**Course title**: Integration of renewable energy systems to the grid

**Code**: SEL059

**ECTS Credits**: 5 ECTS

**Responsible unit**: 240 – ETSEIB – School of Industrial Engineering of Barcelona

**Department**: Electrical Engineering

**Starting course:** 2012/2013

**Degrees**:  MSc Renewable Energy - RenE

 Environomical Pathways for Sustainable Energy Systems - SELECT

**Type of Education Unit**: ??

**Course coordinator**: Oriol Gomis-Bellmunt

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| **Requirements** |

**Prior skills**: Basic electrical and mechanical engineering

Electrical circuits analysis

**Prerequisites**:

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| **Lecturers** |

Oriol Gomis-Bellmunt, Roberto Villafáfila, Agustí Egea, Andreas Sumper

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| **Competencies and learning outcomes** |

At the end of the course the students will be able to:

* Understand how power systems interact with renewable energy systems
* Analyze power systems with a high penetration of renewables
* Understand how renewable energies can be efficiently integrated in power systems
* Understand the smart grid concept and the relevance of renewable energies in it
* Analyze and design microgrids
* Analyze and design supergrids for offshore wind power

UPC Generic skills:

Effective oral and written communication 

Teamwork 

Autonomous Learning 

Solvent use of information resources 

Sustainability and social commitment 

Entrepreneurship and innovation 

English 

Project Management 

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| **EIT Overarching Learning Outcomes Coverage** |

Creativity skills and competencies 

Innovation skills and competencies 

Entrepreneurship skills and competencies 

Research skills and competencies 

Transforming skills and competencies 

Leadership skills and competencies 

Making Value Judgements 

Describe, in the course description, how these learning outcomes are integrated in modules and activities.

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| **Methodology** |

Theory classes, Simulation practices, Project assignment to be developed at home.

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| **Objectives** |

The course will focus on providing the knowledge and the tools needed to understand and analyze the interaction between renewable energies and power systems.

Specific objectives include covering the following topics:

* Analysis of power systems with a high penetration of renewables
* Grid integration of renewables
* Smart grids
* Grid codes
* Isolated and connected Microgrids
* HVDC Supergrids for offshore wind
* The role of energy storage and demand side management

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| **Course description** |

The topics considered in the course will be:

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| **1. Introduction** | **Learning time**: h  Lectures: 2 h  Exercises: 0 h  Autonomous learning: h |
| **Description:**  The module provides an introduction to the field of renewable energies to the electrical power system. The main technologies, trends and challenges will be introduced.  **Learning outcomes:** | |
| **2. Grid support** | **Learning time**: h  Lectures: 2 h  Exercises: 4 h  Autonomous learning: h |
| **Description:** The module introduces grid support from renewable energies, including frequency support, voltage support and power system stability support. The different relevant grid codes are presented. Additional support technologies as energy storage or FACTs (flexible AC transmission systems) are described.  **Learning outcomes:** Voltage support, Frequency support, Grid codes, Energy storage, FACTS.  **Related activities:** Activity 1. | |
| **3. Supergrids** | **Learning time**: h  Lectures: 2 h  Exercises: 6 h  Autonomous learning: h |
| **Description:** The Supergrid concept is presented. It allows integration of large amounts of renewable (as offshore wind), also interconnecting different power system. HVDC transmission systems are introduced and analyzed. Some relevant projects as Desertec, Medgrid, European Supergrid are presented.  **Learning outcomes:** Supergrids.  **Related activities:** Activity 2. | |
| **4. Microgrids** | **Learning time**: h  Lectures: 0 h  Exercises: 10 h  Autonomous learning: h |
| **Description:** The microgrid concept is presented. It allows integration of different renewable energy sources combined with energy storage devices in isolated or grid connected grids. Different microgrid example will be discussed and analyzed.  **Learning outcomes:** Microgrids.  **Related activities:** Project | |

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| **Activities description** |

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| **Activity 1. Grid support** | **Learning time: h**  **Supervised activities: 2 h**  **Laboratory: 2 h**  **Autonomous learning: h** | |
| **Description**: Simulations on grid support from renewables will be performed.  **Resources:** Matlab Simulink  **Deliverables:** An activity report will be submitted. | | |
| **Activity 2. Supergrids analysis** | **Learning time**: h  Supervised activities: 2 h  Laboratory: 2 h  Autonomous learning: h | |
| **Description**: A given power system of a Supergrid will be analyzed using standard tools for power system power flow analysis. Several offshore wind power plants will be included and analyzed.  **Resources:** Offshore wind power plants, Power system parameters, generation parameters.  **Deliverables:** An activity report will be submitted. | | |
| **Project** | **Learning time**: h  Supervised activities: 0 h  Laboratory: 0 h  Autonomous learning: h | |
| **Description**: After discussion with the instructor, a project will be assigned and developed by the students with appropriate tutoring.  **Resources:** to be defined  **Deliverables:** An activity report will be submitted. Oral presentation. | | |
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| **Examination and Grading** | |

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| Written exam (final exam) | 50 |
| Activity 1 | 15 |
| Activity 2 | 15 |
| Project | 20 |

Although final grades are assigned by the examiner, the following criteria are utilized in general:

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| Grade | Relation to learning outcomes |
| 9.0÷ 10 | Excellent performance showing a high level of ambition, initiative, and attention to detail. |
| 7.6÷ 8.9 | Very good performance showing clear efforts to go beyond minimum requirements. |
| 6.0 ÷ 7.5 | Good performance where requirements are met sufficiently and in some cases are exceeded. |
| 5.0 ÷ 5.9 | Adequate performance. |
| Below 5.0 | Inadequate performance |

**Description:**

Written exam (final exam)

The exam will consist of conceptual questions and short exercises which will include the theory contents as well as exercises and activities performed. Time: 2 hours

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| **Course Literature** |

**Basic**:

Course materials

**Complementary**:

Renewable energy in power systems, L. L. Freris, D.Infield, John Wiley and Sons, 2008

Embedded Generation, N. Jenkins, R. Allan, P. Crossley, D. Kirschen and G. Strbac., The Institution of Electrical Engineers, 2000

Wind Turbine Operation in Electric Power Systems: Advanced Modeling, Zbigniew Lubosny, Springer Verlag, 2003

 Wind Power in Power Systems, Thomas Ackermann (Editor), Wiley, 2005

Wind energy generation: Modelling and Control, O. Anaya-Lara, N. Jenkins, J. Ekanayake, P. Cartwright, M. Hughes, John Wiley and Sons, 2009

Grid Converters for Photovoltaic and Wind Power Systems, R. Teodorescu, M. Liserre, P. Rodriguez, F. Blaabjerg, John Wiley and Sons, 2011

**Organizations**

EolicCat http://www.eoliccat.net/

Asociación Empresarial Eólica http://www.aeeolica.es/

British Wind Energy Association http://www.bwea.com/

Danish Wind Industry Association http://www.vindselskab.dk/en/core.htm

German Wind Energy Association http://www.wind-energie.de/en/

European Wind Energy Association http://www.ewea.org/

American Wind Energy Association http://www.awea.org/

Chinese Wind Energy Association http://www.cwea.org.cn/main.asp

World Wind Energy Association http://www.wwindea.org/

International Energy Agency  http://www.iea.org/

International Renewable Energy Agency http://www.irena.org/