



## Course guide

### 820740 - ESF - Solar Photovoltaics

Last modified: 16/04/2024

**Unit in charge:** Barcelona School of Industrial Engineering  
**Teaching unit:** 710 - EEL - Department of Electronic Engineering.

**Degree:** ERASMUS MUNDUS MASTER'S DEGREE IN ENVIRONMENTAL PATHWAYS FOR SUSTAINABLE ENERGY SYSTEMS (Syllabus 2012). (Optional subject).  
MASTER'S DEGREE IN ENERGY ENGINEERING (Syllabus 2013). (Optional subject).  
MASTER'S DEGREE IN INDUSTRIAL ENGINEERING (Syllabus 2014). (Optional subject).  
MASTER'S DEGREE IN ENERGY ENGINEERING (Syllabus 2022). (Optional subject).

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

#### LECTURER

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**Coordinating lecturer:** Silvestre Berges, Santiago

**Others:** Santiago Silvestre Berges  
Guinjoan Gispert, Francisco Juan  
Moradi, Bahareh

#### PRIOR SKILLS

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- Fundamentals of electrical engineering

#### REQUIREMENTS

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- No specific requirements.

#### DEGREE COMPETENCES TO WHICH THE SUBJECT CONTRIBUTES

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**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-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-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.

## TEACHING METHODOLOGY

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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

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### Objectives

The course focuses on technologies using the sun as energy resource. In this case, the technology uses the photovoltaic effect to transform the energy arriving from the sun into electricity.

In this area it is intended that students acquire the knowledge and skills necessary for describing and selecting equipment, as well as for calculating the performance of the different components of the system and aspects of analysis and design at a basic level.

It is intended to provide an overview of the technologies and methods that will enable the student to make judgments, and studies of alternatives in the context of engineering projects.

### Learning Outcomes

At the end of the course, the student is able:

- to understand the role of solar energy in the context of regional and global energy system, its economic, social and environmental connotations, and the impact of technology on a local and global context.
- to understand the physical principles of the photovoltaic (PV) solar cell and what are its sources of losses.
- to understand and apply the basic concepts of solar radiation necessary for dimensioning (sizing) PV systems installations.
- to know the electrical (current-voltage and power-voltage) characteristics of solar cell, panel or generator and how the environment parameters influence it
- to know the most important characteristics of the elements within a PV system and how they work: battery and charge controller, DC/DC converter, DC/AC converter (inverter) and loads.
- to present a software tools for PV system engineering.
- to list the relevant organizations, major projects at the international level, the main sources of information and regulations related to solar photovoltaic technology.
- to know some practical applications that use solar photovoltaic systems and be able to do specify, analyze and design (sizing) of an autonomous photovoltaic system and energy produced by photovoltaic greeed connected systems.
- to know and be able to analyze the behavior of a self-consumtion demand and the measurement of network management.
- to carry out a basic engineering project related to energy supply using solar photovoltaic technology.
- to know the main lines of research in the field of photovoltaic technology and solar energy.
- to bring innovative ideas in the field of solar photovoltaic energy.

## STUDY LOAD

Type	Hours	Percentage
Hours large group	27,0	22.41
Self study	80,0	66.39
Hours small group	13,5	11.20

**Total learning time:** 120.5 h

## CONTENTS

### 1. Introduction to Solar Photovoltaics

**Description:**

The module provides an introduction to Photovoltaic Solar Energy (PVSE) which discusses its importance, advantages, disadvantages, the components of a PV system and typical applications.

**Specific objectives:**

In this module the student will understand the possibilities and applications of PV solar systems

**Related activities:**

any activity related

**Related competencies :**

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.

**Full-or-part-time:** 4h

Theory classes: 2h

Self study : 2h

### 2. Solar Radiation

**Description:**

The module provides an introduction to solar radiation and some important related concepts like blackbody, solar spectrum, irradiance, irradiation, air mass and peak sun hour. Also the student will also use PVGIS (Photovoltaic Geographical Information System), which is a tool that provides monthly and yearly averages of global irradiation at horizontal and inclined surfaces, as well as other climatic and PV-related data. The module provides an introduction to solar radiation and some important related concepts like blackbody, solar spectrum, irradiance, irradiation, air mass and peak sun hour. Also the student will also use PVGIS (Photovoltaic Geographical Information System), which is a tool that provides monthly and yearly averages of global irradiation at horizontal and inclined surfaces, as well as other climatic and PV-related data.

**Specific objectives:**

The student will acquire the knowledge of the most important concepts of solar radiation used in photovoltaic systems and learn to use the PVGIS tool.

**Related activities:**

Any related activities

**Related competencies :**

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.

**Full-or-part-time:** 4h

Theory classes: 2h

Self study : 2h

### 3. Photovoltaic systems

#### Description:

The first part of this module introduces the electrical behavior of a PV solar cell:

- Fundamentals of the physical principle of a PV cell: the photovoltaic effect and how a photovoltaic cell works.
- The electrical behavior of a diode and its curve.
- The Illuminated solar cell with its symbol, equivalent circuit, equations and I-V curve.
- Important parameters like short circuit current ( $I_{sc}$ ), open circuit voltage ( $V_{oc}$ ), voltage and current at the maximum operating power point, efficiency (?) and fill factor (FF).
- The P-V curve and the main factors affecting the performance of the solar cell.
- The effect of atmospheric factors and shadows on an array of PV modules and its effect on the I-V curve.

On the second part of this module we will see the Balance Of System (BOS) and the types of PV systems:

- Batteries.
- Regulators.
- DC/DC converters.
- Inverters (DC/AC converters).
- DC/DC converter as a Maximum Power Point Tracking (MPPT).
- Different configurations of stand-alone and grid-connected PV systems.

#### Specific objectives:

The Students will acquire the knowledge and skills necessary for the description, selection, analysis and sizing the different components within a PV system and their different configurations.

#### Related activities:

1. Photovoltaic system exercises.

#### Related competencies :

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-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-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.

**Full-or-part-time:** 44h 20m

Theory classes: 8h

Laboratory classes: 4h

Guided activities: 5h

Self study : 27h 20m



#### 4. Analysis, sizing and maintenance of plant using photovoltaic systems.

##### Description:

- Sizing a PV stand-alone system
- o Examples of design and calculation of PV systems for different types of applications (residential, water pumping systems, etc).
- Design and obtaining the energy produced from a Grid-Connected PV Systems (GCPVS).
- Simulation of stand-alone and grid-connected photovoltaic systems using the PVSOL software.
- Video-presentation of PV plants.

##### Specific objectives:

Students acquire the knowledge and skills necessary for a project of stand-alone and grid-connected systems, as well as knowing some different types of PV electrical installations with its protections.

##### Related activities:

2. Project of stand-alone/grid-connected PV systems.

##### Related competencies :

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-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-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-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.

**Full-or-part-time:** 72h 40m

Theory classes: 10h 20m

Laboratory classes: 6h 20m

Guided activities: 7h

Self study : 49h

## ACTIVITIES

### 1. Photovoltaic systems exercises

**Description:**

Resolution of exercises in class individually or in small groups with the advice of the lecturer and proposed exercises to resolve at home individually.

**Specific objectives:**

Deepen the theoretical knowledge and its application to solving problems related to PV systems.

**Material:**

- Examples of solved problems.
- Statements of problems with answers (self-learning).
- Statement of solving problems (continuous assessment).

**Delivery:**

The resolution of proposed exercises to resolve at home individually or in small groups.

**Related competencies :**

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.

**Full-or-part-time:** 34h

Laboratory classes: 6h

Guided activities: 6h

Self study: 22h

### 2. Project of stand-alone and grid-connected PV systems

**Description:**

Learning based on the design and planning a project, working in groups to apply and extended knowledge and writing a report, which describes the approach, results and conclusions. The students have to design and sizing a stand-alone or grid connected PV system.

**Specific objectives:**

The student will acquire skills for selecting and sizing the components and equipment most suitable for a solar photovoltaic project, as well as the steps required to carry it out.

**Material:**

- Examples of stand-alone and grid-connected PV projects.
- PVSOL software.
- Video presentation showing some PV installations.

**Delivery:**

A project report will be submitted.

**Related competencies :**

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.

**Full-or-part-time:** 55h

Laboratory classes: 8h

Guided activities: 10h

Self study: 37h



## GRADING SYSTEM

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Exam (PE): 60 %

Homework (TR): 40 %

The qualification of the final exam (PE) must replace, provided that it is higher and that the aspects evaluated coincide, the results obtained in the evaluation acts that have been carried out throughout the course.

## EXAMINATION RULES.

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For the exam, the student may have only one sheet of paper with formulas and a programmable calculator.

The specific rules of individual and group work will be published in the teaching intranet

## BIBLIOGRAPHY

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### Complementary:

- Luque, A.; Hegedus, S. Handbook of photovoltaic science and engineering [on line]. 2nd ed. Chichester, West Sussex, U.K: Wiley, 2011 [Consultation: 20/09/2022]. Available on: <https://onlinelibrary-wiley-com.recursos.biblioteca.upc.edu/doi/book/10.1002/9780470974704>. ISBN 9780470974704.
- Deutsche Gesellschaft für Sonnenenergie. Planning and installing photovoltaic systems : a guide for installers, architects and engineers DGS - Deutsche Gesellschaft für Sonnenenergie [on line]. 3rd ed. London: Earthscan, 2013 [Consultation: 24/03/2023]. Available on: <https://ebookcentral-proquest-com.recursos.biblioteca.upc.edu/lib/upcatalunya-ebooks/detail.action?pg-origsite=primo&docID=1323379>. ISBN 9781849713436.
- Castañer Muñoz, Luis ; Silvestre Berges, Santiago. Modelling photovoltaic systems : using PSpice. Chichester: John Wiley & Sons, 2002. ISBN 9780470845271.
- Alonso Abella, Miguel. Sistemas fotovoltaicos : introducción al diseño y dimensionado de instalaciones de energía solar fotovoltaicas. 2a ed. Madrid: Publicaciones Técnicas, 2005. ISBN 8486913128.
- Alcor Cabrerizo, Enrique. Instalaciones solares fotovoltaicas. 4a ed. Sevilla: PROGENSA, 2008. ISBN 9788495693457.
- Universität Kassel. Photovoltaic Systems Technology [on line]. SS 2003. Kassel: Universität Kassel, 2003 [Consultation: 27/05/2019]. Available on: <https://es.scribd.com/document/26768123/Photovoltaic-Systems-Technology-SS-2003>.