratory set-up.

Based on the model, the optimisation, control and/or diagnostic system is set up to improve the performance of the system, either with regard to power output, energy efficiency, life time extraction, fault detections etc. and the system should be implemented and verified experimentally.

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.f Project on 3rd Semester Mechatronic Control Engineering

Title

M3-6 Mechatronic Systems/Mekatroniske systemer

Prerequisites
The module is based on knowledge achieved when studying the 2nd semester on the Master of Science in Energy Engineering with specialisation in Mechatronic Control Engineering 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 about and comprehension of how to optimize mechatronic systems
- Have knowledge about and comprehension of how to design control and/or diagnostic systems for mechatronic systems
- Have knowledge and comprehension within different system identification and/or diagnostic methods

Skills
- Be able to judge the usefulness of the used different scientific methods for the design of control and/or diagnostic systems for mechatronic systems
- Be able to judge the usefulness of different optimisation algorithms for doing optimisation of a mechatronic system
- Be able to verify the different scientific analysis and evaluate the methods used 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 using optimisation to design mechatronic systems and incorporate control and diagnostics systems
- Be able to show entrepreneurship to define and analyse scientific problems in the area of optimisation, control and/or diagnostic of mechatronic systems, and based on that make and state the reasons for decisions made
- Be able to set up innovative ideas within the area of optimisation, control, and/or diagnostic of mechatronic 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 advanced mechatronic control 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) 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 × number of students in the project group.

The scientific paper will be presented at a conference arranged within the Department of Energy Technology, prior to the project examination.

The project should be based upon a mechatronic system to which an optimisation, control and/or diagnostic system is to be set up.

First the system is to be modelled and different system identification methods can be applied to determine the parameters of the system. The system model is verified by simulations and data time series from either a real system or a laboratory set-up.

Based on the model, the optimisation, control and/or diagnostic system is set up to improve the performance of the system, either with regard to power output, energy efficiency, life time extraction, fault detections etc. and the system should be implemented and verified experimentally.

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.g 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.h Course Module on 3rd Semester: Advanced Analysis of Thermal Machines

Title

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

Prerequisites

The module is based on knowledge achieved when studying the 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 Faculty of Engineering and Science, Aalborg University.

Assessment criteria

As stated in the Joint Programme Regulations.

3.3.i 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 of regulering af effektelektroniske konvertere

Prerequisites

The module is based on knowledge achieved when studying the 2nd semester on the Master of Science in Energy Engineering with an electrical specialisation or 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 Faculty of Engineering and Science, Aalborg University.

Assessment criteria

As stated in the Joint Programme Regulations.

3.3.j 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 is based on knowledge achieved when studying the 2nd semester on the Master of Science in Energy Engineering with a thermal specialisation or 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 Faculty of Engineering and Science, Aalborg University.

Assessment criteria
As stated in the Joint Programme Regulations.

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

Title
M3-11 Battery Energy Storage Systems/Energilagringssystemer til batteri

Prerequisites
The module is based on knowledge achieved when studying the 2nd semester on the Master of Science in Energy Engineering with an electrical or thermal specialisation or 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 Faculty of Engineering and Science, Aalborg University.

Assessment criteria
As stated in the Joint Programme Regulations.

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

Title
M3-12 Biomass Conversion and Biofuels/Avancerede biobrændstoffer

Prerequisites
The module is based on knowledge achieved when studying the 2nd semester on the Master of Science in Energy Engineering with a thermal specialisation or 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 Faculty of Engineering and Science, Aalborg University.

Assessment criteria
As stated in the Joint Programme Regulations.

3.3.m 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: NOx 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 Faculty of Engineering and Science, Aalborg University.

Assessment criteria
As stated in the Joint Programme Regulations.

3.3.n 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 is based on knowledge achieved when studying the 2nd semester on the Master of Science in Energy Engineering with an electrical specialisation or 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 will 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 Faculty of Engineering and Science, Aalborg University.

Assessment criteria
As stated in the Joint Programme Regulations.

3.3.o 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 is based on knowledge achieved when studying 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 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 Faculty of Engineering and Science, Aalborg University.

Assessment criteria
As stated in the Joint Programme Regulations.

3.3.p 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

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 Faculty of Engineering and Science, Aalborg University.

Assessment criteria
As stated in the Joint Programme Regulations.

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

Title
M3-17 Fault Tolerant Control/Fejltolerant regulering

Prerequisites
The module is based on knowledge achieved when studying courses on non-linear control theory and multivariable 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 Faculty of Engineering and Science, Aalborg University.

Assessment criteria
As stated in the Joint Programme Regulations.

3.3.r 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 is based on knowledge achieved when studying 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 Faculty of Engineering and Science, Aalborg University.

Assessment criteria
As stated in the Joint Programme Regulations.

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

Title

M3-19 Modern Electrical Drives/Moderne elektriske drivsystemer

Prerequisites
The module is based on knowledge achieved when studying the 2nd semester on the Master of Science in Energy Engineering with an electrical specialisation or 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 Faculty of Engineering and Science, Aalborg University.

Assessment criteria
As stated in the Joint Programme Regulations.

3.3.t 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 is based on knowledge achieved when studying the 2nd semester on the Master of Science in Energy Engineering with an electrical specialisation or 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 Faculty of Engineering and Science, Aalborg University.

Assessment criteria
As stated in the Joint Programme Regulations.

3.3.u Course Module on 1st Semester: Non-linear Control and Multi-body Systems
Please refer to 3.1.m Course Module on 1st Semester.

3.3.v Course Module on 3rd 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 and self-studies.

Examination format
Oral examination 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.x 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.y 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 is based on knowledge achieved when studying the 2nd semester on the Master of Science in Energy Engineering with an electrical specialisation or 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 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 Thermal Energy and Process Engineering

Title

M4-1 Master's Thesis/Kandidatspeciale

Prerequisites

The module is based on knowledge achieved when studying the 3rd semester on the Master of Science in Energy Engineering with specialisation in Thermal Energy and Process Engineering 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 thermal energy and process engineering at the highest international level
- Be able to critically judge knowledge and identify new scientific problems within the area of thermal energy and process engineering
- Have knowledge about 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 thermal energy and process engineering
- Be able to use advanced laboratory set-ups, data analysis methods and analysis and modelling methods within the field of thermal energy and process engineering
- Be able to communicate about scientific problems both to specialists and the public
- Have obtained skills related to the industrial area within thermal energy and process engineering

Competences

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

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 thermal energy and process engineering. 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 thermal energy and process engineering.

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 longMaster'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 at Faculty of Engineering and Science, Aalborg University.

Assessment criteria

As stated in the Joint Programme Regulations.

3.4.b Master's Thesis on 4th Semester in Fuel Cells and Hydrogen Technology

Title

M4-2 Master's Thesis/Kandidatspeciale

Prerequisites

The module is based on knowledge achieved when studying the 3rd semester on the Master of Science in Energy Engineering with specialisation in Fuel Cells and Hydrogen 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 fuel cells and hydrogen technology at the highest international level
- Be able to critically judge knowledge and identify new scientific problems within the area of fuel cells and hydrogen technology
- Have comprehension for 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 fuel cells and hydrogen technology
- Be able to use advanced laboratory set-ups, data analysis methods and analysis and modelling methods within the field of fuel cells and hydrogen technology
- Be able to communicate about scientific problems both to specialists and the public
- Have obtained skills related to the industrial area within fuel cells and hydrogen technology

Competences
- Be able to control complex/unexpected working and development situations within fuel cells and hydrogen technology, and be able to develop new solutions
- Be able to independently define and analyse scientific problems, and based on that make and state the reasons for decisions made
- Be able to independently continue own development in competence and specialisation
- Be able to independently 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 fuel cells and hydrogen 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 fuel cells and hydrogen 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 of Faculty of Engineering and Science, Aalborg University.

Assessment criteria
As stated in the Joint Programme Regulations.

3.4.c Master's Thesis on 4th Semester in Wind Power Systems

Title

M4-3 Master's Thesis/Kandidatspeciale

Prerequisites
The module is based on knowledge achieved when studying the 3rd semester on the Master of Science in Energy Engineering with specialisation in Wind Power 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 wind power systems at the highest international level
- Be able to critically judge knowledge and identify new scientific problems within the area of wind power systems
- Have comprehension for 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 wind power systems
- Be able to use advanced laboratory set-ups, data analysis methods and analysis and modelling methods within the field of wind power systems
- Be able to communicate about scientific problems both to specialists and the public
- Have obtained skills related to the industrial area within wind power systems

Competences

- Be able to control complex/unexpected working and development situations within wind power 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 wind power 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 wind power 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 Framework Provision at Faculty of Engineering and Science, Aalborg University.

Assessment criteria
As stated in the Joint Programme Regulations.

3.4.d Master's Thesis on 4th semester in Power Electronics and Drives

Title
M4-4 Master's Thesis/Kandidatspeciale

Prerequisites
The module is based on knowledge achieved when studying the 3rd semester on the Master of Science in Energy Engineering specialisation in Power Electronics and Drives 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 power electronics and drives at the highest international level
- Be able to critically judge knowledge and identify new scientific problems within the area of power electronics and drives
- 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 power electronics and drives
- Be able to use advanced laboratory set-ups, data analysis methods and analysis and modelling methods within the field of power electronics and drives
- Be able to communicate about scientific problems both to specialists and the public
- Have obtained skills related to the industrial area within power electronics and drives

Competences

- Be able to control complex/unexpected working and development situations within power electronics and drives, 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 power electronics and drives. 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 power electronics and drives.

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 of Faculty of Engineering and Science, Aalborg University.

Assessment criteria
As stated in the Joint Programme Regulations.

3.4.e Master's Thesis on 4th Semester in Electrical Power Systems and High Voltage Engineering

Title
M4-5 Master's Thesis/Kandidatspeciale

Prerequisites
The module is based on knowledge achieved when studying the 3rd semester on the Master of Science in Energy Engineering with specialisation in Electrical Power Systems and High Voltage Engineering 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 electrical power systems and high voltage engineering at the highest international level
- Be able to critical judge knowledge and identify new scientific problems within the area of electrical power systems and high voltage engineering
- Have comprehension for 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 electrical power systems and high voltage engineering
- Be able to use advanced laboratory set-ups, data analysis methods and analysis and modelling methods within the field of electrical power systems and high voltage engineering
- Be able to communicate about scientific problems both to specialists and the public
- Have obtained skills related to the industrial area within electrical power systems and high voltage engineering

Competences

- Be able to control complex/unexpected working and development situations within electrical power systems and high voltage engineering, 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 electrical power systems and high voltage engineering. 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 electrical power systems and high voltage engineering.

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 of Faculty of Engineering and Science, Aalborg University.

Assessment criteria
As stated in the Joint Programme Regulations.

3.4.f Master's Thesis on 4th Semester in Mechatronic Control Engineering

Title
M4-6 Master's Thesis/Kandidatspeciale

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

The master thesis can be conducted as a long master thesis. If choosing to do a long master thesis, it has to include experimental work and has to be approved by the study board. The amount of experimental work must reflect the allotted ECTS.

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 mechatronic control engineering at the highest international level
- Be able to critical judge knowledge and identify new scientific problems within the area of mechatronic control engineering
- 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 mechatronic control engineering
- Be able to use advanced laboratory set-ups, data analysis methods and analysis and modelling methods within the field of mechatronic control engineering
- Be able to communicate about scientific problems both to specialists and the public
- Have obtained skills related to the industrial area within mechatronic control engineering

Competences

- Be able to control complex/unexpected working and development situations within mechatronic control engineering, 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 mechatronic control engineering. 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 mechatronic control engineering.

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 of Faculty of Engineering and Science, Aalborg University.

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 Faculty of Engineering and Science and enters into force as of September 2017 for all new, enrolled students.

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's 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.

[1] The Study Board can grant exemption from this.

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) programme 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) programme elements from another Danish programme or a programme outside of Denmark at the same level in lieu of programme 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 Faculty of Engineering and Science 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 Rules and requirements for the reading of texts

At programmes taught in Danish, it is assumed that the student can read academic texts in modern Danish, Norwegian, Swedish and English and use reference works, etc., in other European languages (German or other languages can also be mentioned here if relevant). At programmes taught in English, it is assumed that the student can read academic text and use reference works, etc., in English.

5.6 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.