Universidad de Alcalá

TEACHING GUIDE

Control of Switch-mode Power Electronics Converters

Degree in
Industrial Electronics and Automatics Engineering

Universidad de Alcalá

Academic Year 2023/2024

4th Year - 2nd Semester

Approved by the School Board on June 12th, 2023

TEACHING GUIDE

Course Name:	**Control of Switch-mode Power Electronics Converters**
Code:	**600037**
Degree in:	**Industrial Electronics and Automatics Engineering**
Department and area:	**Electrónica** **Electronic Technology**
Type:	**Optional (Generic)**
ECTS Credits:	**6.0**
Year and semester:	**4th Year, 2nd Semester**
Teachers:	Por definir
Tutoring schedule:	Consultar al comienzo de la asignatura
Language:	English

1. COURSE SUMMARY

This course introduces the student into the modeling and feedback control of PowerConverters. It is intended as a second course on Power Electronics, after anintroductory subject were basic DC/DC and DC/AC topics are covered.The subject starts reviewing the dynamic modeling of electric networks in both thetransfer function a state space approach. The second chapter is dedicated to themodeling and control of DC/DC power converters. The last chapter of the subject focuses on the modeling and control of DC/ACconverters. As complementary topics, grid synchronization using phase-locked loopsand common reference frame for three-phase variables are introduced.The lectured theory is complemented by an experimental module, where studentsare encouraged to solve guided practical cases in groups.

Prerequisites:

- Basic Power Electronics.
- Basic handling of MATLAB environment.
- Linear control design and analysis theory.
- Dynamic modeling fundamentals.

2. SKILLS

Basic, Generic and Cross Curricular Skills.

This course contributes to acquire the following generic skills, which are defined in the Section 3 of the Annex to the Orden CIN/351/2009:

Professional Skills

This course contributes to acquire the following professional skills, which are defined in the Section 5 of the Annex to the Orden CIN/351/2009:

Learning Outcomes

After succeeding in this subject the students will be able to:

RA1. Extract the dynamic model of switched-mode power converter, from thebasic DC/DC converters.

RA2. Design basic current and voltage control loop for DC/DC basic topologies.

RA3. Extract the dynamic model for VSC DC/AC converters

RA4. Design current and voltage control loops for VSC DC/AC power converters

RA5. Introductory knowledge of mains synchronization systems. Design basicmains synchronization systems (phase looping) for three-phase andsingle-phase systems.

3. CONTENTS

Contents Blocks	Total number of hours
Module 0. Introduction to power converter control. • Subject's topic. • Situation of the subject in the degree. • Metodology and evaluation.	1 hour
Module 1. Introduction to DC/DC converter dynamic modelling • Dynamic modelling of electric networks. Transfer function and internal representation. • Moving average operator. • Converter modelling in CCM. • Converter modelling in DCM.	15 hours
Module 2. Control of DC/DC converters. • Introduction. Motivations. • Closed-loop functions. • Control strategies. Loopshaping review. • Control objectives. • Antiwindup. • Comercial solutions.	12 hours
Module 3. Control of DC/AC converters. Active rectification. • Introduction to active rectification. • Synchronizations with the grid. Vectorial representation of three-phase variables. Generalized axes transformations. • Dynamic modelling of DC/AC converters. • Introduction to DC/AC converter control. • Current control. • Higher hierarchy control	28 hours

4. TEACHING - LEARNING METHODOLOGIES. FORMATIVE ACTIVITIES.

4.1. Credits Distribution

Number of on-site hours:	58 hours (56 hours on-site +2 exams hours)
Number of hours of student work:	92
Total hours	150

4.2. Methodological strategies, teaching materials and resources

In-classroom hours:	58 hours (56 lectures + lab) +2 hours for exams
Student homework	92 hours (including study, worksheets development and exam preparation)
Total	150 hours

The course is structured in 15 theoretical and practical sessions carried out in the laboratory (one per week).

In each session:

- The theoretical content of the session is given in an expository way
- A compulsory worksheet based on simple practical cases will be proposed.
- Group work will be supervised by the teacher using specialized simulation and design SW.
- Any doubts encountered will be consulted.
- An optional complementary worksheet will be proposed to be done outside the classroom.

5. ASSESSMENT: procedures, evaluation and grading criteria

Preferably, students will be offered a continuous assessment model that has characteristics of formative assessment in a way that serves as feedback in the teaching-learning process.

5.1. PROCEDURES

The evaluation must be inspired by the criteria of continuous evaluation (Learning Assesment Guidelines, LAG, art 3). However, in compliance with the regulations of the University of Alcalá, an alternative process of final evaluation is made available to the student in accordance with the Learning Assesment Guidelines as indicated in Article 10, students will have a period of fifteen days from the start of the course to request in writing to the Director of the Polytechnic School their intention to take the non-continuous evaluation model adducing the reasons that they deem convenient. The evaluation of the learning process of all students who do not apply for it or are denied it will be done, by default, according to the continuous assessment model. The student has two calls to pass the subject, one ordinary and one extraordinary.

Ordinary Call

Continous Assessment:

The main assessment tools will be:

1. **Worksheets (HT).** Worksheets with formative practical cases to be solved using specialized SW in small groups.

2. **Assessment Tests (PE).** Performing written tests focused on both practical and theoretical

aspects of the subject.

Students must attend 100% of the laboratory sessions and deliver the corresponding reports to all laboratory practices. Recovery sessions will be enabled for those students who have not attended any of the sessions and justify it documentarily.

The students, as a group, will deliver the reports of the laboratory practices following the established schedule. These practices will be evaluated by the professor responsible for the laboratory group, to assess if the objectives indicated in the script of the same have been met.

Assessment through final exam:

In the case of evaluation by means of a final exam, the evaluation elements to be used will be the following:

1. **Final Assessment Test (PEF).** Final exam similar to Assessment Test but covering the whole subject.

Extraordinary Call

The procedure will be the same as that described for the assessment by means of a final exam in the ordinary call.

5.2. EVALUATION

EVALUATION CRITERIA

The assessment criteria measure the level in which the competences have been acquired by the student. For that purpose, the following are defined::

CE1. The student is able to obtain an averaged and linearized transfer function around the operating point, given the nominal values of the components and the duty point, to serve as a starting point for the design of a controller.

CE2. The student is able to translate practical specifications (reference tracking and disturbance rejection at different points of the circuit) to the controller design.

CE3. The student uses with solvency the control techniques learned in previous subjects to the problems posed in this course.

CE4. The student is able to design synchronization systems, both in the single-phase and three-phase cases.

GRADING TOOLS

The work of the student is graded in terms of the assessment criteria above, through the following tools:

1. Ordinary call
    a. **Worksheets (HT):** Delivery of developments and resolution of problems and case studies on the design of converter controllers. They will be carried out using specialized simulation and design tools.
    b. **Assessment (PE)**: Tests throughout the course. There will be 2: one will evaluate the content focused on DC/DC conversion and the other on DC/AC conversion.
    c. **Final Assessment (PEF):** A single test with the same characteristics as the EPs, but to be taken only by those students who opt for the final evaluation.
2. Extraordinary call. Final assessment (PEF)

GRADING CRITERIA

In the ordinary call-continuous assessment the relationship between the competences, learning outcomes, criteria and evaluation instruments is as follows.

Learning Outcomes	Evaluation criteria	Grading Tool	Contribution to the final mark
RA1-6	CE1-4	HTs	30 %
RA1, RA2, RA6	CE1-4	PE1	35 %
RA3-5	CE1-4	PE2	35 %

In the ordinary call-final evaluation, the relationship between the competences, learning outcomes, criteria and evaluation instruments is as follows.

Learning Outcomes	Evaluation criteria	Grading Tool	Contribution to the final mark
RA1-6	CE1-4	PEF	100%

Extraordinary call

In the case of the extraordinary call, the same percentages that have been established in the case of the evaluation by means of a final exam will be maintained, as shown in the following table:

Learning Outcomes	Evaluation criteria	Grading Tool	Contribution to the final mark
RA1-6	CE1-4	PEF	100%

6. BIBLIOGRAPHY

6.1. Basic Bibliography

- R. W. Erickson, D. Maksimovic. “Fundamental of Power Electronics”. ThirdEdition. Ed. Springer. http://ecee.colorado.edu/~pwrelect/book/SecEd.html .Fundamental Text of the subject

6.2. Additional Bibliography

- C. P. Basso. “Switch-Mode Power Supplies Simulations and Practical Designs”. McGraw-HillProfessional Engineering. ISBN: P/N 978-0-07-150859-9 of set 978-0-07-150858-2
- Kislovsky A., Redl R. Sokal N. Dynamic Analysis of Switching-Mode DC-DCConverters. Springer; 1edition (August 8, 1991) One of the most comprehensive books on dynamic analysis of switchedDC/DCconverters. It covers almost all topologies and operating modes. It is an advancedbutunderstandable text.
- Yazdani A. Iravani R. Voltage-Sourced Converters in Power Systems. Willey-IEEE.2010
- Teodorescu R. Liserre M. Rodríguez P. Grid Converters for Photovoltaic and WindPower Systems.Willey-IEEE. 2011.

Disclosure Note

During the evaluation tests, the guidelines set out in the Regulations establishing the Rules of Coexistence of the University of Alcalá must be followed, as well as the possible implications of the irregularities committed during said tests, including the consequences for committing academic fraud according to the Regulation of Disciplinary Regime of the Students of the University of Alcalá.