Course guides
820773 - EMGE - Energy Storage

Unit in charge: Barcelona School of Industrial Engineering
Teaching unit: 709 - DEE - Department of Electrical Engineering.
Degree: MASTER'S DEGREE IN ENERGY ENGINEERING (Syllabus 2013). (Optional subject).
Academic year: 2020 ECTS Credits: 5.0 Languages: Catalan, English, Spanish

LECTURER
Coordinating lecturer: FRANCISCO DÍAZ-GONZÁLEZ
Others: FRANCISCO DÍAZ-GONZÁLEZ

PRIOR SKILLS
Autonomous learning capacity, mathematics, experience in simulation tools.

TEACHING METHODOLOGY
The following teaching methodologies are adopted for the course:

- Magistral classes or conferences (CM): dissertations by the professor or by eventual collaborators.
- Participative classes (PART): joint discussions, as well as the resolution of exercises in the room.
- Short activities (PR): individual development (or in groups) of short activities to apply the knowledge gained in the course.
- Project (PA): knowledge based on the design, planning and deployment of a project of relatively long extension about a particular topic and applying the knowledge gained in the subject.
- Final exam (PECC).

LEARNING OBJECTIVES OF THE SUBJECT

Objectives
To gain basic knowledge on energy storage systems in electrical networks, emphasizing in electromechanical systems (flywheels, pumped-hydro installations and compressed-air installations), electric devices (supercapacitors and SMES), electrochemical systems (batteries) and chemical systems (hydrogen-based ones).

Learning results
At the end of the course, the student:

- Should know the principal characteristics of the diverse energy storage systems that can be applied in electrical networks.
- Should know the mathematical expressions (high level ones) so as to size an energy storage system from the energy demands in electrical networks.
- Should know the management and monitoring mechanisms of energy storages.
- Should achieve a global vision of the energy storage possibilities in vehicles, with the objective of addressing the suitability of using one or another storage device according to their particular application in the network.
- Should gain capacities in modeling and simulation of energy systems including storages, as for the case of electrical networks.
- Should gain the knowledge and skills so as to define a project related to the conception, sizing and/or utilization of energy storages in electrical networks.
## STUDY LOAD

<table>
<thead>
<tr>
<th>Type</th>
<th>Hours</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Guided activities</td>
<td>10,0</td>
<td>8.33</td>
</tr>
<tr>
<td>Hours small group</td>
<td>30,0</td>
<td>25.00</td>
</tr>
<tr>
<td>Self study</td>
<td>80,0</td>
<td>66.67</td>
</tr>
</tbody>
</table>

**Total learning time:** 120 h

## CONTENTS

### Introduction to the power network and electrical markets

**Description:**
Brief introduction to the operation of the power network and its associated markets, as a previous step before addressing the services the energy storage systems can provide to the network.

**Specific objectives:**
- To know the mechanisms for the activation of the power reserves in electrical networks, so as to ensure the continuous balance between generation and demand.
- To understand the problems associated to the grid connection of renewable-based generating systems from the point of view of network operation.
- To know the market mechanisms associated to the activation of such power reserves.

**Related activities:**
- The development of a short activity (E1), to be done individually. It should be submitted via email during the course to the professor.

**Full-or-part-time:** 26h
- Theory classes: 5h
- Guided activities: 10h 10m
- Self study: 10h 50m

### Energy storage technologies

**Description:**
Operating principles, characteristics, technologies available in the market, basic calculations for device sizing, description of models for simulation and evaluation of the behavior of the storages while in operation.

**Specific objectives:**
To gain knowledge on diverse energy storage systems.

**Related activities:**
- Project (PA).

**Full-or-part-time:** 52h
- Theory classes: 10h
- Guided activities: 20h 20m
- Self study: 21h 40m
## Cost models for energy storage systems

**Description:**
Development and application of a mathematical model so as to evaluate the costs associated to an energy storage system.

**Specific objectives:**
- To know which are the main costs associated to the installation and operation of an energy storage system.
- To gain enough knowledge so as to be able to apply the cost model in a particular case.

**Related activities:**
Project (PA).

**Full-or-part-time:** 11h
- Theory classes: 2h
- Guided activities: 4h
- Self study: 5h

## Applications of energy storage systems in power networks.

**Description:**
Presentation of the applications that the storages can provide in electrical systems.

**Specific objectives:**
- To gain a general vision on the potential of energy storages to modernize the electrical systems.

**Related activities:**
Project (PA).

**Full-or-part-time:** 16h
- Theory classes: 3h
- Guided activities: 6h 30m
- Self study: 6h 30m

## Regulation and business models

**Description:**
Introduction to the regulatory barriers around the adoption of energy storage systems in electrical networks. Definition of potential business models.

**Specific objectives:**
- To promote innovation capability of students.

**Related activities:**
Project (PA).

**Full-or-part-time:** 10h
- Theory classes: 2h
- Guided activities: 4h
- Self study: 4h
### Recycling and natural resources

**Description:**
To introduce the field of battery recycling. To provide a general vision on the natural resources of strategic materials for manufacturing batteries.

**Related activities:**
Project (PA).

**Full-or-part-time:** 10h
- Theory classes: 2h
- Guided activities: 4h
- Self study: 4h

### ACTIVITIES

#### Magistral classes (CM)

**Description:**
To know, understand and synthetize the topics introduced by the professor or by eventual collaborators.

**Full-or-part-time:** 22h
- Theory classes: 22h

#### Presentations (PS)

**Description:**
To present to the class the results obtained in the project (PA) developed individually or in groups for its evaluation.

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

#### Tutorship (TD)

**Description:**
To progress in the development of the project (PA) in the room, with the help of the professor.

**Full-or-part-time:** 10h
- Theory classes: 10h

#### Short activities (PR)

**Description:**
To develop individually short activities applying the knowledge gained during the course. (Non-presential activity).

**Full-or-part-time:** 10h
- Theory classes: 1h
- Guided activities: 9h
Project (PA)

**Description:** To design, plan and deploy a project of relatively long extension about a particular topic and applying the knowledge gained in the subject.

**Full-or-part-time:** 41h
- Theory classes: 1h
- Guided activities: 40h

Self-learning (EA)

**Description:** To study and complement the contents introduced in the course. (Non-presential activity)

**Full-or-part-time:** 40h
- Self study: 40h

**GRADING SYSTEM**

Final exam (PECC), 50%
Short activities (PR), 15%
Project (PA), 35%

**EXAMINATION RULES.**

The use of a calculator is permitted (and needed) for the final exam (PECC). No additional documentation and any other material could be used in the exam. The short activities (PR) should be addressed individually, not in groups, and should be submitted to the professor through Atenea platform when convenient. Finally, the project (PA) is intended to be conducted either individually or in groups, and should be presented to the class during the last session for the course. The report of this project should be submitted to the professor via email.

**BIBLIOGRAPHY**

**Basic:**