Course guides
295112 - 295II132 - Renewable Energy Systems

Last modified: 04/06/2021

Unit in charge: Barcelona East School of Engineering
Teaching unit: 710 - EEL - Department of Electronic Engineering.
749 - MAT - Department of Mathematics.
709 - DEE - Department of Electrical Engineering.

Degree: MASTER'S DEGREE IN INTERDISCIPLINARY AND INNOVATIVE ENGINEERING (Syllabus 2019). (Optional subject).

Academic year: 2021 **ECTS Credits:** 6.0 **Languages:** English

LECTURER

Coordinating lecturer: Vidal Seguí, Yolanda

Others: Calatayud Camps, Robert
Fillet Castella, Sergi
Martinez Garcia, Herminio
Pozo Montero, Francesc
Velasco Quesada, Guillermo
Vidal Segui, Yolanda

PRIOR SKILLS

Basic electrical and mechanical engineering

REQUIREMENTS

Basic electrical and mechanical engineering

DEGREE COMPETENCES TO WHICH THE SUBJECT CONTRIBUTES

Specific:
CEMUEII-11. Design and manage processing and management systems for the production, storage, conversion and distribution of electrical energy using different technologies. (Specific competence of the Efficient Systems specialty)

Generical:
CGMUEII-01. Participate in technological innovation projects in multidisciplinary problems, applying mathematical, analytical, scientific, instrumental, technological and management knowledge.
CGMUEII-05. To communicate hypotheses, procedures and results to specialized and non-specialized audiences in a clear and unambiguous way, both orally and through reports and diagrams, in the context of the development of technical solutions for problems of an interdisciplinary nature.

Transversal:
05 TEQ. TEAMWORK. Being able to work as a team player, either as a member or as a leader. Contributing to projects pragmatically and responsibly, by reaching commitments in accordance to the resources that are available.
06 URI. EFFECTIVE USE OF INFORMATION RESOURCES. Managing the acquisition, structure, analysis and display of information from the own field of specialization. Taking a critical stance with regard to the results obtained.
03 TLG. THIRD LANGUAGE. Learning a third language, preferably English, to a degree of oral and written fluency that fits in with the future needs of the graduates of each course.

TEACHING METHODOLOGY

The methodology of the course combines theory lessons, laboratory sessions and projects development.

LEARNING OBJECTIVES OF THE SUBJECT

This course provides an overview of key aspects in Renewable systems. First, it gives an insight in the wind turbine main components and terminology, the wind resource and energy output, wind turbine generators, and the controllers involved in modern industrial wind turbines. Second, principles on solar energy and photovoltaic systems are stated. Third, sizing photovoltaic systems and sizing wind and hybrid-energy systems is undertaken. Finally, an introduction to electrical microgrids is given.

STUDY LOAD

Type	Hours	Percentage
Self study	102,0	68.00
Hours large group	22,0	14.67
Hours small group	22,0	14.67
Guided activities	4,0	2.67

Total learning time: 150 h

CONTENTS

Wind Turbine Terminology and Components

Description:
• Different types of wind turbines
• The size of wind turbines
• The main components of horizontal-axis wind turbines:
– Rotor with rotor blades and hub
– Nacelle
• Drivetrain with main bearing, gearbox, brake and generator
• Power electronics consisting of the converter and transformers
– Tower (tubular steel, lattice, …)
– Foundation (onshore, fixed-offshore, floating-offshore)
• The main degrees of freedom:
– Azimuth rotation of the rotor
– Yaw rotation of nacelle about the vertical axis
– Pitch rotation of the blades about their lengthwise axis
• Basic aerodynamics of wind turbines:
– Lift
– Stall

Related activities:
Laboratory session (Activity 1): Analysis and Visualization of wind turbine data (Matlab).

Full-or-part-time: 2h
Theory classes: 2h

The Wind Resource and Energy Output

Description:
• Global and local winds
• Turbulence
• The energy in the wind (air density and rotor area)
• Wind deflection by the wind turbine
• The power of the wind
• Cut-in, cut-out, and rated wind speeds
• Onshore and offshore winds
• Wake effect in wind farms
• Selecting a wind turbine site
• The Weibull distribution
• Betz limit
• Power density function
• Power curve
• The power coefficient

Related activities:
Laboratory session (Activity 2): Modeling a wind turbine using Matlab and Simulink

Full-or-part-time: 4h
Theory classes: 4h

Control Strategies

Description:
• Calculation of aerodynamic power from wind speed, pitch angle and rotor speed using wind turbine power curves
• Pitch controlled wind turbines
• Stall controlled wind turbines
• Active stall controlled wind turbines
• Other control methods (flaps, yaw partly out of the wind,...)

Related activities:
Laboratory session (Activity 3): Wind turbine control design with FAST (Fatigue, Aerodynamics, Structures, & Turbulence software)

Full-or-part-time: 2h
Theory classes: 2h

Wind Turbine Aeroelasticity

Description:
• Inertial, structural and aerodynamic forces
• Basic load considerations (extreme loads, fatigue loads)
• Design load cases

Related activities:
Laboratory session (Activity 4): Wind turbine loads analysis

Full-or-part-time: 2h
Theory classes: 2h

Wind Turbine Generators

Description:
• Model of wind turbine generators
– Vector transformations
– Induction generators
– Synchronous generators
• Power converters in wind turbines
– Two level power converters
– Three level power converters
– Control of power converters
• Wind turbines topologies and configurations
– Fixed speed wind turbine generators
– Variable speed wind turbine generators
• Grid connection
– Isolated wind turbine generators
– Connection of wind turbine generators to the power grid
– Auxiliary elements

Related activities:
Laboratory session (Activity 5): model, simulation and control of wind turbine generators using Matlab

Full-or-part-time: 2h
Theory classes: 2h

Solar Energy and Photovoltaic Systems

Description:
• Introduction to solar energy.
• Classification: Bioclimatic architecture, thermal solar energy, and PV solar energy.
• Photovoltaic (PV) cells and modules.
• Main components of a PV system.
- PV solar array.
- Battery charging and battery-based storage system.
- DC-DC power converters and battery regulators.
- Off-grid and grid-connected inverters.
- Practical aspects and component location.
• Data collection to sizing PV solar systems.
- Consumption profile.
- Solar potential and irradiation.
- Datasheets and manufacturer’s data.
• Examples of sizing of PV solar systems.
- Stand-alone PV systems.
- Sizing of water-pumping PV systems.
- Sizing of grid-connected PV systems.

Related activities:
• Laboratory sessions (Activity 6): Practical experimentation of solar energy systems with laboratory scale models.
• Laboratory sessions (Activity 7): PVsyst software for the sizing of PV solar energy systems.

Full-or-part-time: 4h
Theory classes: 4h

Sizing of Wind and Hybrid-Energy Systems

Description:
• Introduction to hybrid (wind & solar) energy systems.
• Integration of renewable systems.
- Energy buses: AC and DC buses.
• Data collection to sizing hybrid solar systems.
- Consumption profile.
- Solar and wind potentials, irradiation and wind data.
- Datasheets and manufacturer's data.
• Sizing of wind-energy and hybrid systems.
- Sizing of stand-alone wind and hybrid-energy systems.
- Sizing of water-pumping wind and hybrid-energy systems.
- Sizing of grid-connected wind and hybrid-energy systems.

Related activities:
• Laboratory sessions (Activity 8): Practical experimentation of wind energy systems with laboratory scale models.
• Laboratory sessions (Activity 9): MATLAB & Simulink-based simulation environment for the behavioural study of PV solar, wind and hybrid energy systems.

Full-or-part-time: 4h
Theory classes: 4h

Introduction to Electrical Microgrids

Description:
• Introduction to electrical microgrids.
• Elements of a microgrid: Renewable generation, loads and consumers, and prosumers.
- Energy processing and management of microgrid.
• Cooperative and peer-to-peer energy sharing microgrids.
- Energy processing and management of peer-to-peer energy sharing microgrids.

Related activities:
Laboratory sessions (Activity 10): MATLAB & Simulink-based simulation environment for the behavioural study of a households microgrid.

Full-or-part-time: 2h
Theory classes: 2h

GRADING SYSTEM

Partial exam 30%
Final exam 30%
Projects 40%

BIBLIOGRAPHY

Basic:
- Heier, Siegfried. Grid integration of wind energy : onshore and offshore conversion systems [on line]. 3rd ed. Chichester [etc.]: John Wiley & Sons, 2014 [Consultation: 20/04/2020]. Available on: https://onlinelibrary.wiley.com/doi/book/10.1002/9781118703274. ISBN 9781118703274.
- Pareja Aparicio, Miguel. Radiación solar y su aprovechamiento energético. Barcelona: Marcombo, S.A., 2009. ISBN 9788426715593.
- Centro de Investigaciones Energéticas Medioambientales y Tecnológicas. Fundamentos, dimensionado y aplicaciones de la energía solar fotovoltaica. Vol. 1. Madrid: CIEMAT, 2007. ISBN 9788478345403.
- Solar Energy International. Photovoltaics : design and installation manual : renewable energy, education for a sustainable future. Philadelphia, Pa.: New Society Publishers, 2004. ISBN 9709638855.
- Eicker, Ursula. Solar technologies for buildings. Chichester: John Wiley & Sons, 2003. ISBN 047148637X.
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- Burton, Tony [et al.]. Wind energy handbook [on line]. 2nd ed. Chichester, UK: John Wiley & Sons, 2011 [Consultation: 15/04/2020]. Available on: https://onlinelibrary.wiley.com/doi/book/10.1002/9781119992714. ISBN 9781119992714.
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- Jha, A. R. Wind turbine technology. Boca Raton, Fla.: CRC, cop. 2011. ISBN 781439815069.
- Manwell, J. F. ; McGowan, J. G. ; Rogers, A. L. Wind energy explained : theory, design and application [on line]. 2n ed. [Chichester]: John Wiley & Sons, 2010 [Consultation: 20/04/2020]. Available on: http://site.ebrary.com/lib/upcatalunya/docDetail.action?docID=10419452. ISBN 9780470686287.
- Hau, Erich. Wind turbines : fundamentals, technologies, application, economics [on line]. 3rd ed. Berlin, Heidelberg: Springer, 2013 [Consultation: 15/04/2020]. Available on: http://dx.doi.org/10.1007/978-3-642-27151-9. ISBN 9783642271519.

RESOURCES

Computer material:
- Matlab & Simulink. Simulation Software
- PVsyst. Software for the sizing of PV solar energy systems

Other resources:
Solar and wind energy laboratory scale models