Curricular Unit Sheet

1. Curricular Unit Syllabus.

1.1. Curricular Unit

Energy Storage Systems

1.2. Scientific area acronym

EE

1.3. Duration

1 semester

1.4. Total of Working Hours

4,5

1.5. Contact hours

4,5

1.6. ECTS

6

1.7. Observations

Optional course

2. Responsible Academic staff and lecturing load in the curricular unit (enter full name)

Pedro Miguel Neves da Fonte	1,5

3. Other academic staff and lecturing load in the curricular unit

Ricardo Luis Rita Pereira	1,5 1,5

4. Learning outcomes of the curricular unit

Characterize the different existing and emerging technologies of energy storage technologies;

Analyze the functioning and operation principles of energy storage systems;

Understand the principles and energy conversion techniques applied to electric energy storage;

Identify and evaluate the storage technologies suitable to each specific application;

Study and modeling energy storage systems in electric energy systems such as production, transport, distribution and utilization;

Application of energy storage systems on case studies connected and isolated from the power grid; Analysis of hybrid systems of electric energy storage.

Develop skills to project, installation, operation and supervision of electric energy storage systems.

5. Syllabus

Overview of Energy storage systems: Introduction and definition of energy storage; Factors that drive the energy storage; Objectives and strategies for storage systems operation; Energy storage technologies; Classification, characterization and applications of storage systems to electric energy;

Storage systems: Analysis of functioning principles; Application on electric energy systems; hydro pumping; compress air; flywheels; batteries; flux batteries, super capacitors; solar-thermal; Hydrogen.

Analysis of energy conversion techniques applied to electric energy use;

Energy storage in the context of electric energy grid and applications on isolated grids; Applications of energy storage with short and long term. Actual and future applications of energy storage systems. Coordination and operation of energy storage systems in smart grids.

Consolidation of knowledge based on case studies.

6. Demonstration of the syllabus coherence with the curricular unit's objectives

The syllabus aims the students' competences acquisition at the following domains:

Comparative analysis of Energy storage technologies;

Analysis of energy conversion techniques associated to energy storage;

Understanding the significance and contribution of electric energy storage systems in different areas, such as: energy markets, integration of renewable energies, energy quality, distributed generation, smart grids and electric mobility, to allow the achievement and utilization of electric energy on a flexible, trustable and efficient way.

Is intended that students achieve competences in characterization, dimensioning and operation of different electric energy storage methodologies .

In this sense the objectives of the course clearly synthetize the competences to be acquired by the students and are in accordance with the presented syllabus.

7. Teaching methodologies (including evaluation)

In this course the teaching components are: theoretical, theoretical-practical and laboratorial classes.

In the theoretic lectures the theory fundaments of syllabus are addressed on a bidirectional way between professor and student.

In the theoretical-practical lectures the application of acquired knowledge is done through the problems mathematical resolution using simulation environment and aftermost, validation. Some learning techniques based on problems associated to other active learning are used to achieve problems solution

In the laboratory lectures the objectives of case studies are presented as well as the skills to be acquired by the students.

The assessment of the course is based on a problem solved by a team of students. The assessment consists on a numeric simulation which involves Energy storage (SN), with a presentation of the obtained results in a seminar format (S) and delivering of a scientific paper (or report) (A/R). These three components of the assessment are pedagogically fundamental to the final grade.

The final grade (CF) is calculated by the following equation:

CL =0,7.(SN)+0,15.(S)+0,15.(A/R)

8. Demonstration of the coherence between the teaching methodologies and the learning outcomes

To fulfill the objectives of the course, the students should be motivated and be able to apply the theoretical knowledge into practical cases.

There is a high degree of temporal connection between the theoretical, theoretical-practical and laboratorial components that allow to the students achieve a logic and adequate connection between the knowledge and the know how to do.

The demonstration of the coherency between the teaching methodology and learning objectives is done through the students motivation (hardly measurable) associated to the quantity of positive grades (easily measurable)

The adopted methodology and the articulation of the theoretical, theoretical-practical and laboratorial lectures contribute for consolidation and knowledge construction once the students define the process, the methodology and apply the acquired knowledge during the working development process, during the work presentation and in the report or scientific paper delivery.

9. Bibliography

General:

Andrei G. Ter-Gazarian. Energy Storage for Power Systems. (2011);

Robert Huggins. Energy Storage. (2016);

Frank S. Barnes , Large Scale Energy Storage Systems Handbook (2011);

Batteries:

Linden , Handbook Of Batteries (3rd Ed.), (2002);

Jung , Lead-Acid Battery Technologies: Fundamentals, Materials, and Applications, (2016);

Jiang , Fundamentals and Application of Lithium-ion Batteries in Electric Drive Vehicles, (2015);

Super caps:

Petar Grbović. Ultra-Capacitors in Power Conversion Systems. (2014)

John M. Miller. Ultracapacitor Applications. (2011).

Thermal:

İbrahim Dinçer, Marc A. Rosen. Thermal Energy Storage. (2011)

Kun Sang Lee. Underground Thermal Energy Storage. (2013).

Case studies:

Mohd Ali. Wind Energy Systems. (2012)

Shin’ya Obara. Optimum Design of Renewable Energy Systems. (2014)

Junji Tamura S.M. Muyeen. Stability Augmentation of a Grid-connected Wind Farm. (2009)

N. Lymberopoulos, Emmanuel I. Zoulias. Hydrogen-based Autonomous Power Systems. (2008)

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Said Al-Hallaj, Kristofer Kiszynski. Hybrid Hydrogen Systems: Stationary and Transportation Applications. (2011).