Course guide
240292 - 240EN45 - Energy Storage

Last modified: 09/07/2024

Unit in charge: Barcelona School of Industrial Engineering
Teaching unit: 709 - DEE - Department of Electrical Engineering.

Degree: MASTER'S DEGREE IN ENERGY ENGINEERING (Syllabus 2022). (Optional subject).

Academic year: 2024 **ECTS Credits:** 5.0 **Languages:** English

LECTURER

Coordinating lecturer: Francisco Díaz González

Others: Justin Chiu (KTH)
Massimo Santarelli (POLITO)

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 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 energy systems, emphasizing in electrical, thermal and hydrogen-based energy storage technologies.

Learning results

At the end of the course, the student:

• Should know the principal characteristics, performance and limitations of the energy storage systems that can be applied in energy systems.
• Should know the mathematical expressions so as to size an energy storage system from the energy demands in the energy systems they are included to.
• Should know the basis for management and monitoring mechanisms of energy storage systems.
• Should know the basis for the 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 energy systems.

CONTENTS

Technologies for electrical energy storage: mechanical, electrical and electrochemical energy storage technologies.

Description:
Description:
Operating principles, main characteristics, limitations and performance of technologies for storing electrical energy as mechanical energy (pumped hydro, compressed air systems and flywheels), electrical energy (supercapacitors) and chemical energy (batteries). Presentation of basic mathematical expressions for the sizing and modeling of each technology.

Specific objectives:
Specific objectives:
• To learn how to calculate energy storage and power capacity of each technology. To adopt the concepts of state of charge, state of health, efficiency, energy density, cyclability and others fully characterizing the technologies from a system perspective.
• To adopt the methods for the sizing of energy storage technologies considering specific technical limitations that, at the end, are translated into an oversizing.
• To address the mathematical modeling of supercapacitors, flywheels and batteries, so as to envisage technical performance and dynamic behavior. This modeling exercise also serves to derive the applications or services each of the technologies can provide in electrical systems

Related activities:
Related activities:
• Project (PA).
• Short activity (PR). This case study will deal with the sizing and development of a simulation model for a battery in the software Matlab Simulink.

Full-or-part-time: 33h
Theory classes: 10h
Guided activities: 14h
Self study : 9h

Thermal energy storage technologies.

Description:
Description:
Operating principles, main characteristics, limitations and performance of technologies.
• Thermal energy storage as sensible heat. High and low enthalpy heat. Cryogenic, liquid air.
• Thermal energy storage as latent heat. Phase change materials.
• Thermal energy storage as chemical heat. Thermal chemicals.

Specific objectives:
Specific objectives:
• Compare different types of thermal energy storage systems.
• Analyze the pros and cons of different types of thermal energy storage solutions.
• Design thermal storage unit.

Related activities:
Related activities:
• Project (PA).
• Short activity (PR).

Full-or-part-time: 33h
Theory classes: 8h
Guided activities: 16h
Self study : 9h

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Hydrogen and Power-to-X processes and technologies.

Description:
Description:
• Introduction. Power-to-X (P2X) as a paradigm of large-scale long-time energy storage.
• Power-to-Gas (P2G). Processes, technologies, examples (H2, synthetic CH4). Analysis of integration of the grids (electrical-gas).
• Power-to-Liquid (P2L). Processes, technologies, examples (CH3OH, CH3OCH3).
• Power-to-Power (P2P). Round trip process, examples of real DEMOs experiences from H2020 project REMOTE.

Specific objectives:
Specific objectives:
• The processes and technologies to store electric energy in form of chemicals (in form of gas and liquid)
• The design of the processes P2G and P2L
• The process and technology of power-to-power using hydrogen as storage medium.

Related activities:
Related activities:
• Project (PA).
• Short activity (PR). This case study will deal with the design of a power-to-power energy storage system based on the integration of Li-ion battery modules and a H2-based system, applied preferentially in an island, in order to assure the energy independence of the island basing on the local available renewable sources.

Full-or-part-time: 34h
Theory classes: 10h
Guided activities: 14h
Self study : 10h

GRADING SYSTEM

Final exam (PECC): 40% Short activities (PR): 30% Project (PA): 30%

ABOUT RE-TAKE EXAM: Re-take exam is just an option for those students who did not pass the subject at the end of the course (this means getting a final mark for the subject lower than 5 points out 10 points.) In case of opting for and passing the re-take exam, the final mark for the whole subject will be 5 out 10 points.

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:
- Díaz-González, F.; Sumper, A.; Gomis-Bellmunt, O.. Energy storage in power systems. John Wiley and Sons, 2016. ISBN 9781118971321.