Course guide
295111 - 295II131 - Electrical Energy Processing

Last modified: 04/06/2026

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

Degree: MASTER'S DEGREE IN INTERDISCIPLINARY AND INNOVATIVE ENGINEERING (Syllabus 2019). (Optional subject).

Academic year: 2026 **ECTS Credits:** 6.0 **Languages:** Spanish, English

LECTURER

Coordinating lecturer: HERMINIO MARTINEZ GARCIA

Others:

PRIOR SKILLS

A course on basic electronics or fundamental of electronics such as "Electronics Systems" (STI – 820017), taught at the EEBE.

REQUIREMENTS

A course on basic electronics or fundamental of electronics such as "Electronics Systems" (STI – 820017), taught at the EEBE.

DEGREE COMPETENCES TO WHICH THE SUBJECT CONTRIBUTES

Specific:
CEMUEII-11. Design and manage processing and management systems for the production, storage, conversion and distribution of electrical energy using different technologies. (Specific competence of the Efficient Systems specialty)

Generical:
CGMUEII-01. Participate in technological innovation projects in multidisciplinary problems, applying mathematical, analytical, scientific, instrumental, technological and management knowledge.
CGMUEII-05. To communicate hypotheses, procedures and results to specialized and non-specialized audiences in a clear and unambiguous way, both orally and through reports and diagrams, in the context of the development of technical solutions for problems of an interdisciplinary nature.

Transversal:
05 TEQ. TEAMWORK. Being able to work as a team player, either as a member or as a leader. Contributing to projects pragmatically and responsibly, by reaching commitments in accordance to the resources that are available.
06 URI. EFFECTIVE USE OF INFORMATION RESOURCES. Managing the acquisition, structure, analysis and display of information from the own field of specialization. Taking a critical stance with regard to the results obtained.
03 TLG. THIRD LANGUAGE. Learning a third language, preferably English, to a degree of oral and written fluency that fits in with the future needs of the graduates of each course.

TEACHING METHODOLOGY

- Master classes: 60%.
- Lab sessions: 30%.
- Conferences and workshops: 10%.

LEARNING OBJECTIVES OF THE SUBJECT

Following successful completion of the course, students should be able to:

1. Develop techniques for the design, analysis and evaluation of energy processing and management systems in applications such as automation, aerospace, energy distribution and generation, consumer electronics, biomedicine, etc.
2. Analyze, design and evaluate electronic systems for power control and energy conversion.
3. Understand and apply energy processing and management architectures for distributed and integrated applications.
4. Understand and apply energy processing and management subsystems, particularly in an IC context.
5. Understand and apply modulations, control and energy management policies.
6. Design energy processing and management architectures, particularly in an IC context.
7. Analyze, design, simulate and implement energy processing and management subsystems, including circuit and model aspects.
8. Describe the suitable tools leading to the dynamical models of the power processors involved in the photovoltaic and wind energy conversions to electrical power.
9. Analyze the control problems related with photovoltaic and wind energy conversions in different power processing scenarios (stand-alone systems, grid connected systems, etc.).
10. Apply several nonlinear control techniques (nonlinear feedback for global linearization, energy balance techniques -passivity-, variable-structure systems based techniques -sliding mode control-, and fuzzy control) to solve the control problems involved in the photovoltaic and wind energy conversion systems.
11. Compare the features of the advanced controllers with those resulting from classical ones. This comparison will lead to establish several criteria to the selection of the most suitable controllers.

The course consists of a set of lectures to introduce topics on electrical energy conversion devoted to different applications, especially in the framework of renewable energy systems, and then, some lab sessions and personal work supervised by faculty to develop a project. In particular, the course will be PBL oriented in order to design, simulate and implement a battery charger from a PV panel set (or similar), including both the energy processing and management sub-blocks.

STUDY LOAD

Type	Hours	Percentage
Hours small group	21,0	14.00
Hours large group	21,0	14.00
Self study	108,0	72.00

Total learning time: 150 h

CONTENTS

Introduction to Power Electronics within the Context of Renewable Energies.

Description:
• Introduction to the electrical processing and management.
• Signal processing and energy processing: Differences.
• Introduction to power electronics.
• Energy static conversion topologies.
• The one-phase rectifier as a basic AC/DC converter.
• Applications of energy static converters.
- Renewable energy system.
- Power supply systems.
- Electric drive: trains and electric vehicles.
- Lighting.
- Other applications (aerospace applications, communications, etc.).
• Sub-block in energy static conversion systems.
• On passive components in energy static conversion systems: Capacitors, inductors and transformers.
• On switching components in energy static conversion systems: Diodes, transistors, thyristors, triacs, and other switching devices (GTO, IGBT, etc.).
• Simulation software for energy static conversion systems: OrCAD-PSpice® i PSIM®.

Specific objectives:
- To know the context of static conversion subsystems in renewable energy systems.

Related activities:
• Lectures on introduction to energy processing and management.

Full-or-part-time: 11h
Theory classes: 1h
Self study : 10h

AC/DC Conversion within the Context of Renewable Energies.

Description:
• AC/DC switching converters: Classification.
• Example of a basic AC/DC converter: The diode as a grid-frequency uncontrolled rectifier with pure resistive load.
- Analysis of the one-phase single phase voltage rectifier as a basic AC/DC converter.
- Simulation of rectifying circuits with pure resistive load.
• Uncontrolled half-wave rectifiers switched to grid frequency with inductive load.
- Analysis and simulation with RL load. Differences with pure resistive load.
- Operation in discontinuous (DCM) and continuous (CCM) conduction modes.
- Analysis and simulation with generator load (RLE).
- Differences with and without freewheeling diode (FWD).
• Controlled half-wave rectifier switched to grid frequency with pure resistive and inductive loads.
- Analysis and simulation with R and RL loads.
- Differences with the uncontrolled half-wave rectifier.
- Operation in discontinuous (DCM) and continuous (CCM) conduction modes.
- Analysis and simulation with generator load (RLE).
- Use of Puschlowski's abacus.
- Differences with and without freewheeling diode (FWD).
• Uncontrolled full-wave rectifier switched to grid frequency with pure resistive and inductive loads.
- Graetz-bridge one-phase rectifiers.
- Single phase rectifiers with intermediate-connection transformer.
- Analysis and simulation with R and RL loads.
- Analysis and simulation with generator load (RLE).
• Controlled full-wave rectifier switched to grid frequency with pure resistive and inductive loads.
- Graetz-bridge one-phase rectifiers. Differences with the uncontrolled rectifier.
- Single phase rectifiers with intermediate-connection transformer. Differences with the uncontrolled rectifier.

- Analysis and simulation with R and RL loads.
- Operation in discontinuous (DCM) and continuous (CCM) conduction modes.
- Analysis and simulation with generator load (RLE).
• Controlled full-wave rectifier switched to grid frequency working as an inverter.
• Semi-controlled full-wave rectifier switched to grid frequency with pure resistive and inductive loads.
- Graetz-bridge one-phase rectifiers. Differences with the fully-controlled rectifier.
- Analysis and simulation with R and RL loads.
- Operation in discontinuous (DCM) and continuous (CCM) conduction modes.
- Analysis and simulation with generator load (RLE).
- Differences with fully-controlled rectifiers: Comparative and simulation.
• Uncontrolled and controlled three-phase rectifiers.
- Half-wave rectifiers with pure resistive (R), inductive (RL) and generating (RLE) loads.
- Full-wave rectifiers with pure resistive (R), inductive (RL) and generating (RLE) loads.
- Use of the Puschlowski abacus in three-phase rectifier.
• Three-phase rectifiers working as inverters.
• Rectifiers of more than three phases.
- Six-phase rectifiers.
- Twelve-phase rectifiers.
- Use of the Puschlowski abacus in rectifier for more than three phases.
• Control of rectifying systems.
• Powers in a rectifier. Improvement of the power factor.
• Serial and parallel connections of rectifying circuits.
• High-Voltage DC (HVDC) transmission.
- Advantages of the HVDC transmission.
• Block diagram of a linear power supply.
• Obtaining a DC voltage from the electrical grid.
- Elimination of output-voltage ripples: Filtering of output voltage.
- Capacitor-based output filtering.
- Inductance- and capacitors-based output filtering (filters in 'L' and in 'π').
- Operation in discontinuous (DCM) and continuous (CCM)conduction modes.
• Voltage doublers and multipliers.
• Analysis and design of rectifying circuits and linear power sources. Application examples.
• Simulation of rectifying circuits and linear power sources.

Specific objectives:
- To know the context of AC/DC static conversion subsystems in renewable energy systems.

Related activities:
• Lectures on AC/DC conversion within the context of renewable energies.
• Laboratory sessions (Activity 1): Simulation of AC/DC conversion circuits.

Full-or-part-time: 14h
Theory classes: 2h
Laboratory classes: 2h
Self study : 10h

DC/DC Conversion within the Context of Renewable Energies.

Description:
• DC/DC switching converters without galvanic isolation: Topologies, analysis and design.
- Buck (step-down) converter.
- Boost converter (step-up).
- Buck-boost converter.
- Ćuk converter.
- Other switched converters of electrical energy without galvanic isolation: Single-ended primary inductance converter (SEPIC), etc.
- Converter operations in continuous mode (MCC) and discontinuous (MCD) mode.
• DC/DC switching converters wit galvanic isolation: Topologies, analysis and design.
- Flyback converter.
- Forward converter.
- Push-pull converter.
- Converter in full bridge and in semi-bridge.
- Other switched converters of electrical energy with galvanic isolation.
• Analysis and design of chopper circuits. Application examples.
• Simulation of chopper circuits.

Specific objectives:
- To know the context of DC/DC static conversion subsystems in renewable energy systems.

Related activities:
• Lectures on DC/DC conversion within the context of renewable energies.
• Laboratory sessions (Activity 2): Implementation of a DC/DC conversion circuit.

Full-or-part-time: 14h
Theory classes: 2h
Laboratory classes: 2h
Self study : 10h

DC/AC Conversion within the Context of Renewable Energies.

Description:
• Introduction.
• Topologies of single-phase and square-wave wave monophasic waveforms.
• Analysis using Fourier series.
• Quality measurement of the generated waveforms.
- Total harmonic distortion (THD) of the generated waveforms.
- Distortion factor and other parameters of distortion measurement.
• Topologies of one-phase sinusoidal-waveform inverters.
• Control of inverters: PWM (pulse-width modulation) control for elimination of harmonics.
- Definition of amplitude-modulation and frequency-modulation indexes.
- Importance of the frequency modulation ratio.
- Bipolar switching.
- Unipolar switching.
- Study of Harmonics in PWM modulation.
• Amplitude control of the waveform generated in inverter systems.
- Importance of the amplitude-modulation ratio.
- Structure of the control loop.
- Proportional control (P). Effect of the gain proportional to the control loop.
- Improvement of control with PID regulators.
• Effects of over-modulation in sinusoidal inverters.
• Grid-connected inverters.
- Importance of the control in grid-connected inverters.
• Three-phase vacuums.
- Six-steps inverters.
- Three-phase inverters PWM.
• Speed control of induction motors.
• Analysis and design of circuit inverters. Application examples.
• Simulation software for circuit inverters.

Specific objectives:
- To know the context of DC/AC static conversion subsystems in renewable energy systems.

Related activities:
• Lectures on DC/AC conversion within the context of renewable energies.
• Laboratory sessions (Activity 3): Simulation of AC/DC conversion circuits.

Full-or-part-time: 14h
Theory classes: 2h
Laboratory classes: 2h
Self study : 10h

Switched-Mode Power Supply Systems.

Description:
• Introduction to linear and switched power sources.
• Block diagram of a switched power supply.
• Obtaining a DC voltage from the electrical grid.
• Regulation of the output voltage.
• Examples of analysis and design of switched sources.
• Analysis and design of switching power supplies. Application examples.
• Simulation of switching power supplies.
• Power factor correction (PFC) in sources and power systems.
- Types of loads: Linear and nonlinear, resistive and reactive.
- Need for the correction of the PF in lines with linear and nonlinear loads.
- Classification of circuits for PFC: Passives (line-commutated rectifiers) and actives (pulse-width modulated rectifiers).
- Principle of operation of passive circuits for PFC in single phase lines.
- Active circuits for PFC in single phase lines.
- Control of circuits for single-phase PFCs.
- Commercial examples of single-phase PFC circuits.
• EMI filters in input lines.
- Need of the EMI filters at the line input.
- Internal structure and operation.
- Ferrite cores in power cables: Internal structure and operation.

Specific objectives:
- To know the context of switched-mode power supply systems.

Related activities:
• Lectures on switched-mode power supply systems.
• Laboratory sessions (Activity 4): Simulation of a switched-mode power supply system.

Full-or-part-time: 15h
Theory classes: 3h
Laboratory classes: 2h
Self study : 10h

Control of DC/DC Converters and Switched-Mode Power Supply Systems.

Description:
• Introduction. Differences between switched-mode converter and switched-mode regulator.
• Control of DC/DC switching converters: PWM (pulse-width modulation) control and others.
• Review of linear control theory.
- Stability of the control loop.
• Small signal and steady state.
• Analysis in small signal.
- Transfer function of switching devices.
- Transfer function of the filter.
- Transfer function of the PWM modulating circuit.
- Error amplifier with compensation.
• State equations of a converter.
• Transfer functions of interest in power converters in MCC and in MCD.
• Design of the compensated error amplifier (controller) for the control in voltage mode.
• Design of the compensated error amplifier (controller) for the control in current mode.
• Integrated circuits to implement PWM controls.
• Analysis and design of drivers for DC/DC converters and switched power supplies. Application examples.
• Simulation of the feedback control system.

Specific objectives:
- To know the context of control subsystems of DC/DC converters and switched-mode power supply systems.

Related activities:
• Lectures on control of DC/DC converters and switched-mode power supply systems.
• Laboratory sessions (Activity 5): Simulation of control circuits for a switched-mode power supply system.

Full-or-part-time: 21h
Theory classes: 3h
Laboratory classes: 2h
Guided activities: 4h
Self study : 12h

Voltage Linear Regulators.

Description:
• Study of closed-feedback linear regulators with feedback.
• Series linear regulators commercialized in the form of monolithic ICs.
- Voltage linear regulators' standard series.
- LDO regulators (low-dropout regulators).
• Parallel linear regulators.
• Limitation of the maximum load current.
• Protections against short circuits.
• DC-DC converters and switched-mode voltage regulators.
- Switched-mode voltage regulators marketed in the form of monolithic ICs.
• Circuits of supervision of the feeding.
- The MC3425 integrated circuit of Motorola as an example.
• Monolithic voltage sources.
• Switched-capacitor voltage inverters ("charge pumps" circuits).
- SI7660, SI7661 and MAX660 integrated circuits as examples.
• Current sources.
• Examples of analysis and design of linear voltage regulators.
• Simulation of linear voltage regulators.

Specific objectives:
- To know the context of voltage linear regulators.

Related activities:
• Lectures on voltage linear regulators.
• Laboratory sessions (Activity 7): Implementation of voltage linear-regulators.

Full-or-part-time: 13h
Theory classes: 1h
Laboratory classes: 2h
Self study : 10h

Integration of Electrical Energy Conversion Subsystems into Renewable Energy Systems and New Trends in Electrical Energy Processing.

Description:
• Implementation of static structures for the conversion and processing of electrical energy in renewable energy systems.
- Power electronic sub-block used.
• Battery chargers and charge regulators.
- Electrical energy Storage systems.
- Principle of operation of the battery chargers. Constant and constant voltage charging.
- Battery charging process.
- Commercial examples of battery chargers.
• Static converters with maximum power point tracking (MPPT).
- Need for circuits with MPPT in renewable energy systems.
- Algorithms to achieve the maximum power point of a solar photovoltaic system.
- Structure of a renewable energy generation system with MPPT.
- Commercial examples of static converters with MPPT.
• Photovoltaic inverters.
- One-phase and three-phase inverters for isolated facilities.
- One-phase and three-phase inverters for grid connection.
- Inverters with MPPT.
- Commercial examples of inverters.
• Converters in wind-energy applications.
• Circuits for drivers in lighting systems based on LEDs.
- Principle of operation of drivers for LEDs. Power supply in voltage or current.
- Control of drivers for LEDs.
- Lightning control.
- Commercial examples of drivers for LEDs.
• Energy-harvesting systems.
- Principle of operation.
- Classification.
- Examples of application.
- Study of practical cases.
• Electrical microgrids.
- Principle of operation of electrical microgrids.
- Elements of a microgrid: Renewable generation, loads and consumers, and prosumers.
- Modeling of microgrids.
- Energy processing and management of microgrid.
- Control of electrical microgrids.
- Simulation of electrical microgrids.
- Cooperative and peer-to-peer energy sharing microgrids.
- Energy processing and management of peer-to-peer energy sharing microgrids.

Specific objectives:
- To examine in depth some important real applications of static conversion subsystems in renewable energy systems.

Related activities:
• Lectures on integration of electrical energy conversion subsystems into renewable energy systems and new trends in electrical energy processing.
• Laboratory sessions (Activity 8): Simulation of a battery charger system.
• Laboratory sessions (Activity 9): Implementation of a driver for a lighting system based on LEDs.
• Laboratory sessions (Activity 10): Simulation of a microgrid environment.

Full-or-part-time: 21h
Theory classes: 5h
Laboratory classes: 6h
Self study : 10h

AC/AC Conversion within the Context of Renewable Energies.

Description:
• Single phase AC drives or AC regulators.
- Error amplifier with compensation.
- Operation with pure resistive load.
- Operation with inductive charge.
• Three-phase AC drives or AC regulators.
- Resistive loads connected in star and in triangle.
- Inductive loads connected in star and in triangle.
• Cycloconverters.
- Single phase and three-phase circuits.
• Matrix converters.
• Control of AC/AC switched converters.
• Speed control of induction motors.
• Static VAR control (reactive static compensator).
• Analysis and design of AC/AC conversion circuits. Application examples.
• Simulation of AC/AC conversion circuits.

Specific objectives:
- To know the context of AC/AC static conversion subsystems in renewable energy systems.

Related activities:
• Lectures on AC-AC conversion within the context of renewable energies.
• Laboratory sessions (Activity 6): Simulation of AC/AC conversion circuits.

Full-or-part-time: 13h
Theory classes: 1h
Laboratory classes: 2h
Self study : 10h

Resonant Converters.

Description:
• Need for resonant converters.
• Resonant converter with zero-current switch and zero-voltage switch.
• The series resonant inverter.
- Switching losses.
- Amplitude control.
• DC/DC series resonant converter.
• DC/DC parallel resonant converter.
• DC-DC series-parallel converter.
• Comparison of resonant converters.
• The resonant converter with DC intermediate step.
• Analysis and design of resonant converters. Application examples.
• Simulation of resonant converters circuits.

Specific objectives:
- To know the operation and use of resonant converters.

Related activities:
• Lectures on resonant converters.
• Laboratory sessions (Activity 11): Simulation of a resonant converter.

Full-or-part-time: 14h
Theory classes: 2h
Laboratory classes: 2h
Self study : 10h

GRADING SYSTEM

Any academic fraud, plagiarism or use or possession of unauthorised means in an assessment activity leads to a mark of zero (0) for the affected test or assignment. Furthermore, in accordance with the University's regulations, if disciplinary proceedings are initiated the subject is recorded as "Pending Assessment" until a decision is reached. These incidents are managed in accordance with the **Action Framework for Academic Integrity in Assessment at the UPC**.

- Midterm exam: 30%
- Final exam: 30%
- Lab sessions and activities: 20%.
- Guided activities: 20%.

Since it is a course with continuous (ongoing) assessment, there is not final re-assessment test.

EXAMINATION RULES.

It will be published during the first week of the course.

BIBLIOGRAPHY

Basic:
- Hart, Daniel W.. Power electronics. New York: McGraw-Hill, 2011. ISBN 9780071289306.
- Erickson, Robert W.; Maksimovic, Dragan. Fundamentals of power electronics [on line]. 2nd ed. Dordrecht: Kluwer Academic Publishers, 2001 [Consultation: 20/04/2020]. Available on: https://link.springer.com/book/10.1007/b100747. ISBN 0792372700.
- Mohan, Ned. Power electronics : a first course. Hoboken, N.J.: John Wiley & Sons, cop. 2012. ISBN 9781118074800.

Complementary:
- Kassakian, John G.; Schlecht, Martin F.; Verghese, George C. Principles of power electronics. Reading: Addison–Wesley, cop. 1991. ISBN 0201096897.
- Mohan, Ned; Undeland, Tore M.; Robbins, William P. Power electronics : converters, applications, and design. 3rd ed. Hoboken, N. J.: John Wiley & Sons, 2003. ISBN 0471226939.
- Rashid, Muhammad H [ed.]. Power electronics handbook : devices, circuits, and applications [on line]. 3th ed. Burlington [etc.]: Elsevier Butterworth-Heinemann, 2011 [Consultation: 20/04/2020]. Available on: https://www.sciencedirect.com/science/book/9780123820365. ISBN 9780123820365.
- Rashid, Muhammad H. [ed.]. Power electronics handbook. 2a ed. San Diego [etc.]: Academic Press, 2007. ISBN 9780120884797.