PhD Courses 2019
Energy Technology PhD program

DEPARTMENT OF ENERGY TECHNOLOGY
AALBORG UNIVERSITY
Description of the Energy Technology PhD program

The Energy Technology program is a multi-disciplinary doctoral program aiming at solving future challenges in the energy area by means of developing new energy technologies leading to a more efficient and sustainable management of energy. It covers a broad range of energy-related topics focusing on the energy conversion process itself as well as generation, transmission, distribution and efficient use of energy are covered. Inherently it is involving various areas of both classical and new engineering sciences as well as basic research as the physical quantity “energy” and its provision and use spans broadly over almost all activities a modern society faces. Electrical, thermal, mechanical, hydraulics and control engineering sciences merge in various ratios with physics and chemistry to provide front-end knowledge enabling step by step solutions to help fulfilling the climate and emission goals set by international societies. The program is highly experimentally oriented and offers state of the art laboratory facilities. Research cooperation with both Danish and international industries is strong as well as with world class academia.

The program enrolls more than 40 new PhD’s each year and has hosted + 100 PhD’s every year for the last several years and is graduating around 40 new energy technology PhD’s every year. The environment is highly international and hosting the best researchers worldwide.

Research areas:

The program belongs to The Doctoral School of Engineering and Science and focuses among others on:

- Power Electronics (PE) and its applications with special focus on reliability in PE. Another main focus is the interaction of PE with power systems and generation and load units.
- Electrical Power Systems including production, transmission, distribution of electrical energy as well as power quality, stability, control and protection in AC and DC systems.
- High Voltage Engineering with focus on environmentally friendly overhead lines
- Smart grid and micro grid and their application to modern societies
- Energy Efficiency as a universal term spanning the above science areas
- Renewable energy generation technologies incl. wind turbines and offshore wind power plants, photovoltaic, wave energy, thermoelectric, fuel cells and biofuels.
- Reliability, diagnosis and predictive maintenance of electrical and thermal components and systems
- Energy harvesting systems such as thermo-electric generators and systems
- Automotive and industrial drives including the design of electrical motors and generators and gears in combination with their power electronics and control.
- Systems analysis, design and optimization of a wide range of energy processes, machines and systems
- Heating/cooling systems and their distribution networks (domestic heating)
- Biomass to energy systems, including biomass to liquid fuels and end use applications
- Fluid power systems and their control
- Energy storage and power management
- Analysis and optimization of thermal cycles.

Head of Doctoral Program, Professor Claus Leth Bak - clb@et.aau.dk, +4599409281

Link: http://www.et.aau.dk/phd/phd-courses/

Registration: https://phd.moodle.aau.dk/
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AC Microgrids

Organizers:  Assistant Professor Yajuan Guan – Aalborg University, Associate Professor Juan C. Vasquez - Aalborg University

Lecturers:  Professor Josep M. Guerrero - Aalborg University, Associate Professor Juan C. Vasquez - Aalborg University, Professor Ernane Coelho - Federal University of Uberlândia, Brazil, Assistant Professor Yajuan Guan - Aalborg University

ECTS:  2

Date/Time:  23 – 24 April 2019

Max no. of participants:  25

Description:  A Microgrid can be defined as a part of the grid with elements of prime energy movers, power electronics converters, distributed energy storage systems and local loads, that can operate autonomously but also interacting with main grid. The functionalities expected for these small grids are: black start operation, frequency and voltage stability, active and reactive power flow control, active power filter capabilities, and storage energy management. This way, the energy can be generated and stored near the consumption points, increasing the reliability and reducing the losses produced by the large power lines.

The course starts giving some examples of Microgrids in the world. The course participants not only will learn modeling, simulation and control of three-phase voltage source inverters operating in grid-connected mode and islanded mode, but also, how these power electronics converters are integrated in AC Microgrids. Relevant concepts like frequency and voltage droop control as well as the virtual impedance concept are explained in detail. Finally, this course also introduces the study of the hierarchical control of Microgrids for AC electrical distribution systems.

Prerequisites:  Matlab/Simulink knowledge is recommended for the exercises.

Form of evaluation:  The participants will be grouped and asked to team work on several case study scenarios and tasks proposed along the course. The assessment in this course will be done through a final multi-choice test in combination with delivery of exercises reports.

Link:  http://www.et.aau.dk/phd/phd-courses/
Active Fault-Tolerant Control: Theory and Applications

Organizer: Associate Professor Zhenyu Yang - Aalborg University

Lecturers: Associate Professor Zhenyu Yang, Aalborg University, Dr. Jie Chen, Brunel University, UK

ECTS: 4

Date: 18 – 22 March 2019

Place: Aalborg University, Esbjerg Campus, Niels Bohrs Vej 8, 6700 Esbjerg

Max. no. of participants: 30

Description: A Fault-Tolerant Control (FTC) system is referred to a controlled system that poses the capability to accommodate system component faults/failures automatically and is capable of maintaining overall system stability and acceptable performance in the event of such faults. In general, the FTC capability can be possibly achieved through passive or active approaches. The passive FTC is limited by the nominal control system’s robustness, while the active FTC approach often consists of two integrated online functionalities, i.e., Fault Detection and Diagnosis (FDD) and Control Reconfiguration (CR). Thereby, the active FTC is also regarded as a kind of intelligent control solution.

The FTC plays an essential rule in safe-critical systems, which now cover a wide range of engineering systems, from aircrafts, airspace systems and nuclear reactors, to the recent emerging energy systems, such as smart grid systems, offshore wind farms etc. The ultimate objective of applying FTC techniques is to cost-effectively increase engineering system’s reliability, safety availability and maintainability.

The course covers the fundamental essentials and some latest results in FTC research area, along with diverse application case studies. The main content consists of: Historical and technical overview & terminology; FDD techniques (data-driven & model-based); CR techniques (model-matching & model-following): Integration of FDD and CR: fundamental FDD/FTC property analysis and diverse case studies.

The course will be evaluated based on a mini-project after the course. This mini-project expects some illustration that the student can apply some techniques/knowledge learned from this course into their current PhD project.

Literatures: Lecture notes/slides will be provided and the following two books are recommended:


Prerequisites: Basic knowledge of control theory (incl. state-space methods)
Advanced Computational Fluid Dynamics

Organizer: Associate Professor Chungen Yin - Aalborg University

Lecturers: Associate Professor Chungen Yin - Aalborg University
           Associate Professor Torsten Berning - Aalborg University

ECTS: 4

Date/Time: 27 - 30 August 2019

Max no. of participants: 25

Description: Computational Fluid Dynamics (CFD) has been successfully used in innovative design, trouble-shooting, optimization of technologies and facilities in numerous areas. This advanced CFD course will provide a familiarity with and an in-depth understanding of: (1) the finite volume method which is the backbone of the majority of CFD tools, including spatial and temporal discretization schemes, pressure-velocity coupling, boundary conditions and so on; (2) turbulent flows and Reynolds-averaged Navier-Stokes turbulence modeling approach, including different models and their key ideas, pros and cons; (3) multiphase flows and flows through porous media, and their modeling such as Lagrangian method, volume of fluid approach, mixture and Eulerian approach; (4) turbulent combustion flows and their modeling, e.g., species transport/eddy dissipation model or concept, and mixture fraction/PDF; (5) user-defined functions, UDFs, and their use in commercial CFD codes. Lectures will be combined with demos and hands-on sessions, in order to achieve the above purposes.

Prerequisites: Basic knowledge in fluid flow, turbulence, multiphase, combustion, programming

Form of evaluation: (1) source code to numerically solve a general transport equation using the finite volume method; (2) a mini-report on modeling of a turbulent flow using a commercial CFD code both by the default software and by developing and integrating user-defined functions.

Link: http://www.et.aau.dk/phd/phd-courses/
Advanced FPGA-based Controllers for Power Electronic and Drive Applications

Organizer: Associate Professor Juan C. Vasquez - Aalborg University, Professor Josep M. Guerrero - Aalborg University

Lecturers: Professor Eric Monmasson - University of Cergy-Pontoise, France, Assistant Professor Mattia Ricco - Aalborg University.

ECTS: 3

Date/Time: 10 – 12 April 2019

Max no. of participants: 20

Description: Digital controllers are now extremely powerful. With the current Field Programmable Gate Array (FPGA), designing a controller is no longer limited to the programming of a microprocessor but includes also the programming of the architecture of the processor itself along with its peripherals and its computing accelerators. As a consequence, the control designer should be now a system architect who also needs a deep understanding of the final system to be controlled. Along this line, this course aims to propose a rational use of current FPGA-based reconfigurable platforms for controlling power electronic and drive applications.

The following topics are covered in the course:

1st day (optional for students who have already worked with FPGAs): - Introduction, presentation of the current trends in terms of digital control implementation for electrical systems.

- Description of FPGA components (Internal architecture of FPGAs, recent System-on-Chip extension, presentation of the corresponding development tools), VHDL reminders.

- Hands-on basic examples, tutorial on a current FPGA development tool chain.

2nd & 3rd days: - Main design rules of an FPGA-based controller: Control algorithm refinement (design of a time continuous controller, internal delay issues, digital re-design, sampling issues, quantization issues). Architecture refinement (algorithm / architecture matching, IP-modules reusability, Hardware-In-the-Loop (HIL) validation, system-on-chip extension, High Level Synthesis (HLS) design approach).

- Presentation of practical cases: Current control of a synchronous motor drive, sensorless control techniques (Kalman filtering, high frequency injection), Adaptive MPPT for PV applications, Fault tolerant control of Voltage Source Rectifier.

- Hands-on the FPGA-based control of a power converter connected to the grid. Design of different types of regulators (PI current controller, PR current controller, sliding mode current controller, predictive current controller) and their corresponding Simulink-based and HLS-based IP modules. HiL validation.

Form of evaluation: The participants will be grouped and asked to team work on several case study scenarios and tasks proposed along the course. The assessment in this course will be done through a final multi-choice test in combination with delivery of exercises reports

Prerequisites: Matlab/Simulink knowledge and C/C++basic knowledge is recommended for the exercises.

Link: http://www.et.aau.dk/phd/phd-courses/
An Introduction to HVDC and MTDC Transmission System

Organizer: Associate Professor Sanjay K Chaudhary – Aalborg University

Lecturers: Associate Professor Sanjay K Chaudhary – Aalborg University and Professor Remus Teodorescu - Aalborg University

ECTS: 3

Date/Time: 2-4 October, 2019

Max. no. of participants: 15

Description:
This course introduces the HVDC transmission in power systems.

Line commutated converter (LCC) based High Voltage DC (HVDC) has been used worldwide for the transmission of bulk power over long distances. Voltage source converter-based HVDC (VSC-HVDC) transmission provides fast control of active and reactive power in all four quadrants. Nowadays, the concepts of multi-terminal dc (MTDC) grids interconnecting multiple energy resources and grids have been proposed.

A detailed description of the LCC-HVDC, VSC-HVDC (both using the two-level converters and the MMC-HVDC) and MTDC and their basic control schemes will be presented. The course will include lectures and simulation exercises. Simulation tools like PSCAD-EMTDC and DigSILENT will be used to demonstrate these applications.

Main topics are:
- Limitations of ac power transmission and the need for HVDC
- Classic HVDC transmission (LCC HVDC): Introduction, operation and control
- VSC-HVDC transmission for the connection of relatively weak grids, and grid connection of renewable energy sources - Introduction, operation and control
- Evolution of Modular multi-level converters (MMC) and MMC-HVDC - Introduction, operation and control
- Multi-terminal DC transmission system

Prerequisites: A basic knowledge of power transmission system and power converters.

Form of evaluation: The participants will have to write a report of the simulation exercises as a part of the course. Submission of this report via moodle is mandatory for the assessment and award of diploma.

Link: http://www.et.aau.dk/phd/phd-courses/
Application of Phasor Measurement Units for Monitoring of Power System and RTDS Technology

Organizer: Associate Professor Filipe Faria da Silva – Aalborg University, Postdoctoral Researcher Hesam Khazraj – Aalborg University

University Lecturers: Associate Professor Filipe Faria da Silva – Aalborg University, Postdoctoral Researcher Hesam Khazraj – Aalborg University

ECTS: 3

Date/Time: 2 – 5 September 2019

Max no. of participants: 20

Description:
Under the supervision of the smart grid, online visualization of the power system states is highly demanded, due to the growing complexity of the operation of the power system networks. With the advent of the phasor measurement units (PMUs), which are much faster as compared to RTUs, the PMU measurements can be best utilized for the online visualization of the power system states. Additionally, with the introduction of real-time simulation tools, such as the Real Time Digital Simulator (RTDS), real-time test and validation of the power system state estimation is achievable. Such simulations will provide the required confidence in the design of the state estimation and also validate its performance in a real-time environment.

This four-day course provides an overview and hands-on experience into the use of phasor measurement units in novel transmission power system network:
- Motivation for Synchronized Measurements
- Synchrophasor Fundamentals: PMU Measurements
- Synchrophasor Fundamentals: Estimation
- Synchrophasor Fundamentals: Setting PMU
- Synchrophasor Fundamentals: Data Quality
- Synchrophasor Fundamentals: Standards
- PMU Applications
- PMU-Based State estimation
- PMU for Novel State estimations

The course will also focus on the applicability and practical implementation of the models, and cover the following main topics:
- Overview of the principles of operation of the RTDS Simulator and an introduction to the electromagnetic transients algorithm used.
- Introduction to the RSCAD software suite and its modules.
- Build and run a number of power system simulation cases showing the capabilities and limitations of the RTDS Simulator.
- Use of various I/O cards – GTA0, GTA1, GTDO, GTDI and GTFPI.
- Introduction to developing an interface between an external protective relay and the RTDS Simulator for closed-loop testing.
- Use RSCAD’s CBUILDER module to create user defined component models.
- Use scripts to automate the process of running simulation cases.
- Use of RTDS’ GTNET hardware for GOOSE, Sampled Values and MMS Server applications;
- Use of RTDS’ MMS Voyageur software for MMS Client applications;
- Use of RTDS’ Protection and Automation Suite (MMS Server Simulator) software for MMS Server applications;

**Prerequisites:**
Degree in Electrical Power System or similar
Matlab/Simulink knowledge is recommended for the exercises.

**Form of evaluation:**
Exercises during course. Participate in 4 days course. At the end, participants have to do project works based on materials of the course. There are 4 groups (each group consists of 5 persons).
- Group 1: installing PMU based SE for IEEE 14 Bus
- Group 2: Dynamic state estimation for Voltage and Current of IEEE 9 Bus
- Group 3: Data Quality for IEEE 9 Bus system
- Group 4: Simulink to RSCAD (IEEE 9 Bus)
Application-Oriented Modelling of Renewable Energy Sources, Conversion and Energy Storage Systems

Organizer: Assistant Professor Sergiu Spataru, ssp@et.aau.dk, Aalborg University
Associate Professor Dezso Sera, des@et.aau.dk, Aalborg University

Lecturers: Associate Professor Dezso Sera, des@et.aau.dk, Aalborg University
Associate Professor Tamas Kerek, tak@et.aau.dk, Aalborg University
Associate Professor Florin Iov, fi@et.aau.dk, Aalborg University
Assistant Professor Daniel-Ioan Stroe, dis@et.aau.dk, Aalborg University
Assistant Professor Sergiu Spataru, ssp@et.aau.dk, Aalborg University

ECTS: 4

Date/Time: 04-07.03.2019

Max no. of participants: 20

Description: This four-day course provides an overview and hands-on experience into the most common modelling methods used for the design, analysis, and planning of solar photovoltaic (PV) generation, wind power (WP), and energy storage (ES) systems.

The course will focus on the applicability and practical implementation of the models, and cover the following main topics:

i) modelling solar and wind resource: from high frequency variations to hourly, daily, and monthly averaged models;

ii) detailed/dynamic models of the photovoltaic generator (PVG), wind turbine generator (WTG), power electronic converter (PEC) and battery storage system (BSS), used in applications where models with a high bandwidth are required, such as switching converter applications;

iii) averaged, performance, and ageing models of the PVG, WTG, PEC, and BSS used in power system integration studies, power plant design, or performance monitoring and analysis.

The mornings are dedicated to lectures, while the afternoons are spent with off-line application examples and exercises in Matlab/Simulink, and laboratory exercises focusing on Real Time implementation using Opal-RT, where the students will apply the models and methodology in practice. No less than 40% of the course time is spent in the state-of-the-art Photovoltaic Systems Laboratory and the Smart Energy Systems Laboratory at the Department of Energy Technology at Aalborg University.

Prerequisites: Basic Matlab/Simulink knowledge is recommended for the exercises.

Form and criteria of evaluation: The students will be evaluated based on an individual report that must be submitted in maximum 10 working days after the course is finished.

The individual report must document their solutions to the mandatory assignments received during each day the course.
Capacitors in Power Electronics Applications

Organizer: Associate Professor Huai Wang - Aalborg University

Lecturers: Associate Professor Huai Wang - Aalborg University

ECTS: 2

Date/Time: 21 – 22 November 2019

Max no. of participants: 30

Description:
Capacitors are one of the key components in typical power electronic systems in terms of cost, volume, and reliability. Power electronics applications are consuming unprecedented quantities of electrolytic capacitors, film capacitors, and ceramic capacitors. This industrial/PhD course will discuss the sizing, modeling, and reliability analysis of capacitors from an application perspective, focusing on both classical and emerging power electronics applications. It is the latest research outcome of several PhD projects and industrial collaboration activities. The course will cover the following aspects:

1) Basics of capacitors and its functions in power electronic converters
2) Emerging capacitor technologies and latest developments
3) Capacitor sizing criteria in power electronics by considering steady-state performance, transient and stability performance under both normal and abnormal operations
4) Reliability of electrolytic capacitors, film capacitors, and ceramic capacitors
5) Mission profiled based electro-thermal-lifetime modeling of capacitors
6) Condition monitoring and protection of capacitors in power electronics applications
7) Capacitor minimization techniques in power electronic systems
8) Case studies in DC-DC converters, Modular Multi-Level Converters (MMC), photovoltaic inverters, wind power converters, adjustable-speed-drives, Solid-State-Transformers (SST), and ultra-low inductive capacitor bank design.

Prerequisites:
Basic understanding of power electronics circuits and control

Form of evaluation:
Case study exercise, lab measurement, and report submission

Link: http://www.et.aau.dk/phd/phd-courses/
DC Microgrids

Organizer:  Associate Professor Juan C. Vasquez – Aalborg University, Postdoc Enrique Rodriguez - Aalborg University

Lecturers:  Professor Josep M. Guerrero - Aalborg University, Associate Professor Juan C. Vasquez - Aalborg University, Associate Professor Sanjay K. Chaudhary - Aalborg University, Postdoc Enrique Rodriguez - Aalborg University

ECTS:  2

Date/Time:  25 - 26 April 2019

Max no. of participants:  25

Description: DC distribution and transmission systems are a clear trend in electrical networks. The focus of this course is on modeling, control and operation of DC Microgrids, starting with stability and control strategies analyzed in detail, DC droop, virtual impedance concepts and hierarchical control structures for DC microgrids are also introduced. Control of DC-DC and AC-DC converters oriented as DC Microgrid interfaces are evaluated.

Distributed energy storage systems and nature DC output generation systems are presented showing their interaction in DC distribution Microgrids. The course also shows examples of DC microgrids in different applications like telecommunication systems or residential DC electrical distribution systems and hybrid AC-DC microgrids.

Form of evaluation: The participants will be grouped and asked to team work on several case study scenarios and tasks proposed along the course. The assessment in this course will be done through a final multi-choice test in combination with delivery of exercises reports.

Prerequisites Matlab/Simulink knowledge is recommended for the exercises.

Link: http://www.et.aau.dk/phd/phd-courses/
Design Considerations for Robust and Reliable Power Semiconductor Modules

Organizer: Professor Francesco Iannuzzo – Aalborg University

Lecturers: Postdoc Amir Bahman – Aalborg University, Professor Francesco Iannuzzo – Aalborg University

ECTS: 2

Date/Time: 2 – 3 December 2019

Max no. of participants: 30

Description: In this course, the continuously growing importance of power electronics and the need for long and reliable power semiconductor devices will be addressed. First, an introduction to the most widely used power semiconductor devices will be given with a short introduction to its operation principle. Then, the role of the parasitic elements and thermal stresses in real applications, without forgetting about abnormal operations such as short-circuit will be addressed. With the target of accelerating the transition towards long-term lifetime of power electronic systems, four golden rules for reliable power module design will be proposed, which includes reliable operation under both normal and abnormal conditions.

On the second day, an overview of the most common failure mechanisms in silicon IGBTs and SiC MOSFETs will be presented. The prediction of such failure modes is complex since they can be triggered due to many parameters, such as temperature, voltage variation, inductive and capacitance effects, unbalanced current distribution and also EMI (Electro Magnetic Interference). Examples of instabilities will be given and the PhD student will become familiar with the failures that one can find in the field. The student will learn through a software tool, such as PSpice, how to model abnormal operations aiming at increasing the device robustness.

The course is organized in two consecutive days of full-time activities, covering the following:

• Introduction, overview of new developments in SiC MOSFETs and Si IGBTs.
• Importance of parasitic elements in real applications considering thermal aspects.
• The four golden rules for reliable power application design including abnormal operation.
• Introduction to the most common failure mechanisms in silicon IGBTs and SiC MOSFETs.

Prerequisites: Basic knowledge of circuit theory and device semiconductor behavior.

Form of evaluation: The participants must simulate with PSpice a simple semiconductor power module including chips in parallel and inductive elements under both normal and abnormal operations. The exercise can be done in group of 2-3 members. A final report must be submitted by ea

Link: http://www.et.aau.dk/phd/phd-courses/
Design of Modern Power Semiconductors Components

Organizer: Professor Francesco Iannuzzo - Aalborg University

Lecturers: Professor Eckart Hoene – Aalborg University and Fraunhofer IZM, Professor Francesco Iannuzzo - Aalborg University, Professor Kjeld Pedersen - Aalborg University, Professor Vladimir Popok - Aalborg University

ECTS: 3

Date/Time: 30 October – 1 November 2019

Max no. of participants: 20

Description: The main component of modern Power Electronics circuits is the semiconductor power switch. This course presents the fundamentals of Power Switches operations from a physical point of view, together with the specific peculiarities and the reason to use them in a special application. An overview on different packaging technologies and their properties, advantages and disadvantages, is also given. Requirements from the applications and possibilities to tackle them with a semiconductor package solution will be proposed.

Part I) semiconductor theory

This part aims to give an understanding of semiconductor power switch operations. A preliminary introduction to the PN junction and fundamentals of bipolar junction and field-effect transistors will be given. Then, a comparison between traditional semiconductor technologies, like Silicon, and emerging technologies like GaN and SiC will follow. Successively, referring to MOSFETs and IGBTs, several details about the structure of the elementary cell will be introduced together with the explanation of the fundamental mechanisms taking place during operations, like the Miller plateau, voltage/current overshoot and voltage/current tail. An overview of abnormal operations, like unclamped inductive switching (UIS) and short circuit, together with typical unstable phenomenon like current crowding and thermal runaway, will be also discussed. Finally, modern driving strategies, including two-level turn off and anti-desaturation will be introduced.

Part II) Application-driven packaging choice

This part aims to introduce, analyze and discuss packaging techniques for modern semiconductor power switches. The present challenges in terms of power density, stray inductance and resistance, and reliability issues will be broadly discussed from a physics point of view, together with several sample applications. Modern interconnection solutions will be presented together with the research challenges in the field of power electronics packaging like copper bond wires, low-profile packaging, bondless packaging, etc.

Prerequisites: Basic knowledge of circuit theory
**Form of evaluation:** The participants will be grouped and asked to work in team on a real design. Groups will present their work first, then participants will be asked individual questions on the project contents in order to assess their original contribution.

Link: [http://www.et.aau.dk/phd/phd-courses/](http://www.et.aau.dk/phd/phd-courses/)
D-FMEA: Design Failure Mode and Effect Analysis

Organizer: Huai Wang, Associate Professor, Aalborg University

Lecturers: Chief Specialist Philip C. Kjær - Vestas Wind Systems A/S and Professor at Aalborg University, Power Electronics Engineer Rui Wu - Vestas Wind Systems A/S, Associate Professor Huai Wang - Aalborg University and invited industry speakers

ECTS: 4

Date/Time: 28 – 29 October, 8. November + 29 November 2019

Max no. of participants: 30

Description:

The aim of the course is to meet both scientific challenges and industry needs for electrical engineers and scientists with reliability expertise and systems engineering concept, especially the D-FMEA for system design. The lecturers would like to extend for the workshop as a regular PhD course so that it can benefit a wider range of participants.

Design Failure Mode and Effect Analysis (D-FMEA) helps to foresee design issues and to mitigate them at early stages of product development. Best practice of D-FMEA for power electronics design is believed to be of general benefits to the power electronic converter designer across industries and academic research. Based on engineering case studies, this course will introduce a systematical way to perform D-FMEA and its important aspects. Participants will bring their own designs to the course, and will leave with hands-on experiences in building up D-FMEA of their specific applications. The course will mainly cover the following aspects:

1) Introduction to D-FMEA and systems engineering
2) How to formulate functions and failures, link causes and effects, and score risk
3) Examples applicable of mega-watt power converter
4) Training in software tool for D-FMEA (IQ-FMEA) and free-of-charge use of tool for duration of course
5) Hands on exercises of selected projects from course participants (teams or individuals)

Prerequisites:

1. Pre-reading the shared materials
2. Participants should choose their own products for studying in the course, which should be:
   1) a product at an adequate complexity level within power electronics area, for instance, an EMI filter, a Print circuit board (PCB), a magnetic component, discrete semiconductors, a heat sink or a liquid cooling system;
2) a product with new designs, or a product with modifications to the exist design, or a exist product needs FMEA analysis

3. Participants should form a DFMEA team inside their institutes/companies for their design, including: a core team - designers of the product, a support team - assembly, manufacturing, design, analysis/test, reliability, materials, quality, service, and suppliers, as well as designers responsible for the next higher system.

4. Participants should be aware of the customers’ requirements/expectations on their products.

Form of evaluation:

A DFMEA report on the participants’ own project (teams or individuals)

Link: http://www.et.aau.dk/phd/phd-courses/
Electricity Market and Power System Optimization

Organizer: Professor Zhe Chen - Aalborg University, Assistant Professor Jiakun Fang - Aalborg University

Lecturers: Professor Andrés Ramos Galán - Universidad Pontificia Comillas, Spain

ECTS: 3

Date/Time: 25 - 27 February 2019

Max no. of participants: 30

Description:
This course provides a detailed description of decision-making tools for modern power systems under the market environment, addressing the perspectives transmission expansion planning, unit commitment and economic dispatch. These tools rely on stochastic optimization, complementarity theory and decomposition algorithms.

The main topics are as follows:
- Introduction to the electricity market organization
- Modeling the competition in electric energy markets
- Stochastic unit commitment to coop with the renewable generations
- Probabilistic midterm transmission expansion planning in liberalized markets
- Decomposition and acceleration techniques for large-scale optimization problems

Prerequisites: Background in power system optimization, and fundamental knowledge in electricity markets.

Form of evaluation: The mini-project using Matlab/GAMS and the corresponding technical report will be submitted to the lectures for evaluation after the course. Minimum requirements include the clear interpretation of the models, simulation cases and results. Plagiarism is not allowed. Similar reports will be failed. Further details will be announced during the course.

Link: http://www.et.aau.dk/phd/phd-courses/
**Electrochemical Energy Conversion**

**Organizer:**
Associate Professor Torsten Berning - Aalborg University

**Lecturers:**
Associate Professor Torsten Berning - Aalborg University
Associate Professor Vincenzo Liso - Aalborg University
Associate Professor Samuel Araya - Aalborg University

**ECTS:**
4

**Time:**
13 – 16 May 2019

**Place:**
Aalborg University

**Max. no. of participants:**
25

**Description:**
This PhD course is an introduction to electrochemical energy conversion with a focus on fuel cell technology (gas to power) and electrolyzer technology (power to gas). In detail, it will provide:

- An introduction to the thermodynamics of electrochemical energy conversion;
- An overview of the different types of fuel cells and electrolyzers and their materials;
- An introduction of the different ways of modeling of electrochemical devices and systems;
- A familiarity with the different experimental methods to test and characterize electrochemical energy converters;

As the conclusion of the course, an attendee will be well prepared to understand and follow more sophisticated state-of-the-art literature in this field, to be able to understand simple (zero-dimensional) models of fuel cell systems using software such as EES and know the benefits and drawbacks of advanced (multi-dimensional) models of the fluid flow in electrochemical devices that employ the methods of computational fluid dynamics. The attendee will also have an overview of the various experimental methods that can be employed to test electrochemical devices. This PhD course is aimed at recent graduates, professional engineers and the likes.

**Prerequisites:** Basic knowledge in thermodynamics and modeling methods such as Engineering Equation Solver (EES) and/or the methods of computational fluid dynamics (CFD).

**Evaluation:** The groups of students will present the theoretical exercises and discuss their experimental results on the last day of the course. Questions will be asked by the teachers to individual students during the presentation. Evaluation will be “passed” or “failed”.

**Literature:**
- S. Lvov: Introduction to Electrochemical Science and Engineering, CRC Press, 2014

Link: http://www.et.aau.dk/phd/phd-courses/
EMI/EMC in Power Electronics

Organizer: Associate Professor Pooya Davari - Aalborg University

Lecturers: Professor Eckart Hoene - Aalborg University and Fraunhofer IZM, Associate Professor Pooya Davari - Aalborg University

ECTS: 2.5

Date/Time: 18 – 19 November 2019

Max no. of participants: 20

Description: With a rapid advancement of power switching devices and digital signal processing units, power electronics technology has found its way into many applications of renewable energy generation, transmission and consumption. Although power electronics systems are a key enabler as a cross-functional technology in the energy conversion process, their pulse energy conversion with inherent switching behavior exhibit disturbing harmonic emissions and electromagnetic noises. Recently, with the high penetration of power electronic systems and advent of new power semiconductor devices known as wide-band gap (WBG) the importance of understanding and preventing power converters switching disturbances have significantly elevated. The generated harmonic and noise disturbances can result in electromagnetic interference (EMI) and should be controlled within specific limits by applying proper filtering, topology and control scheme. Thereby, in order to prevent the power converters from disturbing their own operation and other nearby electronic devices they should design for electromagnetic compatibility (EMC).

The emphasis of this course is to give a complete and clear picture on EMI issues and mitigation methodologies. Systematic designing of passive EMI filters for differential mode (DM) and common mode (CM) noises in single-phase and three-phase systems will be provided. Printed circuit board (PCB) design criteria, passive and active components parasitic and shielding approaches in reducing near-field couplings will be covered as well. Furthermore, time and frequency domain modeling of conducted low and high frequency emission noises through developing equivalent circuit models of power electronics converters in order to reduce the analysis complexity and prevent from conventional trial and error design approach will be addressed. This course will also focus on new challenges within the new frequency band of 2-150 kHz (i.e., superharmonics) in power electronic based power systems. The course content is combined with real-world application examples and demonstration.
**Prerequisites:** This course is intended for intermediate and advanced researchers and engineers in the field of power electronics and its applications, for EMC specialists and advanced university students exploring new harmonics and EMI challenges in power electronics based power system and WBG-based power electronic systems. General knowledge in power electronics converters operation modes, passive components and basic control theory are preferred. Course exercises and mini-projects will be performed on MATLAB/PLECS software platform.

1. Pre-reading the shared materials
2. Power Electronics
3. Basic understanding of power electronics control

**Form of evaluation:** The participants will work on mini-projects in the final 1-day lecture. The mini-projects are defined based on a real application design and will be assigned to group of four people. Groups will compare and deeply discuss their design method and choices and present their results in presentation form to the class.

1. Mini-projects
2. Power point presentation

Link: [http://www.et.aau.dk/phd/phd-courses/](http://www.et.aau.dk/phd/phd-courses/)
Models, Methods and Optimization Tools for Energy Systems

Organizer: Associate Professor Juan C. Vasquez – Aalborg University, Postdoc Emilio Palacios – Aalborg University

Lecturers: Associate Professor Moises Graells - Technical University of Catalonia, Spain, Associate Professor Eleonora Riva Sanseverino, University of Palermo, Italy, Postdoc Amjad Anvari-Moghaddam – Aalborg University, Postdoc Emilio Palacios – Aalborg University

ECTS: 3

Date/Time: 15 – 17 April 2019

Max no. of participants: 25

Description: Energy is a resource that needs to be managed and decisions need to be made on production, storage, distribution and consumption of energy. Determining how much to produce, where and when, and assigning resources to needs in the most efficient way is a problem that has been addressed in several fields. There are available tools that can be used to formulate and solve these kinds of problems. Using them in planning, operation and control of energy systems requires starting with the basics of math programming techniques, addressing some standard optimization problems, and adapting the solutions to new particular situations of interest.

A first issue is revisiting the modelling concept. The model is a simplified and limited representation of our reality. Complex multi-level problems may need different models and models valid at the operational level (operation and control) may not be useful at the tactical or strategic levels (scheduling and planning). Thus, when addressing optimization problems, detailed physical models based on differential equations will be replaced by algebraic equations expressing the basic relations between lumped parameters. The second issue is the choice of a problem-solving method. It is well known that all optimization methods have at least some limitations and there is no single method or algorithm that works best on all or even a broad class of problems. In order to choose the best method for a given problem, one must first understand the nature of the problem and the type of design space that is being searched.

Students attending this course will learn how to recognise and formulate different optimization problems in planning, operation and control of energy systems, and how to solve them using existing software and solvers such as MATLAB, GAMS, and Excel. Different principal algorithms for linear, network, discrete, nonlinear and dynamic optimization are introduced and related methodologies together with underlying mathematical structures are described accordingly. Several illustrative examples and optimization problems, ranging from the classical optimization problems to the recent MINLP models proposed for the optimization of integrated energy systems (such as residential AC/DC microgrids) will be introduced during supervised hands-on sessions and different tools (such as classic mathematical methods, heuristics and meta-heuristics) will be used for solving the cases. The choice of objective functions, representation of discrete decisions, using formulation tricks and checking the results will be also covered.

The course is intended for those students that, having a general knowledge in mathematics and simulation, have a very limited experience in math optimization and programming, and need to be introduced to these tools for energy systems optimization.

Form of evaluation: The participants will be grouped and asked to team work on several case study scenarios and tasks proposed along the course. The assessment in this course will be done through a final multi-choice test in combination with delivery of exercises reports

Prerequisites Familiarity with basics of real analysis, linear algebra, and probability and statistics.

Link: http://www.et.aau.dk/phd/phd-courses/
Encoderless control of electric drives motors and generators

Organizer: Professor Frede Blaabjerg - Aalborg University
Lecturers: Professor Ion Boldea, IEEE Fellow, DL, Romania
ECTS: 3
Date/Time: 14 – 15 November (ends at 12.00 on 15 November)
Max no. of participants: 30

Description: Variable speed drives are now used for almost 50% of all drives, to control motion (energy flow) to save energy and increase productivity in variable output processes in all industries: from info-gadgets, robotics through transport, pumps, ventilators, compressors etc., home appliances and electric generators for renewable energy conversion and control. Advanced position, speed and torque control that produces high precision and quick response performance requires encoder-precision feedback. In low power (torque) applications, however, the encoder is more expensive than the motor/actuator and in medium and large power they are mechanically fragile; in all drives the accidental stopping of a drive in a safely critical application means large “production interruption costs” until the faulty encoder is replaced. This is how Encoderless control, with position, speed, torque and flux state observers came into play; in general applications only encoderless control is used while in servo drives the encoderless control is available at least for redundancy.

The Intensive Course here presents an Overview of present status and trends in Encoderless control of electric drives as follows:

- V/f and I-f scalar control of ac drives with stabilizing loops for faster torque response, extended speed range and high efficiency with variable load and speed: with sample spectacular results, including regenerative braking experiments
- Encoderless Field Oriented Control (E-FOC) of IMs, SPMSMs, IPMSMs, PM-RSMs and dc excited SMs: with case studies
- Encoderless direct torque and flux control (E-DTFC) of IMs, IPMSMs, PM-RSMs, dc excited SMs: with case studies
- Encoderless FOC of Induction, Doubly fed induction, doubly fed reluctance (brushless), PM and dc excited synchronous variable speed GENERATORS for wind and hydro, with case studies
- Encoderless Direct active and reactive power control (DPQC) of variable speed generator drives, with case studies
- Robust control of advanced electric drives by case studies: feedback linearization and supertwisting sliding mode FOC and DTFC of IMs and IPMSMs

Prerequisites: Basic control theory and MATLAB/Simulink

Form of evaluation: Quiz in class (90%) and attendance rate (10%)

Link: [http://www.et.aau.dk/phd/phd-courses/](http://www.et.aau.dk/phd/phd-courses/)
Hydraulic Servo Systems: Modelling, Identification and Control

Organizer: Professor Torben Andersen – Aalborg University

Lecturers: Professor Torben Andersen – Aalborg University

ECTS: 4

Date/Time: 9 – 12 December 2019

Description: Main objective of the course is to give a theoretical background, experimental results of modelling, identification and control of hydraulic servo systems. Hydraulic servo systems have many advantages over electrical motors; however, they are characterized by highly non-linear dynamics and are difficult to control. The non-linearities is due to compressibility of the oil, friction in the actuator and the complex flow properties from the controlling valves. Advanced control can provide significant improvements of conventional and linear methods. The derivation and identification of suitable models is thus treated in detail.

This course outline both the classical and advanced methods with the intention to provide the fundamentals required to understand, design and implement automatic control of hydraulic drives.

The motivation is to facilitate wider and faster exploitation of Hydraulic Servo Systems by bridging the gap between theory and successful industrial implementation through cooperation and exchange of experience between academic/research and industrial communities. It course is intended for both PhD students and practicing engineers.

Some of the course content is based on recently obtained research results. The main topics are as follows:

- General Description of Hydraulic Servo systems
- Physical Fundamentals of Fluid Properties and Fluid Motion
- Physical Based Modelling and System Identification
- Control System Design; Linear and Non-linear methods
- Application Example and case studies
- Laboratory Exercises (Simulation + Laboratory Demonstration)

Prerequisites: General knowledge and beyond entry stage to fluid power, preferably background at the graduate level.

Matlab/Simulink knowledge is recommended for the exercises.
Form of evaluation: Individual evaluation of the course participants will be performed on a basis of:

- Attendance rate (5%)
- Mini-project (95%)
Introduction to Voltage Stability of Electric Power Systems

Organizer: Professor Zhe Chen - Aalborg University, Denmark

Lecturers: Professor Costas Vournas, NTUA, Greece

ECTS: 3

Date/Time: 6 - 8 February, 2019

Max no. of participants: 30

Description:
The course will provide training and education on the subject of Voltage Stability analysis. The PhD course will include basic knowledge of power transfer limitations in DC and AC systems, the effect of reactive compensation, generator reactive support, and load dynamics and basic concepts of voltage stability monitoring, control and protection.

The main topics are as follows:
- Overview of power system stability and classification
- Basics of stability theory
- Voltage stability and maximum power transfer
- Reactive generation and reactive power limits. Immediate loss of stability
- Fast and slow response including load dynamics.
- Modelling and response of Load Tap Changers
- Voltage Stability Monitoring and Countermeasures

Prerequisites: General knowledge in electrical AC circuits and electrical power engineering, preferably background at graduate level in power systems. Exercises involve Matlab.

Form of evaluation: Written assignments in Matlab to be submitted after the course will undergo individual checking by the lecturer. The assignments will be compounded in a mini-report per student describing the outcome of simulation cases.

Link: http://www.et.aau.dk/phd/phd-courses/
Introduction to Wind Power

 Organizer:  Professor Zhe Chen - Aalborg University

 Lecturers:  Professor Zhe Chen - Aalborg University, Assistant Professor Jiakun Fang - Aalborg University, Postdoc Yanbo Wang - Aalborg University

 ECTS:  4

 Date/Time:  18 - 21 February 2019

 Max no. of participants:  30

 Description:
The course will provide training and education in the field of wind power engineering, covering the electrical aspects of wind turbine systems, including electrical machines, power electronics and power systems.

 The PhD course will include basic knowledge of electrical systems of wind power conversion systems, and operation and control in power systems with high level wind power penetration.

 Some of the course contents are based on recently obtained research results.

 The main topics are as follows:

 - Overview of electrical systems of wind energy conversion systems
 - Wind power generators
 - Configuration and control of power electronic conversion system
 - Operation and control of wind turbines and wind farms
 - Parameter estimation, monitoring and diagnosis of wind turbine systems
 - Offshore wind farms and electrical system optimization
 - Wind turbines in power systems

 Prerequisites: General knowledge in electrical engineering, preferably have a background at graduate level in electrical engineering.

 Form of evaluation: Assignments to be submitted after the course.

 Link: http://www.et.aau.dk/phd/phd-courses/
Liquefaction of Biomass - Fundamentals and Practice

Organizer: Professor Lasse Aistrup Rosendahl - Aalborg University

Lecturers: Professor Lasse Aistrup Rosendahl - Aalborg University, Associate Professor Saqib Sohail Toor - Aalborg University, Assistant Professor Thomas Helmer Pedersen - Aalborg University and Postdoc Daniele Castello - Aalborg University

ECTS: 3

Date/Time: 25 – 27 March 2019

Max no. of participants: 15

Description: The course is designed to teach students about biofuels and biomass liquefaction technologies in the context of energy and chemical products. The course will introduce fundamental principles of liquefaction, focussing on hydrothermal liquefaction and pyrolysis. Based on this, it will move on to process analysis and design, process modeling tools and process implementation. Furthermore, the course discusses analytical techniques for product stream analysis and data interpretation with specific reference to liquefaction product streams and their special characteristics. Throughout the course, material taught will be exemplified by or related to experiences and best-practice methods obtained through designing and operating advanced liquefaction equipment. Through a series of lectures, lab session on product analysis and visit to the CBS pilot plant, students will learn how to design, analyze, and scale up various biomass liquefaction technologies for bioenergy production.

- Energy conversion processes and conversion technologies (hydrothermal liquefaction and pyrolysis).
- Mass and energy balances, unit operations, and thermodynamics in HTL conversion technology.
- Introduction and implementation of Aspen Plus® process simulator.
- Product characterization techniques through laboratory instrumentation.

Prerequisites: chemistry, chemical or process engineering at BSc/MSc level

Form of evaluation: individual mini report

Link: http://www.et.aau.dk/phd/phd-courses/
Managing Harmonic Emissions in Modern Distribution Power Grids

Organizer: Associate Professor Xiongfei Wang – Aalborg University

Lecturers: Jan Meyer - University of Technology, Germany, Associate Professor Xiongfei Wang – Aalborg University, Assistant Professor Dongsheng Yang – Aalborg University

ECTS: 3

Date/Time: 7 – 9 October 2019

Max no. of participants: 30

Description:
The ever-increasing penetration of power-electronic-based sources and loads in distribution power grids poses new challenges on the quality of power supply. This course aims to provide a systematic and holistic discussion on different aspects related to planning, modelling and measuring harmonics in modern distribution power grids. New developments and concepts in determining and assessing emission limits for power electronics based customer installations are discussed. Practical aspects of the harmonic measurement and data analytics in active distribution networks will be discussed, and particular attentions will be given to the challenges of increasing measurement points and data amounts. The theoretical modeling and analysis on the harmonic impact of photovoltaic inverters and electric vehicle chargers in low-voltage (LV) distribution systems will be discussed. Each aspect is illustrated by real world examples. The main topics to be covered include

- Grid codes and compliance assessment for customers with power electronic based sources and loads
- Harmonics measurement techniques and suitability of voltage and current transducers
- Power quality data analytics with special focus on large data amounts
- Harmonic modeling, analysis and measurement of photovoltaic inverters and electric vehicle chargers in low-voltage distribution networks
- Practical implementation issues for harmonic grid simulations in frequency domain

Prerequisites: Prior knowledge of power electronics fundamentals, digital signal processing, and power systems is preferred.

Form of evaluation: Mini-project and report

Link: http://www.et.aau.dk/phd/phd-courses/
Maritime Microgrids

Organizer: Professor Josep M. Guerrero - Aalborg University, Associate Professor Juan C. Vasquez - Aalborg University

Lecturers: Professor Josep M. Guerrero - Aalborg University, Professor Tomasz Tarasiuk - Gdynia Maritime University, Poland, Assistant Professor Giorgio Sulligoi - Triste university, Italy

ECTS: 2

Date/Time: 2 – 3 May 2019

Max no. of participants: 25

Description: Nowadays, an important kind of islanded microgrids can be found in maritime power systems. For example, under normal operating conditions, the ship power system can be considered as a typical isolated microgrid and its characteristics, including variable frequency, are matched to terrestrial islanded microgrids. This course provides an overview of the present and future architectures of such microgrids, associated control technologies, optimization methods, power quality issues and state of the art solutions. The significant role of power electronics in realizing maritime microgrids, challenges in meeting high power requirements and regulations in the maritime industry, state-of-the-art power electronic technologies and future trend towards the use of medium voltage power converters in maritime microgrids are also presented in this course.

Prerequisites: Matlab/Simulink knowledge is recommended for the exercises.

Form of evaluation: The participants will be grouped and asked to team work on several case study scenarios and tasks proposed along the course. The assessment in this course will be done through a final multi-choice test in combination with delivery of exercises reports

Link: http://www.et.aau.dk/phd/phd-courses/
Model Predictive Control of Power Electronic Converters

Organizer: Associate Professor Tomislav Dragičević – Aalborg University

Lecturers: Associate Professor Tomislav Dragičević - Aalborg University,
Associate Professor Ulrik Nyman Aalborg University, Assistant Professor Yongheng Yang - Aalborg University

ECTS: 3

Date/Time: 29 – 31 January 2019

Max no. of participants: 30

Description: Model Predictive Control (MPC) is a conceptually simple yet powerful methodology to control power converters and electric drives. It has many advantages over traditional linear controllers including (i) faster response, (ii) high robustness to parameter variation (iii) explicit multivariable control accounting for the process and actuator constraints. The advances in processing power of digital signal processors have recently promoted MPC into the first commercial applications, which opened a door towards improved performance and efficiency of power electronic converters and drives demanded by the evolving industry applications. This course aims to provide the fundamentals required to understand, design and implement MPC to power electronic converters used for a variety of applications including grid-connected converters, drives and microgrids. The motivation is to facilitate wider and faster exploitation of MPC by bridging the gap between theory and successful industrial implementation through cooperation and exchange of experience between academic/research and industrial communities. It is envisioned for both PhD students and practicing engineers.

Some of the course contents are based on recently obtained research results. The main topics are as follows:

1. Introduction to Model Predictive Control (MPC) for Power Electronic Systems and Drives
2. Power Converter Modelling Fundamentals and Discretization
3. Finite-Control-Set Model Predictive Control (FCS-MPC) Principle
4. Periodic and Dead-Beat Control Principles
5. Quantitative Performance Evaluation of the FCS-MPC
6. Application Example: FCS-MPC in 2-level, 3 phase Voltage Source Converter for AC microgrids

Laboratory Exercises (Simulation + Laboratory Demonstration)

Prerequisites: General knowledge in electrical AC circuits and electrical power engineering, preferably background at the graduate level in power electronics. Matlab/Simulink knowledge is recommended for the exercises.

Form of evaluation: Individual evaluation of the course participant will be performed on a basis of:
- Attendance rate (5%)
- Mini-project (95%)

Course lecturers will design three mini-projects for the Ph.D. course. Each student will be assigned with or select a specific mini-project within the lectured topics, where the students should model the system, design the controllers, and perform simulations. Students are required to finalize the mini-projects within three weeks after the course by submitting a formal technical report with simulation results, which will be assessed by the lecturers in two weeks.

Link: [http://www.et.aau.dk/phd/phd-courses/](http://www.et.aau.dk/phd/phd-courses/)
Modeling and Control of Voltage Source Converters and AC Drives

Organizer: Associate Professor Xiongfei Wang, Aalborg University, Denmark

Lecturers: Associate Professor Xiongfei Wang, Aalborg University, Denmark, Lennart Harnefors, ABB Corporate Research/KTH Royal Institute of Technology, Sweden

ECTS: 4

Date/Time: 20 – 23 May 2019

Max no. of participants: 45

Description:

Voltage Source Converters (VSCs) have commonly been found in renewable power generations, flexible ac and dc power transmission systems, and energy-efficient drives. The dynamic modeling and control of VSCs are thus critical for stably operating those VSC-based systems. This course devotes to cover the fundamentals and state-of-the-art of the small-signal modeling, stability analysis and controller design for VSCs in both power grid applications and variable speed drives. The main topics include

- Small-signal models of VSCs
- Fundamentals of vector control and current control of VSCs
- Stability of current control with L-/LCL-filtered VSCs
- Stability impact of grid synchronization and direct voltage control
- Dynamic models of induction motors and permanent-magnet synchronous motors
- Fundamentals of sensor-less control of ac drives
- Active stabilizing techniques for VSC-fed systems

Prerequisites:

Prior knowledge of power electronics fundamentals, feedback control theory, electrical machines, and three-phase systems is preferred.

Form of evaluation:

The participants will work, either individually or in a group of 2 persons, on the exercise designed on the basis of lectures given each day, and then submit a report from the exercises for evaluation. The exercises will be done in MATLAB/SIMULINK with PLECS Blockset.

Link: http://www.et.aau.dk/phd/phd-courses/
Modelling and Optimization of Thermal Systems

Organizer: Associate Professor Mads Pagh Nielsen – Aalborg University

Lecturers: Associate Professor Mads Pagh Nielsen – Aalborg University, Assistant Professor Thomas Helmer Pedersen – Aalborg University

ECTS: 2

Date/Time: 3 – 4 June 2018

Max no. of participants: 30

Description: The focus of this course will be the modelling and optimization of thermal energy systems including:

- Methods for modelling of thermal and calorimetric properties
- Formulation and solution of thermal system models considering partial load
- Parametric optimization of thermal systems
- Topology optimization of thermal systems (for instance the optimization of heat exchanger networks)

Examples will be given mainly in the Energy Technology area in terms of journals – but most of it has a generic structure in terms of peer review process.

Prerequisites:
A general background with a M.Sc. in mechanical engineering with a thermal system or thermos-fluid background or a background with a M.Sc. within chemical process engineering.

Form of evaluation:
Written evaluation. The participants have to hand in the solution to a minor assignment and will be evaluated passed-not passed based on this.

Link: http://www.et.aau.dk/phd/phd-courses/
Models, Methods and Optimization Tools for Energy Systems

Organizer: Associate Professor Juan C. Vasquez – Aalborg University, Postdoc Emilio Palacios – Aalborg University

Lecturers: Associate Professor Moises Graells - Technical University of Catalonia, Spain, Associate Professor Eleonora Riva Sanseverino, University of Palermo, Italy, Postdoc Amjad Anvari-Moghaddam – Aalborg University, Postdoc Emilio Palacios – Aalborg University

ECTS: 3

Date/Time: 15 – 17 April 2019

Max no. of participants: 25

Description: Energy is a resource that needs to be managed and decisions need to be made on production, storage, distribution and consumption of energy. Determining how much to produce, where and when, and assigning resources to needs in the most efficient way is a problem that has been addressed in several fields. There are available tools that can be used to formulate and solve these kinds of problems. Using them in planning, operation and control of energy systems requires starting with the basics of math programming techniques, addressing some standard optimization problems, and adapting the solutions to new particular situations of interest.

A first issue is revisiting the modelling concept. The model is a simplified and limited representation of our reality. Complex multi-level problems may need different models and models valid at the operational level (operation and control) may not be useful at the tactical or strategic levels (scheduling and planning). Thus, when addressing optimization problems, detailed physical models based on differential equations will be replaced by algebraic equations expressing the basic relations between lumped parameters. The second issue is the choice of a problem-solving method. It is well known that all optimization methods have at least some limitations and there is no single method or algorithm that works best on all or even a broad class of problems. In order to choose the best method for a given problem, one must first understand the nature of the problem and the type of design space that is being searched.

Students attending this course will learn how to recognise and formulate different optimization problems in planning, operation and control of energy systems, and how to solve them using existing software and solvers such as MATLAB, GAMS, and Excel. Different principal algorithms for linear, network, discrete, nonlinear and dynamic optimization are introduced and related methodologies together with underlying mathematical structures are described accordingly. Several illustrative examples and optimization problems, ranging from the classical optimization problems to the recent MINLP models proposed for the optimization of integrated energy systems (such as residential AC/DC microgrids) will be introduced during supervised hand-on sessions and different tools (such as classic mathematical methods, heuristics and meta-heuristics) will be used for solving the cases. The choice of objective functions, representation of discrete decisions, using formulation tricks and checking the results will be also covered.

The course is intended for those students that, having a general knowledge in mathematics and simulation, have a very limited experience in math optimization and programming, and need to be introduced to these tools for energy systems optimization.

Form of evaluation: The participants will be grouped and asked to team work on several case study scenarios and tasks proposed along the course. The assessment in this course will be done through a final multi-choice test in combination with delivery of exercises reports

Prerequisites Familiarity with basics of real analysis, linear algebra, and probability and statistics.

Link: http://www.et.aau.dk/phd/phd-courses/
Modern IGBT gate driving methods for Enhancing Reliability of Power Converters

Organizer: Professor Francesco Iannuzzo – Aalborg University
Lecturers: Professor Francesco Iannuzzo – Aalborg University
ECTS: 2
Date/Time: 9 – 10 September 2019
Max no. of participants: 30

Description: After almost three decades of development, Insulated Gate Bipolar Transistors (IGBTs) are widely used in many high-power industrial applications. The reliability issues have been studied by employing solutions in active and passive components, mechanical structures, packaging designs and control strategies. Meanwhile, the complex and harsh working conditions are demanding for higher reliability of the power conversion systems. Along with the development of IGBT modules, gate drivers have been improved dramatically over the years, significantly contributing to reliability improvement. In fact, as an important interface between IGBT modules and controllers, modern gate drivers do not only can provide optimal switching signals, but also monitor the operation status of IGBT modules themselves. In particular, benefiting from the understanding of semiconductor behavior matured over the years, both wear status and abnormal events can be monitored and detected, respectively, thanks to modern IGBT gate driver technologies. This course has presented an overview of state-of-the-art advanced gate driver techniques for enhancing reliability of IGBT modules. Broadly speaking, methods can be classified in detection methods, optimization methods and protection methods.

The course will cover the following lectures:

L1: Basic IGBT gate driving concepts
   (a) Voltage-source gate drivers
   (b) Current-source gate drivers
   (c) Optimization and protection principles
L2: Fault detection and protection methods
   (a) Voltage and current overshoot
   (b) Overload and short circuit
   (c) Gate voltage limitation
L3: Active gating methods for enhancing switching characteristics
   (a) Closed-loop control methodology
   (b) Closed-loop control implementations
L4: Active thermal control methods using IGBT gate driver
   (a) Principles for thermal mitigation method
   (b) Thermal mitigation methods
   (c) Junction temperature estimation methods
**Prerequisites:** Basic knowledge of power device and power converter operation

**Form of evaluation:** The participants will be grouped in teams of 4-5 people and asked to design an original gate driver for a given application. Students will be asked to give a presentation at the end of the course, with a final evaluation of the contribution.

Link: [http://www.et.aau.dk/phd/phd-courses/](http://www.et.aau.dk/phd/phd-courses/)
Modular Multilevel Converters (MMC)

Organizer: Professor Remus Teodorescu - Aalborg University

Lecturers: Professor Remus Teodorescu - Aalborg University, Associate Professor Sanjay Chaudhary - Aalborg University,

ECTS: 4

Date/Time: 25 – 28 November 2019

Max no. of participants: 30

Description:


The course structure is:

Day 1: MMC fundamentals, topologies, modelling and design
Day 2: Carrier-based and carrier-less modulation and balancing techniques
Day 3: Control
Day 4: Applications of MMC (HVDC, STATCOM)

Around 40% of the time will be spent in exercises using PLECS and Simulink models. A demonstration of several MMC applications will be organized in the state of the art MMC Laboratory.

Prerequisites: Power Electronics, Matlab/Simulink or PLECS

Form of evaluation: The participants will have to submit a report of the simulation exercises via Moodle as a part of the course. The key observations should be described. The results obtained from the simulation should be used to answer the specific questions. A minimum of 50% correctness level is necessary in the for assessing ‘Passed’ or ‘Not Passed’ and award of diploma.
**Multiphysics Simulation and Design of Power Electronics**

**Organizer:** Assistant Professor Amir Sajjad Bahman – Aalborg University

**Lecturers:** Assistant Professor Amir Sajjad Bahman - Aalborg University, Lecturers from ANSYS

**ECTS:** 3

**Date/time:** 4 – 6 December 2019, all days 8:30 – 16:30

**Max no. of participants:** 30

**Description:**
Simulation of power electronic components and systems is key to achieve the Design for Reliability (DfR) approach. Besides, multi-domain, multi-physics and multi-objective optimization tools are required for future integrated power electronics. This industrial/PhD course will equip attendees with the theory, fundamentals and advanced multiphysics simulation and modeling techniques required to effectively design power electronics systems and components. When selecting a new power electronics component, the design engineer must consider thermal management, EMC/EMI, magnetics, mechanics and manufacturability. Although power electronics designers often concentrate on only one critical issue at a time, e.g. thermal management, in a DfR approach, the trend is to take into account multiphysics aspects.

The course targets the design of a 10 kW voltage-source converter by applying the problem based-learning (PBL) teaching method and presents a step-by-step training on design development of power electronics converter and components using multiphysics tools including ANSYS Workbench, Simplorer, Maxwell, Q3D Extractor, Icepak, Mechanical, and DesignXplorer to design power electronics from component level – e.g. power module, heatsink and fuse – to system level – e.g. circuit parasitics. It is expected that some lectures to be given by ANSYS simulation experts. The course contents are based on the latest research outcomes of the Center of Reliable Power Electronics (CORPE). Following the PBL model that focuses on learning by doing and reflection, the course activities will include group work, problem defining and solving applied to real-world case studies, practical exercises, and discussion sessions.

The course is organized in three consecutive days of full-time activities (08:30-16:30). Attendees armed with the knowledge gained from this course will be able to apply advanced simulation tools to streamline and shorten the design cycle, improve the reliability and deliver high quality products.

The course will cover the following lectures:

**Day1:** Circuit level multiphysics simulation and design of power electronics

**Day2:** Component to System levels multiphysics simulation and design of power electronics

**Day3:** Hands-on exercises and discussion

**Prerequisite:** Basic understanding of power electronics circuits and components.
Form of evaluation: Fulfilment of design a simple voltage-source converter based on multiphysics simulation platform. A 30-day trial license of required software will be provided prior to the course. The exercise will be done in group of 2-3 members and final report must be submitted by each group.

Agenda:

Day 1

08:30-10:00 Introduction (Multiphysics Simulation by Design – Trends and Technology Advancements)
10:00-10:30 break
10:30-12:00 System simulation: Simplorer
12:00-13:00 lunch
13:00-14:30 Component Simulation – From FEA (Maxwell) to System (Simplorer)
14:30-15:00 break
15:00-16:30 EMI/EMC – Parasitics (Maxwell&Q3D) to System (Simplorer)

Day 2

08:30-10:00 Thermal Management for Power Electronics – Icepak 1
10:00-10:30 break
10:30-12:00 Thermal Management for Power Electronics – Icepak 2
12:00-13:00 lunch
13:00-14:30 Structural Integrity – Noise-Vibration, Reliability, Thermal-Stress
14:30-15:00 break
15:00-16:30 Robust Design – Parametric Study, Manufacturing tolerances

Day 3

Full day: Workshop and assignment
New Energy technology based Integrated Energy Systems

Organizer:    Professor Zhe Chen - Aalborg University

Lecturers:    Professor Zhe Chen - Aalborg University, Professor Mauro Cappelli - University of L'Aquila, Italy

ECTS:        3

Date/Time:    11 – 13 February 2019

Max no. of participants:  30

Description:
The course will provide training and education on the subject of new energy technology based integrated energy systems.

The Ph.D. course will include fundamental knowledge of energy sources, energy conversion systems, new energy technologies, energy system integration, transmission, and distribution. Basic techniques of analysis, operation and control will be presented. Some contents are based on up-to-date research results.

The main topics are as follows:

- Overview of modern energy resources and systems
- Basics of energy conversion systems
- Renewable energy technologies
- Basics of nuclear energy systems
- Instrumentation and Control (I&C) Systems for Nuclear Applications
- Advanced technologies and emerging facilities for energy system integration
- Optimization techniques applied in integrated energy systems

Prerequisites: General knowledge in electrical AC circuits and electrical power engineering, preferably background at the graduate level in power systems. Exercises involve Matlab.

Form of evaluation: The mini-project using MatLab and the corresponding technical report will be submitted to the lectures for evaluation after the course. Minimum requirements include the clear interpretation of the models, simulation cases and results. Plagiarism is not allowed. Similar reports will be failed. Further details will be announced during the course.

Link: http://www.et.aau.dk/phd/phd-courses/
Photovoltaic Power Systems - in theory and practice

Organizer:  Associate Professor Dezso Sera - Aalborg University

Lecturers:  Professor Remus Teodorescu - Aalborg University, Associate Professor Dezso Sera - Aalborg University, Associate Professor Tamas Kerekes - Aalborg University, Assistant Professor Sergiu Spataru, Aalborg University, Laszlo Mathe, Robert Bosch GmbH, HU, Rasmus Rode Mosbaek (Lithium Balance A/S, DK)

ECTS:  4

Date/Time:  15 - 18 October 2019, 08:30-16:30

Max no. of participants: 25

Description:
The objective of this course is to give an understanding of the operation, design and control of Photovoltaic Power Systems, and to provide insight into some of the key challenges for higher penetration of photovoltaic energy into the electricity network.
The target audience is PhD students and practicing engineers but also researchers who aim to receive a comprehensive overview of modern photovoltaic systems.
The course is structured in four days, covering topics from PV panels through power electronics and their control to PV plant design and grid integration challenges. An industrial guest lecture on Battery Energy Storage Systems for photovoltaic applications will be included. The mornings are dedicated to lectures, while the afternoons are spent with exercises.
No less than 40% of the course time is spent in the state-of-the-art Photovoltaic Systems laboratory at the Department of Energy Technology, Aalborg University. The participants will make design, simulations and experimental tests, using the following advanced setups:

- Grid-connected PV inverter systems, with real-time control using dSpace® platform. The participants will be able to design, experimentally test, and tune parameters of grid controllers, PLL, voltage support, using the real-time graphical user interface Control Desk®
- Real-time simulation platform on dSpace® system, to design and analyse PLL MPPT
- High performance Spi-Sun 5600 SLP Solar simulator from Spire. Demonstration of PV panel measurements and characterisations will be provided
- Detailed Simulink®, PLECS® and Matlab® GUI models for designing and analysing PV inverter topologies, grid synchronisation and PV array modelling
- PVSty Software platform for designing PV plants.

*Selected simulation models will be included in the course material for the participants.*
**Prerequisites:**
A degree in electrical engineering or control engineering and Matlab/Simulink knowledge is strongly recommended. The course language is English.

**Form of evaluation:**
The evaluation is assignment based. Every day the afternoon session is dedicated to laboratory sessions, where the course participants will complete exercises based on the lectures from the morning session. A report from each laboratory exercise is to be submitted (uploaded to Moodle). Passing the course requires completion of all lab exercises, as well as positive assessment of the uploaded lab reports.

Link 1: [http://www.et.aau.dk/research-programmes/photovoltaic-systems/phd-courses/](http://www.et.aau.dk/research-programmes/photovoltaic-systems/phd-courses/)
Link 2: [http://www.et.aau.dk/phd/phd-courses/](http://www.et.aau.dk/phd/phd-courses/)
Power module design, packaging and testing

**Organizer:**  Associate Professor Christian Uhrenfeldt – Aalborg University

**Lecturers:**  Associate Professor Christian Uhrenfeldt, Associate Professor Szymon Beczkowski - Aalborg University, Professor Stig Munk Nielsen - Aalborg University

**ECTS:**  3

**Date/Time:**  8 – 10 April 2019

**Max no. of participants:**  30

**Description:**  Power modules are the work-horses in car, wind, solar and drives applications. Power modules may be destroyed instantaneously however in applications lifetimes are expected to be 20 years. Strong and the same time fragile you need to understand the power modules to design them properly. This course bring you under the skin of power modules and introduces the multidisciplinary knowledge needed to understand packaging assembly processes, materials and layouts as well as failure mechanisms. From the application point of view lifetime monitoring and test methods are introduced.

The course is conducted by physicists and engineers with experience from the university packaging laboratory building fex. 10kV SiC power modules and with experience of analyzing and testing industry standard power modules for higher powers.

The course will contain simulation and experimental exercises.

**Prerequisites:**  Engineers and physicists open for multidisciplinary work. The course is based on the experience and learnings assembly power modules during a some years and therefore the course are intended people who are new to the packaging of power modules. The language will be English and the academic level will be for engineers and physicist the engineers are expected to know application converters and the physicist are expected to know materials and semiconductors.

**Form of evaluation:**

The attendants of the course will have to complete a simulation assignment and hand in a report on the experiments in relation to the simulation results and the topics of the course.

**Link:**  [http://www.et.aau.dk/phd/phd-courses/](http://www.et.aau.dk/phd/phd-courses/)
Power Quality and Synchronization Techniques in Microgrids

Organizer: Professor Josep M. Guerrero – Aalborg University, Associate Professor, Juan C. Vasquez - Aalborg University

Lecturers: Professor Josep M. Guerrero - Aalborg University, Lecturer Alexander Micallef - University of Malta, Assistant Professor Saeed Golestan - Aalborg University.

ECTS: 3

Date/Time: April 29 – May 1 2019

Max no. of participants: 25

Description: Microgrids are deemed as one of the main building blocks of the smart grids; since, are able to facilitate implementation of many smart grid functions. It is expected that in a near future, smart grid emerges as a well-planned plug-and-play integration of microgrids which interact through dedicated highways for exchanging commands, data, and power. Providing a high power quality for the customers is one of the main objectives in smart grids.

On the other hand, the proliferation of different nonlinear and single-phase loads in electrical systems has resulted in voltage harmonic and unbalance as two common power quality problems. In addition, harmonic resonances can be excited giving rise to significant increase of the voltage distortion. These phenomena can cause variety of problems such as protective relays malfunction, overheating of motors and transformers and failure of power factor correction capacitors.

In this course, measurement, compensation and damping of such power quality problems will be addressed through several control approaches. Both three-phase and single-phase voltage source inverters will be considered. The modelling and control of these power electronic converters are discussed and hierarchical and decentralized control approaches are presented in order to enhance the voltage quality. Several simulation exercises will be included in labs which cover about 50% of the course time.

Form of evaluation: The participants will be grouped and asked to team work on several case study scenarios and tasks proposed along the course. The assessment in this course will be done through a final multi-choice test in combination with delivery of exercises reports

Prerequisites: Matlab/Simulink knowledge is recommended for the exercises.

Link: http://www.et.aau.dk/phd/phd-courses/
Preparation of Research Plan for Ph.D.'s - Fall

Organizer: Professor Frede Blaabjerg, fbl@et.aau.dk, Aalborg University

Lecturers: Professor Frede Blaabjerg, Aalborg University
           Associate Professor Chungen Yin, Aalborg University

ECTS: 1

Date/Time: 1 October 2019 (Fall)

Max no. of participants: 25

Description: The objective of this one-day PhD course is to provide a presentation on how to make a good study plan. A PhD study plan typically consists of the following sections: (1) project summary; (2) scientific content of the PhD project, including background, state-of-the-art literature review, objectives, key methods, expected outcome, time schedule and milestone, outline and structure of the PhD thesis, publication strategy and tentative titles of papers; (3) collaboration agreement between supervisor and student; (4) plan for PhD courses; (5) plan for fulfillment of knowledge dissemination; (6) agreements on immaterial rights to patents; (7) plan for external collaboration; (8) financial budget for the project; and (9) reference list.

As a relatively new PhD student, it is hardly possible to give a full and clear description of what you will do and how you will do in the coming three years. You may only have some vague ideas about your project. This course will help you to settle these problems as quickly and as well as possible via an effective literature study. A literature study is not only a potted summary of who did what. You need to find their similarities/difference, point out their contributions and flaws in methodology or gaps in research, and outline what you can utilize and what you can improve in your project. A good literature study will make your ideas about your project clearer and clearer, based on which you can start to write up your study plan, with well-defined what to do, why to do and how to do.

We will also go around different databases to get the latest impact research in the field by using e.g. Web of Science, Scopus and Google Scholar as well as discuss how to make efficient time-planning

Prerequisites: No

Form of evaluation: 1-page written reflection on how to conduct an effective literature survey/review, familiarize yourself with your PhD project topic, gain in-depth knowledge about what to do and how to do, and then prepare a good study plan with well-defined realistic objectives and the corresponding technical tasks / time schedule / publication plan.

Link: http://www.et.aau.dk/phd/phd-courses/
Preparation of Research Plan for Ph.D.’s - Spring

**Organizer:** Professor Frede Blaabjerg - Aalborg University

**Lecturers:**
- Professor Frede Blaabjerg - Aalborg University
- Associate Professor Chungen Yin - Aalborg University

**ECTS:** 1

**Date/Time:** 1 April 2019 (Spring)

**Max no. of participants:** 25

**Description:** The objective of this one-day PhD course is to provide a presentation on how to make a good study plan. A PhD study plan typically consists of the following sections: (1) project summary; (2) scientific content of the PhD project, including background, state-of-the-art literature review, objectives, key methods, expected outcome, time schedule and milestone, outline and structure of the PhD thesis, publication strategy and tentative titles of papers; (3) collaboration agreement between supervisor and student; (4) plan for PhD courses; (5) plan for fulfillment of knowledge dissemination; (6) agreements on immaterial rights to patents; (7) plan for external collaboration; (8) financial budget for the project; and (9) reference list.

As a relatively new PhD student, it is hardly possible to give a full and clear description of what you will do and how you will do in the coming three years. You may only have some vague ideas about your project. This course will help you to settle these problems as quickly and as well as possible via an effective literature study. A literature study is not only a potted summary of who did what. You need to find their similarities/difference, point out their contributions and flaws in methodology or gaps in research, and outline what you can utilize and what you can improve in your project. A good literature study will make your ideas about your project clearer and clearer, based on which you can start to write up your study plan, with well-defined what to do, why to do and how to do.

We will also go around different databases to get the latest impact research in the field by using e.g. Web of Science, Scopus and Google Scholar as well as discuss how to make efficient time-planning

**Prerequisites:** No

**Form of evaluation:** 1-page written reflection on how to conduct an effective literature survey/review, familiarize yourself with your PhD project topic, gain in-depth knowledge about what to do and how to do, and then prepare a good study plan with well-defined realistic objectives and the corresponding technical tasks / time schedule / publication plan.

**Link:** [http://www.et.aau.dk/phd/phd-courses/](http://www.et.aau.dk/phd/phd-courses/)
Reliability Assessment in Electric Power Systems

Organizer: Professor Frede Blaabjerg - Aalborg University, Postdoc Saeed Peyghami - Aalborg University

Lecturers: Professor Mahmoud Fotuhi-Firuzabad - Department of Electrical Engineering, Sharif University of Technology

ECTS: 4

Date/Time: 11 – 14 March

Max no. of participants: 30

Description:
Electric power utilities are facing new challenges and problems in the changing utility environment. The course is aimed at providing an in depth introduction to the range of probabilistic aspects used in the assessment of electric power system reliability. The basic principles of reliability evaluation along with their application, current practices and solution methods in generation, transmission and distribution systems will be discussed.

Benefits of Participants:
- Understanding the fundamental of system reliability engineering
- Understanding the concepts of power system reliability
- Exposure to probabilistic technique applications to power system problems
- Exposure to reliability cost/worth problem and investigating the tradeoff between reliability and economics

Intended Audience:
- Utility personnel involved in system operation, planning and related activities
- Power engineers, graduate students and researchers in utilities and universities

The course will mainly cover the following aspects:
1. Fundamental concepts of reliability Engineering
2. System components and their outage models
3. Techniques used in engineering system risk assessment
4. Basic concepts of adequacy and security in electric power systems
5. Generating capacity reliability assessment
6. Composite generation and transmission system reliability evaluation
7. Application of risk evaluation in transmission developing planning, transmission operation planning, and generation source planning
8. Distribution system reliability evaluation
9. Substation and switching station reliability
10. Reliability cost/worth analysis
11. Reliability data requirements for predictive and performance assessment

Prerequisites:
Pre-reading the shared materials

Form of evaluation:
The participants will be evaluated by exercises on the reliability of power systems.

Biography of the lecturer:

M. Fotuhi-Firuzabad (IEEE Fellow, 2014) Obtained B.Sc. and M.Sc. Degrees in Electrical Engineering from Sharif University of Technology and Tehran University in 1986 and 1989 respectively and M.Sc. and Ph.D. Degrees in Electrical Engineering from the University of Saskatchewan, Canada, in 1993 and 1997 respectively. He is a professor of Electrical Engineering Department, Sharif University of Technology, Tehran, Iran. He is a member of center of excellence in power system control and management in the same department. His research interests include power system reliability, distributed renewable generation, demand response and smart grids. He is the recipient of several national and international awards including PMAPS International Society Merit Award for contributions of probabilistic methods applied to power Systems in 2016. Dr. Fotuhi-Firuzabad is a visiting professor at Aalto University. He serves as the Editor-In-Chief of the IEEE POWER ENGINEERING LETTERS and also Editor of Journal of Modern Power Systems and Clean Energy.

Link: http://www.et.aau.dk/phd/phd-courses/
Reliability in Power Electronics Systems

Organizer: Associate Professor Huai Wang – Aalborg University, Professor Francesco Iannuzzo – Aalborg University

Lecturers: Professor Frede Blaabjerg - Aalborg University, Associate Professor Huai Wang - Aalborg University, Professor Francesco Iannuzzo - Aalborg University, Reliability Advisor Peter de Place Rimmen – Danfoss A/S

ECTS: 3

Date/Time: 11 – 13 September 2019

Max no. of participants: 30

Description:

The course will be the latest research outcomes of the Center of Reliable Power Electronics (CORPE). The 2019 version of the course will focus on failure mechanisms and degradation models of active power devices and capacitors, system-level reliability assessment and design tools, and reliability testing methods. The course will have the following five main parts:

1) Introduction to modern reliability and robustness approach
2) Reliability testing methods and testing data analysis (e.g., Weibull)
3) Long-term wear out and single-event abnormal operation of active power modules and capacitors
4) Power electronics system-level reliability assessment and design tools
5) Condition monitoring and thermal control of critical power electronic components

Prerequisites:

Basic understanding of power electronics, power semiconductor devices, capacitors, and basic statistics.

Form of evaluation:

Case study exercise and report submission

Link: http://www.et.aau.dk/phd/phd-courses/
Reluctance electric motor drives for high efficiency in line start and variable speed applications

Organizer: Professor Frede Blaabjerg - Aalborg University

Lecturers: Professor Ion Boldea, IEEE Fellow, DL, Romania

ECTS: 2.5

Date/Time: 11 – 13 November 2019

Max no. of participants: 30

Description: The need for higher efficiency motors at reasonable initial costs for line start and for variable speed applications is growing by the day. The high cost of high energy PMs has prompted vigorous R&D in Academia and Industry worldwide in “Reluctance electric machines which use less high energy PMs (per Nm), or low cost Ferrite- PMs for still higher efficiency than in IMs, for competitive torque/volume and at reasonable costs”. Recently, reluctance Synchronous Motor (RSM) variable speed drive reached wide markets from 10 to 500 (even 1500) Kw power in 4 pole multiple flux barrier cageless rotors, with distributed stator windings; the same is true for line start 3 and 1 phase cagerotor reluctance PM line start small motors in home appliances. The present Course presents the Status and Trends in Reluctance electric machine drives (REMDs), for line start and variable speed as follows:

Principles, classifications, merits and demerits of:
- Reluctance synchronous motor drives with cageless an cage rotors without and with PMs
- 3- and 1-phase line start Reluctance Synchronous motors without and with PMs for high efficiency, mainly in small power applications; modeling and design with sample simulation and test results
- 3-Phase Reluctance synchronous motor variable speed drives : modeling, optimal design and control: with case studies
- Ferrite- PM- claw- pole- rotor Synchronous Motor drives design and control with sample results of high torque density and high efficiency
- BLDC-MRM (multiphase reluctance motor) drives design and control with case study and experimental results of 4/1 CPSR
- Brushless Doubly Fed Reluctance machine (B-DFRM) drive: design and control for wind energy
- Switching- Flux (double saliency) machine drives with PMs and (or) dc stator excitation for wide CPSR; modeling and control with illustrative implementation examples
- Vernier PM machine drives with higher power factor and high torque density and reasonable efficiency and cost in low speed high torque applications: with case study
- Transverse –Flux machine drives with stator or rotor PMs and without PMs for high torque density, high efficiency at moderate power factor and initial costs in low speed applications
- Flux Reversal machine drives with double saliency, stator or rotor PMs and 6(12) stator non-overlapping multi-polespan ac coils for 3 phase implementation ;with sample results
- Dual Rotor Flux-Modulation machine drives with rotor and or stator PMs and magnetic gear (torque magnification) effects for very low speed high torque direct (pseudo-direct) drives; with sample representative results
**Prerequisites:** Basic theory about machine drives and MATLAB/Simulink.

**Form of evaluation:** Quiz in class (90%) and attendance rate (10%)

Link: [http://www.et.aau.dk/phd/phd-courses/](http://www.et.aau.dk/phd/phd-courses/)
Smart Distribution Systems

Organizer: Professor Birgitte Bak-Jensen, email: bbj@et.aau.dk, Aalborg University

Lecturers: Professor Birgitte Bak-Jensen, Aalborg University, Associate Professor Jayakrishnan Pillai, Aalborg University, Associate Professor Florin Iov, Aalborg University, Associate Professor Rasmus Løvenstein Olsen, Department of Electronic Systems, Aalborg University, Associate Professor Weihao Hu, Aalborg University

ECTS: 3

Date/Time: 24 - 27 September 2019

Max no. of participants: 20

Description: The Smart Grid concept involves integration of information and communication technology from the electricity generation to the consumption sectors. The bulk of the smart grid applications take place in the distribution grids (MV and LV) where significant amounts of renewable generation and flexible demand units are integrated, distribution controls are automated, assets are monitored and proactively managed and consumers are empowered for economic and efficient use of electricity. This course covers important applications and technologies of the smart distribution systems. The technical limitations and means of increasing the hosting capacity of distributed energy resources in intelligent grids are covered. In addition, the course also includes utility practices and guidelines, dynamics of electricity market, communication technologies and case studies relevant to future power distribution systems.

Following topics are covered in the course:

- Modern Distribution Systems.
- Smart grid fundamentals and concepts.
- Market aspects and demand side management in Smart Distribution Systems.
- Grid codes/standards - LV/MV Distribution systems and operation.
- Operation, control and reliability of DER units in the distribution grids.
- Electric vehicles, Heat pumps, Electric boilers, Solar PVs in distribution grids.
- Communication technologies and standards in Smart Distribution grids.
- Simulation tools for distribution systems, examples with DigSilent.

Prerequisites: Electrical engineers and PhD students with knowledge about electrical power and energy systems.

Form of evaluation: Written examination

Link: [http://www.et.aau.dk/phd/phd-courses/](http://www.et.aau.dk/phd/phd-courses/)
Stability and Control of Grid-Forming Power Electronics Systems

Organizer: Associate Professor Xiongfei Wang – Aalborg University

Lecturers: Assistant Professor Dongsheng Yang – Aalborg University, Associate Professor Xiongfei Wang – Aalborg University, Pedro Rodriguez, Loyola University Andalusia, Spain

ECTS: 3

Date: 2 – 4 April 2019

Max no. of participants: 30

Description:
Due to the rapid expansion of the renewable power generations, more unpredictable power is injected into the power grids through power electronics converters, which poses a great challenge to the safe operation of the modern power systems. Grid-connected converters are increasingly required to operate as grid-forming units for regulating the system voltage and frequency. The virtual synchronous machine technique makes converters mimic the self-synchronizing mechanism and the inertial response of synchronous machines, which provides a promising way to stabilize future power-electronic-based power systems. This course provides a systematic discussion on the fundamentals and state-of-art of grid-forming power electronics systems in transmission and distribution systems. The main topics include

- Basics of grid-forming power electronics systems
- Virtual synchronous machine control
- Inertia emulation and coordination with energy storage
- Fault ride-through and fault-current limitation
- Small-signal modeling and stability analysis
- Design-oriented transient stability analysis
- Active damping of power oscillations

Prerequisites: Prior knowledge of power electronics fundamentals, feedback control theory, synchronous machines, and three-phase systems is preferred.

Form of evaluation: Mini-project and report

Link: http://www.et.aau.dk/phd/phd-courses/
Stability of Modern Power Systems with High Penetration of Renewable Energy

Organizer: Sanjay K Chaudhary

Lecturers: Jayakrishnan Radhakrishna Pillai (jrp@et.aau.dk), and Sanjay K. Chaudhary (skc@et.aau.dk)

ECTS: 3

Time: 16-18 Sep 2019

Max. no. of participants: 15

Description:

This course deals with the stability of modern power systems with a high penetration of renewable energy sources.

Power system is undergoing tremendous transformation as non-conventional renewable energy sources like wind and photovoltaic are introduced. While such renewable sources are very good for the sustainable harnessing of energy, they are altering the way power system was designed to operate. First of all they are inherently stochastic in nature due to their dependence upon local weather conditions and secondly they do not use the conventional large synchronous generators. Their power electronic converter interface decouples them from the grid frequency interaction with respect to inertial response and synchronizing power. Moreover, their dependency upon weather may lead to wide variations in power generation capability. At the same time, they might not contribute to the grid frequency stability; especially if they are on maximum power point tracking control. In the event of faults, they have limited power to contribute to the short circuit currents.

On the positive side, the advances in power electronic converter controls, imparts them fast controllability. So they can be controlled to inject reactive current and assist voltage voltage stability. They may also be controlled to provide emulated inertia and primary frequency regulation provided that they have some energy storage.

Key topics include:

- Review of concepts of power system stability
- Frequency and voltage stability with a high penetration of wind and PV power
- Control opportunities and limitations provided by the converter control in RES.
- The concepts would be demonstrated through the appropriate simulation tools like PSCAD and/or DigSILENT.

Prerequisites: A basic knowledge of modern power system.

Form of evaluation: The participants will have to write a report of the simulation exercises as a part of the course. Submission of this report via moodle is mandatory for the assessment and award of diploma.
Storage Systems based on Li-ion Batteries for Grid Support and Automotive Applications

Organizer: Associate Professor Daniel Stroe - Aalborg University
Lecturers: Professor Remus Teodorescu - Aalborg University
Associate Professor Daniel Stroe - Aalborg University
Associate Professor Erik Schaltz - Aalborg University, Dr. Vaclav Knap – Aalborg University, Dr. Maciej Swierczynski – Lithium Balance
ECTS: 4
Date/Time: 22 - 25 October 2019
Max no. of participants: 30

Description: The importance of the Li-ion batteries is booming and after dominating portable electronics applications, they are entering into sectors like grid support, residential and electro mobility applications. The penetration of renewables in the power system is considered to significantly increase in near future; thus, batteries can play a crucial role in the reliable and cost efficient grid-integration of intermittent energy sources. Besides, the grid support applications, Li-ion batteries have begun to play a major role in the automotive market. The use of batteries in automotive applications is a promising option in order to replace the internal combustion engine cars with ideally, zero emissions vehicles (full electric vehicles), or with controlled emission vehicles (hybrid electric vehicles and plug-in hybrid electric vehicles).

The course is divided into 4 days as follows:

DAY1: (Battery technologies and grid applications)
During that first day, state of the art on the energy storage technologies and power converter solutions will be provided with a special focus on the Li-ion batteries. Moreover, the services that the energy storage can provide for grid and residential applications will be discussed. This will be followed by a lecture on operating principles of Li-ion batteries and review of different Li-ion battery technologies. The day will be finished by Matlab exercise on the sizing of storage in different stationary applications.

DAY2: (Modeling of Li-ion batteries)
The second day focuses on Li-ion battery performance testing and modeling. The day starts with an introduction to battery testing and characterization methods. Later, details of Li-ion battery electrical and thermal modeling will be presented. Finally, simulation studies in Matlab will be performed, where course participants will develop their own performance model of the Li-ion battery.

DAY3: (Lifetime of Li-ion batteries)
The third day is dedicated to the ageing, performance degradation and lifetime estimation of Li-ion batteries. Ageing phenomena accelerated lifetime testing and lifetime modeling of Li-ion batteries will be covered. Moreover, methods of online battery state estimation, diagnostics and prognostics will be covered. The day will be closed by an industrial lecturer presentation.

DAY4: (Automotive applications)
The last day is devoted to automotive applications. Li-ion technologies for automotive applications will be discussed. Aspects related to Li-ion battery management systems for vehicles will be covered. Moreover, sizing and control of battery powered vehicles will be addressed. The fourth day will be finished with the exercise on Li-ion battery powered vehicle.

Prerequisites: Basic experience in Matlab/Simulink
Form of evaluation: Students are expected to solve a number of exercises and deliver an individual report with solutions and comments.
Sustainable Biomass Resources and Technology Pathways for Biogas and Biorefineries (AAU - Esbjerg)

Organizer: Associate Professor Jens Bo Holm-Nielsen - Aalborg University and Associate Professor Mette Hedegaard Thomsen - Aalborg University

Lecturers: Associate Professors Jens Bo Holm-Nielsen & Mette Hedegaard Thomsen - Aalborg University and Post Doc Tanmay Chaturvedi, ET - AAU

ECTS: 5

Time: 6 – 10 May 2019

Place: Aalborg University, Esbjerg

Max. no. of participants: 30

Description: The course will give an overview of biomass resource studies and mapping; What is sustainable biomass and how to certify; types of biomass (e.g. woody biomass, forest residues, agricultural residues, energy crops and algae etc.); pretreatment technologies & physical and chemical characteristics; biomass conversion technologies; mainly focused on biochemical (anaerobic digestion and fermentation processes) conversion processes; Biorefinery processes into fuels and higher value products; advanced biofuels from biomass; liquid biofuels for transportation; biogas and methanization; value-added processing of biofuel residues; economic and environmental assessments; policies and future R&D.

- The role of biomass resources in the global renewable energy supply.
- Sustainability & biomass mapping.
- Substrate characteristics & pretreatment methods.
- Conversion processes and conversion technologies for liquid and gaseous biofuels.
- Anaerobic digestion and optimized biogas production – incl. Study tour during the course.
- Biorefinery production of advanced biofuels and other medium to high value refinery products.
Tribo dynamics

**Organizer:** Assistant Professor Per Johansen - Aalborg University, Professor Torben Ole Andersen - Aalborg University

**Lecturer:** Assistant Professor Per Johansen - Aalborg University

**ECTS:** 4

**Time/date:** 4 – 7 November 2019

**Description:**

The focus of this course is on the relationship between motion and friction. The motion of surfaces can vary in complexity, from simple steady sliding to movements that are highly variable in time and direction. Tribology is the study of such surfaces in relative motion and the performance of any tribological interface is directly related to friction. Depending on the desired outcome, the optimal friction may be either maximum or minimum. Tribology enables motion, and system designs rely on a proper understanding of the tribodynamics. This course provides the fundamentals of continuum tribodynamics modelling and simulation. In addition, novel non-invasive experimental techniques are introduced.

The topics include

- Fundamentals of friction
- Reynolds lubrication theory
- Elastohydrodynamics
- Thermo-Elastohydrodynamics
- Contact models and rough surfaces
- Multibody systems with imperfect joints
- Computational tribodynamics
- Introduction to ultrasonic reflectometry methods in tribology

**Prerequisites:** Fundamentals of fluid mechanics, thermodynamics, solid mechanics and multibody dynamics

**Form of evaluation:** Mini-project
Understand how to write good papers for high level journals

Organizer: Associate Professor Kaiyuan Lu – Aalborg University

Lecturers: Professor Frede Blaabjerg - Aalborg University, Associate Professor Kaiyuan Lu – Aalborg University

ECTS: 1.5

Date/Time: 6 – 7 May 2019 (ends around 12 the last day)

Max no. of participants: NO

Description: Publication in good journals is a sign of high international recognition of your work. Writing good papers that can be accepted for publication on high level journals are one of the important tasks during a Ph. D. study. This course tries to help the Ph. D. students to increase their chances to get their papers published in international journals. To serve the goal, in this course:

- First, the procedure about how the paper review process is carried out will be explained (starting from the moment you submit your paper to the time that you get the reviewers’ comments and until the final decision).
- How will the paper is reviewed by reviewers.
- Standard evaluation forms that will be filled in by the reviewers for different journals.
- Important aspects to consider when you write your paper. (Paper structure, what to do and what not to do)
- How to include citations to other work in a paper
- How to write the reply to the response from reviewer.
- Several concrete case studies.
- Exercise.

Examples will be given mainly in the Energy Technology area in terms of journals – but most of it has a generic structure in terms of peer review process.

Prerequisites: No

Form of evaluation: Group exercise based evaluation

Link: http://www.et.aau.dk/phd/phd-courses/
Organizer: Professor Zhe Chen - Aalborg University

Lecturers: Professor Vladimir Terzija – The University og Manchester – Great Britain, Assistant Professor Zhou Liu - Aalborg University

ECTS: 3

Date/Time: 23 - 25 January 2019

Max no. of participants: 30

Description:
The course is focused on the application of novel sensor and ICT technology for improvement of power system monitoring, protection and control. It includes the Synchronized Measurement Technology based Wide Area Monitoring, Protection and Control (WAMPAC) system. The main topics are as follows

- Major building blocks of WAMPAC systems
- Off-line and on-line WAMPAC applications
- Methods for testing WAMPAC systems
- Practical WAMPAC applications including the discussions on the opportunities for implementation of WAMPAC systems in Denmark

Some demonstrations and exercises on the application of WAMPC will be given in this course in laboratory. It is expected that the course attendees will be using a MATLAB based software package for demonstration of WMPAC systems capabilities. A Real Time Digital Simulator (RTDS) and LabVIEW/MATLAB based simulation platform will also be used for demonstration.

Prerequisites: knowledge in Power System Analysis, and skill in using MATLAB

Form of evaluation: Students will be given a Coursework. It is MATLAB based and require programming and analytical skills.

Link: http://www.et.aau.dk/phd/phd-courses/