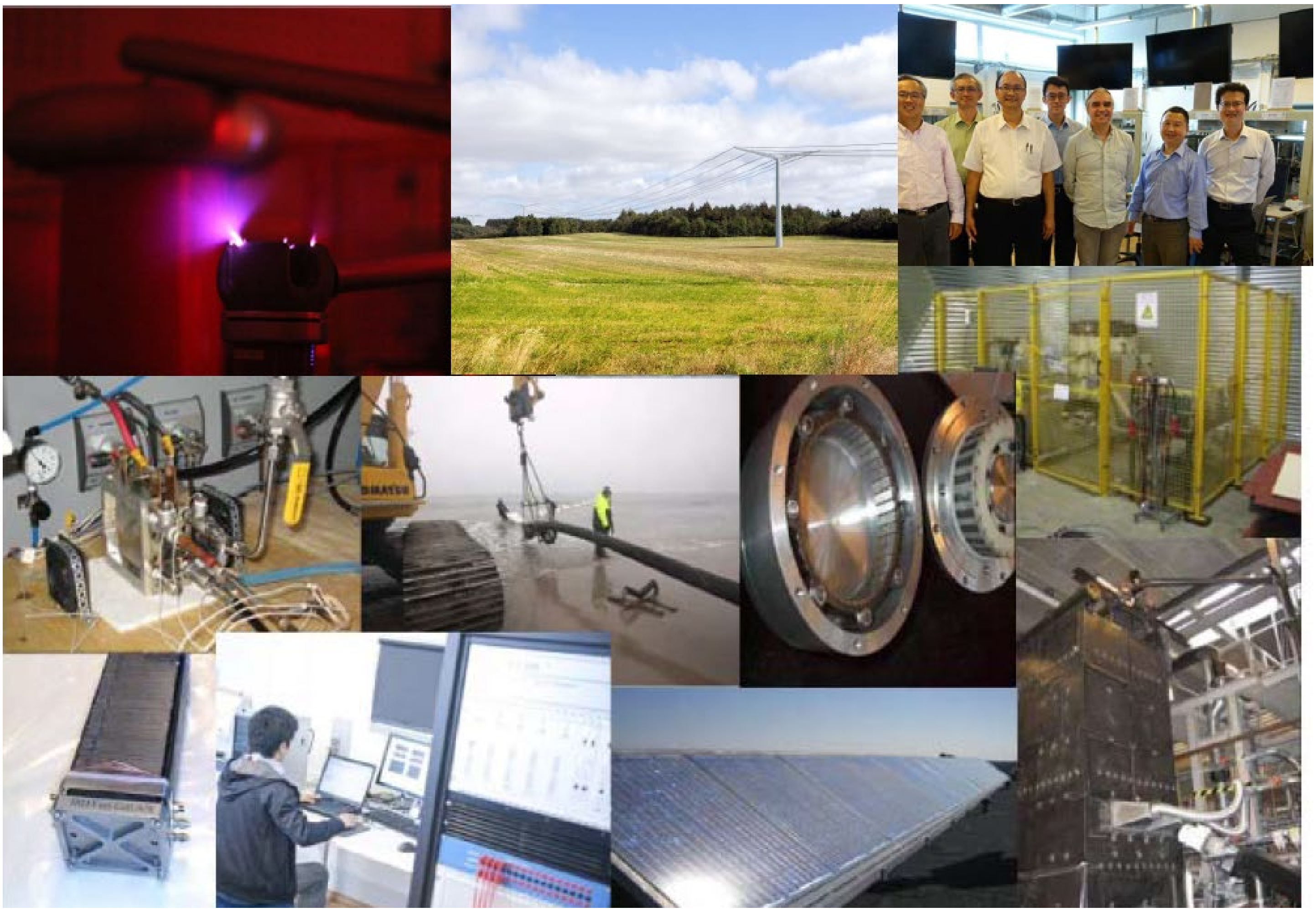
PhD Courses 2021
AAU Energy PhD program



AAU ENERGY

AALBORG UNIVERSITY

Description of the Energy Technology PhD program

The Energy Technology programme is a multi-disciplinary doctoral programme aiming at solving future challenges in the energy area by means of developing new energy technologies leading to a more efficient and sustainable management of energy. It covers a broad range of energy-related topics focusing on the energy conversion process itself as well as generation, transmission, distribution and efficient use of energy are covered. Inherently it is involving various areas of both classical and new engineering sciences as well as basic research as the physical quantity "energy" and its provision and use spans broadly over almost all activities a modern society faces. Electrical, thermal, mechanical, hydraulics and control engineering sciences merge in various ratios with physics and chemistry to provide front-end knowledge enabling step by step solutions to help fulfilling the climate and emission goals set by international societies. The programme 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 programme has hosted + 100 PhD's for the last years and is graduating around 25 new energy technology PhD's every year.

Research areas:

The programme belongs under 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, +4599409281

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

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

PhD courses 2021	Start	End	ECTS	Coordinator
Reliability Assessment in Electric Power Systems (ONLINE)	18-01-2021	21-01-2021	4	Frede Blaabjerg Saeed Peyghami
Advanced measurements techniques in fluid mechanics – theory and practice			6	Henrik Sørensen
Reliability of Power Electronic based Power Systems (PEPS) (ONLINE)	01-02-2021	02-02-2021	2	Frede Blaabjerg Saeed Peyghami
Introduction to Stability of Electric Power Systems (ONLINE)	03-02-2021	05-02-2021	3	Zhe Chen
Introduction to Wind Power (ONLINE)	08-02-2021	11-02-2021	4	Zhe Chen
Maritime Microgrids (ONLINE)	15-02-2021	16-02-2021	2	Juan C. Vasquez Josep M. Guerrero
Low power Energy Harvesting Technologies and Applications (ONLINE)	17-02-2021	19-02-2021	2,5	Alireza Rezaniakolaei
AC Microgrids (ONLINE)	22-02-2021	23-02-2021	2	Juan C. Vasquez Josep M. Guerrero
Power Quality and Synchronization Techniques in Microgrids (ONLINE)	24-02-2021	26-02-2021	3	Juan C. Vasquez Josep M. Guerrero
Liquefaction of Biomass - Fundamentals and Practice (CANCELLED)	01-03-2021	03-03-2021	3	Saqib Toor
Cyber Security of Microgrids (ONLINE)	04-03-2021	05-03-2021	2	Frede Blaabjerg Subham Sahoo
Advanced Optimization Techniques for Energy Systems Planning and Operation (ONLINE)	10-03-2021	12-03-2021	3	Amjad Anvari-Moghaddam
DC Microgrids (ONLINE)	15-03-2021	16-03-2021	2	Juan C. Vasquez Josep M. Guerrero
Models, Methods and Optimization Tools for Energy Systems (ONLINE)	17-03-2021	19-03-2021	3	Juan C. Vasquez Josep M. Guerrero
Application-Oriented Modelling of Renewable Energy Sources, Conversion and Energy Storage Systems (online)	23-03-2021	26-03-2021	4	Tamas Kerekes
Advanced FPGA-based Controllers for Power Electronic and Drive Applications (ONLINE)	30-03-2021	01-04-2021	3	Juan C. Vasquez Josep M. Guerrero
WIDE AREA MONITORING, PROTECTION AND CONTROL (CANCELLED)	15-04-2021	16-04-2021	3	Zhou Liu
Hybrid Power Plants – Modelling, Operation and Control (NEW 2021)	21-04-2021	23-04-2021	3	Florin Iov
Understand how to write good papers for high level journals (ONLINE)	03-05-2021	04-05-2021	1,5	Kaiyuan Lu
Energy Markets and Analytics (ONLINE)	17-05-2021	18-05-2021	2	Amjad Anvari-Moghaddam
Machine Learning, Predictive Modelling, and Validation (NEW 2021)	19-05-2021	20-05-2021	2	Daniel-Ioan Stroe
Modelling and Optimization of Thermal Energy Systems (CANCELLED)	03-06-2021	04-06-2021	2	Mads Pagh Nielsen
Electrochemical Energy Conversion (ONLINE)	08-06-2021	11-06-2021	4	Torsten Berning
Electricity Markets and Power System Optimization (ONLINE)	16-06-2021	18-06-2021	3	Zhe Chen
Open-source Computational Fluid Dynamics – 1. Fundamentals	21-06-2021	22-06-2021	2	Jakob Hærvig Johan Rønby Pedersen
Open-source Computational Fluid Dynamics – 2. Efficient Workflows and Code Customisation	23-06-2021	25-06-2021	3	Jakob Hærvig Johan Rønby Pedersen
New Energy technologies and Systems (ONLINE)	28-06-2021	30-06-2021	3	Zhe Chen
Periodic Control and Filtering in Power Electronic Converter Systems (CANCELLED)	01-07-2021	02-07-2021	2	Yongheng Yang
Stability and Control of Grid-Connected Converters (ONLINE)	11-08-2021	13-08-2021	3	Xiongfei Wang
Multivariable and Intelligent Control of Industrial Electronic Systems	16-08-2021	20-08-2021	5	Amin Hajizadeh Mohsen Soltani
Advanced Computational Fluid Dynamics	17-08-2021	20-08-2021	4	Chungen Yin
Power module design, packaging and testing	23-08-2021	25-08-2021	3	Christian Uhrenfeldt
Sustainable Biomass Resources and Technology Pathways for Biogas and Biorefineries	23-08-2021	27-08-2021	5	Jens Bo Holm-Nielsen Mette H. Thomsen
Electrochemical Impedance Spectroscopy – Theory, Measurement and Analysis	30-08-2021	03-09-2021	5	Søren Højgaard Jensen
Modern IGBT gate driving methods for Enhancing Reliability of Power Converters	30-08-2021	31-08-2021	2	Francesco Iannuzzo
Harmonics in Power Electronics and Power Systems	08-09-2021	10-09-2021	3	Claus Leth Bak
Smart Distribution Systems (SDS)	13-09-2021	16-09-2021	3,5	Birgitte Bak-Jensen
D-FMEA: Design Failure Mode and Effect Analysis for Power Electronic Converters	20-09-2021	24-09-2021	4	Huai Wang
Power Electronics – from Fundamentals to Advanced Topics	28-09-2021	01-10-2021	4	Huai Wang
Managing Harmonics in Modern Power Distribution Networks	05-10-2021	07-10-2021	3	Xiongfei Wang
Photovoltaic Power Systems - in theory and practice	12-10-2021	15-10-2021	4	Tamas Kerekes
Lithium-Ion Batteries. Fundamentals, Modelling, and State Estimation	18-10-2021	20-10-2021	3	Daniel-Ioan Stroe
Lithium-Ion Batteries. Systems and Applications	21-10-2021	22-10-2021	2	Daniel-Ioan Stroe
Electromagnetic Transients in Power Systems	25-10-2021	28-10-2021	3	Filipe Faria da Silva
Vibration-based structural health monitoring - ESBJERG	25-10-2021	29-10-2021	5	Martin Dalgaard Ulriksen Lars Damkilde
Design of Modern Power Semiconductor Components	01-11-2021	03-11-2021	3	Francesco Iannuzzo
Generators and their control (NEW 2021)	01-11-2021	03-11-2021	3	Frede Blaabjerg
Capacitors in Power Electronics Applications	04-11-2021	05-11-2021	2	Huai Wang
Reliability in Power Electronics Systems	09-11-2021	12-11-2021	4	Huai Wang
EMI/EMC in Power Electronics	15-11-2021	16-11-2021	2,5	Pooya Davari
Stability of Modern Power Systems with High Penetration of Renewable Energy	17-11-2021	19-11-2021	3	Sanjay K. Chaudhary
Tribodynamics	22-11-2021	25-11-2021	4	Per Johansen
Multiphysics Simulation and Design of Power Electronics	29-11-2021	01-12-2021	3	Amir Sajjad Bahman
Design Considerations for Robust and Reliable Power Semiconductor Modules	02-12-2021	03-12-2021	2	Francesco Iannuzzo
Future Low Voltage Distribution Grids (NEW 2021)	06-12-2021	08-12-2021	3	Florin Iov
Grid-Forming Inverters: Principles and Practices	13-12-2021	15-12-2021	3	Xiongfei Wang

RELIABILITY ASSESSMENT IN ELECTRIC POWER SYSTEMS

Organizer: Prof. Frede Blaabjerg fbl@et.aau.dk, and Postdoc. Saeed Peyghami sap@et.aau.dk

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

ECTS: 4

Date/Time: 18-21 January 2021: 4-day

Max no. of participants: 40

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

Day 1: 08.30-16.00

L0 Introduction to the course **(Mahmud Fotuhi-Firuzabad) (1.5 h)**
L1 Fundamental concepts of reliability Engineering **(Mahmud Fotuhi-Firuzabad) (2 h)**
L2 System components and their outage models **(Mahmud Fotuhi-Firuzabad) (2 h)**

Day 2: 08.30-16.00

L3 Techniques used in engineering system risk assessment **(Mahmud Fotuhi-Firuzabad) (1.5 h)**
L4 Basic concepts of adequacy and security in electric power systems **(Mahmud Fotuhi-Firuzabad) (2 h)**
L5 Generating capacity reliability assessment **(Mahmud Fotuhi-Firuzabad) (2 h)**

Day 3: 08.30-16.00

L6 Composite generation and transmission system reliability evaluation **(Mahmud Fotuhi-Firuzabad) (2 h)**
L7 Application of risk evaluation in transmission developing planning, transmission operation planning **(Mahmud Fotuhi-Firuzabad) (2 h)**
L8 Power system reliability assessment including renewable sources **(Mahmud Fotuhi-Firuzabad) (1.5 h)**

Day 4: 08.30-16.00

L9 Distribution system reliability evaluation **(Mahmud Fotuhi-Firuzabad) (2 h)**
L10 Substation and switching station reliability **(Mahmud Fotuhi-Firuzabad) (2 h)**
L11 Reliability cost/worth analysis **(Mahmud Fotuhi-Firuzabad) (1.5 h)**

Benefits of Participants:

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

Intended Audience:

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

Prerequisites: Pre-reading the shared materials

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

Biography of the lecturer:

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

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

Advanced measurements techniques in fluid mechanics – theory and practice

Organizer: Ass. Professor Henrik Sørensen, Aalborg University, Denmark

Lecturers: Henrik Sørensen, Jakob Hærvig, Anna Lyhne Jensen and external guest lectures

ECTS: 6

Date/Time: 1-5 February 2021

Max no. of participants: 20

Description: The objective of this course is to give the student a brief overview of measurement techniques in the field of fluid mechanics. Particle Image Velocimetry, Laser Doppler Velocimetry, Constant Temperature Anemometri and flow meters are introduced and discussed in terms of advantages and limitations. Selected techniques are used in 4 different experimental session, where the participants are trained in the use of the equipment. As experimental sessions are an important part of this course, the participants must work together in groups of max 4-5 persons. Topics on data reduction and analysis are offered in addition to the theoretical and experimental aspects.

Day 1: Registration and welcome (ALJ), Overview of measurement techniques in fluid mechanics (HS). Characteristics of tracers used in laser based measurements (JAH). Laser doppler Velocimetry (JAH), Constant temperature anemometry (HS).

Day 2: Flow visualization (HS). Particle Image Velocimetry (GL). Laboratory safety (HS). Experiment #1. Group work.

Day 3: Presentation of Industrial cases (ALJ). Analysis and uncertainty of acquired date (JAH). Experiment #2. Experiment #3. Group work

Day 4: Data reduction for presentation and documentation (ALJ). Design of experimental setups (HS). Experiment #4. Excursion. Group work

Day 5: Using experimental for validation of numerical results (JAH). Mini conference with presentation of results obtained during the course (ALJ, JAH, HS). Closing and feedback (HS).

Prerequisites: Participants must have fundamental knowledge on fluid mechanics and simple data acquisition.

Form of evaluation: The participants must hand in mini-projects in groups and complete a multiple-choice test

Reliability of Power Electronic based Power Systems (PEPS)

Organizer: Prof. Frede Blaabjerg fbl@et.aau.dk and Postdoc Saeed Peyghami, sap@et.aau.dk

Lecturers: Saeed Peyghami, Postdoc, Aalborg University, Denmark

ECTS: 2

Date/Time: 1-2 February 2021: 2-day lecture

Max no. of participants: 30

Description: Modern power electric based power systems (PEPS) are facing new challenges in terms of reliable planning and operation due to proliferation of power electronic converters. The course is aimed at providing an in-depth introduction to the reliability modeling, assessment and enhancement approaches in PEPS. The basic principles of reliability evaluation along with their application, current practices and solution methods in PEPS will be discussed.

Day 1: 08.30-16.00

L0 Introduction to the course
L1 Fundamental concepts of reliability Engineering
L2 Structural reliability and stress strength analysis
L3 Introduction to converter reliability prediction
L4 Impacts of converter control on PEPS reliability

Day 2: 08.30-16.00

L5 Reliability modelling in PEPS
L6 Model-based design for reliability in PEPS
L7 Model-based maintenance scheduling in PPES
L8 Reliability enhancement in PEPS
L9 Challenges and opportunities

Benefits of Participants:

- Understanding the fundamental of PEPS reliability engineering
- Exposure to probabilistic technique applications to PEPS problems
- Bridging the reliability concepts of power electronics and power systems

Intended Audience: Power engineers, graduate students and researchers in utilities and universities

Prerequisites: Pre-reading the shared materials

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

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

Introduction to Stability of Electric Power Systems

Organizer: Z. Chen, Professor, zch@et.aau.dk, Aalborg University, Denmark

Lecturers: Professor Zhe Chen, Aalborg University, Denmark
Assistant Professor Zhou Liu, Aalborg University, Denmark
Assistant Professor Yanbo Wang, Aalborg University, Denmark

ECTS: 3

Date/Time: 3-5 February, 2021 / 8:30-16:00

Max no. of participants: 30

Description: The course will provide training and education in the field of stability theory, stability of modern electric power systems with synchronous generators, power electronics-interfaced renewable generators, and other power electronic systems, such as HVDC and Flexible ac transmission systems (FACTs).
The PhD course will cover basic knowledge of stability theory, electrical power system stability, impacts of power electronic conversion system, electrical machines and renewable energy generators on the system stability, especially, the stability under the large scale integration of renewable generators and significant reduction of conventional synchronous generators.

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

The main topics are as follows:

- Overview of power system stability and classification
- Basics of stability theory
- Frequency stability of power systems
- Voltage stability of power systems
- Multi-time scale and quasi steady state simulation
- Frequency response and regulation of renewable energy plants
- Small signal stability and analysis method
- Large signal stability and analysis method
- Sub-synchronous oscillation
- Stability of power electronic dominated power systems

Day 1:
Overview of power system stability and classification **(ZCH) (1.5h)**
Basics of stability theory **(ZCH) (1.5h)**
Frequency stability of power system **(YWA) (1.5h)**
Frequency response and regulation of renewable energy plant **(YWA) (1h)**

Day 2:
Small signal stability and analysis method **(YWA) (1.5h)**
Large signal stability and analysis method **(YWA) (1.5h)**
Sub-synchronous oscillation **(YWA) (1h)**
Effects of power electronic-dominated renewable energy on stability of power system **(YWA) (1.5h)**

Day 3:
Voltage stability and response dynamics (ZLI) (1.5h)
Multi-time scale and quasi steady state simulation (ZLI) (1.5h)
Demonstration and practice in Digsilent or RTDS **(**ZLI**)** (2h)

Prerequisites: Preferably to have general knowledge in electrical engineering.

Form of evaluation: Assignments to be completed, the reports are to be submitted and evaluated after the class

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

Introduction to Wind Power (Generation and Integration)

Organizer: Z. Chen, Professor, zch@et.aau.dk, Aalborg University, Denmark

Lecturers: Professor Zhe Chen, Assistant Professor Zhou Liu, Assistant Professor Yanbo Wang, Post doc. Fellow Dong Liu, Aalborg University, Denmark

ECTS: 4

Date/Time: 8-11 February, 2021 / 8:30-16:00

Max no. of participants: 30

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

The PhD course will include basic knowledge of wind turbine systems, as well as electrical systems of wind power 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 wind power development
- Wind energy and wind turbine systems
- Wind power generators
- Configuration and control of power electronic conversion system for wind energy conversion system
- Operation and control of wind turbines and wind farms
- Offshore wind power system
- Wind power plant design and optimisation
- Transmission system for offshore wind power plants
- Wind power integration to power grid
- Wind power impacts on power system stability and protection

Day 1:
Overview of energy system and wind power development **(ZCH 1.5hours)**
Basics of wind energy conversion systems **(ZCH 1.5hours)**
Drive train, generators, power electronics (1) **(YWA 1.5hours)**
Drive train, generators, power electronics (2) **(DLI 1.2hours)**

Day 2:
Drive train, generators, power electronics (3) **(YWA 1.5hours)**
Wind turbine systems **(ZCH 1.5hours)**
Offshore wind farms and optimization of wind farms **(ZCH 1.5hours)**
Transmission system for offshore wind farms **(DLI 1.5hours)**

Day 3:
Grid code and power quality **(ZLI 1.5hours)**
Wind power impacts on power system operation **(ZLI 1.5hours)**
Frequency response and regulation technology **(YWA 1.5hours)**
Wind power impacts on power system stability (1) **(YWA 1.2hours)**

Day 4: Topic and short description
Wind power impacts on power system stability (2) **(YWA 1.5hours)**
Wind power impacts on power system protection **(ZLI 1.5hours)**
Simulation analysis and practice **(YWA / DLI 1.5hours)**
Discussion / Homework **(ZCH 0.5hours)**

Prerequisites: Preferably to have general knowledge in electrical engineering.

Form of evaluation: Assignments are to be completed, the reports are to be submitted and evaluated after the class

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

Maritime Microgrids

Organizer: Professor Josep M. Guerrero joz@et.aau.dk, Professor Juan C. Vasquez juq@et.aau.dk

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

ECTS: 2 ECTS

Date/Time: 15-16 February, 2021

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.

Day 1: Introduction on Electric Ships and Signal Processing of Power Quality Disturbances
Josep M. Guerrero (1h) + Tomasz Tarasiuk (5h)

Day 2: DC ship power systems: Evolution and Research Challenges
Josep M. Guerrero (1h) + Giorgio Sulligoi (3h) + Daniele Bosich (1h)

Prerequisites: The course exercises will be done via MathCad and Matlab/Simulink simpowersytems.

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/

Low power Energy Harvesting Technologies and Applications

Organizer: Assoc. Prof. Alireza Rezaniakolaei alr@et.aau.dk; (Low Power Energy Harvesting and i-Solutions Research Programme)

Lecturers: Alireza Rezaniakolaei (ALR), Kaiyuan Lu (KLU), Amjad Anvari-Moghaddam (AAM), Erik Schaltz (ESC), Christian Uhrenfeldt (CHU) – Aalborg University, Denmark

ECTS: 2.5

Date/Time: 17-19 February 2021

Max no. of participants: 25

Description: Low power energy harvesting mechanisms are unique opportunities to provide source of electrical energy for autonomous sensors for predictive maintenance applications, self-powered and wireless micro-actuators, monitoring devices for health care, energy hubs, Internet of Things (IoT)-enabled energy networks etc. This PhD course handles the fundamentals of energy harvesting technologies such as thermoelectric and electromagnetic devices by introducing recent development techniques and detailed module design. This course will continue with integration principles of the energy harvester modules with the system components to enhance output power performance of the modules. Furthermore, control of electrical output of the devices will be discussed for maximum power point tracking by power electronic converting methods. This course also addresses recent applications of such energy harvesting mechanisms with introducing opportunities, challenges and relevant applications in renewable energy IoT industries.

Day 1:

Thermoelectric generator model and module design; Alireza Rezaniakolaei (3 hours)

- The lectures cover history of thermoelectrics, typical thermoelectric systems, basic arrangement & characterizing quantities, challenges for thermoelectrics, contact resistance, effect of geometry and inter-leg heat transfer.

Afternoon: Electromagnetic energy harvesters; Kaiyuan Lu (3 hours)

- The lectures cover the state-of-the-art designs of electromagnetic energy harvesters, typical design principle, device modelling, characterizing quantities, performance improvement challenges etc.

Day 2:

Morning: Integration of heat exchangers with thermoelectric modules; Alireza Rezaniakolaei (3 hours)

- The lectures cover coupled thermoelectric device/thermal system design, high performance cooling technologies, cooling energy vs. power generation, integrated model of thermoelectric & heat sinks.

Afternoon: MPPT and power electronic converters; Erik Schaltz (3 hours)

- The lectures covert thermoelectric generators modelling from power electronics point of view. Fundamentals of Power Electronics, power electronic converters for energy harvester device and maximum power point tracking (MPPT) algorithms for the device will be discussed.

Day 3:

Applications for thermoelectric energy harvesting; Alireza Rezaniakolaei (1:30 hours)

- The lectures cover integration of the thermoelectric generation with solar power systems and autonomous sensor platforms

Photovoltaic energy harvester and packaging solutions for high performance energy harvesters; Christian Uhrenfeldt (2 hours)

- The lecture covers in one part photovoltaic devices for energy harvesting from a material and design perspective and the link energy harvesting systems and in the other part cover packaging schemes and material requirements for efficient energy harvesting platforms.

IoT applications for low power energy harvesting; Amjad Anvari-Moghaddam (2 hours)

- The lecture covers a background on IOT definitions and edge devices, energy harvesting technologies and its requirements IoT applications.

Prerequisites: No

Form of evaluation: Completion of design and metaphysics simulation of a form of the energy harvesting mechanisms or power output management of the chosen energy harvesting technology in the selective list of the tasks. The assignment will be done in groups and each group must submit the final report.

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

AC Microgrids

Organizer: Professor Juan C. Vasquez juq@et.aau.dk and Professor Josep M. Guerrero joz@et.aau.dk

Lecturers: Prof. Josep M. Guerrero, Prof. Juan C. Vasquez, Ass. Prof., Yajuan Guan – AAU
Professor Ernane Coelho, Universidade Federal de Uberlândia, Brazil

ECTS: 2

Date/Time: 22-23 February 2021

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. In addition, as one of current trends and developments the Internet of Things (IoT) is affecting and will shape the society and the world in all respects. The meet of IoT and energy industry naturally brings the promise of Energy Internet round the corner to introduce significant advantages and opportunities: enhanced automation, controllability, interoperability and energy efficiency, smarter energy management, and so on. 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 and how to be extended Energy Internet at a systemic level.

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, stability analysis based on small signal models, as well as Energy Internet-enabled opportunities and advanced solutions.

Day 1: Microgrids Systems Overview, Modelling and Control.
Ernane Coelho (3h), Josep Guerrero (1h), Juan Vasquez (1h) and Yajuan Guan (1h)

Day 2: Distributed Energy Storage Systems, Hierarchical Control, and IoT-enabled energy internet solutions
Josep Guerrero (2h), Juan Vasquez (2h), Yajuan Guan (2h)

Prerequisites: Knowledge on power electronics modelling, control theory and Matlab/Simulink 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 course assessment 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/

Power Quality and Synchronization Techniques in Microgrids

Organizer: Prof. Josep M. Guerrero joz@et.aau.dk, Prof. Juan C. Vasquez juq@et.aau.dk

Lecturers: Professor Josep M. Guerrero (Aalborg University)

Associate Professor Mehdi Savaghebi (University of Southern Denmark)

Lecturer Alexander Micallef (University of Malta)

Assistant Professor Saeed Golestan, Postdoctoral researcher (Gibran Tinajero)

ECTS: 3

Date/Time: 24-26 February, 2021

Max no. of participants: 20

Description: Microgrids as one of the main building blocks of the smart grids which facilitate implementation of many smart grid functions and services. It is expected that in a near future, smart grids shall emerge as 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 the main power quality phenomena 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 (centralized and decentralized) control approaches are presented in order to enhance the voltage quality. As the synchronization system of power converters plays a key role in their performance in the presence of power quality problems, modelling, designing, and tuning of advanced synchronization systems, including phase-locked loops (PLLs), frequency-locked loops (FLLs), and open-loop synchronization systems, are also discussed. Several simulation exercises will be included in labs which cover about 50% of the course time

Day 1: Power Quality in Microgrids, Harmonic Compensation and Virtual Impedance Concept for PQ Improvement
Josep Guerrero (1h), Alexander Micallef (4h), Juan Vasquez (0.5h), Gibran Tinajero (0.5)

Day 2: Primary and Secondary Control for Harmonic and Unbalance Compensation in Microgrids
Josep Guerrero(1h), Mehdi Savaghebi (4), Juan Vasquez (0.5h), Gibran Tinajero (0.5)

Day 3: Synchronization of Power Converters: Introduction, Design and Analysis
Saeed Golestan (6 hours)

The lectures on day 3 are divided into four parts:

1. The first part includes a general description of a standard PLL structure and its modeling, tuning and analyzing its key features, designing advanced PLLs and their modeling and tuning aspects for both single-phase and three-phase systems.
2. The second part includes describing the historical developments of standard single-phase and three-phase FLLs, their modeling and tuning aspects, and extending their structures to deal with power quality problems.
3. The third part includes describing key features of open-loop synchronization systems and presenting two general approaches for designing them.
4. The last part includes a brief description of the dynamic interaction between the power converters and its synchronization system, and modeling and analyzing this interaction.

Prerequisites: MATLAB/Simulink SIMPowerSystem 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 active participation in combination with delivery of exercises reports.

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

Liquefaction of Biomass - Fundamentals and Practice

Organizer: Saqib Sohail Toor, Associate Professor, email: sst@et.aau.dk

Lecturers: Saqib Sohail Toor (Ass. Prof. Aalborg University), Thomas Helmer Pedersen (Ass. Prof. Aalborg University), Daniele Castello (Assis. Prof. Aalborg University), Kamaldeep Sharma (Postdoc. Aalborg University), Anne Vibeke Kofoed Rasmussen (Academic TAP/Senior Chemical Engineer, Steeper Energy, Denmark)

ECTS: 3

Date/Time: 1-3 March, 2021

Max no. of participants: 15

Description: The course is designed to teach students about biofuels and biomass liquefaction technology in the context of energy and chemical products. The course will introduce fundamental principles of liquefaction, focusing on hydrothermal liquefaction. Based on this, it will move on to process analysis and design, process modeling tools and process implementation. Furthermore, the course discusses upgrading technology for biocrudes and drop-in biofuels approach. The course will introduce analytical techniques for product stream analysis and data interpretation with specific reference to liquefaction product streams and their special characteristic. 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 specifically hydrothermal liquefaction.
- Mass and energy balances, unit operations, and thermodynamics in HTL conversion technology.
- Introduction and implementation of Aspen Plus® process simulator for technoeconomical analysis of HTL process -case study.
- Product characterization techniques through laboratory instrumentation.

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

Form of evaluation: individual mini report

PhD Course:

Liquefaction of Biomass- Fundamentals and Practice

1-3 March 2021, 3ECTS

Time	Monday 1.03.2021	Tuesday 2.03.2021	Wednesday 3.03.2021
9:00-9:45	**Welcome** **Energy Outlook Session** (THP) • Scenarios • EU Energy Directives • Markets • Challenges • Biorefineries	**Upgrading Technology Session** (DAC) • Why upgrading? • Oil refinery in a nutshell • The drop-in approach • Different strategies in upgrading • Introduction to hydrotreating	**Experimental Session & Data interpretation-1** (KSH, DAC, AKR) Biocrude analysis • Oil characterization by GCMS • Heating value by Bomb calorimeter • FTIR analysis • CHNS analyser • Ash analyser • Simdist for upgraded oil
9:45-10:30	**Conversion Technologies Session** (SST) • Biomass Resources, Impacts & Pre-treatment • Routes of Biomass Conversion Processes • Thermochemical Processes	**Hydrotreating Session-1** (KSH) • Hydrotreating: typical reactions • Hydrodeoxygenation of biocrude compounds • The problem of denitrogenation • Catalysts: sulfided vs. non-sulfided • Biocrude demineralization	
10:30-10:45	Coffee	Coffee	Coffee
10:45-12:00	**Hydrothermal Liquefaction (HTL) Session-1** (SST) • Sub & Super-critical water • Hydrothermal Processing Concept • Hydrothermal Processing Chemistry • Hydrothermal Liquefaction (HTL) • Process Variables & State of the art	**Hydrotreating Session-2** (DAC) • Reactor technology: batch and continuous • Process variables and performance • Challenges for different feedstocks • Other approaches to upgrading • Case study: Hydrotreating experiments at AAU	**Experimental Session & Data interpretation-2** (KSH, DAC, AKR) Water and Gas phase analysis • KF titration, Moisture analyser • TOC • GC
12:00-12:30	Lunch	Lunch	Lunch
12:30-14:00	**Hydrothermal Liquefaction (HTL) Session-2** (SST) • Thermodynamics, Mass & Energy balances • Case Study-HTL Experiments at AAU • Research Challenges	**Drop-in Session** (KSH) • On the usage of raw and upgraded biocrude • Miscibility and compatibility with fossil streams • Theoretical and practical aspects of compatibility • Case study: Experimental analysis on miscibility and demineralization	**CBS-1 PILOT PLANT VISIT**
14:00-14:15	Coffee	Coffee	
14:15-16:00	**Aspen Plus ® Process simulator** (SST) • Introduction • Technoeconomical analysis-HTL • Case Study-Implementation	**Product Characterization Techniques standard operating procedures**(AKR) • GCMS, Bomb Calorimeter, FTIR • TOC, GC, KF Titration etc....	

Cyber Security of Microgrids

Organizers: Prof. Frede Blaabjerg fbl@et.aau.dk and Dr. Subham Sahoo, Aalborg University

Lecturer: Dr. Subham Sahoo (sssa@et.aau.dk)

ECTS: 2

Date/Time: 4-5 March 2021

Max no. of participants: 30

Description: Microgrids are recently becoming the backbone as the future enabling technology hub to realize a carbon-neutral electric power systems. Alongside their flexibility to be operated in both grid-connected and autonomous modes, they also provide more natural interfaces with many types of RES and ESSs and better compliance with consumer electronics. Moreover, microgrids can be *grid-interactive* by providing grid supportive functions such as frequency response and, regulation, reactive power support and voltage regulation, etc. All these facts lead to more and more deployment of microgrids in transmission and distribution levels. Furthermore, with proliferation of communication technologies, these microgrids are quickly evolving into cyber-physical systems (CPS) that use sophisticated software-based networked control. These increased sophistication imposes numerous new challenges involving coordination, operation philosophy and vulnerability to cyber attacks.

Cyber attacks can be designed in many ways: (a) sensor infiltration, (b) communication infringement. Even though several hard-bound secure protocols are designed to ensure the authenticity of the actual signal, the attackers usually target the control layer as an easy target. Hence, this course aims to focus: (a) identifying the vulnerable access points in microgrid controllers, (b) introduce the most prominent cyber attacks, (c) detection of cyber attacks in in real-time, (d) removal of these attack elements and ensuring stability/preventing system shutdown, (e) design of resilient controllers for microgrids, which heals by itself despite any cyber intrusion attempts. All models will be provided to attendees and experimental lab demonstration is expected as well alongwith discussion on future research ideas.

Day 1: General information about cyber security and its impact in microgrids – Dr. Subham Sahoo (5 hours)

09:00 – 10:00 Microgrids – Role in modern power systems
10:00 – 10:30 Basic control and operation philosophies of microgrids
10:30 – 11:00 Coffee break
11:00 – 12:00 Cyber security in power systems – Lookback into the past events
12:00 – 13:00 Lunch break
13:00 – 14:00 Vulnerability assessment of microgrids to different kinds of attacks
14:00 – 15:00 Design of cyber attack detection and mitigation strategies for microgrids
15:00 – 15:30 Coffee break
15:30 – 16:30 Design of resilient *self-healing* controllers for microgrids

Day 2: Cyber security laboratory exercises. Dr. Subham Sahoo (5 hours)

09:30 – 10:30 Laboratory 1.1: Detection of cyber attacks in microgrids (part 1)

10:30 – 11:00 Coffee break

11:00 – 12:00 Laboratory 1.2: Detection of cyber attacks in microgrids (part 2)

12:00 – 13:00 Lunch break

13:00 – 15:00 Laboratory 2: Design of resilient controllers for microgrids

15:00 – 15:30 Coffee break

15:30 – 16:30 Laboratory 3: Mitigation of cyber attacks in microgrids

Prerequisites:

- General knowledge about electrical engineering field.
- Practicing knowledge in power electronic systems and control theory.
- Experience in using Matlab/Simulink

Form of evaluation: Report evaluated by the lecturers.

Link: http://www.et.aau.dk/phd/phdcourses/

Advanced Optimization Techniques for Energy Systems Planning and Operation

Organizer: Associate Professor Amjad Anvari-Moghaddam, aam@et.aau.dk – Aalborg University

Lecturers: Associate Professor Amjad Anvari-Moghaddam – Aalborg University
Postdoc Behnam Mohammadi-ivatloo – Aalborg University

ECTS: 3

Date/Time: 10 - 12 March 2021

Max no. of participants: 25

Description: Optimal decision-making is a must in energy system planning and operation as the non-optimal decisions may lead to high economic losses and/or technical issues. The course on "Advanced Optimization Techniques for Energy Systems Planning and Operation" is aimed at providing an in-depth introduction to energy system optimization methods. The course will contain a wide range of the basic methods to advanced techniques with hand on examples related to energy systems. The participants will learn how to implement the methods using optimization packages such as GAMS and MATLAB.

Syllabus: The course will mainly cover the following subjects

Day 1 (8:30-16:30- both Lecturers)

1.1. Introduction to optimization
1.2. Linear programming (geometric methods, simplex algorithm, and sensitivity) and duality theories (dual problem, weak duality theory, and strong duality theory)
1.3. Decomposition Techniques for LP (Dantzig Wolfe & Benders)

Day 2 (8:30-16:30- both Lecturers)

2.1. Mixed integer linear programming
2.2. Nonlinear programming (KKT conditions, convexity, duality)
2.3. Application of Metaheuristic Algorithms

Day 3 (8:30-16:30- both Lecturers)

3.1. Multi-objective optimization
3.2. Bi-level programming
3.3. Stochastic Optimization
3.4. Risk Modelling and Management

Prerequisites: Basic knowledge in linear algebra and programming

Form of evaluation: The participants will be evaluated by exercises in a daily basis (both individually and in groups) and a mini-project on the optimization of energy systems at the end of the course.

Intended Audience:

- Utility personnel involved in energy system operation, planning and related activities
- Power engineers
- Policy makers and energy planers
- PhD/Guest PhD Students (Engineering, Mathematics, Economics, Planning)

DC Microgrids

Organizer: Professor Josep M. Guerrero joz@et.aau.dk, Professor Juan C. Vasquez juq@et.aau.dk

Lecturers: Professor Josep M. Guerrero, Aalborg University
Associate Professor Sanjay K. Chaudhary, Aalborg University
Assistant Professor Baoze Wei, Aalborg University
Postdoctoral Researcher Mashood Nasir, Aalborg University

ECTS: 2

Date/Time: 15-16 March 2021

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 mature DC output generation systems including distributed energy storage solutions are presented showing their interaction in DC distribution Microgrids. The course also shows examples of DC microgrids in different applications like telecommunication systems, wind power DC collector grid, residential DC electrical distribution systems and hybrid AC-DC microgrids.

Day 1: DC Microgrids Introduction, Design and Control.
Josep Guerrero (3h), Baoze Wei (2h), Mashood Nasir (1h)

Day 2: DC Collector Grids for WPPs and Hierarchical Control of Microgrids
Sanjay Chaudhary(1.5h), Josep Guerrero(1.5h), Baoze Wei (2h), Mashood Nasir (1h)

Prerequisites: Knowledge on power electronics modelling, control theory and Matlab/Simulink 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/

Models, Methods and Optimization Tools for Energy Systems

Organizer: Professor Juan C. Vasquez juq@et.aau.dk, Professor Josep M. Guerrero joz@et.aau.dk

Lecturers: Professor Eleonora Riva Sanseverino (University of Palermo),
Associate Professor Moises Graells (Technical University of Catalonia)
Postdoctoral Fellow Najmeh Bazmohammadi (Aalborg University)

ECTS: 3

Date/Time: 17-19 March, 2021

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. Finally, the third problem is how to translate the results of the optimization process into concrete actions that will manage the resources. This means that the digital outcome or solution must be interface with physical systems which general involves a communication infrastructure.

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. Moreover, specific real applications of these methods and algorithms will be shown, not only focusing on the optimization by itself but also showing the techniques for interconnecting the computational system with the resources utilizing technologies such as the Internet of Things (IoT) and advanced metering infrastructures (AMI).

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.

Day 1: Introduction Models and Methods – Moises Graells (5h) + Najmeh Bazmohammadi (1h)

Day 2: Optimization Tools – Eleonora Sanseverino (5h) + Najmeh Bazmohammadi (1h)

Day 3: Applications to Energy and Microgrid Systems - Josep Guerrero (3h) + Najmeh Bazmohammadi (3h)

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. Skills regarding Matlab/Simulink is also needed.

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

Application-Oriented Modelling of Renewable Energy Sources, Conversion and Energy Storage Systems

Organizer: Associate Professor Tamas Kerekes, tak@et.aau.dk, Aalborg University

Lecturers: 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
Assistant Professor Sergiu Spataru, sersp@fotonik.dtu.dk, DTU

ECTS: 4

Date/Time: 23 - 26 March 2021

Max no. of participants: 35

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.

Day 1: Modelling of photovoltaic systems – Sergiu Spataru (8 hours)

- Modelling the solar resource, solar cells, modules and arrays
- Performance models of the array, inverter and PV plant
- Modelling of PV panels and systems from measurement data
- Real-time implementation of the model

Day 2: Modelling of power converters – Tamas Kerekes (8 hours)

- Average and switching modelling of the power converters
- Thermal modelling of the switches
- Modelling of different modulators for PWM
- Comparison between the different level of modelling with the experimental results obtained from dSpace

Day 3: Modelling of energy storage systems – Daniel Stroe (8 hours)

- Battery performance testing
- Methods of battery performance modelling and validation
- Development of the static battery model;
- Development of the equivalent electrical circuit based dynamic battery model based on measurement data;
- Validation of battery model

Day 4: Modelling of wind power systems – Florin Iov (8 hours)

- Modelling of wind resource, aeromechanical part and electrical part of different wind turbine concepts
- Performance models for wind turbine systems
- Smart grid applications including storage and PV systems
- Modelling of wind turbine systems components
- Real-time implementation aspects
- HIL testing and verification of models

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/

Advanced FPGA-based Controllers for Power Electronic and Drive Applications

Organizer: Prof. Josep M. Guerrero joz@et.aau.dk, Prof. Juan C. Vasquez juq@et.aau.dk, AAU

Lecturers: Professor Eric Monmasson (University of Cergy-Pontoise)
Assistant Professor Mattia Ricco (University of Bologna)

ECTS: 3

Date/Time: 30 March - 1 April, 2021

Max no. of participants: 16

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:

Day 1. - 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.

Lecturers: Eric Monmasson (4 hours) + Mattia Rico (2 hours)

Day 2 and 3: - 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.

Lecturers**:** Eric Monmasson (4 hours) + Mattia Rico (2 hours)

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/

WIDE AREA MONITORING, PROTECTION AND CONTROL

Organizer: Assistant Professor Zhou Liu - Aalborg University, zli@et.aau.dk

Lecturers: Professor Zhe Chen, Assistant & Professor Zhou Liu - Aalborg University

ECTS: 2

Date/Time: 15-16 April, 2021

Max no. of participants: 30

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

The main topics are as follows：

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

Day 1: Introduction of Smart Grid and WAMPC + Zhe Chen and Zhou Liu (+ 8 hours)

- Smart grid and WAMPAC introduction
- The evolution of energy control centers
- Power system stability and control
- SMT based state estimation
- Off line Apps
- Real time apps

Day 2: RTDS based Demonstration + Zhou Liu (+ 8 hours)

- Overview of RTDS hardware and RSCAD
- RTDS based applications in WAMPC
- System level protection applications and testing
- Hardware in the loop demonstration and hands on exercises

Prerequisites: Knowledge in Power System Analysis, real time digital simulator (RTDS), DIgSILENT and skill in using MATLAB

Form of evaluation: Assignments to be completed, the reports to be submitted and evaluated after the course

Hybrid Power Plants – Modelling, Operation and Control
A Model Based Design Approach

Organizer: Associate Professor Florin Iov, fi@et.aau.dk, Aalborg University

Lecturers: Associated prof. Rasmus Olsen Løvenstein rlo@es.aau.dkm, Aalborg University
Post Doc Karthikeyan Nainar, kan@et.aau.dk, Aalborg University
Post Doc Catalin Iosif Ciontea, cic@et.aau.dk , Aalborg University

ECTS: 3

Date/Time: 21-23 April 2021

Max no. of participants: 20

Description: A recent trend is to augment wind power with solar PV production and various batteries based energy storage systems in so-called hybrid power plants. In this way, a better utilization of plant infrastructure, a steady power output over longer time periods and thus a better integration in energy markets are achieved. Moreover, such a plant can deliver firm ancillary services which may not be provided by the individual components alone. This three days course gives a systematic approach for modelling, control design and operation of Hybrid Power Plants using the Model-Based Design approach. It includes a wide range of hands-on exercises as well as demonstrations in a Real-Time Hardware-In-the Loop framework. The main focus in this course will be on:

- Plant architectures and interoperability
- Balance of plant configuration, topologies and sizing
- Information and communication technologies
- Model based approach for control design
- Grid Monitoring and Ancillary services
- Market participation

Lectures are alternated with practical exercises on each major topic. More than 40% of the course is used for practical exercises and laboratory demonstrations.

Day 1:

Hybrid Power Plants – an overview – Florin Iov (2.5 hours)

- Main components and challenges
- Plant architectures and interoperability layers
- Market integration and grid support services
- Practical considerations on Balance of Plant
- Methodologies and tools for design and assessment (offline simulations and RT-HIL)

Information and Communication Technologies – Rasmus Olsen (3.5 hours)

- Communication networks architectures and technologies
- Protocols and standards
- Performance definitions and classification

- Models for ICT (offline simulations and RT-HIL)
- Practical exercises

Day 2:

Modelling of Assets and Grid – Catalin Iosif Ciontea (2 hours)

- Modelling requirements for specific studies
- Performance models vs detailed models (wind turbines, PV, energy storage, etc.)
- Grid models (voltage control studies, frequency control studies)
- Practical exercises

Grid Monitoring – Karthikeyan Nainar and Florin Iov (2 hours)

- technologies and required functionalities
- signal processing and calculation of main variables (filtering, RMS calculation)
- estimation techniques for frequency and ROCOF
- Practical exercises

Control Design – Florin Iov and Karthikeyan Nainar (2 hours)

- Active and reactive power control
- Runtime power dispatchers
- Intra-plant estimation techniques
- Practical exercises

Day 3:

Ancillary Services – Florin Iov and Karthikeyan Nainar (2 hours)

- Frequency and voltage regulation
- Other advanced functionalities (e.g. PSS like, power smoothening, power firming) • Practical exercises

Market Participation – Karthikeyan Nainar (2 hours)

- Overview of energy and ancillary service markets
- Optimization framework for economic dispatch
- Practical exercises

RT-HIL demonstrations – Catalin Iosif Ciontea (2 hours)

- Architectures and practical considerations for RT-HIL deployment
- Demonstrations of operation and control of a hybrid power plant in a RT-HIL framework

Prerequisites: Basic knowledge on Matlab/Simulink including Toolboxes is recommended for the exercises**.**

Form of evaluation: Individual evaluation of the student assignments received during the lecture and laboratory exercises.

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

Understand how to write good papers for high level journals

Organizer: Associate Professor, Kaiyuan Lu, klu@et.aau.dk, Aalborg University

Lecturers: Prof., Frede Blaabjerg, Assoc. Prof., Kaiyuan Lu

ECTS: 1.5

Date/Time: 3 – 4 May 2021 (1.5 days)

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.

Day 1: Good guidelines for paper writing – Frede and Kaiyuan (8 hours)
We will cover various important issues to secure successful paper writing as mentioned in the course description. You will have a chance to get feedbacks about your own paper from your group supervisor and group discussions during the exercise session.

Day 2: Reply-to-reviewers letter and sharing of various stories – group supervisors (4 hours)
How to prepare the reply-to-reviewers letter will be discussed. Examples will be presented and various advices and storied experienced by the group supervisors will be shared.

Prerequisites: No

Form of evaluation: Group exercise-based evaluation

Energy Markets and Analytics

Organizer: Associate Professor Amjad Anvari-Moghaddam, aam@et.aau.dk – Aalborg University

Lecturer: Associate Professor Amjad Anvari-Moghaddam – Aalborg University
Postdoc Behnam Mohammadi-ivatloo – Aalborg University

ECTS: 2

Date/Time: 17-18 May 2021

Max no. of participants: 25

Description: Energy markets are at the heart of one of the biggest societal challenges of our time - creating a sustainable, reliable and affordable energy provision. Renewable Energies are also new guests and participants in such markets. The PhD/industrial course on "Energy Markets and Analytics" aims at providing an in depth introduction to energy markets and how the renewable energies can be integrated in them safely. The participants will learn how to implement the concepts using appropriate software packages on planning, decision making and optimization.

Syllabus: The course will mainly cover the following subjects:

Day 1 (8:30-16:30- both Lecturers)

1.1. Introduction to energy markets
1.2. Pricing and market clearing mechanisms
1.4. Market participants
1.5. Challenges of participation of renewable energy resources (RER) in markets

Day 2 (8:30-16:30- both Lecturers)

2.1. Policies for integrating RERs in markets around the world
2.2. Impact of RERs on market clearing and market outputs
2.3. Demand side management for RERs integration in energy markets
2.4. Energy storage for RERs integration in energy markets

Prerequisites: No.

Form of evaluation: The participants will be evaluated by exercises on a daily basis (both individually and in groups) and a mini-project on market practices at the end of the course.

Intended Audience:

- Researchers and utility engineers interested in modern energy system operation, planning and related activities
- Actors in decision making and policy process
- (Post-)Graduate students and researchers in energy engineering, planning, economics, and finance.

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

Machine learning, predictive modelling, and validation – an example for battery state-of-health estimation

Organizer: Assoc. Prof. Daniel-Ioan Stroe, dis@et.aau.dk, Aalborg University

Lecturers: Postdoc. Søren B. Vilsen (AAU-MATH)

Assoc. Prof. Daniel-Ioan Stroe

ECTS: 2.0

Date/Time: 19 - 20 May 2021

Max no. of participants: 30

Description: Machine learning (ML) and advanced predictive statistical techniques are gaining widespread use in the field of electrical engineering as a whole, and for state-of-health modelling of Lithium-ion batteries in particular. The introduction of ML and statistics in electrical engineering is a consequence of the field slowly subsidising some of the more expensive laboratory testing by using data collected during real-life operating conditions. The upside of using ML and predictive statistics is that, in many instances, these methods can achieve an acceptable precision using a reduced amount of laboratory testing. However, it comes at the cost of added model complexity and the loss of some of the explanatory power when compared to the physics based state-of-health models.

This two-day course introduces key aspects of machine learning, predictive modelling, and model validation. Focusing on quantitative predictive models for Lithium-ion battery state-of-health modelling. The models will include sequential and non-sequential approaches, univariate and multivariate outcomes, Bayesian and frequentist frameworks, as well as the reduction and selection of features for modelling. The general aim of these methods is to predict capacity degradation, resistance increase, and remaining useful life based on a combination of laboratory and field data.

Exemplifications of some of the discussed topics will be made through exercises in R and Matlab.

Day 1: Introduction to Machine Learning and Bayesian statistics – Søren B. Vilsen & Daniel Stroe (8 hours)

- Overview of machine learning methods, the bias-variance trade-off, and cross-validation.
- Bayesian statistics, sequential model updating, and remaining useful life estimation.
- Auto-regressive models, Kalman-filtering, and state intervention for state-of-charge and state-of health estimation.
- Battery performance parameters for state-of-health estimation

Day 2: Machine learning for battery SOH estimation – Søren B. Vilsen & Daniel Stroe (8 hours)

- Feature reduction using principle components analysis and auto-encoders.
- Feature selection using subset selection, partial least squares, and shrinkage methods.
- Support vector regression, Gaussian process regression, and neural networks.
- Boosting, ensemble learning, and interpreting black-box methods.

Prerequisites: Fundamental understanding of probability, statistics, and is recommended, as is basic knowledge of either R or Matlab. Note: the course language is English.

Form of evaluation: Students are expected to solve a number of exercises and deliver an individual report with solutions and comments.

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

Modelling and Optimization of Thermal Energy Systems

Organizer: Associate Professor Mads Pagh Nielsen, mpn@et.aau.dk – Aalborg University

Lecturers: Associate Professor Mads Pagh Nielsen – Aalborg University

Assistant Professor Thomas Helmer Pedersen – Aalborg University

ECTS: 2

Date/Time: 3 – 4 June 2021

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/

Electrochemical Energy Conversion

Organizer: Associate Professor Torsten Berning - Aalborg University

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

ECTS: 3,5

Time: 8 - 11 June 2021

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.

Day 1: Thermodynamics of electro-chemical energy conversion, Different types of fuel cells and water electrolyzers.
Lecturers: Torsten Berning, Vincenzo Liso. 8h.

Day 2: Fuel cell and electrolyzer components, fuel cell and electrolyzer modeling.
Lecturers: Vincenzo Liso, Samuel Araya. 8h.

Day 3: Experimental methods in theory and practice: Electrochemical impedance spectroscopy, hot wire anemometry, Cyclic Voltammetry, Neutron Radiography.
Lecturers: Samuel Araya, Søren Jensen. 8h.

Day 4: Industrial perspectives: Current and future challenges. A visit by or from a local fuel cell manufacturer.
Lecturers: Søren Jensen, Torsten Berning. 4h.

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

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

Literature:

- R. O'Hayre, S.-W. Cha, W. Colella, F. B. Prinz: Fuel Cell Fundamentals, 3rd ed., Wiley, 2016.
- F. Barbir: PEM Fuel Cells - Theory and Practice, 2nd ed., Elsevier, 2012.
- D. Bessarabov, H. Wang, H. Li, N. Zhao: PEM Electrolysis for Hydrogen Production: Principles and Applications, CRC Press 2015.
- S. Lvov: Introduction to Electrochemical Science and Engineering.

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

Electricity Markets and Power System Optimization

Organizer: Z. Chen, Professor zch@et.aau.dk, Aalborg University, Denmark

Lecturers: Andrés Ramos Galán, Professor Andres.Ramos@comillas.edu, Universidad Pontificia Comillas, Spain

ECTS: 3

Date/Time: 16 - 18 June, 2021 / 8:30-16:30

Max no. of participants: 30

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

The main topics are as follows:

- Introduction to the electricity market organization
- Modeling the competition in electric energy markets
- Stochastic unit commitment to coop with the renewable generation
- Probabilistic midterm transmission expansion planning in liberalized markets
- Decomposition for large-scale optimization problems

Day 1: Impact of renewable energy sources in short-term generation planning. Stochastic Daily Unit Commitment. Implementations in GAMS, Julia and Python. Andrés Ramos (7 h)
Uncertainty and variability of renewable generation resource may drastically affect the short-term operation planning of the electric system. This module will cover how to introduce these specific characteristics of renewables in a unit commitment model.

Day 2: Medium-term Stochastic Hydrothermal Coordination Model. Scenario tree. Stochastic measures. Implementation in GAMS. Andrés Ramos (7 h)
Some generation resources, such as hydro reservoirs, require a medium-term (weekly, monthly, annual) vision for their efficient operation. This module will include this medium-term scope in your decision-making.

Day 3: Generation and Transmission Expansion Planning. Implementation in GAMS. Andrés Ramos (7 h)
Power generators and transmission lines are capital-intensive infrastructure whose lifetimes span from 15 to 40 years. Decisions of today will last several years and may compromise climate change objectives. Expansion planning is the framework to understand the implications of long-term decisions and they can help in climate change policies.

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

Form of evaluation: Assignments to be completed, then the reports to be submitted and evaluated after the course

Open-source Computational Fluid Dynamics – 1. Fundamentals

This course is the first part of the 5 day course on OpenFOAM and covers fundamental aspects. The second part of the course can be found here: https://phd.moodle.aau.dk/course/view.php?id=1658

More detailed information about the course can be found at cfd.aau.dk

Organizer: Assistant Prof. Jakob Hærvig, Dept. of Energy Technology, AAU (jah@et.aau.dk)
Assistant Prof. Johan Rønby, Dept. of Mathematical Sciences, AAU (roenby@math.aau.dk)

Lecturers: Assistant Professor Jakob Hærvig, Dept. of Energy Technology, Aalborg University
Assistant Professor Johan Rønby, Dept. of Mathematical Sciences, Aalborg University

ECTS: 2

Date/Time: 21-22 June 2021

Place: Frederikskaj 10A, 2450 Copenhagen, Denmark

Max no. of participants: 20

Description: Interaction between fluid and a human-made structure or device is design critical in a wide range of engineering disciplines. When designing bridges, cars, wind turbines and when optimising electronics cooling, ship hulls etc. Computational Fluid Dynamics (CFD) software is becoming an ever more important design tool. CFD enables faster design loop iteration by detailed flow analysis in or around a proposed design in a virtual environment.

This course is an introduction to CFD using OpenFOAM which is the most widely used open source toolkit for CFD. The fact that OpenFOAM is open source makes it extremely versatile allowing the user to modify any aspect of the code to his/her needs. While large scale simulations with commercial CFD software can be extremely expensive due to licence fees, OpenFOAM can be run on massively parallel HPC's at no additional cost.

Prerequisites: Participants must have basic understanding of the physics of fluids and the usage of CFD methods. Furthermore, basic skills in general use of computers are expected. The participants will work with exercises on an OpenFOAM installation on Microsoft Azure, so before the first day you must sign up for an account on Azure and preferably log in and verify the installation (more detailed info provided after sign-up).

Form of evaluation: A standard mini-project must be delivered (4-8 pages) in addition to the OpenFOAM code. The mini-report should explain the choices made with regard to the OpenFOAM setup and present the outcome of the simulations.

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

Open-source Computational Fluid Dynamics –
2. Efficient Workflows and Code Customization

This course is the second part of the 5 day course on OpenFOAM and covers efficient workflows and code customisation. The first part of the course can be found here: https://phd.moodle.aau.dk/course/view.php?id=1657.

More detailed information about the course can be found at cfd.aau.dk

Organizer: Assistant Prof. Jakob Hærvig, Dept. of Energy Technology, AAU (jah@et.aau.dk)
Assistant Prof. Johan Rønby, Dept. of Mathematical Sciences, AAU (roenby@math.aau.dk)

Lecturers: Assistant Professor Jakob Hærvig, Dept. of Energy Technology, Aalborg University
Assistant Professor Johan Rønby, Dept. of Mathematical Sciences, Aalborg University

ECTS: 3

Date/Time: 23-25 June 2021

Place: Frederikskaj 10A, 2450 Copenhagen, Denmark

Max no. of participants: 20

Description Interaction between fluid and a human-made structure or device is design critical in a wide range of engineering disciplines. When designing bridges, cars, wind turbines and when optimising electronics cooling, ship hulls etc. Computational Fluid Dynamics (CFD) software is becoming an ever more important design tool. CFD enables faster design loop iteration by detailed flow analysis in or around a proposed design in a virtual environment.

This course is an introduction to CFD using OpenFOAM which is the most widely used open source toolkit for CFD. The fact that OpenFOAM is open source makes it extremely versatile allowing the user to modify any aspect of the code to his/her needs. While large scale simulations with commercial CFD software can be extremely expensive due to licence fees, OpenFOAM can be run on massively parallel HPC's at no additional cost.

Prerequisites: Participants must have basic understanding of the physics of fluids and the usage of CFD methods. Furthermore, basic skills in general use of computers are expected. The participants will work with exercises on an OpenFOAM installation on Microsoft Azure, so before the first day you must sign up for an account on Azure and preferably log in and verify the installation (more detailed info provided after sign-up).

Furthermore, fundamental knowledge of OpenFOAM is expected. We recommend that new OpenFOAM users start with the course "Open-source Computational Fluid Dynamics – 1. Fundamentals". Additionally, basic knowledge in Python programming is recommended.

Form of evaluation: A standard mini-project must be delivered (4-8 pages) in addition to the OpenFOAM code. The mini-report should explain and document an OpenFOAM workflow along with modifications to either a flow solver, boundary conditions or functions objects

New Energy Technologies and Systems

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

Lecturers: Professor Zhe Chen, Assistant Professor Zhou Liu, Assistant Professor Yanbo Wang, Postdoctoral fellow Dong Liu, PhD student Yufei Xi, PhD student Xuewei Wu
Professor Mauro Cappelli (mauro.cappelli@enea.it)

ECTS: 3

Date/Time: 28 - 30 June 2021

Max no. of participants: 30

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

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

Day 1:
Overview of energy resources and systems, Zhe Chen, 1.5 hours
Basics of energy conversion systems, Zhe Chen, 1.5 hours
Energy system integration and Optimization, Zhe Chen, 1.5 hours
Renewable energy transmission: operation and control, Yanbo Wang, 1.5 hours

Day 2:
Basics of nuclear energy systems, Mauro Cappelli, 1.5 hours
Control of nuclear energy systems, Mauro Cappelli, 1.5 hours
Instrumentation and Control (I&C) Systems for Nuclear Applications, Mauro Cappelli, 1.5 hours
Principles of design of a central I&C System, Mauro Cappelli, 1.5 hours

Day 3:
Energy system integration: advanced technologies and emerging facilities, Zhou Liu, 1.5 hours
Optimal management flexible resources (FRs) in multi-energy systems (MES), Yufei Xi, 1.5 hours
Optimal operation of integrated electricity-gas-heat system, Xuewei Wu, 1.5 hours
Discussion and Assignments

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

Form of evaluation: Mini-project

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

Periodic Control and Filtering in Power Electronic Converter Systems

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

Lecturers: Yongheng Yang (YOY), Associate Prof., ET, Aalborg University
Yonghao Gui (YG), Assistant Prof., ES, Aalborg University

ECTS: 2

Date/Time/Location: 1 - 2 July 2021, Aalborg East Campus

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 (YOY & YG)
  - Motivation and background
  - General power converter control
  - Internal model principle
  - Basis function for periodic control and filtering
- Fundamental Periodic Control in Power Electronic Conversion (YG)
  - Repetitive control

    - Resonant control
    - Optimal periodic control
    - Application examples

Day 2:

- Advanced Periodic Control in Power Electronic Conversion (YG & YOY)
    - Digital control issues
    - Frequency adaptive periodic control
    - Application examples
- Periodic Filtering for Power Electronic Conversion (YOY)
    - Harmonics and pre-filtering
    - Periodic filtering for power conversion
    - Application examples
- Extensive Applications of Periodic Control and Filtering (YOY)
- Course wrap-up (YOY & YG)

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: Course lecturers will design mini-projects. 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. A report should be submitted.

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

Stability and Control of Grid-Connected Converters

Organizer: Professor Xiongfei Wang xwa@et.aau.dk, Aalborg University

Lecturers: Prof. Lennart Harnefors, ABB Corporate Research/KTH, Sweden
Prof. Xiongfei Wang, Aalborg University, Denmark.

ECTS: 3

Date/Time: ~~11-13 May~~ **11-13 August, 2021**

Max no. of participants: 60

Description: Grid-connected converters have commonly been used with renewable power generations, flexible ac/dc power transmission systems, regenerative drives, etc. As the increasing use of converters in electrical grids, the dynamic modeling and control of converters become critical for building a stable power-electronic-based power system. This course thus devotes to provide a design-oriented analysis on the control dynamics of grid-connected converters, covering the fundamental and state-of-the-art of modeling, stability analysis and control topics, including:

- Vector current control
- Complex-valued frequency-domain modeling
- Impedance-based stability analysis
- Grid synchronization control and its stability impact
- DC-link and ac-bus voltage control
- Robust damping control techniques

Day 1: Vector Current Control, Prof. Xiongfei Wang (3 hours), Prof. Lennart Harnefors (3 hours)

- Space vectors and coordinate transformation
- Small-signal modeling of converter power stage
- Design of vector current controller and its anti-windup
- Influences of time delay and LCL-filter resonance
- Harmonic current control and practical design

Day 2: Grid Synchronization and Power Control, Prof. Lennart Harnefors (3 hours), Prof. Xiongfei Wang (3 hours)

- Phase-Locked Loop (PLL): small-signal modeling and parameter tuning
- Influence of PLL on grid-converter interactions
- Impedance-based modeling and stability analysis
- Stability of DC-link Voltage Control (DVC)
- Stability of AC-bus Voltage Control (AVC)

Day 3: Robust Damping Control, Prof. Xiongfei Wang (3 hours), Prof. Lennart Harnefors (3 hours)

- Virtual impedance control
- Passivity-based current control
- Power-synchronization control
- Step-by-step design cases

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

Form of evaluation: Exercises and report

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

Multivariable and Intelligent Control of Industrial Electronic Systems

Organizer: Assoc. Prof., Amin Hajizadeh, aha@et.aau.dk and Assoc. Prof. Mohsen Soltani, sms@et.aau.dk

Lecturers: Amin Hajizadeh and Mohsen Soltani, Aalborg University, Esbjerg, Denmark

ECTS: 5

Date/Time: 16-20 august 2021

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

Max no. of participants: 15

Description: Intelligent and multivariable control methods are growing in the industrial electronic systems like power electronic converters, renewable energy systems and electric drives. The course is focused on the application of multivariable control and intelligent control techniques for industrial electronic systems. The main topics are as follows:

- State feedback control theory
- Design and implementation of fuzzy controller for industrial electronic systems
- Design and implementation multivariable Control theory for industrial electronic systems

Day 1: State feedback control theory, stability, controllability and observability by Amin and Mohsen (6 hours)

Day 2: Introduction to Fuzzy Control Theory, Standard fuzzy controller, Adaptive and self-learning fuzzy controllers. Industrial applications of the intelligent control systems in power electronics and electric drives by Amin (6 hours)

Day 3: Industrial applications of the intelligent control systems in power electronics and electric drives by Amin (6 hours)

Day 4: Multivariable Control theory, Robustness Conditions for Multivariable Systems, Singular Values, Modelling Error, Robust Stability, Estimation and Control for Multivariable Systems. By Mohsen Soltani (6 hours)

Day 5: Industrial applications of the multivariable control systems by Mohsen Soltani (6 hours)

Prerequisites: Control theory, power electronics

Form of evaluation: Mini projects

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

Advanced Computational Fluid Dynamics

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

Lecturers: Associate Prof. Chungen Yin, Associate Prof. Torsten Berning, Aalborg University

ECTS: 4

Date/Time: 17-20 August, 2021

Max no. of participants: 25

Description: Computational Fluid Dynamics (CFD) has been successfully used in innovative design, trouble-shooting, optimization of technologies and facilities in numerous areas. This advanced CFD course will provide a familiarity with and an in-depth understanding of the following topics and issues:

Day 1: Fundamentals of CFD (*intro to CFD; the finite volume method for various steady and unsteady problems; different spatial and temporal discretization schemes, their formulation, assessment and applicability*). Lecturer: Chungen Yin; 7.4 hours

Day 2: RANS turbulence modeling (*SIMPLE algorithm for pressure-velocity coupling; fundamentals of turbulence; different isotropic eddy viscosity models; near-wall modeling; meshing impact and strategies*). Lecturer: Chungen Yin; 7.4 hours

Day 3: Multiphase flow modeling (*different methods for multiphase flow modeling such as Lagrangian method, Eulerian method, mixture & volume of fluid approach; modeling multiphase flow in porous media*). Lecturer: Torsten Berning; 7.4 hours

Day 4: **Turbulent combustion modeling and user-defined functions** (*combustion analysis tools; species transport/eddy dissipation or EDC; mixture fraction/PDF; fundamentals & examples of user-defined functions*). Lecturer: Chungen Yin; 7.4 hours

During each of the four days, lectures will be combined with demos and hands-on sessions, in order to achieve the above objectives.

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

Form of evaluation: finish one of the following tasks and the corresponding mini-project report.

1) numerically solve a general transport equation using the finite volume method and the key results; *or*
2) 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/

Power module design, packaging and testing

Organizer: Associate Professor, Christian Uhrenfeldt, chu@et.aau.dk, Aalborg University

Lecturers: Christian Uhrenfeldt (CHU)
Szymon Beczkowski (SBE)
Asger Bjørn Jørgensen (ABJ)
Stig Munk Nielsen (SMN)

ECTS: 3 ECTS

Date/Time: ~~12 – 14 April~~ **23-25 August 2021**

Max no. of participants: 25 (limitation on experimental capabilities) – lectures are open for a wider audience.

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, compact fast switching hybrid GaN power modules and with experience of analyzing and testing industry standard power modules and components for higher powers. The course will contain background information on packaging process simulation, worked examples and case studies of FEM based digital power module design and experimental validation as well as a day spent with experimental hands-on exercises related to packaging and physical analysis in the laboratories.

Day 1: Power modules, Packaging processes and design guidelines. CHU (2.5 hours), SBE (2.5 hours), SMN (1 hour)
Background tutorials and workshop session with worked example of FEM based digital power module design.

Day 2: Laboratory exercise and Design exercise. CHU 6 hours, SBE, 6 hours, , ABJ 6 hours (lab exercises running)
Experimental hands-on experience with packaging processes and physical analysis of prototypes built during exercises.

Day 3: Testing of Power modules and their packaging and example presentation of state of the art power module packaging design. SMN 2 hours, CHU 1 hour, SBE 2 hours, ABJ 2 hours
Packaging challenges case studies: Paralleling dies, Medium Voltage power modules and fast switching hybrid/integrated compact modules.

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 reflectingon the experiment results in relation to the simulation results and the topics of the course.

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

Sustainable Biomass Resources and Technology Pathways for Biogas and Biorefineries

Organizer: Assoc. Prof, Jens Bo Holm-Nielsen jhn@et.aau.dk
Assoc. Prof., Mette Hedegaard Thomsen mht@et.aau.dk

Lecturers: Jens Bo Holm Nielsen, Mette Thomsen, Tanmay Chaturvedi - Aalborg University, Esbjerg

ECTS: 5

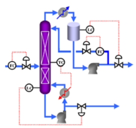
Date/Time: ~~19-23 April~~ **23-27 August 2021**

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

Max no. of participants: 30

Description: The course will give an overview of utilizing biomass as a resource for energy, fuel, and biomass derived chemicals and value added products. The course will topics in:

- Sustainable biomass
- Different types of biomasses available (e.g. woody biomass, forest residues, agricultural residues, energy crops, algae, etc.)
- Competitive pretreatment technologies and how do they differ in physical and chemical characteristics
- Biomass conversion technologies with focus on biochemical (anaerobic digestion and fermentation processes) conversion processes and methanisation
- Biorefinery approach and how processes can turn biomass into fuels and higher value products;
- How to obtain advanced biofuels from biomass
- How are economic and environmental assessments performed for biorefineries
- How will policies shape the future of R&D in the biomass to resources sector

Time / Day	Monday		Tuesday	Wednesday		Thursday	Friday
09:00 - 10:30		Introduction (TC)	The role of biomass resources in the global renewable energy supply (JBHN)		Mass Balances (MHT)	TOUR: Biogas Plants	Biorefinery process design on SuperPro (MHT and TC)
10:40 - 12:00		Biomass Chemistry (TC)	Sustainablity & biomass mapping (JBHN)				
45 mins	LUNCH		LUNCH	LUNCH			LUNCH
12:45 - 14:00		Pretreatment and Enzymatic Hydrolysis (TC)	AD-Biogas planning, optimizing and production (JBHN)		Upstream and Down Stream Processing (MHT)		No Class
14:10 - 16:00		Enzymes and Fermentation Kinetics (TC)			Process Modeling (MHT)		

MHT	Mette Thomsen
JBHN	Jens Bo Holm Nielsen
TC	Tanmay Chaturvedi

Prerequisites: You should have at least BSc level knowledge on topics such as chemistry, mathematics and process engineering.

Form of evaluation: Homework (non graded) and assignment (graded) to be submitted 2 weeks after the end of the course.

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

Electrochemical Impedance Spectroscopy
– Theory, Measurement and Analysis

Organizer: Professor Søren Højgaard Jensen, Aalborg University

Lecturers: Professor Søren Højgaard Jensen
Associate Professor Samuel Simon Araya, Aalborg University

ECTS: 5

Date/Time: August 30th – September 3rd 2021.

Max no. of participants: 20

Description: The course is a full-week course held in week 35.

Day 1: Monday, August 30th: General introduction to impedance spectroscopy.
This part of the course provides an introduction to concepts such as impedance elements, equivalent circuits, time-frequency domain relations, Fourier and Laplace transform and measurement methods. This part explains what creates impedance in electrochemical systems and how the impedance can be measured.
Lecturer: Søren and Samuel

Day 2: Tuesday, August 31st: Measurement optimization and Lab session
This part discusses possible sources of measurement errors and noise. Various methods for error minimization will be presented. Students will form groups of 3-4 persons where at least one person in the group have previous experience with impedance measurements and ideally have a running experiment/test setup. The groups will visit existing test setups, examine the impedance measurement conditions and discuss if there is anything that can be done to improve the impedance measurements.
Lecturer: Søren and Samuel

Day 3: Wednesday, September 1st: Impedance Modeling
The goal of the modeling is to get the most information out of the measured impedance spectra, with due respect to the measurement uncertainties. Various equivalent circuits will be examined and used to model the impedance spectra provided by the students. Modeling tools will be introduced such as ZsimpWin, Zview and Elchemea.
Lecturer: Søren and Samuel

Day 4: Thursday, September 2nd: Advanced electrochemistry, measurement and analysis methods
This part of the course provides an introduction to various advanced measurement methods such as 3-electrode setups, rotating disc measurements, higher harmonics, and systematic test variations. This part also present various advanced analysis methods such as DRT, ADIS and bulk fitting.
Lecturer: Søren and Samuel

Day 5: Friday, September 3rd: Online diagnostics and trends
This part of the course discuss examples of online diagnostics of electrochemical devices and adaptive control thereof. The focus is on opportunities and challenges for further scientific and commercial applications of electrochemical impedance spectroscopy.
Lecturer: Søren and Samuel

Prerequisites: Familiarity with complex numbers and basic calculus.

Form of evaluation: Class discussion, case study exercise, lab measurements, presentation of group work results.

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

Modern IGBT gate driving methods for Enhancing Reliability of Power Converters

Organizer:	Prof. Francesco Iannuzzo, fia@et.aau.dk, Aalborg University
Lecturers:	Prof. Francesco Iannuzzo, fia@et.aau.dk, Aalborg University
ECTS:	2
Date/time:	6-7 September 2021, all days 8:30 – 16:30 (2 days)
Max. no. of participants:	15

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 individual contribution.

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

Harmonics in Power Electronics and Power Systems

Organizer: Professor Claus Leth Bak, clb@et.aau.dk, Aalborg University.

Lecturer: Christian Frank Flytkjær, Energinet.dk
Łukasz H. Kocewiak, Ørsted Wind Power

ECTS: 3

Time: ~~7-9 April~~ **8-10 September 2021**

Place: Aalborg University

Max. no. of participants: 30

Description: This course provides a broad overview of power system harmonic problems, methods of analysing, measuring and effectively mitigating them. Several extended simulation and data pro- cessing tools, among others DIgSILENT PowerFactory, Matlab/Simulink or LabVIEW are used to assess and study the harmonic distortion at different points of power networks. The results of analytical investigation and simulations are validated against measurements applying sophisticated data processing techniques. Furthermore, deep understanding of hardware considerations regarding har- monic measurements in harsh industrial environment is given, using specialized equipment, for in- stance GPS-synchronized measuring instruments.

The course covers the following topics:

- Power Quality definitions. Generation mechanism of power system harmonics. Harmonic indices.
- Voltage vs. current distortion as well as parallel vs. series resonance in modern power systems. Point of Common Coupling (PCC).
- Sources and effects of harmonic distortion.
- Harmonic measuring instruments and measuring procedures in LV, MV and HV networks.
- Mathematical tools and theories for analyzing distorted waveforms. Signal processing and uncertainty analysis.
- Modelling of classical power system components. Harmonic analysis.
- Modelling of grid-connected converters for harmonic analysis purposes and their application in modern power systems including e.g. offshore wind power plants.
- Harmonic load-flow, frequency scan and time domain simulations. Linear and nonlinear analysis techniques.
- Steady-state harmonics vs. harmonic stability. Small-signal representation, sequence and frequency coupling.
- Software tools for harmonic analysis.
- Precautionary (preventive) and corrective (remedial) harmonic mitigation techniques. Passive and active line filters. Filter design.

Day 1: The basics of power system harmonics – modelling, measurements and analysis - (Christian 7.5 hrs.)

Day 2: Harmonics in power electronics – modelling, measurements and analysis (Łukasz 7.5 hrs.)

Day 3: Harmonic evaluation and mitigation – passive and active filtering, international standards (Łukasz 7.5 hrs.)

Prerequisites: Graduate MSc level or equivalent experience

Form of evaluation: Individual assessment

Smart Distribution Systems

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

Lecturers: Prof. Birgitte Bak-Jensen, Assoc. Prof. Jayakrishnan Pillai, Assoc. Prof. Florin Iov, Assist. Prof. Pavani Ponnanganti - Department of Energy Technology, Aalborg University and Assoc. Prof. Rasmus Løvenstein Olsen, Department of Electronic Systems, Aalborg University

ECTS: 3.5

Date/Time: 13-16 September, 2021

Max no. of participants: 20

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

Day 1:

Lecture 1: *Modern Electric Power Distribution Systems* (BBJ) 8:45 – 10:15

a. Problems seen in present and the future distribution system
b. Overall structure of course and introduction of the smart grid layers
c. Presentation of network structures and market perspectives and relations to thermal and electrical system
d. Overall consideration for the modern distribution system

Lecture 2: *Smart electric distribution systems* (JRP) 10:30-12:00

a. Smart grids - System architecture
b. Active distribution grid benefits and challenges
c. Smart distribution grid projects, technologies and trends

Lecture 3: *Grid codes/standards - LV/MV Distribution systems* (JRP) 13:00-14:30

a. LV and MV grid codes
b. Distribution grid integration guidelines for distributed energy resources
c. Utility practices in different countries

Lecture 4: *Demand response* (PAP) 14:45-16:15

a. Types of demand response
b. Application of demand response in distribution grids
c. Case studies of demand response

Day 2:

Lecture 1: *Heat pumps/Electric boilers in distribution grids* (BBJ) 8:45-10:15

a. Heat pump and Electrical boiler basics and types.
b. Operation, control and flexibility
c. Impact on distribution grids
d. Aggregation and control

Lecture 2: *Electric vehicles in distribution grids* (JRP) 10:30-12:00

a. Grid impact studies
b. Charging strategies
c. Grid support from EVs

Lecture 3: *Solar PVs in distribution grids* (FI) 13:00-14:30

a. Technology overview
b. Control strategies
c. Grid support from PV's
d. Grid impact studies

Lecture 4: *Operation, control and reliability of supply* (FI)14:45-16:15

a. Examples of operation and control methods in the smart grid
b. Reliability and security of supply

Day 3:

Lecture 1: *ICT aspects in Smart Distribution grids* (RLO) 8:45-10:15 & 10:30-12:00

a. ICT basics technologies and protocols
b. Performance and reliability
c. Challenges of the ICT network from a smart grid perspective
d. Examples

Lecture 2: *Simulation tool for distribution grids* (JRP) 13-14:30 & 14:45-16:15

a. Basics of DIgSILENT
b. Exercises

Day 4:

Lecture 1: *Simulation tool for distribution grids* (JRP) 8:45-10:15 & 10:30-12:00

a. Simulation Exercises in DIgSILENT (Continued)

Written Examination (JRP) 13:00 – 15:00

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

Form of evaluation: Written examination

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

D-FMEA: Design Failure Mode and Effect Analysis for Power Electronic Converters

Organizer: Huai Wang hwa@et.aau.dk, Professor, Aalborg University

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

ECTS: 4

Date/Time: 20-24 September, 2021 (including 1-day project team hands-on exercises)

Max no. of participants: 30

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

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

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

Day 1 – Introduction of D-FMEA, Systems Engineering (Lecturers: Philip C. Kjær, Rui Wu, and Huai Wang, 08:30 – 16:30)

08:30 – 09:00	Welcome, introduction to the course
09:00 – 10:30	Introduction to D-FMEA
10:30 – 12:00	Introduction to systems engineering
12:00 – 13:00	Lunch
13:00 – 15:30	Exercise on functions & failures
15:30 – 16:30	Participant team project support

Day 2 – Failure Cause & Effect and Risk Scoring (Lecturers: Philip C. Kjær, Rui Wu, and Huai Wang, 08:30 – 16:30)

08:30 – 09:00	Recap from Day 1
09:00 – 10:30	Converter – a worked example
10:30 – 12:00	Cause & effect analysis
12:00 – 13:00	Lunch
13:00 – 14:00	Converter – a worked example
14:30 – 15:30	D-FMEA risk scoring
15:30 – 16:30	Software training of IQ-FMEA (I)

Day 3 – Failure Cause & Effect and Risk Scoring (Lecturers: Philip C. Kjær, Rui Wu, and Huai Wang, 08:30 – 16:30)

08:30 – 09:00	Recap from Day 2
09:00 – 11:30	Software training of IQ-FMEA (II)
11:30 – 12:00	Participant team project discussions
12:00 – 13:00	Lunch
13:00 – 15:00	Participant team project presentation
15:00 – 16:30	Participant team project discussions

Day 4 – Participant Team Project Implementation and Exercises (it is mainly performed intensively by the course participants in teams, lecturers can provide support upon the request, otherwise, no formal lecturers on this day)

Day 5 – Participant Team Project Presentations and Discussions (Lecturers: Philip C. Kjær, Rui Wu, and Huai Wang, 08:30 – 16:30)

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

Form of evaluation: A DFMEA report on the participants' own project (teams or individuals)

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

Power Electronics – from Fundamentals to Advanced Topics

Organizer: Professor Huai Wang, hwa@et.aau.dk Aalborg University, Denmark

Lecturers: Professor Huai Wang, Assistant Professor Haoran Wang (Aalborg University)
Postdoc Yanfeng Shen (University of Cambridge)

ECTS: 4

Date/Time: 28 September– 1 October 2021

Max no. of participants: 40

Description: The course was initiated in 2020 aiming to lay a solid foundation in power electronics could be beneficial to them independent of which power electronic topics they are working on, which provides also a wider scope of power electronics besides their specific research topics. It will have in-depth introduction of circuit theories, modeling methods, and hands-on prototyping of power electronic converters. The emphasis is on those aspects that are generic and not limited to specific applications. Moreover, a design case study will be used during the entire course for illustrating how to implement a converter prototype step-by-step, from component sizing, circuit design, control, simulation, prototyping, and testing. PCB assemblies will be available for the participants to perform laboratory testing.

Day 1: Power electronic circuit theories + design case (Lecturer: Huai Wang, 8:30-16:30)
It will cover the topics: duality in time and circuit elements, state-plane switching trajectories; inductor-capacitor based switching circuits, switched-capacitor circuits, switched-inductor circuits, zero-ripple techniques, interleaved techniques, extra element theorem, circuit operation-mode analysis, etc.

Day 2: Power electronic modeling and control methods + design case (Lecturer: Haoran Wang and Yanfeng Shen, 8:30-16:30)
It will cover the topics: how a "switch" can be removed for converter modeling; origins of time-domain and frequency-domain modeling methods and its limitations; basic ideas of time-domain control methods for power electronic converters and its advantages and limitations; most widely used frequency-domain control methods for power electronic converters; what are the common and different aspects in modeling and simulation of Si, SiC and GaN devices.

Day 3: Magnetic component modeling and design + design case (Lecturer: Huai Wang, 8:30-16:30)
It will cover the topics: magnetic diffusion, core losses, winding losses, high-frequency magnetics, integrated magnetics, and magnetic circuit representation, design considerations, etc.

Day 4: Power electronic converter prototyping and testing (Lecturer: Haoran Wang and Yanfeng Shen, 8:30-16:00)

This is a continuation of the design case for actual prototype implementation and testing. It will cover the topics: PCB design techniques and considerations; participants make their own magnetics and be given PCB assemblies; run tests in the lab)

Prerequisites: A basic understanding of power electronic components, topologies, and control methods are necessary, the participants are supposed to have already attended a master-level power electronic course or equivalent.

Form of evaluation: Converter case study design and testing report.

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

Managing Harmonics in Modern Power Distribution Networks

Organizer: Professor Xiongfei Wang xwa@et.aau.dk, Aalborg University

Lecturers: Dr. Jan Meyer, Technical University of Dresden, Germany

Prof. Xiongfei Wang, and Dr. Ariya Sangwongwanich, Aalborg University, Denmark.

ECTS: 3

Date/Time: 5-7 October 2021

Max no. of participants: 45

Description: The ever-increasing penetration of power-electronic-based sources and loads in power distribution networks poses new challenges to the quality of electricity supply. This course intends to provide a systematic discussing on the modeling, analysis and measurement of harmonics in modern power distribution systems. The theoretical modeling and analysis on the harmonic impacts of photovoltaic (PV) inverters in distribution systems will be introduced first. New developments and concepts in determining and assessing the harmonic emission limits and, in particular the supraharmonics above 2 kHz will then be reviewed. Next, practical aspects of harmonic measurements and the impedance identifications of network and devices will be discussed. Lastly, the system-level harmonic studies in low-voltage (LV) distribution networks with PV and electric vehicles (EVs) will be presented. Each aspect is illustrated by real world examples. The main topics to be covered include:

- Harmonic modeling and analysis of PV inverters considering the control impacts with different grid strengths
- Latest grid codes, standards and compliance assessment for power electronic based devices
- Supraharmonics (2 kHz - 150 kHz): sources, mechanisms, propagation and resonances
- Harmonic measurement techniques and suitability of voltage and current transducers
- Frequency-dependent impedance measurement of LV distribution networks
- "Black-box" harmonic and impedance measurements of PV inverters and EVs
- Harmonic studies of LV distribution power networks due to PV and EVs

Day 1: Harmonic Modeling and Analysis of PV Inverters, Prof. Xiongfei Wang (4 hours), Dr. Ariya Sangwongwanich (2 hours)

- Introduction to harmonic generation mechanisms of PV inverters
- Representations of PV inverters for harmonic analysis
- Case studies with different grid strengths and voltage distortions
- Interharmonics analysis and mitigation in PV inverters

Day 2: Standards and Practical Measurements of Harmonics, Dr. Jan Meyer (6 hours)

- Latest update on grid codes, standards, and compliance assessment
- Supraharmonics (2 kHz – 150 kHz): sources, propagation and resonances
- Harmonic measurement techniques
- Suitability of voltage and current transducers

Day 3: Harmonic Studies in Modern LV Distribution Networks, Dr. Jan Meyer (6 hours)

- Frequency-dependent impedance measurement of LV distribution networks
- "Black-box" impedance measurement of PV inverters and EV chargers
- Measurement case studies on a 1-MW PV power plant and a 12-MW wind park
- Harmonic modeling and analysis of LV distribution networks

Prerequisites: Prior knowledge of power electronics fundamentals, digital signal processing, and power quality basics are preferred.

Form of evaluation: Exercises and report

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

Photovoltaic Power Systems - in theory and practice

Organizer: Associate Professor Tamas Kerekes, tak@et.aau.dk, Aalborg University

Lecturers: Associate Professor Tamas Kerekes, tak@et.aau.dk, Aalborg University
Associate Professor Yongheng Yang, yoy@et.aau.dk, Aalborg University
Assistant Professor Sergiu Spataru, sersp@fotonik.dtu.dk, DTU
Postdoc Ariya Sangwongwanich, ars@et.aau.dk, Aalborg University
Kamran Ali Khan Niazi, kkn@et.aau.dk, Aalborg University
Laszlo Mathe, Robert Bosch GmbH, Hungary

ECTS: 4

Date/Time: 12 – 15 October 2021

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. 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.
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, where the students will apply the models and methodology in practice.

Day 1: PV panels and arrays - Kamran Ali Khan Niazi & Sergiu Spataru (08.30-16.30)

- L1A2 - PV Systems Overview, Technology & Trends - *Sergiu Spataru DTU (2 hr.)*
- L1B – Photovoltaic panels and systems – performance - *Sergiu Spataru DTU (2 hr.)*
- L1C– PV systems Modelling - *Sergiu Spataru DTU (2 hr.)*
- E1D1 – PV Modelling (SIM – Matlab GUI)
- E1D2 – Spire Demo (EXP – Spi-Sun 5600SLP

Day 2: PV inverters - Tamas Kerekes (08.30-16.30)

- L2A – PV Inverters Structures, Topologies and Filter Design
- L2B – Inverter Control & Harmonic Compensation
- E2C1 – Converter Topologies (SIM - PLECS)
- E2D1 – Current Control Design (SIM - MATLAB)
- E2D2 - Current Control (EXP)

Day 3: Grid interaction - Tamas Kerekes, Yongheng Yang & Ariya Sangwongwanich (08.30-16.30)

- L3A – Maximum Power Point Tracking
- L3B – MV Grid Requirements & Support with PV inverters
- E3C – MPPT (SIM - dSpace)
- E3D – Control of PV Inverters under Grid faults

Day 4: PV plants and Grid integration - Tamas Kerekes, Yongheng Yang & Laszlo Mathe (08.30-16.30)

- L4A1 – Grid Synchronization
- L4A2 – Design of PV Plants
- L4B1 - LV Grid Connection & Support Requirements
- L4B2 – Grid Support in LV network with PV inverters
- E4C1 – PLL (SIM – dSpace)
- E4C2 - Design of PV Plants (SIM)
- E4D1 – Voltage Support (EXP)

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

Lithium-Ion Batteries. Fundamentals, Modelling, and State Estimation

Organizer: Assoc. Prof. Daniel Stroe, Aalborg University

Lecturers: Assoc. Prof. Daniel Stroe dis@et.aau.dk, Aalborg University
Assoc. Prof. Erik Schaltz esc@et.aau.dk , Aalborg University
Dr. Vaclav Knap vkn@et.aau.dk , GomSpace,
Dr. Jussi Sihvo jussi.sihvo@tuni.fi, Tampere University of Technology (Finland)

ECTS: 3.0

Date/Time: 18 - 20 October 2021

Max no. of participants: 30

Description: Lithium-ion batteries have become the key energy storage technologies for various applications, such as electric vehicles, microgrids, (nano-)satellites, or for enhancing renewables' grid integration. This has become possible due to their superior characteristics in terms of gravimetric and volumetric energy density, efficiency, lifetime etc. Nevertheless, Lithium-ion batteries are highly non-linear energy storage devices with their performance (electrical) and degradation (lifetime) behavior strongly influenced by the operating conditions (e.g., temperature, load current, number of cycles, idling time etc.). Therefore, in order to benefit from Lithium-ion batteries' characteristics, precise knowledge about the performance and degradation behavior has to be known at all moments during the lifetime.

Thus, this three-day course provides an overview of the status of Lithium-ion batteries, fundamentals and a deep understanding of their performance and degradation behavior. Different methods for battery performance (electrical) and degradation (lifetime) modeling will be introduced together with suitable parametrization approaches (from data-sheet to laboratory experiments), respectively. These models will be subsequently used to introduce various Li-ion battery state-of-charge (SOC) and state-of health (SOH) estimation techniques.

Exemplifications of some of the discussed topics will be made through exercises in Matlab/Simulink.

Day 1: Energy storage technologies and Lithium-ion batteries – Daniel Stroe (8 hours)

- Overview of energy storage technologies
- Lithium-ion battery construction and operation
- Lithium-ion battery chemistries
- Performance parameters for Lithium-ion batteries (capacity, resistance, power, efficiency etc.)
- Influence of operating conditions (e.g., load current/power, temperature etc) on the performance parameters of the Lithium-ion batteries

Day 2: Electrical modeling of Lithium-ion batteries – Daniel Stroe, Vaclav Knap, Jussi Sihvo (8 hours)

- Laboratory testing of Lithium-ion batteries for electrical and lifetime modeling
- Approaches for battery electrical modeling
- Parametrization of Lithium-ion battery modeling
- Thevenin-based Lithium-ion battery electrical models
- Impedance-based Lithium-ion battery models

Day 3: Lifetime and state estimation of Lithium-ion batteries – Daniel Stroe, Erik Schaltz, Vaclav Knap (8 hours)

- Aging mechanisms of Lithium-ion batteries
- Performance-degradation of Lithium-ion batteries
- Lifetime modeling approaches for Lithium-ion batteries
- State-of-Charge and State-of-Health estimation of Lithium-ion batteries

Prerequisites: Fundamental (basic) electrical knowledge, engineering degree and Matlab/Simulink and Matlab/Simulink knowledge are strongly recommended. The course language is English.

Form of evaluation: Students are expected to solve a number of exercises and deliver an individual report with solutions and comments.

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

Lithium-Ion Batteries. Systems and Applications

Organizer: Assoc. Prof. Daniel Stroe, Aalborg University

Lecturers: Prof. Remus Teodorescu ret@et.aau.dk, Assoc. Prof. Daniel Stroe dis@et.aau.dk, Assoc. Prof. Erik Schaltz esc@et.aau.dk, Aalborg University
Dr. Vaclav Knap vkn@et.aau.dk, GomSpace
Dr. Maciej Swierczynski mas@lithiumbalance.com, Lithium Balance A/S

ECTS: 2

Date/Time: 21 – 22 October 2021

Max no. of participants: 30

Description: Lithium-ion (Li-ion) batteries have become a key technology in our daily routine, from powering our portable electronics devices and electric vehicles to offering grid support and playing a crucial role in the reliable and cost efficient grid integration of intermittent energy sources.

The objective of this two-day course is to provide the attendees with an extensive overview of the Lithium-ion battery applications, such as EVs, grid support, nano-satellites and forklifts. Battery requirements for these applications as well as Li-ion batteries operation (power and energy management & mission profiles) in these applications will be thoroughly discussed. All the aforementioned application require power electronics solutions (e.g., BMS, chargers, power converters etc.) in order to assure Li-ion battery pack safety, high-efficiency, and reliable operation. Power electronics play three important roles in the battery applications: charge/discharge management, battery cell balancing, and safety protection. In consequence, this course will provide an extensive state-of-the-art on the power electronics solutions for battery charge/discharge management.

Day 1: Power Electronics Solutions for Lithium-ion Batteries – Daniel, Remus & Maciej (8 hours)

- Overview of Lithium-ion batteries applications
- Battery Management Systems (BMS): functionalities, architectures etc.
- Power converter topologies for Lithium-ion battery systems
- EV chargers
- Smart battery packs using Lithium-ion Batteries

Day 2: Lithium-ion Batteries Applications – Erik, Maciej & Vaclav (8 hours)

- The operation of Lithium-ion batteries in stationary applications
  - Residential systems
  - Grid support
- Lithium-ion batteries in space applications – an example for nano-satelites
- Lithium-ion batteries in vehicle applications
  - Modeling, sizing and control of battery powered vehicles

Prerequisites: A degree in electrical engineering or control engineering and Matlab/Simulink knowledge are strongly recommended. The course language is English.

Form of evaluation: Students are expected to solve a number of exercises and deliver an individual report with solutions and comments.

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

Electromagnetic Transients in Power Systems

Organizer: Associate Professor, Filipe Faria da Silva, ffs@et.aau.dk, Aalborg University

Lecturers: Associate Professor, Filipe Faria da Silva, ffs@et.aau.dk, Aalborg University

ECTS: 3

Date/Time: 25-27 October 2021

Max no. of participants: 15

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, typically.

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 and put them out-of-service. As a result, extensive investigations are made when installing new high voltage equipment as transformers or new lines, 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 using examples and real-life cases. When relevant, the respective countermeasures will be explained and examples given on how to do the respective choice.

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 define the modelling requirements for different transient phenomena.

Phenomena that will be studied in the course are:

- Energisation and de-energisation of capacitor banks, shunt reactors, lines, transformers, …;
- 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;
- Impact of resonance points;
- Guidelines for network modelling:
    - Network size;
    - Modelling precision;
    - Model validation;

Day 1:

- Basic concepts;
- Introduction to PSCAD;
- Basic switching operations (capacitor banks, shunt reactor);
- Travelling waves and modal domain**;**

Day 2:

- Phenomena typical to underground cables;
- Transformers energization and deenergisation;
- Lightning related phenomena;
- Resonances;

Day 3:

- Faults;
- Temporary Overvoltages;
- Interruption of inductive currents;
- Network modelling for different phenomena;
- Presentation of exercises for evaluation;

Prerequisites: Master degree in Electric Power Systems or similar

Form of evaluation: Several exercises consisting in the simulation and analysis of different phenomena in an EMTP-type software must be done after the course. The attendees are expected to do a proper simulation of the phenomena, to comment the results and to propose solutions to the main issues, in a manner similar to an insulation co-ordination study.

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

Vibration-based structural health monitoring

Organizers: Martin Dalgaard Ulriksen mdu@et.aau.dk (AAU ET) and Lars Damkilde (AAU Build)

Lecturers: Assistant Professor Martin Dalgaard Ulriksen (MDU), Aalborg University, Esbjerg
Professor Lars Damkilde (LD), Aalborg University, Esbjerg

ECTS: 5

Date/Time: 25-29 October 2021; each day from 8.15 to 16.15.

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

Max no. of participants: 25

Description: The aim of this course is to give the participants an insight into the use of vibration measurements to assess the integrity of structural systems and components. This procedure is referred to as vibration-based structural health monitoring (SHM), which is of interest within several engineering disciplines; including energy, civil, mechanical, and aerospace. Here, SHM can be used as a key component in optimization of operation and maintenance procedures.

In the course, we will address the following topics:

- Structural damages, their appearance in engineering structures, and potential consequences
- Theoretical, numerical, and experimental deterministic and stochastic vibration analysis
- Deciding on the spatial distribution of sensors for capturing vibration signatures
- Signal processing of vibration signatures for discrimination between damage-induced anomalies and environmental and/or operational variability
- Characterization of structural damages using signal-processed vibration signatures
- Industrial perspectives and real-life application examples

The course consists of lectures, solving theoretical exercises, and conducting experimental studies to increase the physical understanding of the theory. The target audience is PhD students within energy, civil, and mechanical engineering or similar, but young researchers and professionals from the industry with an interest in the topics of the course are also welcome.

An assignment will be given as homework. Satisfactory answers to the homework are a prerequisite for passing the course.

Day 1: Introduction, vibration analysis I, and exercises. Lecturers: MDU & LD. Duration: 8 hours.
From 8:15 to 10:00, an introduction to the course and the topic will be given.
From 10:15 to 12:00, a lecture on basic vibration analysis will be given.
From 12:30 to 14:15, the students will conduct experiments in the laboratory.
From 14:30 to 16:15, the students will solve exercises.

Day 2: Vibration analysis II, system identification, and exercises. Lecturers: MDU & LD. Duration: 8 hours.
From 8:15 to 10:00, a lecture on advanced vibration analysis will be given.
From 10:15 to 12:00, a lecture on system identification will be given.
From 12:30 to 14:15, the students will conduct experiments in the laboratory.
From 14:30 to 16:15, the students will solve exercises.

Day 3: FEM, damage detection I, and exercises. Lecturers: MDU & LD. Duration: 8 hours.
From 8:15 to 10:00, a lecture on the finite element method (FEM) will be given.
From 10:15 to 12:00, a lecture on basic damage detection will be given.
From 12:30 to 14:15, the students will conduct experiments in the laboratory.
From 14:30 to 16:15, the students will solve exercises.

Day 4: Damage detection II, model updating, and exercises. Lecturer: MDU. Duration: 8 hours.
From 8:15 to 10:00, a lecture on advanced damage detection will be given.
From 10:15 to 12:00, a lecture on model updating will be given.
From 12:30 to 14:15, the students will conduct experiments in the laboratory.
From 14:30 to 16:15, the students will solve exercises.

Day 5: Damage diagnosis, assignment information, and closing. Lecturers: MDU & LD. Duration: 8 hours.
From 8:15 to 10:00, a lecture on basic damage diagnosis will be given.
From 10:15 to 12:00, a lecture on advanced damage diagnosis will be given.
From 12:30 to 14:15, information on the assignment will be provided.
From 14:30 to 16:15, the course will be evaluated and closed.

Prerequisites:

- Master degree in Engineering or similar
- Basic knowledge on calculus and linear algebra, as obtained through engineering studies
- Basic knowledge on MATLAB or any other programming language
- Basic knowledge on structural mechanics and dynamics.

Form of evaluation: Written in the form of an assignment.

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

Design of Modern Power Semiconductor 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: 1-3 November 2021, all days 8:30 – 16:30

Max no. of participants: 15

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.

Day 1
Lecture 1: 08.30-12.00 (V. Popok, K. Pedersen)

- Junction theory, PN- and PIN-diodes.
- Fundamentals of bipolar junction and field-effect transistors.
- MOSFET and IGBT in power electronics.
- Emerging (wide band-gap) technologies.

Lecture 2: 13.00-16.30 (F. Iannuzzo)

- Operation of MOSFETs and IGBTs. On state, off state, switching theory. Miller plateau, voltage/current overshoots and voltage/current tails. Power loss calculation.
- Overview of abnormal operations: Safe Operating Area (SOA), unclamped inductive switching (UIS) and short circuit.
- Principle of instability theory: current crowding and thermal runaway. Negative capacitance.
- Modern driving strategies: including two-level turn off and desaturation protection

Day 2
Lecture 3: 08.30-12.00 (E. Hoene)

- Introduction on packaging techniques for modern semiconductor power switches.
- Challenges in terms of power density, stray inductance/resistance and reliability.
- Modern interconnection solutions: copper bond wires, low-profile packaging, bondless packaging, etc.

Group work, part 1: 13.00-16.30

Day 3
Group work, part 2: 08.30-12.00
Final lecture: 13.00-16.30 (F. Iannuzzo, E. Hoene)

- Project presentations by groups, Collective project verification and discussion

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. Attendees are asked specific questions about the developed design to be answered individually.

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

Generators and their control

Organizer: Prof. F. Blaabjerg fbl@et.aau.dk, Aalborg University

Lecturers: Prof. Ion Boldea, Politehnica University of Timisoara, Romania
Prof. F. Blaabjerg, Aalborg University, Denmark

ECTS: 3

Date/Time: ~~26-28 April~~ 1-3 November 2021 (3+2= 5 hours/day)

Max no. of participants: 15-20

Description: Fractional KVA ratings PWM Converter variable wind(hydro) generators de sign and control: recent progress

Motivation and brief Contents description: Fractional KVA(MVA) ratings PWM converter variable speed generators represent 50 % of all installed wind power by DFIG systems which underwent staggering progress in optimal design and advanced control in strong and weak Grid and standalone applications, with asymmetric voltage sags etc. But in an effort to eliminate the slip-rings and brush system to transmit power from DFIG rotor to fractional KVA(MVA) ratings(30-40%)PWM Converter, quite a few BRUSHLESS solutions have been developed spectacularly in the last decade: like BDFIG,BDFRG, Dual stator winding cage CRIG, open winding CRIG, dual rotor dual stator winding flux modulation PM brushless generators which also enjoy the Fractional KVA ratings PWM converter in the control stator winding while the power stator winding is connected to the grid or , in a standalone mode, to a diode rectifier.

The main scope of these solutions is initial and maintenance cost reduction with still high efficiency for limited(+-30%) speed variation range in wind(hydro) energy conversion but also in standalone applications with ac or dc controlled output(say as marine vessel, or aircraft starter-generators with gas turbine or Diesel engine prime movers etc applications.

All the above issues are treated in detail based on IEEE representative seminal and recent lit. and our own research results to endow the participants with solid knowledge for designing and controlling BRUSHLESS variable speed generators with fractional KVA(MVA) ratings PWM converters of the Future.

Day 1: (3+2=5 hours)
Recent Progress in variable speed DFIG design and control for Grid applications:

Day 2: (2+3=5hours)

1. Stand-alone variable speed DFIG with control dc output and constant and variable stator frequency control (2 hours)
2. Brushless DFI(R)Gs design and advanced control recent progress (3 hours)

Day 3: (2+2+1=5 hours)

1. Brushless dual stator winding(DSW) variable speed CRIG with fractional KVA PWM converter and dc (or dc+ ac)controlled output (2hours)
2. Brushless Dual rotor DSW PM high efficiency high torque density variable speed generators (2 hours)
3. Recap dialogue…(1 hour)

Prerequisites: basic electrical machinery, power electronics and control knowledge

Form of evaluation: The participants will be given upon course commencing (via :D.O.I. IEEE number) a recent (2020)representative IEEE Trans. on PEL paper related to the subjects but adjacent(different)in Contents: to assess with improvements proposals in an one page Report(on paper) delivered on the end of Day 2 for the Lecturers to appraise; and discuss in the last hour in the 3rd day in the Recap-Dialogue time.

Slides presentation with in between Q&As will be used for the lectures. All throughout

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

Capacitors in Power Electronics Applications

Organizer: Professor Huai Wang, hwa@et.aau.dk, Aalborg University

Lecturers: Professor Huai Wang, Assistant Professor Haoran Wang

ECTS: 2

Date/Time: 4-5 November, 2021

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.

Day 1 – Introduction to capacitors and its electro-thermal-lifetime modeling and accelerated testing
(Lecturer: Huai Wang, 08:30 – 16:30)

L1	Basics of capacitors and emerging capacitor technologies
L2	Electro-thermal-lifetime modelling of capacitors
Exc 1	Mission profile based capacitor lifetime modelling
Lab 1	Capacitor thermal characterization
L3	Accelerated degradation testing of capacitors
Exc 2	Step-by-step capacitor lifetime data analysis
L4	Capacitor condition monitoring

Day 2 – Capacitor sizing in power electronic applications (Lecturer: Haoran Wang, 08:30 – 15:30)

L5	Capacitor sizing criteria in power electronics
L6	Active capacitors with semiconductor circuits
L7	Capacitor application case studies
Exc 3	Step-by-step capacitor sizing for a power converter with specified reliability specifications

Prerequisites: Basic understanding of power electronics circuits and control

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

Reliability in Power Electronics Systems

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

Lecturers: Professor Huai Wang, Aalborg University
Professor Francesco Iannuzzo, Aalborg University
Assistant Professor Dao Zhou, Aalborg University
Reliability Advisor Peter de Place Rimmen

ECTS: 4

Date/Time: 9-12 November 2021

Max no. of participants: 30

Description: The course will be the latest research outcomes of the Center of Reliable Power Electronics (CORPE). Since 2013, more than 170 participants from universities and companies have been trained in this 3-day course. By considering the feedbacks from participants and newly obtained research results from CORPE in the last few years, the 2021 version of the course will be 4 days focusing 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

Day 1 – Modern reliability engineering approach (Lecturer: Peter de Place Rimmen, 08:30 – 16:30)
L1 Training in understanding Weibull
Exercises 1 - Basic concepts of statistics
L2 Introduction to modern reliability in Industry
L3 MCF curve, cost of poor reliability, robustness
L4 Lifetime budgets, degradation
Exercise 2 - Lifetime estimation using provided data

Day 2 – Reliability of Power Electronic Components (Lecturers: Huai Wang and Francesco Iannuzzo, 08:30 – 16:30)
L5 Reliability of active switching devices (IGBT modules and SiC MOSFETs)

L6   Reliability of passive components (capacitors and magnetic components)

Day 3 – Reliability of Power Electronic Systems – Part 1 (Lecturers: Huai Wang and Dao Zhou, 08:30 – 16:30)
L7   Reliability challenges in power electronics and design for reliability concept
L8 Reliability prediction of a single converter – case study for fuel-cell backup power supply
Exercise 3 - Design of a PV inverter with 10 years of B10 lifetime (Class exercises based)

Day 4 – Reliability of Power Electronic Systems – Part 2 (Lecturers: Huai Wang and Dao Zhou, 08:30 – 15:30)
L9   System-level thermal modeling and reliability prediction – case study for a modular multi-level converter
L10 Simplification methods for electro-thermal-lifetime modeling
L11 Reliability prediction of multiple converter systems

The course also includes 3 lab sessions scheduled on Day 2 and Day 3.

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/

EMI/EMC in Power Electronics

Organizer: Associate Professor Pooya Davari, pda@et.aau.dk, Aalborg University

Lecturers: Professor Eckart Hoene - Aalborg University and Fraunhofer IZM
Dr. Christian Wolf, Lead Specialist, EMC & Power Electronics - Grundfos Holding A/S
Associate Professor Pooya Davari - Aalborg University

ECTS: 2.5

Date/Time: 15-16 November 2021

Max no. of participants: 20

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

The emphasis of this course is to give a complete and clear picture on EMI issues and mitigation methodologies. Systematic designing of passive EMI filters for differential mode (DM) and common mode (CM) noises in single-phase and three-phase systems will be provided. Printed circuit board (PCB) design criteria, passive and active components parasitic and shielding approaches in reducing near-field couplings will be covered as well. Furthermore, time and frequency domain modeling of conducted low and high frequency emission noises through developing equivalent circuit models of power electronics converters in order to reduce the analysis complexity and prevent from conventional trial and error design approach will be addressed. This course will also focus on new challenges within the new frequency band of 2-150 kHz (i.e., suparharmonics) in power electronic based power systems. The course content is combined with real-world application examples and demonstration.

In the first day the course will focus on basics of harmonics generated by switching, EMI issues in PWM converters, components parasitic, measurement requirement, interference mechanisms, filtering component and strategy. In the second day there will be more focus on advanced topics such as magnetic coupling, EMI prediction, Shielding and new standard requirements. The second day will be supported with industrial examples and real-world design experience regarding different aspects of EMI/EMC in power electronics.

Day1

- **09:00 – 12:00 Topic1: EMI Issues and Measurement in PWM Converters (Basics) [Pooya]**
    - **09:00 – 09:45 Disturbances Generated by Switching**

09:45 – 10:00 Break

- **10:00 – 11:00 Components Parasitic**

11:00 – 11:15 Break

- **11:15 – 12:00 Measurement requirement**

12:00 – 13:00 Lunch

- **13:00-13:45 Topic2: Interference Mechanisms [Eckart/Pooya]**
- **13.45-14:30 Topic3: Filtering Components and Strategy [Eckart/Pooya]**

14:30 – 14:45 Break

- **14:45 – 15:15 Topic4: Filtering Components (Advanced) [Eckart]**
- **15:15 – 16:15 Topic5: Prediction [Eckart/Pooya]**
- **MINI PROJECTS**

Day2

- **08:30 – 09:00 Topic6: Mechanisms [Eckart]**
- **09:00 – 09:45 Topic7: Design Strategies for Power Electronic Devices [Eckart]**

09:45 – 10:00 Break

- **10:00 – 10:45 MINI PROJECTS: 45 min presentation from groups [Students]**
- **10:45-11:15 Topic8: New 2- 150 kHz Frequency Range Standard [Pooya]**
- **11:15-12:00 Topic9: Overview: for interference, propagation, remedies and limits [Eckart]**

12:00 – 13:00 Lunch

- **13:00-13:45 Topic10: EMC Demonstrator [Christian]**
    - **13:00-13:30 EMC Demonstrator Conducted Mode**
    - **13:30-13:45 EMC Demonstrator Radiated Mode**
- **13:45-14:10 Topic11: Resonance Phenomenon [Christian]**
- **14:10-14:30 Topic12: EMC filters and mechanical layout [Christian]**

14:30 – 14:45 Break

- **14:45-15:30 Topic13: Crosstalk – Ground plane [Christian]**
- **15:30-16:00 Topic14: SMPS and layout [Christian]**
- **16:00 – 16:30 Feedback**

Prerequisites: This course is intended for intermediate and advanced researchers and engineers in the field of power electronics and its applications, for EMC specialists and advanced university students exploring new harmonics and EMI challenges in power electronics-based power system and WBG-based power electronic systems. General knowledge in power electronics converters operation modes, passive components and basic control theory are preferred. Course exercises and mini-projects will be performed on MATLAB/PLECS software platform.

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

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

1- **Mini-projects**
2- **Power point presentation**

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

Stability of Modern Power Systems with High Penetration of Renewable Energy

Organizer: Sanjay K. Chaudhary (skc@et.aau.dk), Aalborg University

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

ECTS: 3

Date/Time: 17-19 November 2021, Time: 08:30 – 16:30

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.

Day 1: Overview of Conventional Power System Structure Modern Power System, and Introduction to Power system stability by Sanjay K Chaudhary and Jaykrishnan R. Pillai (3.5 hours lecture + 3.5 hours simulation exercise and discussion)

Day 2: Frequency stability and Voltage stability, by Sanjay K Chaudhary (3.5 hours lecture + 3.5 hours simulation exercise and discussion)

Day 3: Transient Stability, LVRT and Small signal stability analysis, by Sanjay K Chaudhary (3.5 hours lecture +3.5 hours simulation exercise and discussion)

Prerequisites: A basic knowledge of modern power system.

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

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

Tribodynamics

Organizer: Associate Professor, Per Johansen pjo@et.aau.dk, Aalborg University

Lecturers: Per Johansen

ECTS: 4

Date/Time: 22-25 November 2021

Max no. of participants: 30

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

Day 1: Lecturer: Per Johansen (8 hours)

- Fundamentals of friction
- Reynolds lubrication theory
- Thermohydrodynamic lubrication

Day 2: Lecturer: Per Johansen (8 hours)

- Elastohydrodynamics
- Thermo-Elastohydrodynamics
- Contact models and rough surfaces

Day 3: Lecturer: Per Johansen (8 hours)

- Computational tribodynamics
- Multibody systems with imperfect joints

Day 4: Lecturer: Per Johansen (8 hours)

- Ultrasound reflectometry in tribology
- Adaptive ultrasound reflectometry
- Tribotronic control systems

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

Form of evaluation: Mini-project

Multiphysics Simulation and Design of Power Electronics

Organizer: Associate Professor Amir Sajjad Bahman, amir@et.aau.dk

Lecturers: Assoc. Prof. Amir Sajjad Bahman, Aalborg University, Denmark
Prof. Eckart Hoene, Fraunhofer IZM, Trainers from EDRMedeso (ANSYS Channel Partner)

ECTS: 3

Date/Time: 29 November – 1 December 2021, all days 8:30 – 16:30 (3 days)

Max no. of participants: 50

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 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, RMxprt, HFSS, SIwave, Icepak, Mechanical and Sherlock to design power electronics from component level – e.g. power module, heatsink and fuse– to system level – e.g. circuit parasitics. 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
08:30 – 09:00 Course Information and Introduction to Multiphysics (Amir Sajjad Bahman)
09:00 – 09:30 Lecture on Introduction to ANSYS (Amir Sajjad Bahman)
09:30 – 10:00 Lecture on Inverter System Design (Simplorer) (Amir Sajjad Bahman)
10:00 – 10:30 Break

10:30 – 12:00 Workshop on Inverter Design (Amir Sajjad Bahman)
12:00 – 13:00 Lunch Break
13:00 – 14:00 Lecture on Motor Design (RMxprt/Maxwell) (EDRMedeso)
14:00 – 14:30 Break
14:30 – 16:30 Workshop on Motor Design (EDRMedeso)

Day 2
08:30 – 09:30 Lecture on EMI/EMC Design (Eckart Hoene)
09:30 – 10:15 Lecture on EMI/EMC Simulation (Q3D/SIWave) (EDRMedeso)
10:15 – 10:30 Break
10:30 – 12:00 Workshop on Inverter EMC Modeling (EDRMedeso)
12:00 – 13:00 Lunch Break
13:00 – 13:30 Lecture on Thermal Design (Amir Sajjad Bahman)
13:30 – 14:00 Live Demonstration of Heatsink Modeling (SpaceClaim) (Amir Sajjad Bahman)
14:00 – 15:00 Workshop on Static Thermal Modeling (Icepak/Q3D) (Amir Sajjad Bahman)
15:00 – 15:30 Break
15:30 – 16:30 Workshop on Transient Thermal Modeling (Icepak/Simplorer) (Amir Sajjad Bahman)

Day 3
08:30 – 09:00 Lecture on Reliability Design (Amir Sajjad Bahman)
09:00 – 09:30 Live Demonstration of Reliability Simulation (Sherlock) (EDRMedeso)
09:30 – 10:00 Break
10:00 – 12:00 Updated Inverter System Design (Simplorer/ROMs/Digital Twin) (Amir Sajjad Bahman)
12:00 – 13:00 Lunch Break
13:00 – 16:00 Assignments (three optional tasks based on previous models)
16:00 – 16:30 Summary and wrap up

Prerequisite: Basic understanding of power electronics circuits and components.

Form of evaluation: Fulfilment of assignment and sending a report to the organizer. A 30-day trial license of required software will be provided prior to the course. The exercise will be done in group of 1-2 members and final report must be submitted by each group.

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

Design Considerations for Robust and Reliable Power Semiconductor Modules

Organizer: Professor Francesco Iannuzzo, fia@et.aau.dk, Aalborg University

Lecturers: Professor Francesco Iannuzzo, Assist. Prof. Amir Sajjad Bahman, AAU

ECTS: 2

Date/Time: 2-3 December 2021, all days 8:30 – 16:30

Max no. of participants: 15

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:

Day 1:

Lecture 1: Introduction, overview of new developments in SiC MOSFETs and Si IGBTs (Iannuzzo).
Lecture 2: Importance of parasitic elements in real applications considering thermal aspects (Bahman).

Day 2:

Lecture 3: The four golden rules for reliable power application design including abnormal operation (Iannuzzo).
Lecture 4: Introduction to the most common failure mechanisms in silicon IGBTs and SiC MOSFETs (Iannuzzo).

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

Form of evaluation: the PhD student 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. Assessment is on individual basis, with oral Q&A session.

Future Low Voltage Distribution Grids
- A practical approach

Organizer: Associate Professor Florin Iov, fi@et.aau.dk, Aalborg University

Lecturers: Associated prof. Rasmus Olsen Løvenstein rlo@es.aau.dk, Aalborg University
Post Doc Karthikeyan Nainar, kan@et.aau.dk, Aalborg University
Post Doc Catalin Iosif Ciontea, cic@et.aau.dk, Aalborg University

ECTS: 3

Date/Time: 6-8 December 2021

Max no. of participants: 20

Description: Low-voltage (LV) distribution grids are undergoing a major change with the additions of resources such as PVs, electric vehicles etc. At present, LV grids are not observable in near realtime due to which DSOs are unable to perform active grid management. By implementing an advanced metering infrastructure and leveraging the ICT, DSOs can utilize the existing grid assets for monitoring, control and planning of LV grids. This three days course gives a systematic approach for modelling, design and operation of future LV grids using the model based design approach and the Smart Grid Architecture Model (SGAM). The course includes a wide set of hands-on exercises and demonstrations in a Real-Time Hardware-In-the Loop framework. The main focus in this course will be on:

- DSO challenges on operation, control and planning
- SGAM framework
- Real-Time modelling of future low voltage distribution grids
- ICT and data collection mechanisms
- Data Security and Privacy Aspects
- Runtime Data Driven Control and Protection
- Asset management
- RT-HIL validation and testing of smart-grid solutions

Lectures are alternated with practical exercises on each major topic. More than 40% of the course is used for practical exercises and laboratory demonstrations.

Day 1:

Future Low Voltage Grids – DSO and societal challenges – Florin Iov (2 hours)

- Current and future challenges
- Introduction to SGAM framework
- Smart grid enabling technologies (smart meters, smart inverters, smart EV chargers)
- Methodologies and tools for design and assessment (offline simulations and RT-HIL)

Real-Time Modelling of LV Distribution Grids – Florin Iov (2 hours)

- Challenges in LV grids (unbalances, grounding, faults, etc)
- Positive sequence vs 3-phase modelling
- Benchmarking of simulation tools
- Practical exercises

Real-Time Modelling of Assets – Catalin Iosif Ciontea (2 hours)

- Modelling requirements for specific LV studies
- Assets modeling (wind turbines, PV, energy storage, smart meters, electric loads etc.)
- Statistical versus historic data (load, wind, solar)
- Practical exercises

Day 2:

Grid Observability for Real-Time Monitoring and Control – Karthikeyan Nainar (2 hours)

- Technologies and required functionalities (Smart Meters, RTUs, grid inverters, etc.)
- Measurements (filtering, RMS calculation)
- State estimation techniques (WLS, Kalman filter, etc.)
- Practical exercises

Information and Communication Technologies – Rasmus Olsen (2.5 hours)

- Communication networks architectures and technologies
- Data collection mechanisms, protocols and standards
- Performance definitions and classification
- Models for ICT (offline simulations and RT-HIL)
- Practical exercises

Data Security and Privacy Aspects – Rasmus Olsen (1.5 hours)

- GDPR Challenges
- Data handling mechanisms
- Data protection measures

Day 3:

Runtime Data Driven Control and Protection – Karthikeyan Nainar and Catalin Iosif Ciontea (2 hours)

- Active and Reactive power management (voltage profiles, loss minimization, capability and utilization of existing infrastructure)
- Outage management and power supply restoration
- Practical exercises

Asset Management – Florin Iov and Karthikeyan Nainar (2 hours)

- Key Performance Indicators using historical data (quality of service, reliability of power supply)
- Medium and long term planning (hosting capacity, expansion scenarios, impact assessment studies)
- Practical exercises

RT-HIL demonstrations – Catalin Iosif Ciontea (2 hours)

- Architectures and practical considerations for RT-HIL deployment
- Laboratory demonstrations on a Danish case study using RT-HIL framework

Prerequisites: Basic knowledge on Matlab/Simulink including Toolboxes is recommended for the exercises**.**

Form of evaluation: Individual evaluation of the student assignments received during the lecture and laboratory exercises.

Grid-Forming Inverters: Principles and Practices

Organizer: Professor Xiongfei Wang xwa@et.aau.dk, Aalborg University

Lecturers: Prof. Pedro Rodriguez, University of Loyola, Spain
Prof. Xiongfei Wang, Aalborg University

ECTS: 3

Date/Time: 13-15 December 2021

Max no. of participants: 60

Description: Inverter-based generation and transmission systems are vastly used in modern power grids, driven by the sharp cost reduction of renewable energy resources and the advances of power electronics technology. To secure a stable inverter-based power system, the grid-forming control is increasingly used with grid-connected inverters, who operate as voltage sources to regulate the grid voltage and frequency. There is thus an important need to address this timely and important topic among both power electronics and power system engineers and researchers. This course intends to provide a systematic discussion on the principles and design practices of grid-forming inverters.

The main topics include, but not limited to:

- Grid-synchronization of inverters
- From synchronous generators to grid-forming inverters
- Overview of virtual synchronous generators
- Synchronous power control – damping, inertia and virtual impedance
- Small-signal modeling and stability analysis
- Design-oriented transient stability analysis
- Active damping of power oscillations

Day 1: From Synchronous Generators to Grid-Forming Inverters (Prof. Pedro Rodriguez, 6 hours)

- Grid-synchronization of inverters
- Fundamental concepts of grid-forming inverters
- Overview of virtual synchronous generators

Day 2: Synchronous Power Control (Prof. Pedro Rodriguez, 3 hours) and Voltage Control (Prof. Xiongfei Wang, 3 hours)

- Synchronous power control: principles and industry practices
- Damping, inertia and virtual impedances
- Design principles and practices of voltage control
- Small-signal modeling and passivity-based analysis

Day 3: Small-Signal and Transient Stability Analysis (Prof. Xiongfei Wang, 6 hours)

- Small-signal modeling of power control
- Analysis and damping of synchronous resonance
- Analysis and damping of sub-synchronous resonance
- Large-signal modeling of power control
- Transient stability analysis

Prerequisites: Prior knowledge on the fundamentals of power systems and synchronous machines, power electronics, as well as feedback control theory are preferred.

Form of evaluation: Exercises and report

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