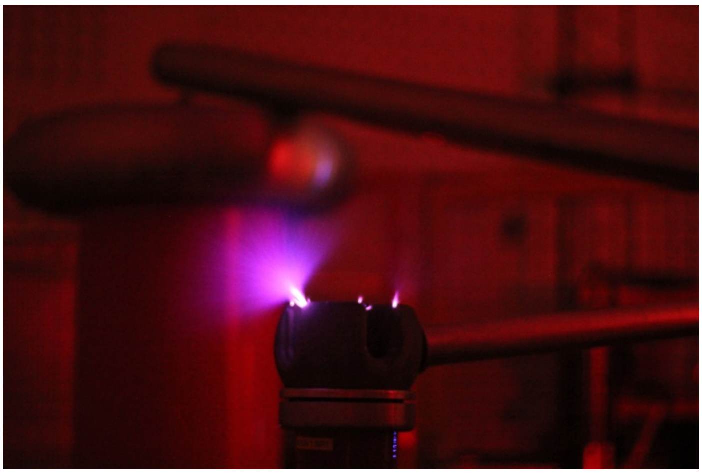
PhD Courses in 2018 at the Department of Energy Technology

Aalborg University

Doctoral School of Engineering and Science

Energy Technology PhD Program



Description of 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 it’s 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 25 new PhD’s each year and has hosted + 100 PhD’s every year for the last several years and is graduating around 25 new energy technology PhD’s every year.

Research areas:

The program belongs to The Doctoral School of Engineering and Science and focuses 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, 99409281

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

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

Courses - incoming for 2018	ECTS	Start	End	Organiser
AC Microgrids	2	18.06.18	19.06.18	Juan C. Vasquez
Advanced Computational Fluid Dynamics	4	27.08.18	30.08.18	Chungen Yin
Advanced FPGA- Based Controllers for Power Electronic and Drive Applications	3	24.04.18	26.04.18	Josep M. Guerrero
An Introduction to HVDC and MTDC Transmission System	3	01.10.18	03.10.18	Sanjay K Chaudhary
Application of Phasor Measurement Units for monitoring of power system And RTDS Technology **NEW**	3	12.11.18	16.11.18	Filipe Faria da Silva
Application-Oriented Modelling of Renewable Energy Sources, Conversion and Energy Storage Systems	4	05.03.18	08.03.18	Sergiu Spataru
Capacitors in Power Electronics Applications	2	22.11.18	23.11.18	Huai Wang
DC Microgrids	2	25.06.18	26.06.18	Juan C. Vasquez
Design Considerations for Robust and Reliable Power Semiconductor Modules **NEW**	2	01.11.18	02.11.18	Paula D Reigosa
Design of Modern Power Semiconductors Components	3	08.10.18	10.10.18	Francesco Iannuzzo
D-FMEA: Design Failure Mode and Effect Analysis **NEW**	3	24.10.18	25.10.18	Huai Wang
D-FMEA: Design Failure Mode and Effect Analysis **NEW** **04.10.18/22.10.18**				
Dispersed Generation of Electricity	3,5	11.09.18	14.09.18	Birgitte Bak-Jensen
Electricity Market and Power System Optimization	3	26.02.18	28.02.18	Zhe Chen
Electrochemical Energy Conversion	4	14.05.18	17.05.18	Torsten Berning
Electromagnetic Transients in power systems	3	24.01.17	26.01.17	Filipe Faria da Silva
Encoderless control of electric drives motors and generators	3	08.11.18	09.11.18	Frede Blaabjerg
Introduction to Voltage Stability of Electric Power Systems	4	12.02.18	14.02.18	Zhe Chen
Introduction to Wind Power (Generation and Integration)	4	05.02.18	08.02.18	Zhe Chen
Liquefaction of Biomass - Fundamentals and Practice **NEW**	3	26.03.18	28.03.18	Lasse Rosendahl
Maritime Microgrids **NEW**	2	14.06.18	15.06.18	Juan C. Vasquez
Model Predictive Control of Power Electronic Converters **NEW**	3	31.01.18	02.02.18	Tomislave Dragicevic
Modeling and optimization of thermal systems	2	11.10.18	12.10.18	Mads Pagh Nielsen
Modelling of dense multiphase flows using CFD and DEM **NEW**	2	12.03.18	14.03.18	Henrik Sørensen
Models, Methods and Optimization Tools for Energy Systems	3	27.06.18	29.06.18	Juan C. Vasquez
Modern Electrical Machine and Drive Systems	5	04.06.18	08.06.18	Kaiyuan Lu
Modern IGBT gate driving methods for Enhancing Reliability of Power Converters **NEW**	2	03.09.18	04.09.18	Haoze Luo
Modular Multilevel Converters MMC	4	27.11.18	30.11.18	Remus Teodorescu
Multiphysics Simulation and Design of Power Electronics **NEW**	3	19.11.18	21.11.18	Amir Sajjad Bahman
Periodic Control and Filtering in Power Electronic Converter Systems	2,5	09.04.18	11.04.18	Yongheng Yang
Photovoltaic Power Systems - in theory and practice	4	16.10.18	19.10.18	Dezso Sera
Power module design, packaging and testing **NEW**	3	07.05.18	09.05.18	Christian Uhrenfeldt

Power Quality and Synchronization Techniques in Microgrids	3	20.06.18	22.06.18	Josep M. Guerrero
Preparation of research plan for PhD's - Spring	1	16.03.18	16.03.18	Frede Blaabjerg
Preparation of research plan for PhD's - Fall	1	21.09.18	21.09.18	Frede Blaabjerg
Reliability in Power Electronics Systems	3	05.09.18	07.09.18	Frede Blaabjerg
Reluctance electric motor drives for high efficiency in line start and variable speed applications	2,5	06.11.18	07.11.18	Frede Blaabjerg
Renewable Energy based Integrated Energy Systems	3	19.02.18	21.02.18	Zhe Chen
Stability and Control of Grid-Connected Voltage-Source Converters	3	16.04.18	18.04.18	Xiongfei Wang
Stability of Modern Power Systems with High Penetration of Renewable Energy	3	17.09.18	19.09.18	Sanjay K Chaudhary
Storage Systems based on Li-ion Batteries for Grid Support and Automotive Applications	4	23.10.18	26.10.18	Remus Teodorescu
Understand How to write good papers for high level journals	1,5	01.03.18	02.03.18	Kaiyuan Lu
Wide-Area Monitoring and Control of Smart Transmission Systems	2	22.02.18	23.02.18	Zhe Chen

AC Microgrids

Organizer: **Associate Professor Juan C. Vasquez, Professor Josep M. Guerrero, Postdoctoral Felllow Yajuan Guan**

Lecturers: **Professor Josep M. Guerrero, Associate Professor Juan C. Vasquez, Professor Ernane Coelho, Postdoctoral Felllow Yajuan Guan.**

ECTS: **2**

Date/Time: **June 18-19, 2018**

Max no. of participants: **20**

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/

Advanced Computational Fluid Dynamics

Organizer: **Associate Professor Chungen Yin, email: chy@et.aau.dk**

Lecturers: **Associate Professor Chungen Yin, Aalborg University**
Associate Professor Anders Christian Olesen, Aalborg University

ECTS: **4.0**

Date/Time: **August 27-30, 2018**

Max no. of participants: **25**

Description: Computational Fluid Dynamics (CFD) is a very powerful tool which has been successfully used in innovative design, problem-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 – one of the very key approaches of CFD, 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. To achieve the purposes, some demos and hands-on sessions will be planned, besides lectures.

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: **Professor Josep M. Guerrero, Associate Professor, Juan C. Vasquez**

Lecturers: **Professor Eric Monmasson, University of Cergy-Pontoise, Assistant Professor Mattia Ricco (AAU).**

ECTS: **3**

Date/Time: **April 24 -26, 2018**

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.

Prerequisites: Matlab/Simulink knowledge and C/C++basic 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/

An Introduction to HVDC and MTDC Transmission System

Organizer: **Sanjay K Chaudhary, skc@et.aau.dk**

Lecturers: **Sanjay K Chaudhary, skc@et.aau.dk, Remus Teodorescu ret@et.aau.dk**

ECTS: **3**

Date/Time: **October 1-3, 2018**

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: Assignment report.

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, email: ffs@et.aau.dk, Aalborg**

Lecturers: **Associate Professor Filipe Faria da Silva, email: ffs@et.aau.dk, Aalborg,**
Postdoc Hesam Khazraj, email: hkh@et.aau.dk, Aalborg

ECTS: **3**

Date/Time: **November 12-16, 2018**

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 – GTAO, GTAI, 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).

Group1: installing PMU based SE for IEEE 14 Bus
Group2: Dynamic state estimation for Voltage and Current of IEEE 9 Bus
Group3: Data Quality for IEEE 9 Bus system
Group4: Simulink to RSCAD (IEEE 9 Bus)
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Link: http://www.et.aau.dk/phd/phd-courses/

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 Kerekes, 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** **Associate Professor Maciej Swierczynski, mas@et.aau.dk, Aalborg University** **Assistant Professor Sergiu Spataru, ssp@et.aau.dk, Aalborg University** **Assistant Professor Laszlo Mathe, laszlo2mathe@gmail.com, Industry**
ECTS:	**4**
Date/Time:	**March, 05-08. 2018**
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 of evaluation: Individual evaluation of the student assignments received during the lecture and laboratory exercises.

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

Capacitors in Power Electronics Applications

Organizer: **Associate Professor Huai Wang, hwa@et.aau.dk**

Lecturers: **Associate Professor Huai Wang**

ECTS: **2**

Date/Time: **November 22-23, 2018**

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, Professor Josep M. Guerrero Postdoctoral Fellow Enrique Diaz**

Lecturers: **Professor Josep M. Guerrero, Associate Professor Juan C. Vasquez, Associate Professor Sanjay K. Chaudhary, Postdoctoral Fellow Enrique Diaz**

ECTS: **2**

Date/Time: **June 25-26, 2018**

Max no. of participants: **20**

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.

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/

Design Considerations for Robust and Reliable Power Semiconductor Modules

Organizer: **Postdoc. Paula Díaz Reigosa, pdr@et.aau.dk , Aalborg University**

Lecturers: **Postdoc. Paula Díaz Reigosa, AAU, Postdoc. Amir Bahman, Prof. Francesco Iannuzzo, AAU**

ECTS: **2**

Date/Time: **November 1-2, 2018**

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: **Prof. Francesco Iannuzzo, fia@et.aau.dk, Aalborg University**

Lecturers: **Prof. Eckart Hoene, AAU and Fraunhofer IZM; Prof. Francesco Iannuzzo, AAU; Prof. Kjeld Pedersen, AAU, Prof. Vladimir Popok, AAU**

ECTS: **3**

Date/Time: **October 8 -10 October 2018**

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 compare and deeply discuss the achievements and the design choices in the final 1-day lecture.

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

D-FMEA: Design Failure Mode and Effect Analysis

Organizer: Huai Wang, Associate Professor, Aalborg University

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

ECTS: 4

Date/Time September 24-25,2018 :
2-days lecture for FMEA theory, AAU
October 4,2018 : 1-day exercise and consultancies, AAU(2 hours per project)
October 22, 2018: 1-day project presentation and feedback, AAU or on-line (1 hour per project)

Max no. of participants: 20

Description: This PhD course proposal is based on a three-day D-FMEA workshop held at Aalborg University in 2017, where more than 20 participants participated. The aim 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, a 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.

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/

Dispersed Generation of Electricity

Organizer: **Associate Professor Birgitte Bak-Jensen, e-mail: bbj@et.aau.dk**

Lecturers: **Associate Professor Birgitte Bak-Jensen, Associate Professor Jayakrishnan R. Pillai, Associate Professor Florin Iov**

ECTS: **3.5**

Date/Time: **September 11-14, 2018**

Max no. of participants: **30**

Description: Environmental concerns and various benefits of small on-site generation have resulted in significant penetration of dispersed generation in many distribution systems. But, this has resulted in various operational problems. This course aims to address various challenges and opportunity with having a lot of dispersed generation in a network. It focuses on the balancing, stability and reliability problems in the network together with power quality. In addition, various aspects of islanded operation of distribution systems with dispersed generation are also discussed. The course also covers the role of electric vehicles and other flexible loads as a provider of ancillary services in the future electric power systems.

Following topics are covered in the course:
- The energy demand and supply of power.
- Power quality issues.
- Grid reconnection and requirements.
- Future trends & smart grids.
- Synchronization and island detection.
- Control and operation of dispersed generation in islanded scenario.
- Electric vehicles, Flexible loads and Power system stability.
- Impacts of electric vehicle and flexible loads on distribution network.
- Simulation tools for dispersed generation system.

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/

Electricity Market and Power System Optimization

Organizer: **Professor Zhe Chen, email: zch@et.aau.dk, Aalborg University, Assistant Professor Jiakun Fang, email: jfa@et.aau.dk, Aalborg University**

Lecturers: **Professor Andrés Ramos Galán - Institute for Research in Technology UK**

ECTS: **3**

Date/Time: **Febuary 26-28, 2018**

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 topics include

- 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: Mini-project

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

Electrochemical Energy Conversion

Organizer: **Associate Professor Torsten Berning, e-mail: tbe@et.aau.dk**

Lecturers: **Associate Professor Torsten Berning, Aalborg University, Associate Professor Vincenzo Liso, Aalborg University, Associate Professor Anders Olesen, Aalborg University, Associate Professor Samuel Araya, Aalborg University**

ECTS: **4.0**

Date/Time: **May 14-17, 2018**

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 elecytrolyzers 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).

Form of 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

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

Electromagnetic Transients in Power Systems

Organizer: **Filipe Miguel Faria da Silva**

Lecturers: **Filipe Miguel Faria da Silva**

ECTS: **3**

Date/Time: **January 24-26, 2018**

Max no. of participants: **20**

Description: Power systems are constantly subjected to disturbances and switching actions. These actions can go from a normal connection/disconnection of a load or line to the opening of a faulted line after a short circuit or the incidence of lightning strokes, among others. These events are known as electromagnetic transients and have a short duration in the range of microseconds/milliseconds.

Even being short duration phenomena, electromagnetic transients are of fundamental importance, as the system is subjected to high currents, voltages and frequencies during those micro/milliseconds, which may damage the electrical equipment. As a result, extensive investigations are made when installing new high voltage equipment, in order to assure that the equipment is not subjected to high stresses.

The participants in the course will learn how to analyse electromagnetic transients and different transient phenomena will be explored through the use of examples and theoretical explanations. The respective countermeasures will be explained and examples given on how to select them.
The course will also focus in the use of software tools for the simulation of the transients, more specifically EMTDC/PSCAD, which will be introduced and explained during the course. The importance of having a proper modelling of the equipment (e.g., overhead lines, underground cables, transformers, …) in function of the phenomena will be demonstrated and guidelines will be provided on how to choose the minimum modelling requirements for different transient phenomena.
Phenomena that will be studied in the course are:

- Basic RLC transients;
- Energisation and de-energisation of capacitor banks;
- Travelling waves and switching phenomena;
- Particularities of switching in HVAC cables (zero-missing, influence of bonding, etc…);
- Energisation of transformers (inrush currents and other resonances);
- Lightning simulation and back flashover;
- Fault transients;
- Resonances due to switching;
- Guidelines for network modelling;

Prerequisites: Master Degree in Electrical Power System or similar

Evaluation: A list of exercises to be delivered after the course will be given. The exercises will consist in the simulation and analysis of different phenomena in an EMTP-type software. Data will be provided for each phenomenon.

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

Encoderless control of electric drives motors and generators

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

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

ECTS: **3**

Date/Time: **November 8-9, 2018 (ends at 12.00 on the 9th of 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/

Introduction to Voltage Stability of Electric Power Systems

Organizer: **Professor Zhe Chen, email: zch@et.aau.dk, Aalborg University**

Lecturers: **Professor Costas Vournas, vournas@power.ece.ntua.gr, NTUA, Greece**

ECTS: **4**

Date/Time: **February 12-14, 2018**

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
- Multi-time scale and quasi steady state simulation

- ☐ 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: Mini-project

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

Introduction to Wind Power (Generation and Integration)

Organizer:	**Professor Zhe Chen, mail: zch@et.aau.dk, Aalborg University**
Lecturers:	**Professor Zhe Chen, Assistant Professor Chi Su, Associate Professor Weihao Hu, Postdoc Yanbo Wang, Assistant Professor Jiakun Fang**
ECTS:	**4**
Date/Time:	**February 5-8, 2018**
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 optimisation
- Wind turbines in power systems

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

Form of evaluation: Mini-project

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

Liquefaction of Biomass - Fundamentals and Practice

Organizer:	**Professor Lasse Aistrup Rosendahl, email: lar@et.aau.dk, 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. External lecturers tbd.**
ECTS:	**3**
Date/Time:	**March 26-28, 2018**
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 characteristica. 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/

Maritime Microgrids

Organizer:	**Associate Professor Juan C. Vasquez, Professor Josep M. Guerrero Amjad Anvari-Moghaddam, Postdoc, AAU**
Lecturers:	**Josep M. Guerrero, Prof., AAU; Tomasz Tarasiuk, Professor, Gdynia Maritime University, Poland, Amjad Anvari-Moghaddam, Postdoc, AAU; Zheming Jin, PhD, AAU; Assistant prof, Giorgio Sulligoi, Triste university, Italy**
ECTS:	**2**
Date/Time:	**June 14-15, 2018**
Max no. of participants:	**20**

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**

Lecturers: **Associate Professor Tomislav Dragičević, Department of Energy Technology,mail: tdr@et.aau.dk;**
Associate Professor Ulrik Nyman, Department of Computer Science, mail: ulrik@cs.aau.dk;
Assistant Professor Yongheng Yang, Department of Energy Technology, mail: yoy@et.aau.dk;

ECTS: **3**

Date/Time: **February 31-02, 2018**

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/

Modelling and Optimization of Thermal Systems

Organizer: **Mads Pagh Nielsen**

Lecturers: **Mads Pagh Nielsen & Thomas Helmer Pedersen**

ECTS: **2**

Date/Time: **13.-15. november**

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/

Modelling of dense multiphase flows using CFD and DEM

Organizer: **Henrik Sørensen, email: hs@et.aau.dk, Aalborg University**

Lecturers: **Associate professor Henrik Sørensen, Aalborg University, professor Lasse Aistrup Rosendahl, Assistant Professor Jakob Hærvig, Aalborg University. External lecturers tbd.**

ECTS: **3**

Date/Time: **March 12-14, 2018**

Max no. of participants: **15-20**

Description: The course is designed to give students insight into and knowledge about modelling of dense multiphase systems using computational fluid dynamics (CFD) and discrete element modelling (DEM) approaches. The course will give a brief introduction to CFD fundamentals, focusing on the finite volume approach and applied to turbulent flows. From this, the fundamentals of the DEM method for particle-particle interaction as well as coupling these to the fluid dynamic system will be discussed. Special cases such as particle agglomoration/break up and cohesive particle structures will be introduced, and exemplified through examples and hands-on sessions. Altough theoretical aspects will be applicable to all software suites, the hands-on sessions and examples will be based on open source software such as OpenFoam and LIGGGHTS.

Prerequisites: fundamental fluid mechanics and turbulence; access to lab top with simulation software

Form of evaluation: individual mini report

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

Models, Methods and Optimization Tools for Energy Systems

Organizer: **Associate Professor Juan C. Vasquez, Professor Josep M. Guerrero**

Lecturers: **Associate Professor Moises Graells (Technical University of Catalonia), Associate Professor Eleonora Riva Sanseverino (University of Palermo), Postdoctoral Fellow Amjad Anvari-Moghaddam, Postdoctoral Fellow Emilio Palacios García.**

ECTS: **3**

Date/Time: **June 27-29, 2018**

Max no. of participants: **20**

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 Electrical Machine and Drive Systems

Organizer: **Assoc. Prof., Kaiyuan Lu, klu@et.aau.dk**

Lecturers: **Assoc. Prof. Kaiyuan Lu, Peter O. Rasmussen and Assis. Prof. Dong Wang**

ECTS: **5**

Date/Time: **June 4-8, 2018**

Max no. of participants: **20**

Description: This is a special course combining closely the electrical machine theory with advanced control technologies for different types of electrical machines. The understanding of an electrical machine for many engineers is still a simple mathematical model represented in e.g. a dq-reference frame. This course uses several step-by-step Finite Element models to visualize the working principle and evaluate the performance of electrical machines. The link between the electromagnetic behaviour inside a machine to the well-known mathematical model is then made straight forward. This will provide a firm understating of an electrical machine, and get the participants prepared for more advanced topics and applications of electrical machines. A unique machine comparison concept will be introduced, leading to a unified approach to compare easily and illustratively the performance of permanent magnet machines, synchronous reluctance machines and induction machines. New topics on magnetic gear technologies will also be covered.

Based on a good understanding of an electrical machine, advanced control (mainly sensorless control) technologies will be presented and analysed. Various topics like inverter voltage error effects, machine nonlinear behaviour effects will be evaluated and handled. Dedicated lab facilities using dSPACE systems will be provided for the participants to implement, test, and analyze sensorless control technologies. The emphasis on the practical lab exercise of this course will guarantee that the participants will gain solid experience about electrical drives that will benefit their own work

Prerequisites: It is required that the participants have basic knowledge about electromagnetic theory, dynamic modelling of electrical machines as well as classical control theory.

Form of evaluation: Group exercise based evaluation

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

Modern IGBT gate driving methods for Enhancing Reliability of Power Converters

Organizer: **Postdoc. Haoze Luo**

Lecturers: **Postdoc. Haoze Luo, AAU, Prof. Francesco Iannuzzo, AAU**

ECTS: **2**

Date/Time: **September 3-4, 2018**

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 contributio

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

Modular Multilevel Converters (MMC)

Organizer:	**Professor Remus Teodorescu**
Lecturers:	**Professor Remus Teodorescu, ret@et.aau.dk, Aalborg University, Associate Professor Mattia Ricco mri@et.aau.dk, Aalborg University, Associate Professor Sanjay Chaudhary, skc@et.aau.dk, Aalborg University, Cristian Lascu, cla@et.aau.dk, Aalborg University.**
Guest Lecturers:	**Prof. Massimo Bongiorno, massimo.bongiorno@chalmers.se Chalmers University, Minos Kontos, E.Kontos@tudelft.nl, TU Delft**
ECTS:	**4**
Date/Time:	**November 27–30, 2018**
Max no. of participants:	**30**

Description: Description: MMC has been established as the technology of choice for HVDC, large utility scale STATCOM and Multi-MW drives. This course will present the fundamentals, dynamics, modelling and simulation, modulation, control and balancing as well as control under unbalanced grid. Control and operation challenges for MMC application in HVDC and STATCOM will be presented. The course structure is:

Day 1: MMC fundamentals, topologies and design

Day 2: Modulation and individual capacitor balancing

Day 3: Control and arm balancing

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

Reference material: Design, Control, and Application of Modular Multilevel Converters for HVDC Transmission Systems, by Kamran Sharifabadi, Lennart Harnefors, Hans-Peter Nee, Staffan Norrga, Remus Teodorescu, ISBN: 978-1-118-85156-2 . External participants will receive a copy (cost included in the registration fee).

Prerequisites: Power Electronics, Matlab/Simulink or PLECS

Form of evaluation: Assignment report

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

Multiphysics Simulation and Design of Power Electronics

Organizer: **Assistant Professor Amir Sajjad Bahman asb@et.aau.dk**

Lecturers: **Assistant Professor Amir Sajjad Bahman, AAU, Professor Francesco Iannuzzo, AAU, and Associate Professor Huai Wang, AAU**

ECTS: **3**

Date/Time: **November, 19-21,2018**

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 level multiphysics simulation and design of power electronics

Day3: Hands-on exercises and discussion

Prerequisites: 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.

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

Periodic Control and Filtering in Power Electronic Converter Systems

Organizer: **Yongheng Yang, Assistant Professor**yoy@et.aau.dk

Lecturers: **Yongheng Yang, Assistant Professor, Aalborg University**
Keliang Zhou, Senior Lecturer, University of Glasgow
Tomislav Dragičević, Associate Professor, Aalborg University

ECTS: **2.5**

Date/Time: **April 9-11, 2018**

Max no. of participants: **30**

Description: A key issue for power electronic converters is the ability to tackle periodic signals in electrical power processing (e.g. sinusoidal voltage/current regulation, power harmonics mitigation, synchronous frame transformation, grid synchronization, etc.) in such a way to precisely and flexibly convert and regulate electrical power. Classical controllers (e.g., PID control) are not able to remove the dynamic periodic error completely. The residual periodic errors will not only degrade the power quality and even the stability and reliability of the electrical power systems.

This Ph.D. course is thus to lay a foundation of the Internal Model Principle (IMP) -based periodic control and filtering theory with basic theory, derivation of applied equations, know-how on the control synthesis, and some most recent progress, which is found to provide power electronic converters with a superior control solution to the compensation of periodic signals with high accuracy, fast dynamic response, good robustness, and cost-effective implementation. This course also contributes to this discipline combined with demonstrative practical examples of the application of periodic control and filtering to: standalone/grid-connected power converters; high frequency link converters; shunt active power filters; and PLLs for grid synchronizations, which can be fruitful in future controller designs, and the control methods are in some cases already applied in industry.

As an emerging topic, the periodic control has the great potential to be one of the best control solutions for power converters but not limited to, and to be a very popular standard industrial controller like the PID control.

The course will be organized as:

Day 1:

- Fundamentals of Periodic Control and Filtering
    - Motivation and background
    - General power converter control
    - Internal model principle
    - Basis function for periodic control and filtering
- Fundamental Periodic Control in Power Electronic Conversion
    - Repetitive control
    - Resonant control
    - Optimal periodic control
    - Application examples

Day 2:

- Advanced Periodic Control in Power Electronic Conversion
    - Digital control issues
    - Frequency adaptive periodic control
    - Application examples
- Periodic Filtering for Power Electronic Conversion
    - Harmonics and pre-filtering
    - Periodic filtering for power conversion
    - Application examples

Day 3 (half-day):

- Extensive Applications of Periodic Control and Filtering
- Course wrap-up

Prerequisites: This course is intended for researchers and engineers in the field of power electronics and their applications, for control specialists exploring new applications of control theory in power electronics, and for advanced university students in these fields. General knowledge in power electronic converters, and basic control theory are preferred. Course exercises will be performed on MATLAB/Simscape/Sim Power Systems.

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 simulation 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/

Photovoltaic Power Systems - in theory and practice

Organizer: **Dezso Sera**

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

ECTS: **4.0**

Date/Time: **October 16-19, 2018**

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
- PVSyst 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 (10 in total) 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/
Link 2: http://www.et.aau.dk/phd/phd-courses/

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

Power module packaging and testing

Organizer: **Christian Uhrenfeldt**

Lecturers: **Christian Uhrenfeldt, Szymon Beczkowski, Stig Munk Nielsen**

ECTS: **3 ECTS**

Date/Time: **May 7-9, 2018**

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/

Power Quality and Synchronization Techniques in Microgrids

Organizer: **Professor Josep M. Guerrero, Associate Professor, Juan C. Vasquez, , Postdoctoral Researcher Saeed Golestan.**

Lecturers: **Professor Josep M. Guerrero, Associate Professor Mehdi Savaghebi, Lecturer Alexander Micallef (University of Malta), Postdoctoral Researcher Saeed Golestan.**

ECTS: **3**

Date/Time: **June 20-22, 2018**

Max no. of participants: **20**

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.

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/

Preparation of Research Plan for Ph.D.'s

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: **March 16, 2018 (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: Attendance Rate

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

Preparation of Research Plan for Ph.D.'s

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: **September 21, 2018 (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: Attendance Rate

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

Reliability in Power Electronics Systems

Organizer: **Prof. Frede Blaabjerg, fbl@et.aau.dk**

Lecturers: **Professor Frede Blaabjerg Associate Professor Huai Wang**
Professor Francesco Iannuzzo, Reliability Advisor Peter de Place Rimmen

ECTS: **3**

Date/Time: **September 5-7, 2018**

Max no. of participants: **30**

Description: The course will be the latest research outcomes of the Center of Reliable Power Electronics (CORPE). The 2018 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

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Reluctance electric motor drives for high efficiency in line start and variable speed applications

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

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

ECTS: **2.5**

Date/Time: **November 6-7, 2018**

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
- Flux- modulation REMDS: Flux –modulation principle and its application to Switching -Flux, Vernier, Flux-Reversal, Transverse-Flux, Dual- Rotor Flux- Modulation motor/generator drives (with magnetic gear effects)
- 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/

Renewable Energy based Integrated Energy Systems

Organizer: **Professor Zhe Chen, mail: zch@et.aau.dk, Aalborg University**

Lecturers: **Professor Zhe Chen, Assistant Professor Chi Su, Associate Professor Weihao Hu, Postdoc Yanbo Wang, Assistant Professor Jiakun Fang**

ECTS: **3**

Date/Time: **February 19-21, 2018**

Max no. of participants: **30**

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

The Ph.D. course will include fundamental knowledge of energy sources, energy conversion systems, renewable energy integration, transmission, and distribution. Basic techniques of analysis, operation and control will be presented. The market issue will also be introduced. 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
- Advanced technologies and emerging facilities for energy system integration
- Optimization techniques applied in integrated energy systems
- Impact of renewable power integration and mitigation methods
- Future energy market with significant renewable energy penetration
- Renewable energy transmission: operation and control

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: Mini-project

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

Stability and Control of Grid-Connected Voltage-Source Converters

Organizer: **Xiongfei Wang**

Lecturers: **Xiongfei Wang, Lennart Harnefors, Tuomas Messo**

ECTS: **3**

Date/Time: **April 16-18, 2018**

Max no. of participants: **35**

Desciption: Voltage Source Converters (VSCs) have commonly been used with renewable power sources, flexible ac and dc power transmission or distribution systems, regenerative drives, and transportation electrification. As the increasing use of VSCs in electrical grids, the dynamic characterizations of VSCs are playing a critical role in building a stable and resilient power-electronic-based power system. This course thus devotes to cover the fundamentals and state-of-the-art of modeling, stability analysis, and control topics for the VSCs in the grid-connected applications.

1. Vector current control
2. Grid synchronization and direct voltage control
3. Impedance-based modeling and validation
4. Stability of current control with LCL-filters
5. Stability impacts of grid synchronization and direct voltage control
6. Active stabilizing techniques for VSC-fed systems

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

Form of evaluation: Exercises and report

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

Stability of modern power system with high penetration of renewable energy

Organizer: **Sanjay K Chaudhary**

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

ECTS: **3**

Date/Time: **September 17-19, 2018**

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: Assignment report

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

Storage Systems based on Li-ion Batteries for Grid Support and Automotive Applications

Organizer: **Prof. Remus Teodorescu, Aalborg University**

Lecturers: **Prof. Remus Teodorescu ret@et.aau.dk, Assoc. Prof. Maciej Swierczynski mas@et.aau.dk, Assist. Prof. Daniel Stroe dis@et.aau.dk , Assoc. Prof. Erik Schaltz esc@et.aau.dk, Aalborg University, Dr. Vaclav Knap vkn@et.aau.dk**

ECTS: **4.0**

Date/Time: **23-26 October 2018**

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 a report (individual or in small groups) with solutions and comments.

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

Understand how to write good papers for high level journals

Organizer: **Asso. Prof., Kaiyuan Lu, klu@et.aau.dk:**

Lecturers: **Prof., Frede Blaabjerg, Asso. Prof., Kaiyuan Lu**

ECTS: **1.5**

Date/Time: **March 1-2, 2018**

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/

Wide-Area Monitoring and Control of Smart Transmission Systems

Organizer:	**Professor Zhe Chen, email: zch@et.aau.dk, Aalborg University Chi Su, Assistant Professor, email: csu@et.aau.dk, Aalborg University**
Lecturers:	**Associate Professor Luigi Vanfretti - Royal Institute of Technology - Sweden**
ECTS:	**2**
Date/Time:	**February 22-23, 2018**
Max no. of participants:	**30**

Description: This course provides a detailed description on the simulation, stability analysis and control of power transmission systems using wide-area monitoring systems (WAMS). The content of the course covers simulation tools, measuring and data transfer, analytical methodologies to design novel power system stabilizers, etc.

The topics include:

- Modeling and simulation tools for smart transmission systems
- Introduction to the wide-area measuring and data transfer in power systems
- Analysis of electromechanical oscillations in power systems based on phasor measurements
- Design of the WAMS based power system stabilizers

Prerequisites: Background in power system stability dynamic and control, fundamental knowledge in control theory, and basic skills in simulation of power system for transient stability study.

Form of evaluation: Mini-project

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