COURSE SYLLABUS
2015-2016

GENERAL INFORMATION

Course information	
Name	Power and Energy
Code	DEA-TEL-322
Degree	Degree on Telecommunication Engineering
Year	3rd
Semester	2nd (Spring)
ECTS credits	4.5 ECTS
Type	Compulsory
Department	Electronics, Automation and Communications
Area	
Coordinator	Aurelio García Cerrada

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DETAILED INFORMATION

Contextualization of the course
Contribution to the professional profile of the degree
This course explains the importance of electric energy on the development of Information Technologies through the study of the basic principles of electric energy generation and, above all, its transformation to be used in electronic devices. Since Power Electronics plays an essential role in the two processes (generation and transformation of electrical energy for electronic circuits), this course focuses on the fundamentals and applications of this technology in order to provide graduates with the necessary tools to understand and evaluate the contribution of Power Electronics to the performance of the electronic devices which they surely encounter in their professional activities. Lectures will be complemented with laboratory experiments to illustrate fundamental principles and demonstrate the save use of typical instrumentation of a Power Electronics laboratory.
Prerequisites
Students willing to take this course should be familiar with elementary theory of DC and AC circuits

CONTENTS

Contents

Theory

Chapter 1. Introduction

1.1 The importance of electric energy on Information Technologies
1.2 Power Electronics: definition
1.3 Applications: energy conversion, DC-DC, AC-DC and DC-AC.

Chapter 2. DC-to-DC converters

2.1 Fundamental principles: switching and filtering. Power Transistors. Average and RMS values of electric magnitudes. Buck DC-to-DC converter with uninterrupted inductor current: steady-state analysis.
2.2 Buck DC-to-DC converter design. Uninterrupted vs interrupted inductor current. Component design. Losses.
2.3 Boost and Buck-Boost DC-to-DC converters: steady-state analysis. General procedure to analyse a DC-to-DC converter: examples. Four-quadrant operation.
2.4 Introduction to average models and the control problem.

Chapter 3. DC-to-DC converters with transformers

3.1 Transformers for Power Electronics: introduction.
3.2 Flyback DC-to-DC converter: steady-state analysis.
3.3 Forward DC-to-DC converter: steady-state analysis.

Chapter 4. CA-to-CC converters. Rectifiers

4.1 Introduction to rectifying circuits. Power factor and THD. Harmonics in electric circuits.
4.2 Single-phase, full-wave uncontrolled rectifier: steady-state analysis, component design. LC and C filters.
4.3 Controlled rectifiers: introduction. Thyristors.
4.4 Active power factor correction.
4.5 Three-phase applications: introduction.

Chapter 5. DC-to-AC converters: Inverters

5.1 Principles of DC-to-AC electric energy conversion: voltage source converters and current source converters.
5.2 Single- and three-phase voltage source converters.
5.3 PWM

Chapter 6. Electric Energy and the environment

6.1 Introduction to electric power systems.
6.2 Conventional and distributed generation.
6.3 Non-conventional generators: photovoltaic energy, wind energy, batteries and fuel cells.
6.4 Power systems in remote locations

Chapter 7. Electromagnetic Compatibility

7.1 Electromagnetic disturbances in power electronics circuits.
7.2 Common and Differential mode disturbances. Narrow-band and wide-band signals.
7.3 Norms and regulations in electromagnetic compatibility

Chapter 8. Modelling and control of DC-to-DC converters

8.1 Average-variable models
8.2 The control problem in Power Electronics
8.3 Control alternatives for switched-mode power supplies.

8.4 Commercial circuits for control of switched-mode power supplies.

Laboratory

Lab 1. Introduction to simulation in power electronics

In this first lab session, students will become familiar with the power electronics simulation tool available in the laboratory

Lab 2. Simulation of a DC-to-DC converter: open loop and steady state

Students will be asked to simulate a DC-to-DC converter using the simulation tool in the laboratory. Only open loop and steady state will be analysed in this session. Through this example, students will have to opportunity to review the fundamentals of steady-state analysis of DC-to-DC converters, investigate the effect of losses and disturbances and illustrate the problems of simulating electric circuits with switching devices.

Lab 3. Simulation of a DC-to-DC converter: closed-loop control

Students will be asked to simulate a DC-to-DC converter using the simulation tool in the laboratory including a simple closed-loop voltage control. Steady state and transient will be analysed in this session. Through this example, students will have to opportunity to understand the dynamics involved in power electronics and the benefits of closed-loop control. The controller design process will be guided intuitively so that no previous knowledge on control systems will be required. Again, the students will investigate the effect of losses and disturbances and illustrate further the problems of simulating electric circuits with switching devices.

Lab 4. Analysis of a prototype of DC-to-DC converter: open loop and steady state

Students will be asked to analyse the behaviour of a DC-to-DC converter available in the laboratory (including the control integrated circuit). Only open loop and steady state will be analysed in this session. Through this example, students will have to opportunity to review the fundamentals of steady-state analysis of DC-to-DC converters, investigate the effect of losses and disturbances, get to know a commercial IC for control of switched-mode power supplies and use typical instrumentation in a power electronics laboratory. The DC-to-DC converters available in the laboratory have EMC problems and they can be used to illustrate the nature of these problems and some possible solutions.

Lab 5. Analysis of a prototype of DC-to-DC converter: closed-loop control

Students will be asked to analyse the behaviour of a DC-to-DC converter available in the laboratory which includes a simple closed-loop voltage control based on a commercial IC. Steady state and transient will be analysed in this session. Through this example, students will have to opportunity to understand the dynamics involved in power electronics and the benefits of closed-loop control. The controller analysis process will be guided intuitively so that no previous knowledge on control systems will be required. Again, the students will investigate the effect of losses and disturbances.

Lab 6. Study of an AC-to-DC-to-DC conversion system: understanding a switched-mode power supply

Students will be asked to analyse the behaviour of a DC-to-DC converter available in the laboratory connected to the mains through a step-down transformer and a single-phase, full-wave, uncontrolled rectifier. The analysis will focus on the different switching frequencies of the semiconductors, the importance of closed-loop control of the output voltage. However, the students will also have the opportunity of reviewing the fundamentals of AC-to-DC converters, including the differences between the performance with interrupted and uninterrupted inductor current.
This session will also illustrate the advantages of galvanic isolation and the use of special instrumentation in power electronics laboratories.

Competences and Learning Outcomes

Competences

General Competences

CGT1. Competence to write, carry out and sign telecommunication engineering projects tailored to the design, development or exploitation of networks, services and applications of information technologies (in agreement with order CIN 352/2009).

CGT3. Knowledge on basic and technological subjects which will help graduates to quickly understand new methods and techniques and to adapt to new situations with flexibility.

CGT4. Capacity to solve problems and take decision with creativity and self-initiative. Capacity to communicate knowledge with the responsibility and ethic required for a professional telecommunication engineer.

CGT5. Knowledge to carry out measurements, calculations, assessments, estimations, reports, task scheduling and any other work required in telecommunication engineering work.

CGT6 The ability to make use of technical specifications, norms and standards.

CGT7 The ability to analyse and assess the social and environmental impact of technical solutions.

CGT9 Capacity for team work in multidisciplinary projects within a bi-lingua environment, being able to communicate (orally and in written form) knowledge, procedures, results and ideas related with telecommunication engineering and electronics.

Basic Competences

Specific Competences

CRT11 Knowledge to apply several energy sources (especially thermal and photovoltaic). Knowledge of the fundamentals of electrical engineering and power electronics.

Learning outcomes

By the end of the course students should

RA1. Understand the importance of electric energy in Information Technologies.

RA2. Understand the fundamentals of electrical engineering to be applied in the analysis of electric circuits and electric power systems.

RA3. Know different ways to feed Information Technologies and understand its advantages and disadvantages.

RA4. Be able to specify, analyse and design power electronics devices to feed Information Technologies.

TEACHING METHODOLOGY

General methodological aspects	
The course material will emphasise the importance of electrical energy and its conversion in the world of Information Technologies. All course activities will be tailored to motivate students to seek a deep insight into the fundamental topics.	
In-class activities	**Competences**
▪ **Lectures and problem-solving sessions (30 hours)**: The lecturer will introduce the fundamental concepts of each chapter, along with some practical recommendations, and will go through worked examples to support the explanation. Active participation will be encouraged by raising open questions to foster discussion and by proposing short application exercises to be solved in class.	CGT1, CGT3, CGT4, CGT6, CGT7, CGT9, CRT11
▪ **Lab sessions (12 hours):** Under the instructor's supervision, students, divided in small groups, will apply the concepts and techniques covered in the lectures to real problems and will become familiar with the most widespread hardware and software tools. Students will be asked to fill a lab notebook with the procedures applied and results obtained.	CGT4, CGT5, CGT6, CGT9, CRT11
▪ **Evaluation (6 hours):** Quizzes and final exam	CGT1, CGT3, CGT4, CGT5, CGT6, CGT7, CGT9, CRT11
▪ **Tutoring** for groups or individual students will be organized upon request.	CGT1, CGT3, CGT6,CGT7, CGT9, CRT11
Out-of-class activities	**Competences**
▪ Personal study of the course material and resolution of the proposed exercises (65 hours).	CGT4, CGT5, CGT6, CGT9, CRT11
▪ Lab session preparation to make the most of in-class time (19 hours).	CGT1, CGT3, CGT6,CGT7, CGT9, CRT11
▪ Lab results analysis, including lab notebook (6 hours).	CGT1, CGT3, CGT6,CGT7, CGT9, CRT11

ASSESSMENT AND GRADING CRITERIA

Assessment activities	Grading criteria	Weight
Quizzes	▪ Understanding of the theoretical concepts. ▪ Application of these concepts to problem solving and/or lab. ▪ Critical analysis of numerical results.	20%
Final exam	▪ Understanding of the theoretical concepts. ▪ Application of these concepts to problem-solving and/or lab. ▪ Critical analysis of numerical results.	50%
Lab Notebook	▪ Data recording procedure. ▪ Day-to-day record in the notebook. ▪ Previous work for each lab session. ▪ Accuracy of the results recorded and details.	15%
Individual contribution	▪ Participation in class. ▪ Laboratory work and skills shown. ▪ Contribution to group work. ▪ Evaluation of laboratory knowledge through individual questions.	15%

GRADING AND COURSE RULES

Grading

Regular assessment

- **Theory** will account for 70%, of which:
  - Quizzes: 20%
  - Final exam: 50%
- **Lab** and individual evaluation will account for the remaining 30%, of which:
  - Lab notebook: 15%
  - Individual evaluation (including lab skills shown and direct questions answered about the lab work): 15%

In order to pass the course, the global mark, calculated with the weighting above, must be greater than or equal to 5 points. However, the mark of the final exam must be greater than or equal to 4 points before all elements can be weighted. If the limiting condition is not satisfied, the global mark will be equal to the one obtained in the final exam.

Retakes

The global mark calculated in the retake evaluation must be greater than or equal to 5 points with the following conditions:

- Students who have failed in the regular-assessment period will have to resit the final exam. The mark obtained this time will account for 70% of the final mark and has to be greater than or equal to 4 points. Otherwise the global mark will be equal to the mark obtained here.
- The mark of the laboratory notebook will account for 15% of the global mark. Students can resubmit the laboratory notebook before they resit the final exam.
- The individual evaluation of the laboratory work will account for 15% of the global mark. This mark could be maintained from the regular assessment or modified if the students go

through lab experiments or resubmit some of the individual activities proposed during the regular course. This mark will also reflect the answers given by the student to any direct question answered about the lab work, during the retake period.

Course rules

- Class attendance is mandatory according to Article 93 of the General Regulations (Reglamento General) of Comillas Pontifical University and Article 6 of the Academic Rules (Normas Academicas) of the ICAI School of Engineering. Not complying with this requirement may have the following consequences:
  - Students missing lectures may be denied the right to take the final exam during the regular assessment period.
  - Students missing laboratory sessions might be denied the right to take the final exam of the regular assessment period and the retake. In any case, missed sessions with no justified reason, will be penalized in the final grade.

WORK PLAN AND SCHEDULE[1]

In- and out-of-class activities	Date/Periodicity	Deadline
Quiz1 and Quiz2	Week 5 and week 8	
Final exam	May	
Lab sessions	Weeks 9 to 15 (approx.)	
Review and self-study of the concepts covered in the lectures	After each lecture	–
Lab preparation	Before every session	–
Lab notebook	Previous work checked at the beginning of each session	The final version of the lab notebook must be submitted by the final-exam day
Final exam preparation	May	–

STUDENT WORK-TIME SUMMARY			
IN-CLASS HOURS			
Lectures	**Problem-solving**	**Lab sessions**	**Assessment**
23	7	12	6
OUT-OF-CLASS HOURS			
Self-study	**Lab preparation**	**Lab result analysis.**	**Lab notebook writing**
65	19	6	0
		ECTS credits:	**4.5 (138 hours)**

[1] A detailed work plan of the subject can be found in the course summary sheet (see following page). Nevertheless, this schedule is tentative and may vary to accommodate the rhythm of the class.

BIBLIOGRAPHY

Basic bibliography

- Handouts and lecture notes prepared by instructors (available in Moodle).
- D.H. Hart. Power Electronics. McGraw-Hill, 2010 (Available in hardback ISBN 978-0-07-338067-4 and paperback ISBN 978-007-128930-6)

Complementary bibliography

- Mohan, N.; Undeland, T.M. And Robbins, W.P. Power Electronics: Converters, Applications and Design. 3Rd edition. Wiley, 2003
- Mohan, N. Power Electronics. A first course. Wiley. 2011.
- Mohan, N. Electric Power Systems: A first course. Wiley. 2012
- Erickson, R.W; Maksimovic, D. Fundamentals of Power Electronics. Springer. 2001.
- Tihanyi, L. “EMC in Power Electronics”. IEEE Press, 1995.
- Patel, M.R. “Spacecraft Power Systems” CRC Press.2004.

	IN-CLASS ACTIVITIES				OUT-OF-CLASS ACTIVITIES				LEARNING OUTCOMES
Week	h/w	LECTURE & PROBLEM SOLVING	LAB	ASSESMENT	h/w	SELF-STUDY	LAB PREPARATION AND REPORTING	OTHER ACTIVITIES	Learning Outcomes
1	3	Introduction (1h), Buck converter, switches and losses, mean and RMS values (2h)			3	Review and self study (1h). Problem solving (2h)			RA1
2	3	Buck (cont), Boost (1h). Buck-boost and Exercises (2h)			4	Review, self-study and problem-solving (4h)			RA2,RA4
3	3	Capacitor ripple (buck) and exercises (boost) (1h). Examples (more complex converters) and circuits for conduction losses (2h)			4	Review, self-study and problem-solving (4h)			RA2,RA4
4	3	Transformers in DC-to-DC converters (1h). Flyback and Forward converters. Exercises (2h)			4	Review, self-study and problem-solving (4h)			RA2,RA4
5	3	Quiz 1, Exercises of loss calculations, interrupted current, PWM generation and full bridge (3h)		Quiz 1 (50mm): DC-to-DC converters	4	Review, self-study and problem-solving (4h)			RA2,RA4
6	3	Rectifiers: Introduction, RMS and avrage values (1h). Power factor, cos(phi); design (2h)			4	Review, self-study and problem-solving (4h)			RA2,RA4
7	3	Exercises (AC-to-DC) (2h). Interrupted vs uninterrupted inductor current and review "from AC to controlled DC" (1h)			4	Review, self-study and problem-solving (4h)			RA2,RA4
8	3	Quiz2	Introduction to simulation (computer room) (2h) [Could be on week 9]	Quiz 2 (50mm): AC-to-DC converters	4	Review, self-study and problem-solving (4h)			RA2,RA4
9	3	Introduction to DC-to-AC converters (1h)	Simulation on DC-to-DC converter (open loop) (2h)		9	Review, self-study and problem-solving (4h)	Lab. Preparation (5h)		RA2,RA4
10	3	Solar and wind generation (1h)	Simulation on DC-to-DC converter (closed loop) (2h)		12	Review, self-study and problem-solving (5h)	Lab. Preparation and revision (7h)		RA2,RA3,RA4
11	3	Solar and wind generation (1h)	Lab work with DC-to-DC converter (open loop) (2h)		10	Review, self-study and problem-solving (5h)	Lab. Preparation and revision (5h)		RA2,RA3,RA4
12	3	Phasors and power flow in AC systems	Lab work with DC-to-DC converter (closed loop) (2h)		11	Review, self-study and problem-solving (5h)	Lab. Preparation and revision (6h)		RA2,RA4
13	3	Exercises DC-to-AC converters and power flow in AC systems (1h)	Lab work with AC-to-DC plus DC-to-DC converters (2h)		7	Review, self-study and problem-solving (5h)	Lab. revision (2h)		RA2,RA4
14	3	Power systems in remote locations (2h). Exercises (1h). Possible Quiz 3		Possible Quiz 3 (50mm): DC-to-AC converters	5	Review, self-study and problem-solving (5h)			RA2,RA3,RA4
15	3	EMC in power electronics (2h). Exercises (1h)			5	Review, self-study and problem-solving (5h)			RA1, RA2,RA3,RA4