Course guide
230927 - PEE - Electric Power Processing

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

Degree: BACHELOR'S DEGREE IN ELECTRONIC ENGINEERING AND TELECOMMUNICATION (Syllabus 2018). (Compulsory subject).

Academic year: 2024 **ECTS Credits:** 6.0 **Languages:** Catalan, Spanish, English

LECTURER

Coordinating lecturer: FRANCISCO JUAN GUINJOAN GISPERT

Others: Segon quadrimestre:
EDUARDO JOSE ALARCON COT - 13
MARCO AURELIO AZPÚRUA AUYANET - 11, 12
OLIVER MILLÁN BLASCO - 11, 12, 13
SANTIAGO SILVESTRE BERGES - 11, 12, 13

PRIOR SKILLS

Circuit theory, signal processing, control theory, electronic components and electromagnetism

DEGREE COMPETENCES TO WHICH THE SUBJECT CONTRIBUTES

Specific:
CE16. (ENG) GREELEC: Capacitat d'utilitzar distintes fonts d'energia i en especial la solar fotovoltaica i tèrmica, així com els fonaments de l'electrotècnia i de l'electrònica de potència. (Mòdul comú a la branca de telecomunicació).

Generical:
CG6. (ENG) GREELEC: Facilitat per al maneig d'especificacions, reglaments i normes d'obligat cumpliment.

Transversal:
CT2. (ENG) GREELEC: Sostenibilitat i compromís social. Conèixer i compendre la complexitat dels fenòmens econòmics i social típics de la socitetat del benestar; tenir caapcitat per relacionar el benestar amb la globalització i la sostenibilitat; aconseguir habilitats per a utilitzar de forma equilibrada i compatible la tècnica, la tecnologia, l'economia i la sostenibilitat.

TEACHING METHODOLOGY

Master class. Laboratory practice. Cooperative training. Autonomous work. Problem-based / project-based learning

LEARNING OBJECTIVES OF THE SUBJECT

Establishment of the specifications of a power system for different energy scenarios.
Design, sizing, control and verification of the proper operation of a power system.

STUDY LOAD

Type	Hours	Percentage
Hours small group	13,0	8.67
Self study	85,0	56.67
Hours large group	52,0	34.67

Total learning time: 150 h

CONTENTS

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Description:
Generation, transport and distribution of electrical energy. Need for power electronics. Application examples. The energy conversion chain. Need and control objectives of power processors. Examples.

Specific objectives:
Present the academic characteristics of the course.
ï± Introduce the concepts of generation, transmission and distribution in the electrical network.
ï± Introduce the fundamentals of three-phase systems.
ï± Present the need of power electronics through application examples.
ï± Define the energy conversion chain and the objectives of a power converter
ï± Define the circuit elements of a converter and its main characteristics.
ï± Present basic AC-DC, DC-AC and DC-DC conversion topologies.
ï± Define the control objectives of a power converter depending on the application.

Full-or-part-time: 9h
Theory classes: 9h

Synthesis of switching DC-DC converters

Description:
Components modelling for synthesis purposes. Connection rules. Switch implementation by means of semiconductor devices.

Specific objectives:
ï± Presentation of a synthesis methodology for switching converters.
ï± Obtaining DC-DC elemental conversion topologies.

Full-or-part-time: 3h
Theory classes: 3h

Steady-state analysis of switching DC-DC converters

Description:
Introduction. General analysis procedure. Steady state analysis of the boost converter in continuous and discontinuous conduction modes. . Bidirectional converters. Inclusion of losses in the steady-state analysis

Specific objectives:
Presentation of the classical/geometric analysis procedure of the steady-state behavior of switching converters.
ï□± Electrical variables waveforms of the converters operation in continuous conduction mode.
ï□± Deduction of the analytical relationships between the electrical variables of interest and the design specifications.
ï□± The discontinuous conduction mode: waveforms, input to output relationships and critical condition.
ï□± Application of the previous study to the design of converters in steady state.
ï□± Presentation of bidirectional converters.
ï□± Delimitation of the usefulness of classical analysis techniques when converter losses are considered.

Full-or-part-time: 6h
Theory classes: 6h

Converter dynamics and regulator design

Description:
Introduction. State space averaging method. Design of the feedback loop. Single loop DC-DC switching regulator. Comparison with linear regulators.

Specific objectives:
Recognize the nonlinear and discrete-time behavior of switching converters.
ï□± Show the usefulness of continuous averaged models for this type of systems.
ï□± Present the state space averaging method.
ï□± Deduce the transfer functions of the small signal dynamic behavior of the converters.
ï□± Apply linear dynamic models to the design of the feedback loop of a switching regulator.

Full-or-part-time: 9h
Theory classes: 9h

Magnetics

Description:
Basic theory. Characteristics of ferromagnetic materials. Modeling of magnetic components. Inductor design. transformer design

Specific objectives:
Introduce the design fundamentals of inductors and transformers for switching DC-DC converters.
ï□± Review the properties of the materials used as magnetic cores and the inclusion of air gaps.
ï□± Provide an equivalent circuit model of the magnetic components.
ï□± Present various design procedures for inductors and transformers.

Full-or-part-time: 6h
Theory classes: 6h

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Transformer based switching converters

Description:
Features and drawbacks of transformer based converters. Including the transformer in switching converters. Basic topologies

Specific objectives:
Present the features and drawbacks of transformer-based converters.
ï□± Introduce the main conversion topologies that include galvanic isolation. Flyback, forward, push pull.
ï□± Analyze the influence of the transformer conversion ratio on the sizing of the converter components.
ï□± Evaluate the effects of transformer non-idealities on converter behavior.

Full-or-part-time: 3h
Theory classes: 3h

Introduction to AC power

Description:
Power of periodic signals. Average power, rms value, harmonic content, harmonic distortion, power factor, active, reactive and apparent powers.

Specific objectives:
Present the concept of instantaneous and average power in the presence of periodic signals.
Define the concepts of rms value, harmonic distortion, power factor and active, reactive and apparent powers.
Apply the above concepts to linear and nonlinear circuits in AC and the passive correction of the power factor for linear circuits.

Related activities:
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Full-or-part-time: 3h
Theory classes: 3h

Applications to photovoltaic solar energy and UPS

Description:
Modeling of the electrical characteristics of a photovoltaic (PV) solar panel. Basic battery parameters. Solar battery charger. Introduction to Uninterruptible Power Supplies (UPS).

Specific objectives:
Present the characteristics and main parameters of photovoltaic generators and batteries.
ï□± Analyze the design problems of a solar battery charger.
ï□± Introduce the basic architectures and modes of operation of Uninterruptible Power Supplies (UPS) and their main characteristics.

Full-or-part-time: 5h
Theory classes: 5h

Mid-term and Final exams

Description:
Mid-term written exam (2h). Final written exam (3h)

Specific objectives:
Course assesment

Full-or-part-time: 5h
Theory classes: 5h

Power MOSFET and auxiliary circuits.

Description:
Static characteristics of the MOSFET. Dynamic features. Gate excitation circuits: drivers. Protection networks and switching improvement. Snubbers.

Specific objectives:
ï± Circuits simulations for obtaining static and dynamic characteristics of power MOSFET.
ï± Present the auxiliary switching aid circuits.

Full-or-part-time: 3h
Laboratory classes: 3h

PWM converters operating at fixed and variable switching frequency

Description:
Fixed frequency PWM converters: open loop buck converter. Closed loop buck converter with proportional control of the output voltage. Variable frequency PWM converters: open loop series resonant converter. Spectral distribution of power as a function of the duty cycle. Regulation of the output voltage by means of the switching frequency.

Specific objectives:
ï±Show the waveforms and spectrums of switching converters both in open loop and in closed loop, through LTSpice circuit simulation.
ï± Present the differences between the operating principles of conventional converters and resonant converters (soft-switching).

Full-or-part-time: 3h
Laboratory classes: 3h

The Pulse Width Modulator

Description:
SG3524 PWM modulator integrated circuit. Functional blocks. Experimental verification of operating margins. Features.

Specific objectives:
ï± Know and measure the operation of a commercial integrated circuit for the control of switching converters.

Full-or-part-time: 2h
Laboratory classes: 2h

Simulation of converter models. Application to voltage regulation

Description:
ï± Use different simulation models for switching converters and compare their characteristics. Use these models to simulate the behavior of the regulator with different compensations.

Specific objectives:
Simulation of the buck-boost converter using the LTSpice models of the transistor and the diode.
ï± Simulation of the converter using ideal switches.
ï± Simulation of the converter using the model of controlled sources of the switch.
ï± Comparison between the four previous simulation cases
ï± Closed loop converter. Simulation with instantaneous and averaged models.

Full-or-part-time: 2h 30m
Laboratory classes: 2h 30m

Analysis and experimental verification of the response of a switching regulator based on a buck converter

Description:
Voltage-voltage buck converter in open and closed loop. Measurement of waveforms and regulation performance

Specific objectives:
ï□± Present the components of a switched regulator, and show its complete implementation through a specific prototype.
ï□± Experimentally characterize the behavior of the regulator and show the non-idealities introduced by the implementation.

Full-or-part-time: 2h 30m
Theory classes: 2h 30m

GRADING SYSTEM

Mid-term exam. Final exam divided in two parts, part 1 and part 2. Laboratory practice.
Final mark=0,2 *(Laboratory practice)+0,8*[0,5*max(Mid-term exam; Final exam part 1); 0,5*(Final exam part 2)]

EXAMINATION RULES.

The student who pass the Mid-term exam (Part I) can only attend to the Part II of the final exam, or improve the mark of the Mid-term exam.In this last case the best mark will hold.
If the student doesn't pass the Mid-term exam, he should attend to both parts of the final exam.

BIBLIOGRAPHY

Basic:
- Erickson, Robert W; Maksimovic, Dragan. Fundamentals of power electronics [on line]. Cham: Springer, 2020 [Consultation: 08/09/2022]. Available on: https://link-springer-com.recursos.biblioteca.upc.edu/book/10.1007/978-3-030-43881-4. ISBN 9783030438814.
- Castañer, Luis; Silvestre, Santiago. Modelling photovoltaic systems : using PSpice. Chichester: John Wiley and Sons, 2002. ISBN 9780470845288.
- Lorenzo, Eduardo. Electricidad solar fotovoltaica (Vol. 3): Ingeniería Fotovoltaica,. Mairena de Aljarafe: Progensa, 2014. ISBN 9788495693327.