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# 820747 - IERXE - Integration of Renewables in the Electric Grid (DRAFT VERSION)

Coordinating unit: 820 - EUETIB - Barcelona College of Industrial Engineering

Teaching unit: 709 - EE - Department of Electrical Engineering

Academic year: 2014

Degree: MASTER IN ENERGY ENGINEERING (Syllabus 2013). (Teaching unit Optional)
ERASMUS MUNDUS MASTER IN ENVIRONOMICAL PATHWAYS FOR SUSTAINABLE ENERGY SYSTEMS (Syllabus 2012). (Teaching unit Optional)

ECTS credits: 5 Teaching languages: English

## Teaching staff

Coordinator: Gomis Bellmunt, Oriol

Others: Gomis Bellmunt, Oriol

## Prior skills

Basic electrical and mechanical engineering
Electrical circuits analysis

## Requirements

Basic electrical and mechanical engineering
Electrical circuits analysis

## Degree competences to which the subject contributes

Specific:

CEMT-1. Understand, describe and analyse, in a clear and comprehensive manner, the entire energy conversion chain, from its status as an energy source to its use as an energy service. They will also be able to identify, describe and analyse the situation and characteristics of the various energy resources and end uses of energy, in their economic, social and environmental dimensions, and to make value judgments.

CEMT-2. Identify and describe the components of electrical systems (production, transportation, distribution, markets, procurement and consumption) and evaluate the technological solutions used in the production of electricity.

CEMT-3. Assess the economic, social and environmental impact of the production, use and management of energy, with a holistic view of the life cycle of the different systems, and recognise and value the most remarkable developments in the fields of energy efficiency and the rational use of energy.

CEMT-4. Efficiently collect data on renewable energy resources and their statistical treatment and apply knowledge and endpoint criteria in the design and evaluation of technology solutions for using renewable energy resources, for both isolated systems and those connected to networks. They will also be able to recognise and evaluate the newest technological applications in the use of renewable energy resources.

CEMT-5. Employ technical and economic criteria to select the most appropriate thermal equipment for a given application, dimension thermal equipment and facilities, and recognise and evaluate the newest technological applications in the production, transportation, distribution, storage and use of thermal energy.

CEMT-6. Employ technical and economic criteria to select the most appropriate electrical equipment for a given application, dimension thermal equipment and facilities, and recognise and evaluate the newest technology applications in the field of production, transport, distribution, storage and use of electric energy.

CEMT-7. Analyse the performance of equipment and facilities in operation to carry out a diagnostic assessment of the use system and establish measures to improve their energy efficiency.

CEMT-8. Understand, describe and analyse, in a clear and comprehensive manner, the functioning of energy markets

and carry out the optimum procurement of energy supplies

CEMT-9. Undertake projects related to energy management in production and service sectors, recognise and value advances and developments in the field and contribute innovative ideas.

## Teaching methodology

The course teaching methodologies are as follows:
- Lectures and conferences: knowledge exposed by lecturers or guest speakers.
- Participatory sessions: collective resolution of exercises, debates and group dynamics, with the lecturer and other students in the classroom; classroom presentation of an activity individually or in small groups.
- Theoretical/practical supervised work: classroom activity, carried out individually or in small groups, with the advice and supervision of the teacher.
- Homework assignment of reduced extension: carry out homework of reduced extension, individually or in groups.
- Homework assignment of broad extension (PA): design, planning and implementation of a project or homework assignment of broad extension by a group of students, and writing a report that should include the approach, results and conclusions.
Training activities:
The course training activities are as follows:
Face to face activities
- Lectures and conferences: learning based on understanding and synthesizing the knowledge presented by the teacher or by invited speakers.
- Participatory sessions: learning based on participating in the collective resolution of exercises, as well as in discussions and group dynamics, with the lecturer and other students in the classroom.
- Presentations (PS): learning based on presenting in the classroom an activity individually or in small groups.
- Theoretical/practical supervised work (TD): learning based on performing an activity in the classroom, or a theoretical or practical exercise, individually or in small groups, with the advice of the teacher.
Study activities
- Homework assignment of reduced extension (PR): learning based on applying knowledge and presenting results.
- Homework assignment of broad extension (PA): learning based on applying and extending knowledge.
- Self-study (EA): learning based on studying or expanding the contents of the learning material, individually or in groups, understanding, assimilating, analysing and synthesizing knowledge.

## Learning objectives of the subject

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

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

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- Analyze and design microgrids
- Analyze and design supergrids for offshore wind power

## Study load

| | | | |
|---|---|---|---|
| Total learning time: 125h | Hours large group: | 0h | 0.00% |
| | Hours medium group: | 0h | 0.00% |
| | Hours small group: | 30h | 24.00% |
| | Guided activities: | 15h | 12.00% |
| | Self study: | 80h | 64.00% |

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## Content

### Introduction

Learning time: 11h

Small group/Laboratory: 1h
Self study : 10h

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.

### Grid support

Learning time: 26h

Small group/Laboratory: 6h
Self study : 20h

Degree competences to which the content contributes:
CEMT-1 (Specific)
CEMT-2 (Specific)
CEMT-3 (Specific)
CEMT-4 (Specific)
CEMT-5 (Specific)

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.

Related activities:
Activity 1.

Specific objectives:
Voltage support, Frequency support, Grid codes, Energy storage, FACTS.

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| Supergrids | Learning time: 28h<br>Small group/Laboratory: 8h<br>Self study : 20h |
|---|---|

Degree competences to which the content contributes:
CEMT-1 (Specific)
CEMT-2 (Specific)
CEMT-3 (Specific)
CEMT-4 (Specific)
CEMT-5 (Specific)

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.

Related activities:
Activity 2.

| Microgrids | Learning time: 28h<br>Small group/Laboratory: 8h<br>Self study : 20h |
|---|---|

Degree competences to which the content contributes:
CEMT-1 (Specific)
CEMT-2 (Specific)
CEMT-3 (Specific)
CEMT-4 (Specific)
CEMT-5 (Specific)

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.

Related activities:
Activity 3

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## Planning of activities

| Grid support | Hours: 12h<br>Self study: 10h<br>Laboratory classes: 2h |
|---|---|

Degree competences to which the activity contributes:

Description:
Simulations on grid support from renewables will be performed.

Support materials:
Matlab Simulink

Descriptions of the assignments due and their relation to the assessment:
An activity report will be submitted.

| Supergrids analysis | Hours: 12h<br>Self study: 10h<br>Laboratory classes: 2h |
|---|---|

Degree competences to which the activity contributes:

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.

Support materials:
Offshore wind power plants, Power system parameters, generation parameters.

Descriptions of the assignments due and their relation to the assessment:
An activity report will be submitted.

| Microgrids | Hours: 12h<br>Self study: 10h<br>Laboratory classes: 2h |
|---|---|

Degree competences to which the activity contributes:

Description:
After discussion with the instructor, a project on microgrids will be assigned and developed by the students with appropriate tutoring.

Support materials:
to be defined

Descriptions of the assignments due and their relation to the assessment:
An activity report will be submitted. Oral presentation.

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## Bibliography

Basic:

Freris. Renewable energy in power systems.

Jenkins. Embedded Generation.

Ackermann . Wind Power in Power Systems.

Anaya-Lara. Wind energy generation: Modelling and Control.

Van Hertem. Building the grid of the future using HVDC.