Co-funded by the European Union

STUDENT HANDBOOK

Erasmus Mundus Joint Master Degree

International Master in Electric Vehicle Propulsion and Control: E-PiCo+
Project 101180198 - E-PiCo Plus

CENTRALE NANTES	**CENTRALE NANTES**
C A U Kiel University Christian-Albrechts-Universität zu Kiel	**CHRISTIAN-ALBRECHTS-UNIVERSITÄT ZU KIEL**
POLITEHNICA BUCHAREST 205 YEARS OF INNOVATION 1818 NUST	**NATIONAL UNIVERSITY OF SCIENCE AND TECHNOLOGY POLITEHNICA BUCHAREST**
	UNIVERSITÀ DEGLI STUDI DELL'AQUILA
Cinvestav	**CENTRO DE INVESTIGACION Y DE ESTUDIOS AVANZADOS DEL INSTITUTO POLITÉCNICO NACIONAL**

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1. WELCOME

Welcome to the Erasmus Mundus Master E-PiCo+. The purpose of this handbook is to explain how **E-PiCo+** works and what you can expect from it. This information is intended to help you integrate smoothly into postgraduate life and make the most of your academic journey. The handbook outlines the structure of the program, the resources available, the roles of partner institutions, and the procedures to follow in case of any difficulties. Please read this handbook carefully, as understanding the regulations and procedures will be in your best interest. If you have any doubts about the information provided, do not hesitate to contact your course coordinator. We hope your experience as part of the E-PiCo+ community will be enriching and fulfilling.

E-PiCo+ builds upon the foundations of E-PiCo, addressing the latest advancements and challenges in electric propulsion and energy management. It offers a unique combination of academic and industrial training, covering the entire scope of next-generation electric propulsion systems, including charging optimization, advanced energy management, battery sustainability, power electronics, powertrain control, and performance enhancement. With contributions from leading universities and industry partners, **E-PiCo+** ensures that students receive cutting-edge expertise tailored to the evolving demands of sustainable mobility. As in the previous program, all course units of **E-PiCo+** delivered in English are mutually recognized by all consortium partners. The core curriculum over the first three semesters will provide a comprehensive understanding of electric propulsion components and applications, preparing graduates for impactful careers in the field.

2. DISCLAIMER

The Consortium has made all reasonable efforts to ensure that the information contained within this publication is accurate and up-to-date when published but can accept no responsibility for any errors or omissions. The Consortium reserves the right to revise, alter or discontinue modules and to amend regulations and procedures at any time, but every effort will be made to notify interested parties. It should be noted that **not every module listed in this handbook may be available every year, and changes may be made to the details of the modules.**

3. E-PICO+ AT A GLANCE

3.1. The “International Master in Electric Vehicle Propulsion and Control: E-PiCo+” Master course is an integrated Master’s program conducted by five European and international institutions:

- École Centrale de Nantes (ECN) – France
- Christian-Albrechts-Universität zu Kiel (CAU) / Kiel University – Germany
- Università degli Studi dell’Aquila (UAQ) – Italy
- National University of Science and Technology Politehnica Bucharest (UNSTPB) – Romania

- Centro de Investigación y de Estudios Avanzados del Instituto Politécnico Nacional (CINVESTAV) – Mexico

3.2. E-PiCo+ also benefits from the collaboration of several associated industrial and academic partners, including leading automotive, aerospace, and energy companies, ensuring strong industry connections and hands-on training opportunities.

3.3. The E-PiCo+ Master program is an Erasmus Mundus Joint Master's Degree granted by the European Commission under the grant Agreement number 101180198 - E-PiCo Plus, concluded between the European Education and Culture Executive Agency and Centrale Nantes on 25/10/2024.

3.4. The E-PiCo+ Master leads to a combination of joint and/or national degree according to the mobility scheme of the student. These degrees will be granted by all European institutions where the student completes at least one semester and will include co-supervision of the Master's thesis by academic and industrial experts.

4. ABSTRACT

International Master in Electric Vehicle Propulsion and Control (**E-PiCo+**) is a 2-year master programme devised to train students in the field of electric propulsion with its control, to be future experts in Electric Vehicles (EVs). It will provide technical and scientific solutions for making EV's:

- More affordable whilst ensuring high standards of safety and reliability
- Providers of electricity in the near future
- More accessible by transforming ICE-conventional based vehicles to EV (Retrofit)

By doing so the students will be at the forefront of the global energy transformation. The E-PiCo+ master's programme is thus aligned with the world's growing need for EVs (in industries, infrastructures, etc.) and trains future EV experts capable of dealing with the energy transition. The programme is fully taught in English and implies mobility within a minimum of two countries among 4 EU and 1 outside EU institutions.

Students will complete their studies in **at least two different countries**, including **at least one European country**. In the first three semesters, mobility will occur across European and/or non-European partner institutions. The fourth semester may take place in any country, following **EACEA** regulations for Erasmus Mundus scholarship holders.

Candidates must hold a Bachelor's degree and will be selected based on academic excellence and prerequisites in Electrical Engineering, Automatic Control, and Embedded Systems.

The programme structure includes:

- **1st semester (ECN, France)**: Theoretical knowledge on automatic control, signal processing, embedded systems and electric vehicles (fundamentals and simulation)
- **2nd semester (UAQ, CAU, UNSTPB, or CINVESTAV):** common modules related to e-mobility with updates to more applications in EVs (Power electronics converters, Electrical machines and drive, Renewable energy, storage systems, Nonlinear control systems) and one compulsory elective module.

- **3rd semester:** Specialization in one of the following areas:
  - **Specialization (A) in ECN:** Electric propulsion control (battery and fuel-cell based)
  - **Specialization (B) in UNSTPB:** Energy storage and energy management in e-mobility systems
  - **Specialization (C) in CAU:** Power electronics, drives and batteries
  - **Specialization (D) in UAQ**: Embedded systems and Advanced control.
  - **Specialization (E) in CINVESTAV**: AI techniques, application in EV

The Master's thesis will be supervised by **ECN, CAU, UAQ, UNSTPB**, and **CINVESTAV**, with strong support from academic and industrial partners.

The program will contribute to the European Commission goal by increasing the European electric vehicle sales to make it challenging enough for new companies to enter the market; disseminating new solutions to the environmental impact of fossil fuel transportation at the European and worldwide levels, the key motivation being environmental, economic, technical personal and demographic factors; addressing key technological restriction by using e-mobility systems and improving European electric propulsion system experts' employment and competitiveness.

5. OBJECTIVES

E-PiCo+ is designed within the framework of the Erasmus Mundus programme to:

- Provide technical and scientific solutions for the issues of fossil fuel consumption and greenhouse gas emissions.
- Train students in the field of e-mobility to help them work towards an ecological transition by training future experts in electric propulsion systems.

Upon graduation, students will master various aspects of e-mobility systems to disseminate innovative solutions to the environmental impact of fossil fuel transportation both at the European and global levels. The key motivations are environmental, economic, technical, personal, and demographic factors, particularly focusing on issues such as battery life, driving range, poor acceleration, and noise.

The e-mobility sector is a crucial area for both European and international industrial recovery. The demand for highly qualified professionals in the labor market is confirmed by studies, which encourage the E-PiCo+ partners to offer this Master's programme. According to the European Climate Foundation, by 2030, e-mobility should help create **206,000 net additional jobs in Europe.**

6. E-PICO+ KEY ELEMENTS

The programme of study lasts two academic years (120 ECTS), divided into four equally loaded semesters. **E-PiCo+** student mobility paths will take place in a minimum of two countries, including at least one European country. For the first three semesters, students will spend:

- **1st semester** at ECN (30 ECTS)
- **2nd semester** at UNSTPB, CAU, UAQ, or CINVESTAV (30 ECTS)
- **3rd semester** at ECN, UNSTPB, CAU, UAQ or CINVESTAV (30 ECTS)

For the **4th semester**, **E-PiCo+** students may move to any countries following the EACEA regulations.

The curriculum is structured as follows:

- 50% of the curriculum is common (the 1st semester and 50% of the 2nd semester), with the remaining 50% at the discretion of each partner institution.
- Consequently, students joining an HEI (Higher Education Institution) for their 3rd semester will have the same fundamental knowledge of the subject and be ready for M2-level teaching.
- The 3rd semester is dedicated to specializations offered by each HEI, covering the full theoretical field of electrical propulsion.
- The Master's thesis is integrated, co-organized, co-supervised, and co-validated by the five partner HEIs (ECN, CAU, UAQ, UNSTPB and CINVESTAV) and their academic and industrial partners, with a common defense and harmonized assessment.

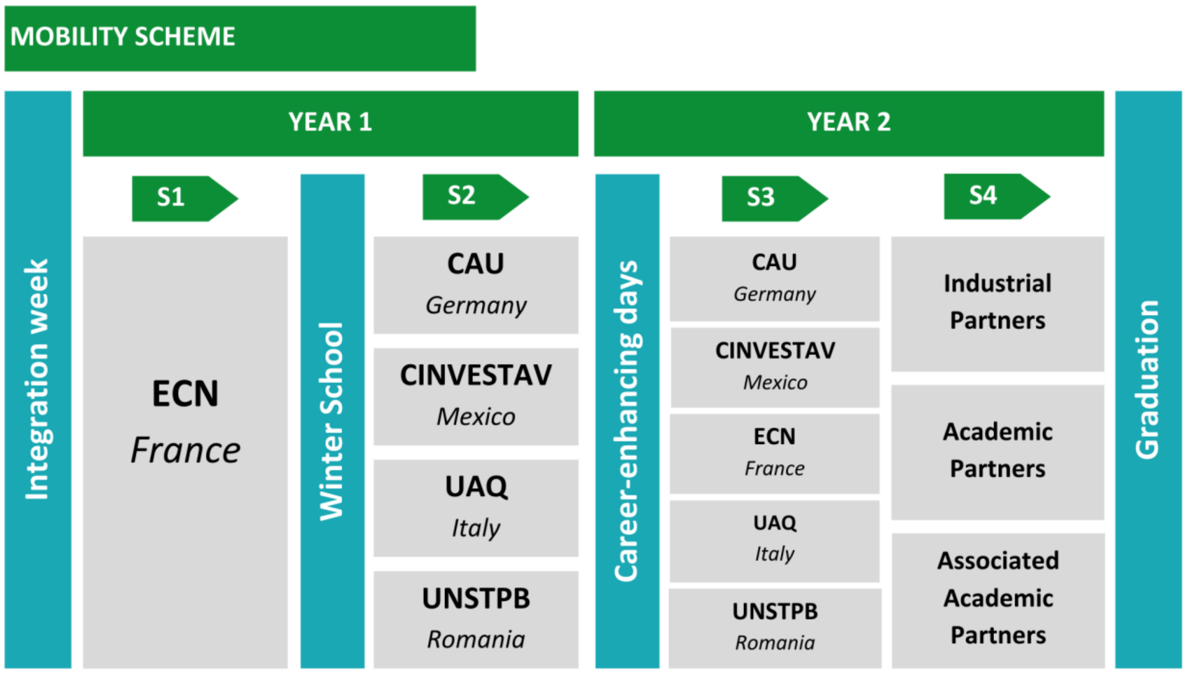

Figure 1. E-PiCo+ mobility scheme

6.1. Degree awarded

Students that graduate from the E-PiCo+ Master course will **obtain a combination of joint and/or national degree according to the mobility scheme of the student** from the institutions where they studied the first, second and third semesters. The obtained degrees are officially recognised and give full access to PhD study programs. The Consortium will deliver Diploma Supplement describing the nature, level, context, content and status of the studies that were pursued and successfully completed by the student.

6.2. Summary of Study Programme

The language of instruction and examination is **English**, and local language and culture courses of the hosting countries are included in the programme of study. The aim of the first two semesters is to provide students with a solid interdisciplinary background across the main areas of **automatic control, electrical engineering**, and an introduction to **electric vehicle systems**.

During the third semester, depending on the host institution, students will focus on one or more of the following sectors:

- Control, optimization, observation, diagnostic/prognostic and energy management issues dedicated to electric propulsion systems (ECN)
- Battery storage systems (UNSTPB)
- Power electronics converters, fast charging stations, drives and batteries technologies (CAU)
- Embedded systems implementing advanced control laws (UAQ)
- Artificial Intelligence with applications to EVs (CINVESTAV)

The fourth semester is dedicated to the **Master's thesis**. The student will carry out their research work under the joint supervision of advisors that can be from two different consortium institutions (ECN, CAU, UAQ, UNSTPB, and CINVESTAV).

6.3. Admission requirements

The Master course applies to European and third country-students who already hold a first university degree with **180 ECTS**, **after at least three years of university studies** (at the level of Bachelor of Science), in a field related to electrical systems, such as: automatic control, electrical engineering, mechatronics, computer science, embedded systems, physics, and applied mathematics.

The applicants have to be fluent in writing and reading in English (TOEFL (score 220 CBT, 550 PBT, 80 IBT), Cambridge B2 First test (score 173 or higher), Cambridge C1 Advanced test (score 160 or higher), IELTS (score 6.5 or higher), TOEIC (800). The admission is decided based on excellence of the academic records of the student, the quality of her/his former studies, motivations, and general skills for foreign languages.

7. CALENDAR

Each institution will provide to students a precise calendar with dates of exams, holidays. Though the local start and end dates of courses may vary from one institution to another, the official academic year dates for the programme are:

- First and Third semester: September 1st to February 28th

- Second and Fourth semester: March 1st to August 31st

8. IMPORTANT LINKS AND RESOURCES

E-PiCo+ students have access to the following resources at the host institution:

- Library
- Rooms equipped with computers
- WiFi
- List and contact information of teachers/researchers involved in the program

Details and operational procedures will be provided by the host institution at the beginning of the academic year.
The receiving institution will guide incoming mobile participants in finding accommodation, in line with the requirements of the Erasmus Charter for Higher Education. Additional information and assistance can be directly provided by the following information sources:

Housing	
ECN	https://www.ec-nantes.fr/english-version/campus/accommodation
CAU	https://www.international.uni-kiel.de/en/incomings/planning-arrival-and-stay/accomodation
UPNSTPB	https://international.upb.ro/about-us/campus-life/culture?fragment=studentLife
UAQ	https://www.univaq.it/en/section.php?id=912
CINVESTAV	https://cinvestav.mx/guadalajara

9. ASSESSMENT RULES

To test knowledge and understanding of the material presented in the lectures and associated practicals, students will be assessed through a combination of written examinations, oral presentations, essays, poster presentations, laboratory experiment write-ups, and/or fieldwork reports. Summative assessment contributes to marks and typically includes a combination of written examinations (at the end of the study module) and coursework (which includes essays, project reports, computing practicals, etc.). Assessment of knowledge and understanding will primarily occur through these summative methods; in addition, students will receive feedback on all formally assessed work.

9.1. Progression Rules

9.1.1. The following applies to progression from one semester to the next:

- A student must achieve the pass mark for all modules forming part of that semester, as determined by the progression regulations (or equivalent regulations) of the relevant partner institution. This includes fully accredited exemptions for work or prior learning completed outside the programme, if deemed equivalent to part of the programme in accordance with its regulations.
- Examinations passed and credits earned at one partner institution will be fully recognized by the other institutions in accordance with their recognition rules.
- In case of non-validation of one module during semesters 1 to 3, the student may progress to the next semester by validating the corresponding module or an equivalent one at the same or the next hosting institution.
- With a partly uniform programme structure, Semesters 3 and 4 can build on specific knowledge regardless of the students' place of study during Semester 2.

9.1.2. In order to complete the programme, the following applies:

- To receive degrees from the hosting institutions, students must validate 90 ECTS and successfully complete their Master's thesis.
- Unless permitted by local regulations, students are not allowed to defend their thesis if they have not acquired the 90 ECTS from the modules of the first three semesters.

9.2. Master Thesis Rules

9.2.1. A student may commence research for the thesis project immediately after successfully progressing to Semester 2. Thesis topics will be offered and allocated to students from a set of thesis topics proposed by the **Joint Programme Board (JPB)**. Students are encouraged to take the initiative in searching for internship opportunities on their own.

9.2.2. A principal supervisor(s) from the hosting **institution of Semester 3** will be appointed for each candidate, responsible for ensuring that studies are conducted according to the institution's good practice guidelines. **A second and/or third co-supervisor** from the first-year hosting institution(s) could be appointed. The thesis defense will be scheduled in coordination between supervisors from the two or three institutions involved. All hosting institutions where the student has studied must receive the Master thesis report.

9.2.3. Every student must submit a final draft of the thesis to be assessed by the JPB, where thesis drafts are pre-assessed before final submission for evaluation.

9.2.4. The Master thesis will be judged following the procedure agreed upon by the University **Academic Committee** (UAC) of the institution where the student presents the thesis. The thesis must be written and defended in front of a jury, which will consist of representatives nominated by each UAC in accordance with their respective regulations. Additionally, an external reviewer will participate in the assessment process, either “in situ” or “virtually” (using online communication software). The defence of the thesis must be fixed before the jury in ECN, i.e. before the second week of September.

9.3. General Principle

In order to complete the program, the following applies:

9.3.1. To receive a degree from the hosting institutions, the student must validate **90 ECTS** and successfully complete their **Master thesis**. In total, students must acquire **120 ECTS** throughout the program.

9.3.2. For each additional semester (more than 4), the Consortium may allow the student to continue in E-PiCo+ programme. The student might need to pay the **local registration fees** to the hosting institutions they attended in the first two years, according to the local regulations. For information in ECN, the fees are €4,500.

9.3.3. Appeals by a student against decisions of an Examination Board will be considered according to the procedures of the institution where the decision being appealed was originally made.

9.3.4. Re-take exams **or compensating module:** Students may have the possibility of re-taking exams or compensating if progression requirements have not been met. The conditions and dates for re-taking exams and compensating will be established according to the internal rules and requirements of the hosting institutions.

9.3.5. Students who are eligible to progress to the next semester are not allowed to repeat any module for which credit has already been awarded, in order to improve their performance.

9.4. Marking Criteria

Due to the collaborative nature of E-PiCo+, the Consortium is committed to the ECTS grading structure. Examinations and assessments will be marked out of 100 points. The marks will then be converted to ECTS grades, as outlined in the table below:

ECN	CAU	UAQ	UNSTPB	CINVESTAV
A^+	1	30L, 30, 29	10	10
A	1.3	28	10	9.5
A^-	1.3	27	10	9
B^+	1.7	26	9	9-
B	2	25	9	8.5
B^-	2	24	9	8
C^+	2.3	23	8	8-
C	2.7	22	7	7.5

C-	3	21	7	7
D	3.3	20	6	7-
D	3.7	19	6	7-
D	4	18	5	7-
F	5	17	1-4	1-6.5

Table 2 : Marking criteria

9.5. Final Award

9.5.1. At the end of each semester, the **Examination Committee** will convene to make award decisions for students pursuing **E-PiCo+**.

9.5.2. Appeals against award decisions will be considered according to the appeals procedures established by the **Examination Committee**, and administered by the partner institution concerned, in line with their own awarding institutional regulations.

9.5.3. At the end of the second year, successful students will be awarded a **double/triple Master's** degree from the first, second, and third institutions where they studied.

9.5.4. Degrees will be awarded according to national assessment structures. For example, in France, the final grade will be based on the average of the **M1 and M2** results:

- **Très Bien (90-100)**: Excellent
- **Bien (80-89)**: Very Good
- **Assez Bien (70-79)**: Good
- **Passable (60-69)**: Satisfactory
- **Échoué (0-59)**: Fail

9.5.5. The original diploma will be issued around April of the year following graduation. Prior to the issuance of the original diploma, the following certificates will be provided to assist the student in seeking employment or a Ph.D. position:

- **Transcripts of M2** will be issued once S**emesters S3 and S4** are validated.
- **Certificate of Success**, which will include the results of the Master's program, based on the average of the four semesters.
- **Diploma Supplement** (will be delivered along with the original diploma).

9.6. Unfair Practice

9.6.1. Students must ensure that they do not engage in any form of unfair practice, whereby they take actions that may result in them obtaining for themselves or others an unpermitted advantage.

9.6.2. Unfair practice is defined as any act whereby a person may obtain for himself/herself or for another an unpermitted advantage. This includes actions during, or in relation to, a formal examination, coursework, or any form of assessment undertaken as part of the **E-PiCo+** program.

9.6.3. Examples of unfair practice in examination conditions include:

- Introducing any unauthorized material into an examination room, such as books, manuscripts, data, loose papers, or electronic devices (e.g., programmable calculators, pagers, mobile phones) that provide unauthorized information.
- Copying from or communicating with another person in the examination room, except as authorized by an invigilator.
- Communicating electronically with another person during the examination.
- Impersonating an examination candidate or allowing oneself to be impersonated.
- Presenting false or falsified evidence of special circumstances to examination boards or misleading the board in any way.
- Submitting an examination script as your own work when it includes material obtained through unauthorized means, such as plagiarism.

9.6.4. Examples of unfair practice in non-examination conditions include:

- **Plagiarism:** Using another person's work without acknowledgment and submitting it as your own. This includes copying or unacknowledged paraphrasing (see 6.2.3 below).
- **Collusion:** Two or more students working together without prior authorization from the academic member of staff to produce similar or identical pieces of work and attempting to present the work as their own. Collusion also includes one student submitting another student's work with the originator's knowledge.
- **Falsification of data:** Altering the results of laboratory, fieldwork, or other data collection and analysis.

9.6.5. Examples of plagiarism include:

- Using quotations from published or unpublished work of other persons without clearly identifying them by placing them in quotation marks and acknowledging the source.
- Summarizing another person's ideas, judgments, figures, software, or diagrams without referencing the original author in the text and in the bibliography.
- Using "ghostwriting" services to prepare assessed work.
- Using unacknowledged material downloaded from the Internet.

9.6.6. Students suspected of engaging in unfair practice or assisting another student in unfair practice (either in coursework or during examinations) will be subject to the unfair practice procedures of the institution where they are studying.

9.6.7. Each institution will investigate any suspected unfair practice in accordance with their internal procedures and will inform the **E-PiCo+ Consortium** of the results.

9.6.8. Students accused of unfair practice will be given an opportunity to present their case, either in writing or in person.

9.6.9. Students found guilty of unfair practice will face penalties, including:

- Annulment of the applicable examination or test, or recognition of a course.
- The institution where the student is registered will decide on the appropriate solution for the case.

9.6.10. Students have the right to appeal against substantiated allegations of unfair practice, in accordance with the appeals procedure adopted by the **E-PiCo+ Consortium Management Committee.**

9.7. Attendance Policy

9.7.1. Students are required to attend the entire Master program. The partner institutions are responsible for monitoring and verifying student attendance.

9.7.2. In case of non-attendance in the courses, the local coordinator will contact the student to clarify the reason for the absence. The local coordinator will inform the E-PiCo+ coordinator and the management committee, which will determine the appropriate actions based on the reason for the extended absence.

9.7.3. If a student misses an examination without valid justification (such as medical certificates or prior permission from the **E-PiCo+** coordinator), the student will be allowed to retake the exam or for compensating. If the student still does not show up for the retake or the compensation, they will be given a score of 0.

9.8. Transferring Schemes, Suspending, and Withdrawing Policy

9.8.1. **Transferring Schemes:** Students will be assigned a mobility scheme based on their preferences and the decision of the **E-PiCo+** management committee. Once the student accepts the mobility scheme, no changes will be permitted, except in cases of force majeure. Any requests for changes will be reviewed by the management committee, and a derogation may be granted depending on the student's circumstances.

9.8.2. **Suspension:** If a student needs to suspend their participation in the program, they must provide a reason and submit all necessary supporting documentation to the local coordinator within five days of the start of their absence. The validity of the suspension will be evaluated by the academic jury of the semester in question.

9.8.3. **Withdrawal:** A student wishing to withdraw from the program must notify the local coordinator via email within five days. The student must be in compliance with all administrative aspects of the program, including fees, and will not receive any official documents until the compliance is confirmed.

9.9. Disciplinary Issues

In the case of a disciplinary issue, the local coordinator will inform the **E-PiCo** coordinator and the management committee, which will take appropriate action based on the nature of the issue.

9.10. Complaint and Appeal against Non-Academic Decisions

If a student wishes to file a complaint or appeal regarding non-academic decisions, they must address the request to the local coordinator. The local coordinator will inform the **E-PiCo+** coordinator and the management committee, who will make the final decision on the matter.

10. STRUCTURE OF THE PROGRAMME

10.1. The first semester modules in ECN (details in Annex 1)

MODULES	ECTS
1 Control system	4
2 Research methodology	4
3 Embedded computing	4
4 Statistical signal processing and estimation theory	4
5 Fundamentals of electric and hydrogen vehicle system	4
6 Electric and hydrogen vehicle modelling and simulation	4
7 Project E-PiCo+	4
8 French language	2
SEMESTER TOTAL ECTS:	**30**

*Table 3. Subjects offered by ECN during Semester **1***

10.2. The second semester modules (details in Annex 2*)*

10.2.1. Second semester at UNSTPB:

MODULES	ECTS
1 Power electronics converters*	3
2 Electrical machines*	4
3 Renewable energy and storage systems*	3
4 Nonlinear control systems*	3
5 Machine learning for autonomous systems	4
6 Romanian language and culture	3
7 Research Activity and Practical Work S2	10
SEMESTER TOTAL ECTS:	**30**

Table 4a. Subjects offered by UNSTPB during Semester 2

** This module is offered at all three partner Institutions where students can spend the second semester. By offering a partly uniform programme, Semester 3 and Semester 4 can build on specific knowledge regardless of the students' place of study during Semester 2.*

10.2.2. Second semester at CAU:

MODULES	ECTS
1 Design of power electronics converters*	5
2 Electric drives for EVs*	5
3 Renewable energy systems*	5
4 Nonlinear control systems*	5
5 Compulsory elective module** (choice of 1 out of 5) List of the elective modules • Battery cell engineering • Design of DC/DC converters • Applied nonlinear dynamics • Control of PDE systems • Advanced methods in nonlinear control	5
6 German language course	5
SEMESTER TOTAL ECTS:	**30**

Table 4b. Subjects offered by CAU during Semester 2

** This module is offered at all three partner Institutions where students can spend the second semester. By offering a partly uniform programme, Semester 3 and Semester 4 can build on specific knowledge regardless of the students' place of study during Semester 2.*
*** Students who are in the second semester at Kiel University and will be studying at the University of L'Aquila in the third semester and would like to obtain a degree from the University of L'Aquila must take either the module "Applied nonlinear dynamics" or the module "Advanced methods in nonlinear control" as compulsory elective module in the second semester at Kiel University.*

10.2.3. Second semester at UAQ:

MODULES	ECTS
1 Power converters*	5
2 Electrical machines and drives*	5
3 Renewable energy and storage systems*	5
4 Nonlinear control systems*	5
5 Compulsory elective module (choice of 1 out of 2) List of the elective modules • Instrumentation for Control of Energy Systems • Hybrid Systems Control and Simulation	5
6 Italian language course	5
SEMESTER TOTAL ECTS:	**30**

Table 4c. Subjects offered by UAQ during Semester 2

** This module is offered at all three partner Institutions where students can spend the second semester. By offering a partly uniform programme, Semester 3 and Semester 4 can build on specific knowledge regardless of the students' place of study during Semester 2.*

10.2.4. Second semester at CINVESTAV:

MODULES	ECTS
1 Power converters*	5
2 Electrical machines and drives*	5
3 Renewable energy and storage systems*	5
4 Nonlinear control systems*	5
5 Compulsory elective module (choice of 1 out of 2)	5
6 List of the elective modules	5

Energy quality in Power Systems Hybrid Systems Control and Simulation Spanish language course	
SEMESTER TOTAL ECTS:	**30**

Table 4d. Subjects offered by CINVESTAV during Semester 2

** This module is offered at all three partner Institutions where students can spend the second semester. By offering a partly uniform programme, Semester 3 and Semester 4 can build on specific knowledge regardless of the students' place of study during Semester 2.*

10.3. The Third semester modules (details in Annex *3)*

10.3.1. Third semester at ECN (Specialization A):

	MODULES	ECTS
1	Optimization, energy management of electric/hydrogen vehicle charging/refuelling	5
2	Control of power converters for electric and hydrogen propulsion systems	5
3	Observation and Diagnosis for electric and hydrogen propulsion systems	5
4	Advanced control of electric and hydrogen propulsion systems	5
5	Case study application dedicated to electric and hydrogen vehicle topology	5
6	Project	5
	SEMESTER TOTAL ECTS:	**30**

Table 5a. Subjects offered by ECN during Semester 3

10.3.2. Third semester at UNSTPB (Specialization B):

Specialization B: Energy storage and energy management in e-mobility systems

	MODULES	ECTS
1	Battery chargers	4
2	Modern communication technologies for connected EVs	4
3	Battery management systems for EVs	4
4	Retrofit, control of electrical machines	4
5	Microprocessor applications for real time systems	4
6	Scientific Research and Practical Work S3	10
	SEMESTER TOTAL ECTS:	**30**

Table 5b. Subjects offered by UNSTPB during Semester 3

10.3.3. Third semester at CAU (Specialization C)

Specialization C: Power electronics, drives and batteries

	MODULES	ECTS
1	Modelling and control of power electronics converters	5

2	Battery chargers for EV's	5
3	Seminar Power electronics	5
4	M.Sc. Laboratory Power electronics - Renewable energy - Drive engineering	5
5	Compulsory elective module 1 (choice of 1 out of 6)	5
6	Compulsory elective module 2* (choice of 1 out of 6) List of the elective modules • Advanced digital signal processing • Optimization and optimal control • Microcontroller and FPGA technique for power electronics applications • Battery systems • Seminar on selected topics in systems and control • M.Sc. Laboratory Advanced control	5
	SEMESTER TOTAL ECTS:	**30**

Table 5c. Subjects offered by CAU during semester 3

** Students who are in the second semester at University of L'Aquila and will be studying at the Kiel University in the third semester and would like to obtain the degree from University of L'Aquila must take the module "Optimization and optimal control" as compulsory elective module in the third semester at Kiel University.*

10.3.4. Third semester at UAQ (Specialization D)

Specialization D: Embedded systems and advanced control

	a) ECTS Distribution by Module	**ECTS (*) TOTAL**
1	Systems identification and data analysis	6
2	Embedded systems	9
3	Advanced control systems	9
4	Optimal Control	6
	SEMESTER TOTAL ECTS:	**30**

Table 5d. Subjects offered by UAQ during Semester 3

**Students who are in the second semester at Kiel University and will be studying at the University of L'Aquila in the third semester and would like to obtain the degree from the University of L'Aquila must take either the module "Applied nonlinear dynamics" or the module "Advanced methods in nonlinear control" as compulsory elective module in the second semester at Kiel University.*

10.3.5. Third semester at CINVESTAV (Specialization E)

Specialization E: AI techniques, application in EV

	a) ECTS Distribution by Module	**ECTS (*) TOTAL**
1	Computer Vision	7.5
2	Neural nets techniques for EV control	7.5
3	AI techniques for EV mobility	7.5
4	Machine learning with application to EV's	7.5
	SEMESTER TOTAL ECTS:	**30**

Table 5e. Subjects offered by CINVESTAV during Semester 3

ANNEX 1 - SYLLABUS SEMESTER 1

SEMESTER 1 - ECN

<table>
<tr><th colspan="3">CONTROL SYSTEMS</th></tr>
<tr><td>Credits</td><td>4 ECTS</td><td rowspan="6">Semester 1
ECN</td></tr>
<tr><td>Lectures</td><td>18 h</td></tr>
<tr><td>Tutorials</td><td>4 h</td></tr>
<tr><td>Labs</td><td>8 h</td></tr>
<tr><td>Exam</td><td>2 h</td></tr>
<tr><td>Total</td><td>32 h</td></tr>
<tr><td colspan="2">Instructor</td><td>Guy LEBRET - guy.lebret@ec-nantes.fr
Franck PLESTAN - franck.plestan@ec-nantes.fr</td></tr>
<tr><td colspan="2">Objectives</td><td>At the end of the course (30 hours + personal work) the students will be able to have basic skills on the analysis and the control of linear and non-linear systems with the state approach.</td></tr>
<tr><td colspan="2">Content</td><td>Part 1: Linear systems
• Systems analysis (commandability, observability)
• Controllers synthetizes (state feedback, observers, output feedback)
• Lab1: Inverse pendulum stabilization with linear controller
Part 2: Nonlinear systems
• Systems analysis (accessibility, observability)
• Controllers synthetizes (input-output linearization, robust control)
• Lab2: Inverse pendulum stabilization with nonlinear controller</td></tr>
</table>

RESEARCH METHODOLOGY		
Credits	4 ECTS	**Semester 1** **ECN**
Lectures	8 h	
Tutorials	10 h	
Labs	12 h	
Exam	2 h	
Total	32 h	
Instructor		Mohamed Assaad HAMIDA – mohamed.hamida@ec-nantes.fr
Objectives		• Understand research terminology. • Know the researcher qualities. • Describe quantitative, qualitative and mixed methods approaches to research. • Prepare bibliographic research.
Content		Digital ID of researchers Qualitatives research methods Literature review: • Systematic literature review • Content analysis • Citation bibliography management Scientific writing • Foundation of scientific writing • Structured scientific writing • Writing a research proposal • Writing a journal paper

<table>
<tr><th colspan="3">EMBEDDED COMPUTING</th></tr>
<tr><td>Credits</td><td>4 ECTS</td><td rowspan="6">Semester 1
ECN</td></tr>
<tr><td>Lectures</td><td>12 h</td></tr>
<tr><td>Tutorials</td><td>4 h</td></tr>
<tr><td>Labs</td><td>16 h</td></tr>
<tr><td>Exam</td><td>2 h</td></tr>
<tr><td>Total</td><td>34 h</td></tr>
<tr><td colspan="2">Instructor</td><td>Mickaël HILAIRET - mickael.hilairet@ec-nantes.fr</td></tr>
<tr><td colspan="2">Objectives</td><td>At the end of the course the students will be able to:
understand the architecture of a microcontroller;
design a low-level driver to access to a peripheral of a microcontroller and deal with microcontroller interrupts ;
design a bare metal application</td></tr>
<tr><td colspan="2">Content</td><td>The first part deals with the software environment for deeply embedded systems:
cross compiler: bit operations, memory model, common C design rules, low level C and assembly specific attributes
link script to declare the memory model to the application
debugging with a JTAG probe (breakpoints, memory watch, …)
The second part introduces hardware peripherals of a microcontroller to interact with the environment:
standard GPIO
timers + PWM
serial communication peripherals
interrupts
The third part of the module focuses on the design of applications and pilots, including concurrent execution of both software and hardware parts.</td></tr>
</table>

STATISTICAL SIGNAL PROCESSING AND ESTIMATION THEORY		
Credits	4 ECTS	**Semester 1** **ECN**
Lectures	12 h	
Tutorials	10 h	
Labs	8 h	
Exam	2 h	
Total	32 h	
Instructor		Eric LE CARPENTIER - eric.le-carpentier@ec-nantes.fr
Objectives		This course addresses the characterization and the processing of random signals by means of statistical tools. It provides the theoretical foundations used in practical problems to estimate a quantity of interest and to retrieve sought information. At the end of the course the students will be able to: • Provide a statistical description of a random process • Solve a statistical estimation problem in a practical situation • Derive a numerical algorithm to calculate and to characterize the solution • Introduction to Kalman filter
Content		• Probability theory: random vectors, density, mean, variance. • Time analysis, frequency analysis: random signals, autocorrelation, power spectral density. • Classical estimation Theory, Bayesian estimation: maximum likelihood (ML) estimation, minimum mean square error (MMSE) estimator, maximum a posteriori (MAP) estimator, linear minimum mean square error (LMMSE). • Markov chains, Markov processes • Statistical filtering: from Bayes filter to Kalman filter

<table>
<tr><th colspan="3">FUNDAMENTAL OF ELECTRIC VEHICLE SYSTEMS</th></tr>
<tr><td>Credits</td><td>4 ECTS</td><td rowspan="6">Semester 1
ECN</td></tr>
<tr><td>Lectures</td><td>18 h</td></tr>
<tr><td>Tutorials</td><td>4 h</td></tr>
<tr><td>Practical</td><td>8 h</td></tr>
<tr><td>Exam</td><td>2 h</td></tr>
<tr><td>Total</td><td>32 h</td></tr>
<tr><td colspan="2">Instructor</td><td>Malek GHANES - malek.ghanes@ec-nantes.fr</td></tr>
<tr><td colspan="2">Objectives</td><td>At the end of the course the students will be able to:
• Policy ambitions and policy instruments for electric mobility
• Role of electric vehicles (EV) and hybrid electric vehicles (HEV) in the energy transition
• EV/HEV architectures topologies
• Different components of EV system</td></tr>
<tr><td colspan="2">Content</td><td>• Electrified vehicle systems: history, environmental and economic impacts
• Architectures, Topologies of EV (and HEV)
• Power Electronics: Components and Converters
• Electrical Machines for EV and HEV
• Energy Storage system for EV and HEV
• Demonstration of electric vehicle propulsion chain</td></tr>
</table>

Electric and hydrogen vehicle modelling and simulation		
Credits	4 ECTS	**Semester 1** **ECN**
Lectures	18 h	
Practical	4 h	
Labs	8 h	
Exam	2 h	
Total	32 h	
Instructor		Malek GHANES - malek.ghanes@ec-nantes.fr
Objectives		At the end of the course the students will be able to: • Modeling and simulation of electric vehicle components • Models for electric vehicles • Design of electric vehicle model and simulator on Matlab-Simulink. • Design of electric vehicle model and simulator on industrial tool AMESIM
Content		Electric and hydrogen vehicles will be studied and simulated using advanced powertrain component analysis and modeling. An in-depth analysis and study of power flows, losses, and energy usage are examined for isolated powertrain components and HEV configurations. Simulation tools will be developed and applied to specify powertrain and vehicle components and to develop control and calibration for a constrained optimization to vehicle technical specifications. • Brief recall on Different EV components • Introduction to the electric vehicle components modelling • View of energy flows • Computerized simulation of electric vehicle propulsion system using Matlab/Simulink • Introduction to industrial simulation tool AMESIM • Electric vehicle propulsion chain simulation using AMESIM

<table>
<tr><th colspan="3">FRENCH LANGUAGE COURSES</th></tr>
<tr><td>Credits</td><td>3 ECTS</td><td rowspan="3">Semester 1
ECN</td></tr>
<tr><td>Lectures</td><td>30 h</td></tr>
<tr><td>Total</td><td>32 h</td></tr>
<tr><td colspan="2">Instructor</td><td>Silvia ERTL - silvia.ertl@ec-nantes.fr</td></tr>
<tr><td colspan="2">Objectives</td><td>The objective is to familiarize the learner with the French language and French culture through an entertaining task-based communicative language teaching, focused on speaking combined with:
Phonetics
Self-correcting exercises on our learning platform
Learning Lab activities
Project work
Tutoring</td></tr>
<tr><td colspan="2">Content</td><td>Full range of practical communication language exercises: reading comprehension, listening comprehension, written expression, oral expression.
Learners will be able to use the foreign language in a simple way for the following purposes:
Giving and obtaining factual information:
personal information (e.g. name, address, place of origin, date of birth, education, occupation)
non-personal information (e.g. about places and how to get there, time of day, various facilities and services, rules and regulations, opening hours, where and what to eat, etc.)
Establishing and maintaining social and professional contacts, particularly:
meeting people and making acquaintances
extending invitations and reacting to being invited proposing/arranging a course of action
exchanging information, views, feelings, wishes, concerning matters of common interest, particularly those relating to personal life and circumstances, living conditions and environment, educational/occupational activities and interests, leisure activities and social life
Carrying out certain transactions:
making arrangements (planning, tickets, reservations, etc.) for travel, accommodation, appointments, leisure activities
making purchases
ordering food and drink</td></tr>
</table>

ANNEX 2 - SYLLABUS SEMESTER 2

SEMESTER 2 - UNSTPB

POWER ELECTRONIC CONVERTERS		
Credits	5 ECTS	**Semester 2** **UNSTPB**
Lectures	28 h	
Labs	14 h	
Exam	2 h	
Total	44 h	
Instructor		Associate Professor Adriana FLORESCU
Objectives		To develop the knowledge and the abilities in the interdisciplinary domain of processing the electric power, with applications in communications, IT, industry, medicine etc.
Content		• Introduction in modern electric power conversion: circuit structure and application fields. • Electric power converters structure and functions: optimized structures. • Frequency and time analysis of switching topologies. • CA - CC, CA - CA, CC - CA and CC - CC converters used in electric vehicles. • Digital elements in power electronics. • Control in power electronic converters; microsystems implementation in electric vehicles

ELECTRICAL MACHINES		
Credits	5 ECTS	**Semester 2** **UNSTPB**
Lectures	14 h	
Tutorials	6 h	
Labs	8 h	
Exam	2 h	
Total	30 h	
Instructor		Prof. dr. Ing. Tiberiu TUDORACHE
Objectives		To understand and to learn electrical machines and transformers notions and their use in electrical vehicle propulsion: principles of operation, symbols, mathematical equations, characteristic variables
Content		• Electrical transformer. Transformer construction. Rated data and symbols. Theory and equations of single-phase transformer. Electric diagrams and phasor diagrams. Transformer power balance and efficiency. Operation characteristics of electrical transformers. Three-phase transformers. • DC machine. Construction of DC machine. Rated data and symbols. Magnetic fields in a DC machine. Theory and equations of DC generators and motors. Electromagnetic torque and power. Power balance and efficiency of DC machines. Operation characteristics of DC machines. Starting, braking and speed control methods of DC motors. Special DC motors. • Induction machine. Construction of induction machine. Rated data and symbols. Rotating magnetic fields and synchronous speed. Theory and equations of induction motor. Electric diagram and phasors diagram. Mechanical torque and power. Electromagnetic torque. Power balance of induction motor. Operation characteristics of induction motors. Kloss formula. Starting, braking and speed control methods of induction motors. • Synchronous machine. Construction of synchronous machine. Rated data and symbols. Theory of synchronous machine. Equations, electric diagrams and phasors diagrams of synchronous machine. Operation characteristics of synchronous machines. Special synchronous machines.

<table>
<tr><th colspan="3">RENEWABLE ENERGY AND STORAGE SYSTEMS</th></tr>
<tr><td>Credits</td><td>5 ECTS</td><td rowspan="5">Semester 2
UNSTPB</td></tr>
<tr><td>Lectures</td><td>14 h</td></tr>
<tr><td>Labs</td><td>12 h</td></tr>
<tr><td>Exam</td><td>2 h</td></tr>
<tr><td>Total</td><td>28 h</td></tr>
<tr><td colspan="2">Instructor</td><td>Prof. dr. Eng. Adriana FLORESCU</td></tr>
<tr><td colspan="2">Objectives</td><td>The initiation in the interesting, useful and dynamic reality of unconventional energy sources. Presentation of the main types of power electronic converters used in solar, eolian and fuel cells systems. Accustoming students with the performance parameters specific to the power electronic converters used in some of the unconvention power conversion systems.</td></tr>
<tr><td colspan="2">Content</td><td>1. Introduction in renewable energy sources
• Types of renewable energy sources and their dynamics
• Basic structers and functioning principles of renewable energy sources
• The components of solar, eolian and fuel cells systems
2. Converter topologies used in photovoltaic systems
• Single-phase converter topologies for photovoltaic systems
• Three-phase converter topologies for photovoltaic systems
3. Converter topologies for eolian systems
• Single level converter topologies for eolian systems
• Multi-level converter topologies for eolian systems
4. Converter topologies used in hydrogen fuel cells
• Voltage source inverters
• Current source inverters
• Z inverter
• Multilevel converter for hydrogen fuel cells systems
• Modular DC-DC converters for modular fuel cells
• Converter systems for medium power fuel cells systems
5. Grid synchronization of single-phase and three-phase converters
6. Dedicated systems used in the command and control of the converters
7. International reglemantation regarding renewable energy sources electronics</td></tr>
</table>

NON LINEAR CONTROL SYSTEMS		
Credits	5 ECTS	**Semester 2** **UNSTPB**
Lectures		
Practical		
Exam		
Total		
Instructor		Prof. dr. Ing. Ciprian LUPU
Objectives		Comprehensive analysis and synthesis of linear analogical control systems. Control systems and their constituent parts analysis by means of transfer functions and state variables. Knowledge of control system performance in time and frequency. Familiarizing students with simple control system design. Description of basic control system constituents: transducers, signal conditioners, controllers
Content		• Introduction: Classical control structures. • Processes and phenomena nonlinearities analysis: nonlinearities in continuous processes, nonlinearities in mechanic and electrical processes, nonlinearities determined by hardware and software implementations. • Real time hardware and software architectures for for electric mobile systems. • Multimodel systems: multimodel structures; Optimum number of models/algorithms determination; selecting the best model/algorithm; multimodel system stability. • Internal model systems: internal model structures; internal model structures specific problems;internal model construction;control algoritm design. • Adaptive systems: adaptive structures; adaptive structures specific problems. Control design; stability. • Multivariable process driving: control loop coupling and decoupling; implementing solutions.

<table>
<tr><th colspan="3">MACHINE LEARNING FOR AUTONOMOUS SYSTEMS</th></tr>
<tr><td>Credits</td><td>5 ECTS</td><td rowspan="5">Semester 2
UNSTPB</td></tr>
<tr><td>Lectures</td><td>28 h</td></tr>
<tr><td>Labs</td><td>14 h</td></tr>
<tr><td>Exam</td><td>4 h</td></tr>
<tr><td>Total</td><td>46 h</td></tr>
<tr><td colspan="2">Instructor</td><td>Prof. dr. Ing. Anamaria RADOI - anamaria.radoi@upb.ro</td></tr>
<tr><td colspan="2">Objectives</td><td>The main objective is to understand the fundamental concepts related to machine learning, to learn and to use the main methods of classification, clusterization and neural networks. This course combines fundamental aspects from the Machine Learning domain with practical aspects that can be encountered in autonomous systems. The activities performed during the semester familiarize the students with the basic theoretical and applicative aspects that allow solving problems that require knowledge in the field of artificial intelligence</td></tr>
<tr><td colspan="2">Content</td><td>1. Introduction to Machine Learning
2. Probability theory and information theory:
• Probability densities
• Expectations and covariances
• Gaussian distribution
• Binary random variables
• Multimodal random variables
• Entropy
• Mutual information
3. Decision theory:
• Bayes rule
• Cost functions
• Minimizing the expected loss
• Decision
• Inference
• Regression
4. Estimation
• Maximum aposteriori estimation
• Maximum likelihood estimation
5. Clustering
• K-means
• Gaussian Mixture Models
• Hierarchical clustering
6. Unsupervised classification
• K-Nearest Neighbors
7. Support Vector Machines
8. Artificial Neural Networks
• Feed-forward neural network
• Gradient descent optimization
• Error backpropagation
9. Convolutional Neural Networks</td></tr>
</table>

ROMANIAN CULTURE, CIVILIZATION AND LANGUAGE		
Credits	5 ECTS	**Semester 2** **UNSTPB**
Lectures	6 h	
Labs	6 h	
Exam	2 h	
Total	14 h	
Instructor		Yolanda-Mirela CATELLY – yolandamirelacatelly@yahoo.com
Objectives		To ensure trainees' access to comprehensive yet general information on the Romanian culture and civilization. To enable them to reach level A2 – CEFR in terms of Romanian language competences. To develop students' further autonomous learning strategies and skills in the field of Romanian culture, civilization and language.
Content		• A brief introduction into the Romanian culture, civilization and language - General aspects: geography, history, economy, tourism, arts, main Romanian personalities; first language 'pill': essential information on the Romanian alphabet, pronunciation of letters, vocabulary for survival. • Cultural Stereotypes - What is your own nationality stereotype? To what extent do you think there are nationality types? Critical incidents; aspects connected with the topic of multiculturalism; additional language pill – survival kit. Applications: tasks to discuss and compare approaches to multicultural groups; understanding and developing tolerance and an open-mindedness towards diversity and variety; presenting critical incidents from the trainees' own experience • The Seven Arts In Romania – A Discussion Of Culture And Civilization - architecture, sculpture, painting, music, poetry, dance, theater/cinema. Applications: students are asked to react to music and paintings, to solve quizzes about main Romanian cultural personalities, language linked to the cultural topics • Economy of Romania - General; History; Free market transition; Natural resources; Energy; Physical infrastructure; Agriculture; Industry; Services; Foreign trade. Miscellaneous data on: Telecommunications; Social welfare; Science and technology; Education; Healthcare; Media; Sports. Some rankings of Romania. Applications: end-of-course comparative discussion with students about the situation in their own countries, as well as in the countries they also studied in within the project; language activities – for each subsection of the course input, essential words are given and practice is organized based on them • An invitation to visit Romania – main touristic sights - general information about touristic Romania - links, other sources; advisable itineraries around Romania; maps and other information; suggested itineraries and sights; tourism language in pills on: hotel, money, transport by car/air/train etc.; important signs and notes; Language - days of the week; months of the year. Applications: students are invited to share from their own experience in Romania; express their preferences and interests so that to receive more information about them; 10-question final quiz to check attention and capacity of retention of information from course 5 • The Significance of the National Day of Romania: history, echoes etc. National Anthem – presentation of 1918 events; revision of Romanian language. Applications: revision of language knowledge • End-of-course test - four sections: Romanian language knowledge; Romanian language in use; Romanian culture and civilization; Romanian memories. End-of- Course Evaluation Sheet

SEMESTER 2 - CAU

DESIGN OF POWER ELECTRONICS CONVERTERS		
Credits	5 ECTS	**Semester 2 CAU**
Lectures	30 h	
Exercises	22.5 h	
Exam	Not specified	
Total	52.5 h	
Instructor		Prof. Dr.-Ing. Marco LISERRE
Objectives		The students have an in-depth knowledge in the design process of power electronics converters characterized by high efficiency and high reliability. The students have developed a working understanding about how to handle the electrical energy conversions in applications ranging from power supplies to renewable energies and electric drives. The students focus on power converters based on Pulse Width Modulation, and are able to design the power converter starting from the components (mainly semiconductors, passive elements and cooling system) toward the choice of the proper topology and consequently the selection of the modulation strategy.
Content		The course is a basic course for developing a career in power electronics. The current drivers in power electronics design are efficiency, reliability and cost. Reliability has become only recently one of the main topics in power electronics and it is expected to be a major player in future years, due to the growing use of power electronics and the consequent safety concerns. Furthermore reliability affects deeply the cost of the system because of the cost of maintenance. Both reliability and efficiency depend on the management of the temperature, hence thermal models are very important. The topologies of PWM converters and the modulation have a deep impact on efficiency and reliability as well as on the power quality. Topics overview: • Design of a power electronics converter (semiconductors and drivers, soft and hard switching, busbar design, EMC problems and remedies, thermal model) • Topologies of PWM power converters (dc/dc, dc/ac, ac/ac): single-cell and multi-cell converters, matrix converters etc. • PWM modulation (single-phase, three-phase, space-vector, multilevel, interleaving, continuous/dis- continuous, optimized)

<table>
<tr><th colspan="3">ELECTRIC DRIVES FOR EVs</th></tr>
<tr><td>Credits</td><td>5 ECTS</td><td rowspan="5">Semester 2
CAU</td></tr>
<tr><td>Lectures</td><td>30 h</td></tr>
<tr><td>Exercises</td><td>22.5 h</td></tr>
<tr><td>Exam</td><td>Not specified</td></tr>
<tr><td>Total</td><td>52,5 h</td></tr>
<tr><td colspan="2">Instructor</td><td>Prof. Dr.-Ing. Marco LISERRE</td></tr>
<tr><td colspan="2">Objectives</td><td>The students have in-depth understanding on the control of electric drives. The students can formulate the dynamical model of the most adopted electrical machines in electric drives, and consequently choice the design of their controllers. The students have developed experience in the control design of electrical machines through simulation software, like Matlab, and have validated the control strategies in Simulink environment.</td></tr>
<tr><td colspan="2">Content</td><td>Electric drives are a key technology for reducing energy consumption of industrial processes, for modern wind energy power generation and for enabling green-transportation (electric and hybrid vehicles, electric trains, more electric ships and airplanes). Moreover electric drives are starting to be widespread making easier everyday life with automation and robotics. The course starts from a deep modeling phase of ac electrical machines, nowadays the most used. Then the field oriented control of the asynchronous and synchro- nous (Permanent Magnet) machines are treated in details due to their wide use and importance in modern electric drives. Exercises are carried out with CAE-tools (Matlab/Simulink).

Topics overview:
Space vector representation of electrical machines
Dynamic model of the synchronous machine
Dynamic model of the asynchronous machine
Overview of PWM modulation
Overview of current control techniques
Vector control of the permanent magnet synchronous machine: Current control loop and speed control loop
Vector control of the asynchronous machine: Flux observer</td></tr>
</table>

<table>
<tr><th colspan="3">RENEWABLE ENERGY SYSTEMS</th></tr>
<tr><td>Credits</td><td>5 ECTS</td><td rowspan="5">Semester 2
CAU</td></tr>
<tr><td>Lectures</td><td>30 h</td></tr>
<tr><td>Exercises</td><td>22.5 h</td></tr>
<tr><td>Exam</td><td>Not specified</td></tr>
<tr><td>Total</td><td>52.5 h</td></tr>
<tr><td colspan="2">Instructor</td><td>Prof. Dr.-Ing. Marco LISERRE</td></tr>
<tr><td colspan="2">Objectives</td><td>The students have a general knowledge about how renewable energy systems (especially Wind and Photo- voltaic) work, how they are structured and how they are organized in parks. The students understand the issues related to the interaction with the electric grid, and they are able to analyze national grid codes and international standards compliance, mostly regarding faults and islanding conditions regulations. The students can generally discuss on advanced topics related to ancillary services, use of storage, micro-grid operation, Combined Heat and Power plants, Bio-gas and special connection using High Voltage DC Transmission.</td></tr>
<tr><td colspan="2">Content</td><td>Due to the increasing energy demand especially in emerging countries, and environmental concerns, the penetration of renewable energies and distributed electric power generation is changing the face of the power system. The course covers those aspects that do not imply a deep knowledge of power electronics converters but that are anyway crucial for their proper design.

Topics overview:
Basic principles of wind and photovoltaic
PV-system design and control procedure
WT-system design and control procedure
Islanding
Microgrid
HVDC
Biomass & Bio CHP plant & Geothermal plants
Energy storage systems basics & Modelling and economic analysis
E-mobility and smart grid: Basics</td></tr>
</table>

NON LINEAR CONTROL SYSTEMS		
Credits	5 ECTS	**Semester 2** **CAU**
Lectures	45 h	
Exercises	15 h	
Exam	Not specified	
Total	60 h	
Instructor		
Objectives		The students have an in-depth understanding of nonlinear control systems. They understand the underlying differential geometric concepts and are able to apply these to new problems. The students are able to analyze control theoretic properties. They have a comprehensive understanding of the nonlinear control design methods and are able to independently apply these methods to nonlinear control problems.
Content		• Introduction to the dynamic analysis of nonlinear systems • Lyapunov theory and Lyapunov-based design methods • Differential geometric basics and methods • Exact input-output linearization and exact input-state linearization • Differential flatness • Computer-algebra-systems in control design

<table>
<tr><th colspan="3">BATTERY CELL ENGINEERING (Option)</th></tr>
<tr><td>Credits</td><td>5 ECTS</td><td rowspan="5">Semester 2
CAU</td></tr>
<tr><td>Lectures</td><td>30 h</td></tr>
<tr><td>Exercises</td><td>15 h</td></tr>
<tr><td>Exam</td><td>Not specified</td></tr>
<tr><td>Total</td><td>45 h</td></tr>
<tr><td colspan="2">Instructor</td><td>Prof. Dr.-Ing. Marco LISERRE</td></tr>
<tr><td colspan="2">Objectives</td><td>Students will gain in-depth knowledge of conventional and advanced lithium-ion battery materials and their design optimization. Students will develop a deep understanding of the electrochemical cell, its testing and characterization, modeling and state estimation.</td></tr>
<tr><td colspan="2">Content</td><td>Lithium-ion batteries are changing the face of energy systems and electromobility. They are electrochemical systems that need to be further developed in terms of energy density, safety and lifetime. The importance of these parameters varies depending on the application. To overcome these challenges, a comprehensive understanding of electrochemical cells is essential. This includes studying and characterizing the conventional battery electrodes, electrolyte and separator at micro-scale and identifying the most important factors affecting energy density, safety and lifetime. Mathematical modeling and state estimation techniques are used to further improve battery performance.

Topics overview:
Application-specific battery design
Battery cell production
Battery cell characterization
Next generation batteries
Battery Parameter Identification
Battery Modeling
State-Estimation</td></tr>
</table>

DESIGN of DC/DC Converters (Option)		
Credits	5 ECTS	**Semester 2** **CAU**
Lectures	30 h	
Exercises	22.5 h	
Exam	Not specified	
Total	55.2 h	
Instructor		Prof. Dr. Nadia TAN
Objectives		Power electronics is the key enabling technology for sustainable electrification of transportation. With many renewable energy sources such as solar Photovoltaic and fuel cells and energy storage devices such as batteries and ultracapacitors providing dc output power, dc-dc converters are essential for efficient conversion and conditioning of dc power to be supplied to dc loads or ac loads with ac-dc converters. Therefore, this course provides a comprehensive content that enables students to understand the selection of semiconductor devices, design magnetic components, and appreciate the theoretical and practical aspects of design and modulation of non-non-isolated and isolated dc-dc-converters. Topics Overview: • Design of DC-DC converters (semiconductors and drivers, magnetic components, soft and hard switching) • Topologies of DC-DC converters (non-isolated and isolated, unidirectional and bidirectional, resonant) • Modulation (continuous/discontinuous, optimized)
Content		By the end of this course, student will be able to: • Appreciate the differences in Si, SiC and GaN devices • Design magnetic components such as inductors and transformers • Understand the principles of operation and design non-isolated and isolated dc-dc converters • Appreciate the practical considerations in designing dc-dc converters

APPLIED NONLINEAR DYNAMICS (Option)		
Credits	5 ECTS	**Semester 2** **CAU**
Lectures	30 h	
Tutorials	15 h	
Exam	Not specified	
Total	45 h	
Instructor		
Objectives		The students are able to explain fundamental system properties using terminology from linear and nonlinear system analysis. They can analyze the stability properties and existence conditions for stationary and periodic solutions of dynamical systems using local and non-local approaches. The students know the differences between the basic types of bifurcations in one and two-dimensional continuous and discrete-time systems. They are able to implement basic numerical solvers for performing simulations of dynamical systems.
Content		• Linear and nonlinear dynamical systems • Qualitative behavior of vector fields • Local and non-local bifurcations • Discrete-time nonlinear systems • Introduction to deterministic chaos

CONTROL OF PDE SYSTEMS (Option)		
Credits	5 ECTS	**Semester 2** **CAU**
Lectures	30 h	
Exercises	15 h	
Exam	Not specified	
Total	45 h	
Instructor		
Objectives		The students have an in-depth understanding of control design methods for distributed parameter systems governed by partial differential equations. They understand the underlying mathematical concepts and are able to apply these to new problems. The students are able to analyze control theoretic properties for distributed parameter systems. They have a comprehensive understanding of the control design methods and are able to independently apply these methods to control problems involving partial differential equations.
Content		• Introduction to the distributed parameter systems: Mathematical modeling, classification, solution techniques for partial differential equations • Analysis and control design in frequency domain: input-output stability, output feedback control • Analysis and control design in time domain: controllability and observability, stability theory, state feedback control, backstepping • Flatness-based methods for trajectory planning and tracking control

ADVANCED METHODS IN NONLINEAR CONTROL (Option)		
Credits	5 ECTS	**Semester 2** **CAU**
Lectures	30 h	
Exercises	15 h	
Exam	Not specified	
Total	45 h	
Instructor		
Objectives		The students are able to explain the first and second method of Lyapunov and apply them for the stability analysis of nonlinear systems. They are able to decide for an appropriate control design method on the basis of the structural properties of a given system. The students can design controllers for nonlinear systems using different approaches and perform closed-loop stability analysis. They are able to implement basic numerical solvers for performing simulations of nonlinear control systems and discuss the performance of the closed-loop system.
Content		• Lyapunovs first and second method • Passivity-based control • Backstepping control • Extremun-seeking control • Sliding-mode control

SEMESTER 2 - UAQ

POWER CONVERTERS		
Credits	5 ECTS	Semester 2 UAQ
Lectures	30 h	
Tutorials	20 h	
Exam	2 h	
Total	52 h	
Instructor		Concettina BUCCELLA - concettina.buccella@univaq.it
Objectives		The course will introduce some fundamental concepts related to power electronics converters, in particular, those suitable for transportation electrification: electric power trains and recharging infrastructures.
Content		• Power devices for transportation electrification: diode, MOSFET, IGBT; silicon and wide band gap devices • DC/DC Converters for electric vehicles • AC converters for electric vehicles • Fundamental control techniques for power converters for transportation electrification • Modulation of power converters • Wired and wireless recharging systems Simulation of electric power trains and recharging systems.

<table>
<tr><th colspan="3">ELECTRICAL MACHINES AND DRIVES</th></tr>
<tr><td>Credits</td><td>5 ECTS</td><td rowspan="5">Semester 2
UAQ</td></tr>
<tr><td>Lectures</td><td>30 h</td></tr>
<tr><td>Tutorials</td><td>20 h</td></tr>
<tr><td>Exam</td><td>2 h</td></tr>
<tr><td>Total</td><td>52 h</td></tr>
<tr><td colspan="2">Instructor</td><td>Carlo CECATI - carlo.cecati@univaq.it</td></tr>
<tr><td colspan="2">Objectives</td><td>The course will introduce some basic concepts related to modeling, analysis, simulation and control of electric machines and their operations in electric vehicles. The interaction between the electric machine and the power converter will also be highlighted.</td></tr>
<tr><td colspan="2">Content</td><td>Principles of electro-mechanical energy conversion
DC machines and their static and dynamic models
Rotating magnetic field and AC machines
Induction motors, permanent magnets synchronous motors
Static and dynamic models of AC machines
Scalar and vector control of AC machines
Sensorless control of AC machines
Power converters for electric power trains and their interaction with the electrical machine.</td></tr>
</table>

RENEWABLE POWER ENERGY AND STORAGE SYSTEMS		
Credits	5 ECTS	**Semester 2** **UAQ**
Lectures	30 h	
Tutorials	20 h	
Exam	2 h	
Total	52 h	
Instructor		Carlo CECATI - carlo.cecati@univaq.it
Objectives		The course will introduce some basic concepts related to generation of electric energy from sun, wind and hydro and their conversion in forms suitable for utilization in electric vehicles and in storage systems. The interaction between the electric powertrain and the battery energy storage system will also be highlighted.
Content		• Principles of photovoltaic energy systems and their operations • Principles of wind and hydro energy systems and their operations • Principles of Fuel Cells and their operations • Maximum Power Point Tracking and optimization of energy conversion • Principles of electrochemical conversion and control • Power converters for Renewable Energy Systems and for Battery Management Systems • Integration of energy storage systems with the grid.

NONLINEAR CONTROL SYSTEMS		
Credits	5 ECTS	**Semester 2** **UAQ**
Lectures	40 h	
Tutorials	20 h	
Exam	2 h	
Total	62 h	
Instructor		Stefano DI GENNARO - stefano.digennaro@univaq.it
Objectives		The aim of the course is to provide the student with knowledge of the fundamental properties of nonlinear systems and on some design techniques of controllers, and with skills in designing such controllers some relevant classes of such systems. On successful completion of this module, the student will be able to design controllers for the stabilization of nonlinear systems and for the tracking of desired trajectories.
Content		Introduction to nonlinear systems and examples. Fundamental properties: Existence and uniqueness, continuous dependence on initial conditions and parameters. Differentiability of solutions and sensitivity equations. Comparison principle. Lyapunov stability of autonomous and nonautonomous systems. The invariance principle. Linear systems and linearization. Center manifold theorem. Converse theorems. Perturbed systems and ultimate boundedness. Input-to-state stability. Some design techniques: regulation theory (introduction), stabilization via linearization, backstepping, sliding mode control.

Compulsory elective module (choice of 1 out of 2)		
Credits	5 ECTS	**Semester 2** **UAQ**
Lectures	40 h	
Tutorials	20 h	
Exam	2 h	
Total	62 h	
Instructor		Maria Domenica DI BENEDETTO - mariadomenica.dibenedetto@univaq.it
Objectives		The course is intended to provide students with fundamental knowledge about modeling, control and simulation of complex systems. In the first part of the course, networked multi-agent systems are introduced and analyzed. In the second part, hybrid systems are considered, and their specific properties investigated. At the end of the course, the student will be able to model complex systems and master the tools for control design based on consensus techniques, and controller synthesis with stability requirements and logic specifications.
Content		Hybrid systems models and their use in the design of control systems, with particular emphasis on cyber-physical distributed systems. • Modeling: Finite state automata, transition systems, timed automata, hybrid automata, switching systems, hybrid systems. Safety properties, liveness, deadlocks. • Stability of switching systems. • Analysis and Control: Reachability and safety problems. Simulations and bisimulations. • Abstractions and verification by abstraction. • Observability of hybrid systems and hybrid observers. • Security problems and resilience properties with respect to malicious attacks. • Symbolic models and formal methods for control and verification. • Simulations tools for hybrid systems. • Applications: autonomous driving, control of electric vehicles, micro-grids.

SEMESTER 2 - CINVESTAV

<table>
<tr><th colspan="3">POWER CONVERTERS</th></tr>
<tr><td>Credits</td><td>5 ECTS</td><td rowspan="5">Semester 2
CINVESTAV</td></tr>
<tr><td>Lectures</td><td>60 h</td></tr>
<tr><td>Tutorials</td><td>4 h</td></tr>
<tr><td>Exam</td><td>4 h</td></tr>
<tr><td>Total</td><td>68 h</td></tr>
<tr><td colspan="2">Instructor</td><td></td></tr>
<tr><td colspan="2">Objectives</td><td>The objective of this course is to provide students with a comprehensive understanding of power electronic converters, their operation, design principles, and applications in modern electrical systems. By the end of this course, students will be able to:

1. Understand the Fundamentals of Power Conversion
2. Analyze and Design DC-DC Converters
3. Examine AC-DC and DC-AC Conversion Techniques
4. Explore AC-AC Conversion and Soft Switching Techniques
5. Implement Control Strategies for Power Converters
6. Apply Power Converters in Real-World Systems

By completing this course, students will gain the theoretical knowledge and practical skills necessary to design, analyze, and implement power converter circuits for industrial, renewable energy, and transportation applications.</td></tr>
<tr><td colspan="2">Content</td><td>1. Introduction to Power Electronics & Converters
• Importance and applications of power converters
• Basic concepts of power electronics
• Overview of power semiconductor devices (MOSFETs, IGBTs, Thyristors)
2. DC-DC Converters
• Buck, Boost, and Buck-Boost converters
• Cuk and SEPIC converters
• Isolated DC-DC converters (Flyback, Forward, Push-Pull, Half-Bridge, Full-Bridge)
• Converter efficiency and performance analysis
3. AC-DC Converters (Rectifiers)
• Uncontrolled rectifiers (Diode-based)
• Controlled rectifiers (Thyristor-based)
• Power Factor Correction (PFC) techniques
• Harmonic analysis and reduction
4. DC-AC Converters (Inverters)
• Single-phase and three-phase inverters
• Sinusoidal Pulse Width Modulation (SPWM)
• Space Vector Pulse Width Modulation (SVPWM)
• Multi-level inverters and their applications
5. AC-AC Converters
• Cycloconverters
• Matrix converters</td></tr>
</table>

	• Voltage and frequency control techniques 6. Soft Switching Techniques • Zero Voltage Switching (ZVS) • Zero Current Switching (ZCS) • Resonant converters 7. Control of Power Converters • Closed-loop control techniques (PI, PID, Sliding Mode Control) • Digital control of converters • Voltage-mode and current-mode control 8. Applications of Power Converters • Power supplies (Switched-mode power supplies - SMPS) • Renewable energy systems (Solar PV inverters, Wind power converters) • Electric vehicle (EV) drive systems • Industrial motor drives 9. Protection & Reliability of Power Converters • Overvoltage and overcurrent protection • Thermal management and cooling techniques • Electromagnetic interference (EMI) and filtering

Electrical machines and drives		
Credits	5 ECTS	**Semester 2** **CINVESTAV**
Lectures	60 h	
Tutorials	4 h	
Exam	4 h	
Total	68 h	
Instructor		
Objectives		The objective of this course is to provide students with a **fundamental understanding of electrical machines and their control in drive systems**. By the end of this course, students will be able to: 1. **Understand the working principles of electrical machines**, including DC and AC machines. 2. **Analyze and model electrical machines**, considering their performance characteristics and equivalent circuits. 3. **Explore power electronic converters** used for machine control. 4. **Develop control strategies** for motor drives, including scalar and vector control techniques. 5. **Apply electrical machines in real-world applications**, such as industrial automation, electric vehicles, and renewable energy systems.
Content		**Module 1: Fundamentals of Electrical Machines** • Magnetic circuits and electromagnetic principles • Energy conversion principles • Losses and efficiency in electrical machines **Module 2: DC Machines**

	• Construction and working principles • Types of DC motors and generators • Speed-torque characteristics • Control of DC motors (armature and field control) • Applications of DC motors **Module 3: Transformers** • Construction and working principles • Equivalent circuit and phasor diagrams • Efficiency and regulation • Auto-transformers and three-phase transformers **Module 4: Induction Machines** • Construction and operating principles • Equivalent circuit and torque-speed characteristics • Starting and speed control of induction motors • Efficiency and performance evaluation • Applications of induction motors in industry **Module 5: Synchronous Machines** • Synchronous generators and motors • Equivalent circuit and phasor diagrams • Power factor control and efficiency • Synchronization and applications in power systems **Module 6: Power Electronics for Electrical Drives** • Introduction to power converters (rectifiers, inverters, choppers) • PWM techniques for motor drives • Regenerative braking and energy recovery **Module 7: Control of Electric Drives** • Open-loop vs closed-loop control • Scalar control (V/f control) • Vector control (field-oriented control, direct torque control) • Digital control and microcontroller-based motor control **Module 8: Special Machines and Applications** • Stepper motors and servo motors • Brushless DC motors (BLDC) and permanent magnet synchronous motors (PMSM) • Applications in electric vehicles, robotics, and renewable energy systems **Module 9: Case Studies and Practical Implementations** • Industrial automation with electric drives

	• Electric traction systems (railways, EVs) • Wind and solar energy applications

Renewable energy and storage systems		
Credits	5 ECTS	**Semester 2** **CINVESTAV**
Lectures	60 h	
Tutorials	4 h	
Exam	4 h	
Total	68 h	
Instructor		
Objectives		It´s designed to introduce the basic concepts of energy systems considering the process of storage energy and the coupling of the generate energy to the electrical net, using the smart grids tools. The course will focus in the basic operation of solar thermal, PV systems, wind energy, hydroelectric, biomass, hydrogen, and other renewables technologies. Real cases studies of some renewable energies are considered, including some application for electromobility and the maintenance services implemented in the energy sector.
Content		Section 1: Energy and Power Basics and Overview • Definitions, units and conversions. • Fundamental types of energy: heat, chemical, radiative, potential, kinetic, nuclear. • Energy conversion: thermodynamics • Energy flows: conduction, convection, radiative, insulation. • Energy usage: electricity-heating, cooling, lighting; fuels: transportation, heat • Issues in energy systems: technical, economics, sustainability, climate change • Renewable energy sources: overview Section 2: Solar-Based Processes • Solar resource: solar models, radiation on the earth, variation of solar radiation • Solar thermal fundamentals • Solar thermal for heating (water, air), active and passive solar, heat pumps • Solar thermal for electricity: concentrating solar power, steam turbines, efficiency • Photovoltaics (PV): basic operation, technologies, modules, system components, loads, • applications, PV systems, design Section 3: Wind Systems • Wind resource: sources, global and local resources, measurement • Power from wind turbines: power curve, measured resource data • Operation of wind turbines: blades, aerodynamics, wind turbine components Section 4: Hydrogen Systems • Electrochemical, thermal, hydrogen storage, mechanical, electrical; electrochemical storage, primary and • Secondary batteries, thermodynamics and kinetics of storage, Li-ion battery, redox-flow battery, Na-S battery.

	Section 5: Bioenergy: • Biomass • Algae Section 6: Storage: • Batteries • Fuel Cells • Other storage: pumped hydro, compressed air, etc. Section 7: Grid Integration of Renewables • Electrical grid: generation, transmission, distribution, loads, EVs • Effects of renewable energy intermittencies, role of storage • Regulation and public policy • Renewable energy futures Section 8: Maintenace services of Renewables Systems • Preventive service • Predictive service • Corrective service

Nonlinear control systems		
Credits	5 ECTS	**Semester 2** **CINVESTAV**
Lectures	60 h	
Tutorials	4 h	
Exam	4 h	
Total	68 h	
Instructor		
Objectives		This course provides a comprehensive introduction to nonlinear systems, focusing on their analysis, stability, and control. Students will explore nonlinear system behavior using analytical and computational techniques, covering phase portraits, Lyapunov stability, input-output stability, and bifurcations. The course also includes applications in engineering, robotics, and control systems.
Content		Module 1: Introduction to Nonlinear Systems (5 Hours) • Differences between linear and nonlinear systems • Examples of nonlinear systems in engineering • Fundamental properties of nonlinear systems (superposition, homogeneity, etc.) Module 2: Phase Plane Analysis (7 Hours) • Phase portraits and vector fields • Equilibrium points and their classification • Limit cycles and periodic orbits • Linearization of nonlinear systems Module 3: Lyapunov Stability Theory (8 Hours) • Stability definitions (Lyapunov, asymptotic, exponential) • Direct and indirect methods of Lyapunov • Construction of Lyapunov functions • Invariance principles Module 4: Input-Output Stability and Passivity (5 Hours) • Small-gain theorem • Passivity and dissipativity concepts • Circle criterion for stability Module 5: Perturbation and Bifurcation Theory (6 Hours) • Perturbation methods (regular, singular) • Bifurcations in nonlinear systems • Hopf bifurcation and applications Module 6: Feedback Linearization and Nonlinear Control (7 Hours) • State feedback and exact linearization

	• Input-output linearization • Sliding mode control Module 7: Chaos and Nonlinear Oscillations (6 Hours) • Basics of chaotic systems • Lorenz and Rössler attractors • Nonlinear oscillators (Van der Pol, Duffing) Module 8: Applications and Case Studies (4 Hours) • Applications in robotics, power systems, • Computational tools (MATLAB, Python, Simulink) • Implementation of a nonlinear control project

Energy Quality in Power System (choice of 1 out of 2)		
Credits	5 ECTS	**Semester 2** **CINVESTAV**
Lectures	60 h	
Tutorials	4 h	
Exam	4 h	
Total	68 h	
Instructor		
Objectives		This course is designed to provide students with a comprehensive understanding of energy quality in power systems, including the analysis, measurement, and mitigation of power quality issues. The course covers a wide range of topics such as voltage sags, harmonics, transients, power factor, and flicker, along with practical approaches for improving energy quality. Upon completion, students will be equipped with the knowledge and tools to analyze and manage power quality issues in modern power systems.
Content		**Module 1: Introduction to Power Quality (5 Hours)** • Overview of power quality and its importance in electrical systems • Common power quality issues and their impact on equipment and operations • Regulatory standards and guidelines for power quality (IEEE, IEC, etc.) • Power quality monitoring techniques and equipment **Module 2: Voltage Sags and Interruptions (6 Hours)** • Definition and causes of voltage sags and interruptions • Impact of voltage sags on industrial and commercial loads • Methods for detecting and analyzing voltage sags • Mitigation techniques for voltage sags: UPS, static transfer switches, and custom power devices • **Module 3: Harmonics in Power Systems (8 Hours)** • Harmonics and their sources in power systems (non-linear loads, power electronics) • Harmonic analysis: Fourier series, THD (Total Harmonic Distortion) • Impact of harmonics on power system components (transformers, cables, motors, etc.) • Harmonic mitigation techniques: filters, active filters, and passive filters **Module 4: Transients and Surges (5 Hours)** • Definition and causes of transients and surges

	• Types of transients: impulse, oscillatory, and switching transients • Protection devices for transients: surge arresters, surge protection devices (SPDs), and filtering techniques • Transient modeling and analysis in power systems **Module 5: Power Factor and Reactive Power Compensation (6 Hours)** • Definition of power factor and its significance in power systems • Effects of low power factor on the power system (increased losses, voltage instability) • Power factor correction methods: capacitors, synchronous condensers, and static VAR compensators (SVC) • Introduction to reactive power management and its role in maintaining energy quality **Module 6: Flicker and Voltage Fluctuations (5 Hours)** • Understanding flicker and its causes in power systems • Measurement of flicker and related standards (IEC 61000-4-15) • Impact of flicker on sensitive equipment and lighting systems • Mitigation strategies for flicker: dynamic voltage regulation, flicker filters, and load management **Module 7: Quality of Supply in Distributed Generation Systems (6 Hours)** • Impact of distributed generation (DG) on power quality • Power quality challenges in renewable energy sources (solar, wind, etc.) • Integration of DG systems into the grid and their effect on energy quality • Solutions for improving the energy quality of DG systems: inverters, grid synchronization, and power management systems **Module 8: Power Quality Monitoring and Standards (5 Hours)** • Power quality monitoring equipment and software tools • Data acquisition and analysis for power quality assessment • International standards and regulations for power quality (IEEE 519, IEC 61000 series) • Case studies on power quality monitoring and compliance **Module 9: Case Studies and Applications in Power Systems (4 Hours)** • Real-world case studies of power quality issues in industrial, commercial, and residential sectors • Application of power quality improvement techniques in various industries • Design of power quality improvement solutions • Group discussions on practical challenges and solutions **Module 10: Final Project and Review (3 Hours)** • Group projects: Propose a solution to a power quality issue in a real-world scenario • Presentation and discussion of final projects • Course review and Q&A

	• Final examination

Hybrid Control Systems (choice of 1 out of 2)		
Credits	5 ECTS	**Semester 2** **CINVESTAV**
Lectures	60 h	
Tutorials	4 h	
Exam	4 h	
Total	68 h	
Instructor		
Objectives		This course aims to provide students with introductory understanding of hybrid control systems, focusing on the integration of continuous and discrete dynamics. The course will cover the theoretical foundations, methodologies, and applications of hybrid systems.
Content		**Module 1. Introduction** • The modeling framework • Examples in science and engineering • Control system examples • Connections to other modeling frameworks • Notes **Module 2. The solution concept** • Data of a hybrid system • Hybrid time domains and hybrid arcs • Solutions and their basic properties • Generators for classes of switching signals • Notes **Module 3. Uniform asymptotic stability, an initial treatment** • Uniform global pre-asymptotic stability • Lyapunov functions • Relaxed Lyapunov conditions • Stability from containment • Equivalent characterizations • Notes Module 4. Applications • Hybrid observers • Hybrid regulation

<table>
<tr><th colspan="3">Spanish language course</th></tr>
<tr><td>**Credits**</td><td>5 ECTS</td><td rowspan="5">**Semester 2**
CINVESTAV</td></tr>
<tr><td>**Lectures**</td><td>60 h</td></tr>
<tr><td>**Tutorials**</td><td>4 h</td></tr>
<tr><td>**Exam**</td><td>4 h</td></tr>
<tr><td>**Total**</td><td>68 h</td></tr>
<tr><td colspan="2">**Instructor**</td><td></td></tr>
<tr><td colspan="2">**Objectives**</td><td>This course aims to develop fundamental Spanish language skills, including speaking, listening, reading, and writing. Students will gain practical communication abilities for everyday situations, along with an introduction to Spanish-speaking cultures. The course follows a communicative approach, integrating grammar, vocabulary, and pronunciation with real-life scenarios.</td></tr>
<tr><td colspan="2">**Content**</td><td>**Module 1: Introduction to Spanish (5 Hours)**
• Spanish alphabet and pronunciation
• Basic greetings and introductions
• Numbers, dates, and time
• Formal vs. informal speech

Module 2: Basic Grammar and Sentence Structure (7 Hours)
• Nouns and gender (masculine/feminine)
• Definite and indefinite articles
• Subject pronouns
• Basic sentence structure (subject-verb-object)

Module 3: Verbs and Conjugation (8 Hours)
• Present tense of regular verbs (-AR, -ER, -IR)
• Common irregular verbs (ser, estar, tener, hacer, ir)
• Reflexive verbs
• Expressing likes and dislikes (gustar)

Module 4: Everyday Conversations (6 Hours)
• Introducing yourself and others
• Talking about hobbies and daily activities
• Asking and giving directions
• Ordering food in a restaurant

Module 5: Expanding Vocabulary and Expressions (6 Hours)
• Family and relationships
• Describing people, places, and things
• Common adjectives and adverbs
• Expressing opinions and preferences

Module 6: Past and Future Tenses (7 Hours)
• Preterite and imperfect past tenses
• Talking about past experiences
• Simple future tense and expressing plans

Module 7: Practical Communication Skills (6 Hours)
• Shopping and bargaining
• Making phone calls and appointments
• Travel-related vocabulary (airport, hotel, transportation)</td></tr>
</table>

	Module 8: Cultural Awareness and Final Project (5 Hours) • Overview of Spanish-speaking countries and cultures • Common idioms and cultural expressions • Final project: Conversational role-play or written presentation

ANNEX 3 - SYLLABUS SEMESTER 3

SEMESTER 3 - ECN - SPECIALIZATION A

Optimization, energy management of electric/hydrogen vehicle charging/refuelling		
Credits	5 ECTS	Semester 3 ECN
Lectures	12 h	
Tutorials	10 h	
Labs	8 h	
Exam	2 h	
Total	32 h	
Instructor		Raphael CHENOUARD – raphael.chenouard@ec-nantes.fr
Objectives		The lecture presents different theoretical and computational aspects of a wide range of optimization methods for solving a variety of problems in electrical vehicles. The main objective of this courses is to give the students the ability to formalise, select the appropriate method, implement the optimisation problem and then analyse the results in order to take the best decision regarding the objectives, variables and the constraints.
Content		• Basic concepts of optimization • Gradient based methods • Evolutionary algorithms • Multi objective optimization methods • Robust optimization methods • Multidisciplinary optimization problems • Programming aspects Practical Work: exercises and project on the design optimisation of energy management and vehicle charging. The students will be able to: Understand different theoretical and computational aspects of a wide range of optimization methods, use of optimization toolbox, and apply these methods in electric vehicle system.

<table>
<tr><th colspan="3">Control of power converters for electric and hydrogen propulsion systems</th></tr>
<tr><td>Credits</td><td>5 ECTS</td><td rowspan="6">Semester 3
ECN</td></tr>
<tr><td>Lectures</td><td>14 h</td></tr>
<tr><td>Tutorials</td><td>8 h</td></tr>
<tr><td>IABS</td><td>8 h</td></tr>
<tr><td>Exam</td><td>2 h</td></tr>
<tr><td>Total</td><td>32 h</td></tr>
<tr><td colspan="2">Instructor</td><td>Malek GHANES - malek.ghanes@ec-nantes.fr</td></tr>
<tr><td colspan="2">Objectives</td><td>Objectives of this course are:
• Analysis of power converters used in electric vehicle
• Power converters design
• Power converters modelling and control</td></tr>
<tr><td colspan="2">Content</td><td>This course considers the design and control of power converters in electric drive vehicles. The course includes an overview of system architectures and covers system-level dynamic modeling and control using MATLAB/Simulink at levels appropriate to determine requirements and validate the performance of switched-mode power converters in the vehicle system. Analysis, modeling and design of switched-mode power converters in electric-drive vehicle systems are then covered, including battery DC-DC converters, battery management electronics, motor drive inverters and battery chargers.
• Power converters for motor drives (DC-AC)
- Bi-directional DC-AC converter
- Sensing and digital control
• Power converters for energy storage (DC-DC converters)
- Energy storage cells, battery management system electronics
- Bi-directional DC-DC converter
- Sensing and digital control
• Power converters for battery chargers (AC-DC)
- Charger requirements
- Bi-directional AC-DC
• Control and coordination with BMS</td></tr>
</table>

<table>
<tr><th colspan="3">Observation and Diagnosis for electrical systems</th></tr>
<tr><td>Credits</td><td>5 ECTS</td><td rowspan="6">Semester 3
ECN</td></tr>
<tr><td>Lectures</td><td>12 h</td></tr>
<tr><td>Tutorials</td><td>10 h</td></tr>
<tr><td>Labs</td><td>8 h</td></tr>
<tr><td>Exam</td><td>2 h</td></tr>
<tr><td>Total</td><td>32 h</td></tr>
<tr><td colspan="2">Instructor</td><td>Malek GHANES - malek.ghanes@ec-nantes.fr</td></tr>
<tr><td colspan="2">Objectives</td><td>Measuring the state by a physical sensor of a given system may fail because sometimes the measurements are impossible and sometimes, possible, but too expensive.
That is why estimating the state of the system by means of software sensors (observers) is an important issue. The first part of this lecture investigates several methods of observer design for nonlinear systems.
Moreover, faults in sensors, actuators or process components may lead to the degradation of the overall system performance and could cause serious damage.
From this point of view, the second part of this lecture will give some basic definitions and different existing methods of diagnosis. Then, the diagnosis problem will be mainly investigated by using observers (studied in the first part) in case of fault estimation (simultaneous state and parameters estimation). Finally fault tolerant control problem is briefly studied.
Examples and labs will illustrate the well founded of these two parts in the framework of academic and real applications (mainly electric vehicles).</td></tr>
<tr><td colspan="2">Content</td><td>

Introduction to Observation and Diagnosis Problems
Observation:

Observability study
Estimation of the internal states of the system (observer-based or software sensors)
Parameter identification/estimation (observer-based or left invertibilty)
Simultaneous State and Parameter estimation, i.e. Adaptive Observation,
Estimation of unmeasured perturbations

Diagnosis:

Fault Detection and Isolation Problems
Fault Tolerant Control

Applications for electric vehicles (power converters, DC and AC machines, energy storage, …)

</td></tr>
</table>

Advanced control of electric and hydrogen propulsion systems		
Credits	5 ECTS	**Semester 3** **ECN**
Lectures	14 h	
Tutorials	8 h	
Labs	8 h	
Exam	2 h	
Total	32 h	
Instructor		Malek GHANES – malek.ghanes@ec-nantes.fr
Objectives		After having followed the course, the candidate shall have obtained thorough insight in and understanding of: • Control of nonlinear systems • Stability of nonlinear systems • Advanced controls (sliding mode, backstepping, …) • Application for electric machines • Application to energy management of EV powered by fuel cell (FC) and supecrcapcitors (SC) (or batteries).
Content		This course gives the concept of nonlinear control and their stability, focusing on advanced controls with application to electric motors and energy management for and in electric vehicle application. Initially, the introduction to nonlinear systems control and their stability will be conducted, then advanced control will be developed that will be useful in understanding the dynamic control. Advanced control techniques are applied to optimize the performance of ac motor drives and energy management of EVs. • Performances improvement of AC machines control • Sensorless control of AC machines • Enegy management of EV powered by FC and SC

<table>
<tr><th colspan="3">Case study application dedicated to electric and hydrogen vehicle topology</th></tr>
<tr><td>Credits</td><td>5 ECTS</td><td rowspan="6">Semester 3
ECN</td></tr>
<tr><td>Lectures</td><td>12 h</td></tr>
<tr><td>Labs</td><td>4 h</td></tr>
<tr><td>Project</td><td>14 h</td></tr>
<tr><td>Exam</td><td>2 h</td></tr>
<tr><td>Total</td><td>32 h</td></tr>
<tr><td colspan="2">Instructor</td><td>Malek GHANES – malek.ghanes@ec-nantes.fr</td></tr>
<tr><td colspan="2">Objectives</td><td>The aim of this course is to immerse students in concrete applications of electric mobility, through practical projects, advanced simulations and presentations by industry and academic experts.</td></tr>
<tr><td colspan="2">Content</td><td>• Rapid prototyping and experimental implementation of sensorless control for permanent magnet synchronous machines (PMSM) :
- rapid prototyping with dSPACE
- the hardware used (boards, sensors, inverters),
- bench operation

• Industrial case studies related to electric vehicles
- Present real cases of electric powertrain deployment
- Discuss challenges and innovations (hydrogen EV, …)
- Share future prospects for the sector (V2G, smart charging, materials, etc.)

• Introduction to the design of electronic control boards
- Production of control boards for three-phase and multi-phase inverters
- Integration of voltage, current and temperature sensors
- First steps towards prototyping and manufacturing printed circuit boards dedicated to electromobility

• Teaching methods
- Project-based learning
- Practical work on experimental benches
- Interactive sessions with industry professionals
- Use of MATLAB/Simulink and dSPACE</td></tr>
</table>

SEMESTER 3 - UNSTPB - SPECIALIZATION B

<table>
<tr><th colspan="3">BATTERY CHARGERS (FOR ELECTRIC VEHICLE)</th></tr>
<tr><td>Credits</td><td>4 ECTS</td><td rowspan="6">Semester 3
UNSTPB</td></tr>
<tr><td>Lectures</td><td>28 h</td></tr>
<tr><td>Tutorials</td><td>6 h</td></tr>
<tr><td>Labs</td><td>14 h</td></tr>
<tr><td>Exam</td><td>2 h</td></tr>
<tr><td>Total</td><td>50 h</td></tr>
<tr><td colspan="2">Instructor</td><td>Assist. Prof. Dr. Ing. Stefan George ROSU</td></tr>
<tr><td colspan="2">Objectives</td><td>Students attending this lecture should be able to design, implement and demonstrate the operation of a power electronic converter solution for a battery charging system in the field of electric vehicles. Knowledge about the advantages and disadvantages of different power electronics circuits including the operational characteristics should be acquired. Differences between analog and digital control along with specific practical implementations versus computer simulations should be learnt.</td></tr>
<tr><td colspan="2">Content</td><td>Automotive electronics for battery chargers
• automotive charger structures, classifications, grid interface.
Single-phase AC-DC converters with power factor correction
• operation, specific parameters, control methods
Three-phase AC-DC converters with power factor correction
• two-, multi-level or modular topologies for level 3 chargers
DC-DC converters with unidirectional and bidirectional power flow
• non-isolated conversion topologies - buck, boost
• high frequency transformer isolated conversion topologies - LLC, DAB
Wireless power transfer (WPT) battery chargers
• static and dynamic WPT battery chargers
• transmitter and receiver coils and converters
• command and control methods
Practical realization of battery chargers
• control circuits with real time microcontrollers
• interface and protection circuits
• use of new generation semiconductor devices - GaN, SiC</td></tr>
</table>

Modern communication technologies for connected EVs		
Credits	4 ECTS	**Semester 3** **UNSTPB**
Lectures	20 h	
Tutorials	6 h	
Labs	4 h	
Exam	2 h	
Total	32 h	
Instructor		Prof. Dr. Ing. Daniel OANCEA - dianel.oancea@upb.ro
Objectives		Knowledge of different energy storage methods, of its specific requirements, ensures the best technical solution in the field of electric traction. The current state, as well as the subsequent developments in the field, determines the decision of the final choice of the energy storage solution.
Content		• The need for energy storage. Energy storage methods • Mechanical energy storage • Electrochemical storage of energy • Electrical and electromagnetic storage of energy • Chemical energy storage • Requirements for sizing energy storage elements • Perspectives on energy storage elements • Final verification

Battery management systems for EVs		
Credits	4 ECTS	**Semester 3** **UNSTPB**
Lectures	26 h	
Tutorials	12 h	
Labs	14 h	
Exam	4 h	
Total	56 h	
Instructor		As. Prof. Dr. Ing. Alexandru VASILE – alexandru.vasile@cetti.ro
Objectives		This course presents the state-of-the-art in research and development of battery technologies and Battery Management Systems (BMS) used in Electric Vehicles (EV) or Energy Storage Systems (ESS). It summarizes their features in terms of performance, cost, service life, management, charging facilities, and safety.
Content		• Introduction to Energy Storage Systems. History and evolution of batteries. Actual applications: Electric Vehicles (EV), Photovoltaic (PV) systems. • Battery modelling and design. Battery chemistries. Electrochemical and electrochemical-thermal models. Performance parameters. Measuring techniques and estimation algorithms. • Battery charging methods. Constant Voltage, Constant Current and Hybrid methods. • Battery Monitoring Systems (BMS). Design and manufacturing requirements. • BMS architectures. Voltage and current measurement techniques. Passive balancing technique. Active balancing techniques. Communication protocols for data acquisition and remote control. • Case studies on different commercial BMS. • Thermal management for batteries and electronic units. • Battery recycling policies. Abilities: After completing this course the students will be able to: • understand BMS architecture and balancing techniques; • design and development of BMSs for specific battery packs; • installation and configuration of after-market BMSs on large battery packs; • understand and apply safety rules in manufacturing and maintenance of battery packs..

Retrofit, control of electrical machines		
Credits	4 ECTS	**Semester 3** **UNSTPB**
Lectures	28 h	
Tutorials	14 h	
Labs	14 h	
Exam	2 h	
Total	58 h	
Instructor		As. Prof. Dr. Ing. Bogdan Cristian FLOREA – bogdan.florea@upb.ro
Objectives		Comprehensive analysis and synthesis of linear analogical control systems. Sensorless control techniques using mathematical models and state estimation applied for electrical machine. Control systems and their constituent parts analysis by means of transfer functions and state variables. Knowledge of control system performance in time and frequency. Familiarizing students with simple control system design. Description of basic control system constituents: transducers, signal conditioners, controllers. Transitioning from sensor-based to sensorless control
Content		• Definitions • Open control systems and feedback control systems • Classification of control systems • Electrical machines • Classification of electrical machines • Electrical machines modelling • Electrical machines control techniques • Sensors for electrical machines control • Types of sensors • Sensor based control • State estimation • Controlability and observability of a system • State estimation using observers • Integrating state observers in LCCS • Sensorless control • Open loop and closed loop sensorless drives • Performance of sensorless control Abilities: After completing this course the students will be able to: • Analyse and model electrical machines • Design and implement state observers and analyse the controllability of a system Design open loop and closed loop sensorless control algorithms

Microprocessor applications for real time systems		
Credits	4 ECTS	**Semester 3** **UNSTPB**
Lectures	28 h	
Tutorials	14 h	
Labs	28 h	
Exam	4 h	
Total	74 h	
Instructor		Prof. Dr. Ing. Corneliu BURILEANU
Objectives		Students attending this course should be able to implement applications, in typical situations, of basic methods of signal acquisition and processing and implement knowledges, concepts and basic methods that refer to the computer systems, microcontrollers, programming languages and techniques
Content		1. Microcomputer Structure. Definitions 1.1. Microcomputer Functional Blocks 1.2. CISC and RISC Microprocessors 1.3. Information in Digital Systems 1.4. Conventions 2. Overview of a CISC, General Purpose Microprocessor Core 2.1. First Step Approach: Data register and Address Register 2.2. Second Step Approach: General-Purpose Registers 2.3. Third Step Approach: Arithmetic Processing Unit 2.4. Forth Step Approach: Memory Addressing Control Unit 2.5. Fifth Step Approach: Microprocessor Control Unit 2.6. Functional Blocks of 16 or 32 bit Microprocessor 3. Fundamentals of a Typical CISC Architecture 3.1. Registers 3.2. Microcomputer Memory Architecture 3.3. Data Transfers 3.4. Addressing Techniques 3.5. Types of Instructions 4. Fundamentals of a Typical RISC Architecture 4.1. Registers 4.2. Instruction Set and Addressing Techniques 4.3. Microprocessor Control Unit 4.4. Software Layer for RISC Architecture 5. Input/Output Strategies 5.1. Input/Output Devices Map 5.2. Typical Input/Output Techniques 5.3. Interrupt System for General Purpose Microprocessor 5.4. . Interrupts for x86 Intel Microprocessor (IA-32) in Real Mode 6. Time-Dimension of a General Purpose Microprocessor Architecture 6.1. CISC Instruction Timing 6.2. Speed Increase for Advanced CISC Microprocessor 6.3. RISC Instruction Timing 7. An Overview of Intel x86 Architecture (IA-32) in Real Mode 7.1. Block Diagram 7.2. Registers 7.3. Memory Organization 7.4. Port Organization 7.5. Addressing Modes

Scientific Research and Practical Work S3		
Credits	10 ECTS	**Semester 3** **UNSTPB**
Lectures	28 h	
Tutorials	14 h	
Labs	28 h	
Exam	4 h	
Total	74 h	
Instructor		Prof. Dr. Ing. Corneliu BURILEANU
Objectives		Students attending this course should be able to implement applications, in typical situations, of basic methods of signal acquisition and processing and implement knowledges, concepts and basic methods that refer to the computer systems, microcontrollers, programming languages and techniques
Content		1. Microcomputer Structure. Definitions 1.1. Microcomputer Functional Blocks 1.2. CISC and RISC Microprocessors 1.3. Information in Digital Systems 1.4. Conventions 2. Overview of a CISC, General Purpose Microprocessor Core 2.1. First Step Approach: Data register and Address Register 2.2. Second Step Approach: General-Purpose Registers 2.3. Third Step Approach: Arithmetic Processing Unit 2.4. Forth Step Approach: Memory Addressing Control Unit 2.5. Fifth Step Approach: Microprocessor Control Unit 2.6. Functional Blocks of 16 or 32 bit Microprocessor 3. Fundamentals of a Typical CISC Architecture 3.1. Registers 3.2. Microcomputer Memory Architecture 3.3. Data Transfers 3.4. Addressing Techniques 3.5. Types of Instructions 4. Fundamentals of a Typical RISC Architecture 4.1. Registers 4.2. Instruction Set and Addressing Techniques 4.3. Microprocessor Control Unit 4.4. Software Layer for RISC Architecture 5. Input/Output Strategies 5.1. Input/Output Devices Map 5.2. Typical Input/Output Techniques 5.3. Interrupt System for General Purpose Microprocessor 5.4. . Interrupts for x86 Intel Microprocessor (IA-32) in Real Mode 6. Time-Dimension of a General Purpose Microprocessor Architecture 6.1. CISC Instruction Timing 6.2. Speed Increase for Advanced CISC Microprocessor 6.3. RISC Instruction Timing 7. An Overview of Intel x86 Architecture (IA-32) in Real Mode 7.1. Block Diagram 7.2. Registers 7.3. Memory Organization 7.4. Port Organization 7.5. Addressing Modes

SEMESTER 3 - CAU - SPECIALIZATION C

MODELLING AND CONTROL OF POWER ELECTRONICS CONVERTERS		
Credits	5 ECTS	Semester 3 CAU
Lectures	30 h	
Exercises	22.5 h	
Exam	Not specified	
Total	52,5 h	
Instructor		Prof. Dr.-Ing. Marco LISERRE
Objectives		The students are able to derive the mathematical models of PWM dc/dc and dc/ac converters. The students are able to design their controllers using average model and small-signal linearization. The students know basic of digital control and learn how to apply to power converters. The students have understanding of power theories and their application to power quality conditioner.
Content		The course is focused on dc/dc and dc/ac PWM converters, their model and their control. Particularly, since most of the adopted dc/ac converters in electric drives and renewable energies are voltage source converters, the current control is the first and most important control stage and it is responsible of high dynamical behavior and low harmonic content. Finally the course focuses on how to select current references to achieve the desired active and reactive powers even in unbalance situations, using the instantaneous power theory, nowadays an indispensable tool for smart grid technologies. Topics overview: • dc/dc converter model • Average model, small-signal linearization, transfer functions • Design of the controller for dc/dc converters • dc/ac converter model: ac dynamics in different reference frames • Continuous and discrete current control (PI, resonant controller, deadbeat) • dc voltage control, active and reactive power controls

<table>
<tr><th colspan="3">BATTERY CHARGERS FOR EV's</th></tr>
<tr><td>Credits</td><td>5 ECTS</td><td rowspan="5">Semester 3
CAU</td></tr>
<tr><td>Lectures</td><td>30 h</td></tr>
<tr><td>Exercises</td><td>22.5 h</td></tr>
<tr><td>Exam</td><td>Not specified</td></tr>
<tr><td>Total</td><td>52.5 h</td></tr>
<tr><td colspan="2">Instructor</td><td>Prof. Dr. Nadia TAN</td></tr>
<tr><td colspan="2">Objectives</td><td>By the end of this course, student will be able to:
Understand the fundamental principles of battery charging
Analyse and design battery charging converters for EVs
Understand the trends and challenges in EV charging</td></tr>
<tr><td colspan="2">Content</td><td>Electric vehicles (EVs) are a sustainable transportation solution with batteries as the key element. Battery chargers such as fast charging stations or on-board chargers for slow charging have different requirements in design, operation and performance. This course provides comprehensive content that enables students to deal with different aspects of battery chargers such as requirements, topology, design, efficiency, control, trends and challenges.
Topics overview:
Introduction to the elements and classifications of battery chargers and requirements
On-board chargers for electric vehicles
Fast charging stations
Extreme fast charging infrastructure of EV batteries
Trends and challenges in electric vehicle charging</td></tr>
</table>

<table>
<tr><th colspan="3">SEMINAR POWER ELECTRONICS</th></tr>
<tr><td>Credits</td><td>5 ECTS</td><td rowspan="4">Semester 3
CAU</td></tr>
<tr><td>Seminar</td><td>30 h</td></tr>
<tr><td>Exam</td><td>Not specified</td></tr>
<tr><td>Total</td><td>30 h</td></tr>
<tr><td colspan="2">Instructor</td><td>Prof. Dr.-Ing. Marco LISERRE</td></tr>
<tr><td colspan="2">Objectives</td><td>The students can formulate a research question for independent analysis in the area of power electronics. The students can perform a literature search and organize publications by relevance. They can summarize and explain the content of the scientific publications. The students can compare the results and assess them critically. The students can present the results, discuss them and recommend further research steps on the research topic.</td></tr>
<tr><td colspan="2">Content</td><td>The students will investigate a scientific or technical problem by means of several publications and collect, reproduce and evaluate the material in a seminar paper. Possible fields of interest are:
Power semiconductors
Power electronic circuits
Electric drives
Control of electric drives
Renewable energy production</td></tr>
</table>

M. Sc. LABORATORY POWER ELECTRONICS - RENEWABLE ENERGY - DRIVE ENGINEERING		
Credits	5 ECTS	**Semester 3** **CAU**
Labs	75 h	
Exam	Not specified	
Total	75 h	
Instructor		Prof. Dr.-Ing. Marco LISERRE
Objectives		The students learn abilities to measure electrical quantities in experimental evaluations and they are able to analyze these measurement results for essential power electronic, renewable energy, and drive technology systems. The students can formulate theories and apply solutions formulated by themselves to solve specific technical problems.
Content		Laboratory exercises for power electronics, renewable energies, and drive technologies

ADVANCED DIGITAL SIGNAL PROCESSING (Option)		
Credits	5 ECTS	**Semester 3** **CAU**
Lectures	45 h	
Exercises	15 h	
Exam	Not specified	
Total	60 h	
Instructor		Prof. Dr.-Ing. Gerhard SCHMIDT
Objectives		Students have an in-depth understanding of the differences of analog and digital processing. They apply robust and efficient versions of digital signal processing structures. They compare different filter approaches. Students deepen their knowledge on sampling and complexity reduction.
Content		• Digital processing of continuous-time signals - Sampling and sampling theorem - Quantization - AD- and DA-conversion • Efficient FIR structures - Block-based approaches • DFT and FFT - Leakage effect - Windowing - FFT structure • Digital filters - FIR filters - Structures - Linear phase filters - Least-squares frequency domain design - IIR-filters - Structures - Finite word-length effects • Multirate digital signal processing - Decimation and interpolation - Filters in sampling rate alteration systems - Polyphase decomposition and efficient structures Digital filter banks

<table>
<tr><th colspan="3">OPTIMIZATION AND OPTIMAL CONTROL (OPTION)</th></tr>
<tr><td>Credits</td><td>5 ECTS</td><td rowspan="5">Semester 3
CAU</td></tr>
<tr><td>Lectures</td><td>45 h</td></tr>
<tr><td>Exercises</td><td>15 h</td></tr>
<tr><td>Exam</td><td>Not specified</td></tr>
<tr><td>Total</td><td>60 h</td></tr>
<tr><td colspan="2">Instructor</td><td></td></tr>
<tr><td colspan="2">Objectives</td><td>The students have an in-depth understanding of static and dynamics optimization with constraints. They understand the underlying mathematical concepts and are able to apply these to new problems. They have a comprehensive understanding of optimization methods and are able to independently apply these methods to static and dynamic optimization problems. The students know different numerical solution approaches, comprehend their working principles and are able to implement them for optimization problems.</td></tr>
<tr><td colspan="2">Content</td><td>Fundamentals of static and dynamic optimization problems
Static optimization without and with constraints
Dynamic optimization without and with constraints
Introduction to numerical methods for optimization.</td></tr>
</table>

MICROCONTROLLER AND FPGA TECHNIQUE FOR POWER ELECTRONICS APPLICATIONS (Option)		
Credits	5 ECTS	Semester 3 CAU
Lectures	30 h	
Exercises	15 h	
Exam	Not specified	
Total	45 h	
Instructor		Prof. Dr.-Ing. Marco LISERRE
Objectives		The students learn about the principles, structure and functionality of microcontrollers (MCUs) and FPGAs. They will be able to use MCUs and FPGAs for applications in power electronics such as PWM converters used in renewable power generations and motor drives used in electric vehicles. Furthermore, they will be able to design essential modules to control electric drives and PWM converters.
Content		Using microcontroller units is necessary basic for every field of technology. This lecture introduces principle and structure of MCUs and FPGAs, and how the MCUs and FPGAs work for applications in power electronics such as PWM converters used in renewable power generations and motor drives used in electric vehicles. The application refers mainly to power electronics, electrical drives and design of digital circuit. In the exercises, the content of the lecture will be implemented on microcontrollers. And In the simulations, essential modules for the control of PWM converter/inverters will be designed. Detail contents of the lecture are as follow: • Overview of MCU and FPGA • Memory map and DMA • Timer, GPIO and Interrupt • ePWM, eQEP for position/speed measurement • ADC, DAC and Commincations (SCI, SPI, CAN) • Basic Programming and actual applications on example • Simulation (FPGA: design of essential modules)

BATTERY SYSTEMS (Option)		
Credits	5 ECTS	**Semester 3** **CAU**
Lectures	30 h	
Exam	Not specified	
Total	30 h	
Instructor		Prof. Dr.-Ing. Marco LISERRE
Objectives		The students attending this module can formulate a research question for independent analysis in the area of battery technologies and for battery integration. The students can perform a literature search and organize publications by relevance. They can summarize and explain the content of the scientific publications. The students can compare the results and assess them critically. The students can present the results, discuss them and recommend further research steps on the research topic.
Content		Several topics related to battery technologies, modelling and control and power conversion and applications, such as: • Materials for Li-Ion Batteries • Design and Production of Lithium Batteries • Battery equivalent circuit model • Battery thermal modelling • State estimation • Battery management system and cell equalization • Battery integration in power electronics • Battery energy storage economics

SEMINAR ON SELECTED TOPICS IN SYSTEMS AND CONTROL (Option)		
Credits	5 ECTS	**Semester 3** **CAU**
Seminar	30 h	
Exam	Not specified	
Total	30 h	
Instructor		
Objectives		The students comprehend advanced control and observer design methods. They can independently review and organize existing literature. They can summarize and explain the content of the scientific publications. The students can compare the results, can design and evaluate controllers for nonlinear systems, and can assess them critically. They know presentation techniques and have developed presentation skills. The students can present the results, discuss them and recommend further research steps on the research topic.
Content		In the seminar current research topics in systems and control are considered.

M. Sc. LABORATORY ADVANCED CONTROL (Option)		
Credits	5 ECTS	**Semester 3** **CAU**
Labs	60 h	
Exam	Not specified	
Total	60 h	
Instructor		
Objectives		The students have an in-depth understanding of computer-assisted modeling and control design methods for nonlinear systems. They understand the underlying mathematical and algorithmic concepts and are able to apply these to new practical problems. The students are able build and analyze simulation models. They have the ability to implement nonlinear controllers using symbolic and numerical computational tools taking into account real-time aspects.
Content		Experiments addressing the themes: • Mathematical modeling and control design using computer-algebra-systems • Computer-assisted nonlinear control design (primary focus of laboratory) • Implementation and experimental validation

SEMESTER 3 - UAQ - SPECIALIZATION D

SYSTEM IDENTIFICATION AND DATA ANALYSIS		
Credits	6 ECTS	**Semester 3** **UAQ**
Lectures	60 h	
Tutorials	30 h	
Exam	2 h	
Total	92 h	
Instructor	Vittorio DE LULIIS - vittorio.deiuliis@univaq.it	
Objectives	• The objective of this course is to initiate the students to the study of stochastic estimation theory, with focus on dynamical system identification and state estimation by filtering theory. After the completion of this course a student will be able to formulate and analyze problems of estimation and identification of dynamical models from noisy measurements, proposing various possible solutions and defining their statistical properties. The notions acquired in this course will increase the student's capability of modeling, simulation and control design. • At the end of this course the student: - will know methods and fundamental results of stochastic estimation theory; - will know the main methodologies of dynamical system estimation with noisy measurements; - will have deep knowledge of state estimation and filtering for linear and nonlinear systems, both in Gaussian and non-Gaussian framework; - will be able to write simulation programs to evaluate the accuracy of models estimated from noisy measurement of a dynamical system; - will be able to write simulation programs to evaluate the accuracy of dynamical system state estimation; - will be able to evaluate which estimation technique is more suitable for a given problem in the field of stochastic system estimation; - will be able to read and understand advanced scientific textbooks and articles on the topics of the course	
Content	• Fundamentals of probability theory: events, sigma-algebras; random variables, integrals on probability spaces; expected value and higher order moments; measures induced by random variables and distribution functions; covariance matrices and their properties; standardizing random variables. Vector Gaussian distribution and its properties; conditional probability and conditioned random variables; properties of conditional expectation; independency of events and random variables. Computing the conditional expectation of Gaussian random variables; the Hilbert space of finite-variance random variables; conditional expectation and projection. Orthogonalization of sequences of random variables. • Estimation theory: minimum variance estimation; conditional expectation as a minimum variance estimator; optimal estimation and orthogonal projection; optimal estimation for Gaussian random variables; sub-optimal estimator and projections on subspaces of finite-dimensional functions;	

	orthogonality conditions and optimal polynomial estimation; maximum likelihood estimation; likelihood ratio and likelihood function; parameter estimation; examples for Gaussian variables. Markov estimator. • Stochastic dynamical systems and Kalman Filter: separating noise and signal; signal-generating model and white noise model; linear discrete-time stochastic systems; definition and properties of state and output innovations; equivalence theorem; the Kalman Filter as the optimal estimator: recursive equations; recursive computation of the Kalman filter covariances and gain (Riccati equations). Optimal predictor and optimal smoothing with the extended state. Continuous-time stochastic systems with sampled observations: simplified model of white noise, discretization and Kalman filtering. Steady-state solution of Riccati equations and their unicity and convergence: detectability of (A,C) and stabilizability of (A,F). State estimation of nonlinear systems: extended Kalman filter. • Parameter estimation for stochastic systems: maximum-likelihood parameter estimation, heuristic solution of combined state-parameters estimation with Kalman Filter. • Fundamentals of subspace methods for linear system identification: singular value decomposition of a matrix and least squares methods; projection of vectors on subspaces; Ho-Kalman method for stochastic realization; MOESP/N4SID methods for linear subspace identification.

EMBEDDED SYSTEMS		
Credits	9 ECTS	**Semester 3** **UAQ**
Lectures	30 h	
Tutorials	30 h	
Labs	30 h	
Exam	2 h	
Total	92 h	
Instructor		Luigi POMANTE - luigi.pomante@univaq.it
Objectives		The goal of this module is to provide the fundamental set of concepts and techniques that relate to "HW/SW Dedicated Systems Engineering". In fact, it presents the main issues related to the design of dedicated (i.e. application-specific) HW/SW electronic devices that are also typically "embedded" (i.e. integrated into a more complex heterogeneous system) and/or with real-time constraints. In such a context, the course recalls the main HW/SW technologies and the related design methodologies and tools (both academic and commercial), providing also a unified (typically model-based) vision of all the involved concepts.
Content		Introduction: goals and structure of the course, general features of embedded systems, main design issues. Technologies: unified vision of basic HW technologies (ASIC, FPGA), HW components (processors, memories, timers, interfacing, communication) and HW/SW interaction. Architecture: system on-board, systems on-chip, networked/distributed embedded systems (in particular HW and SW technologies for Wireless Sensor Networks). Methodologies and tools: system-level design flow and tools, HW/SW design flow and tools, RTOS and advanced OS concepts. Case studies.

ADVANCED CONTROL SYSTEMS		
Credits	9 ECTS	**Semester 3** **UAQ**
Lectures	60 h	
Tutorials	30 h	
Exam	2 h	
Total	92 h	
Instructor		Pierdomenico PEPE - pierdomenico.pepe@univaq.it
Objectives		Ability to design continuous-time and digital stabilizers, for nonlinear finite dimensional and nonlinear retarded systems.
Content		Recalls on elementary theory of nonlinear feedback. Nonlinear Observer: the autonomous and the forced case. Nonlinear separation principle. Example of application to a continuous stirred tank reactor. Recalls on the Input-to-state stability. ISS redesign for attenuation of actuation disturbances effects. Artstein's theory for controller design by Lyapunov functions. Sontag's and Freeman's universal stabilizers. Continuous and discontinuous state feedbacks yielding negative Dini directional derivative of the control Lyapunov function. Clarke's theory of practical stabilization in the sample-and-hold sense. Sampled-data emulation of continuous-time, state feedback stabilizers. Sampled-data emulation of continuous-time, observer-based stabilizers. Global exponential stability preservation under sampling for globally Lipschitz systems. Example of application to an actuated inverted pendulum. Introduction to nonlinear retarded systems. Internal and external stability. Lyapunov-Krasovskii criteria. Methods based on Linear Matrix Inequalities. Elementary theory of nonlinear feedback for forward complete, retarded systems. Stabilization. Input-to-State Stabilization. State observers for retarded systems. Example of application to a glucose-insulin system. Basics of predictor design for linear systems with input/output delays.

OPTIMAL CONTROL		
Credits	6 ECTS	**Semester 3** **UAQ**
Lectures	40 h	
Tutorials	20 h	
Exam	2 h	
Total	62 h	
Instructor		Claudio ARBIB - claudio.arbib@univaq.it
Objectives		Be able to: formulate integer linear programming problems, identify major combinatorial optimization problems, distinguish among them according to computational complexity, understand and reproduce main solution methods
Content		• Graphs. Finite graphs, vertex and edge set, degrees. Reflexive, non-reflexive, loopless, symmetric, transitive graphs. Regular graphs: examples. Graph isomorphism: examples. Cliques and stable sets. Complement of a graph. Walks, paths, circuits and cycles. Eulerian graphs and Hamiltonian graphs. Making a graph Eulerian. Node degrees and arc set. Odd degrees, Euler Theorem (enunciate). Hamiltonian paths. Connectivity. Trees and forests. Bipartite graphs and their characterization. More optimization problems on graphs: coloring. Applications. • Combinatorial optimization and 01 LP formulations. Transversal, stable set, dominating set, edge-cover, (perfect) matching in a graph. 01 linear programming formulations. Examples of applications and of formulation. The shortest path problem. Formulation as 01 LP, limits of the formulation. The spanning tree problem. Combinatorial optimization problems in general. Relation to linear programming. Other examples of 01 LP formulation (graph isomorphism problem, PLA folding, maximum cut problem etc.). • Computational complexity. Complexity of an algorithm, examples. Complexity of a problem, examples. Turing machine. The class P. Polynomial-time reduction. The class NP. The sarisfiability problem. Cook's Theorem (enunciate) and the class NP-complete. Examples of reduction: clique. • Totally unimodular matrices. The simplex method in a nutshell. LP in general and in standard form, reductions; basis, basic (feasible) solutions. Unimodular and totally unimodular matrices. A sufficient condition for the integrality of basic solutions. Necessary/sufficient conditions for total unimodularity. • Dynamic Programming. From partial to total order. Topological order of a graph, and DAGs. Bellman condition. Recursive computation of the best path in a DAG. Examples of application (covering a requirement at minimum cost, Levenshtein distance, Knapsack 01 etc.). • Fundamentals of Duality Theory in LP. Convex polyhedra: algebraic vs. geometric form. Projecting a polyhedron: Fourier-Veronese's Theorem (enunciate). Compatibility of systems of linear inequalities. Fourier-Motzkin elimination algorithm: numerical computation, particular cases. From Fourier-Veronese's Theorem to Duality in LP. Theorems of the Alternative: Gale's Theorem. • Matching theory. Matching and its relation to edge-cover, transversal and stable set. Gallai's Theorems. Primal-dual

	relations: Koenig's matching and edge-cover theorems. Bipartite matching and total unimodularity. Augmenting paths and a characterization of max matching. Bipartite matching: algorithms for the unweighted and weighted case. Non bipartite matching: Edmonds' formulation. Bi-stochastic matrices: introduction and definitions. Arithmetical magic squares and their construction. Semi-magic squares and bi-stochastic matrices: Sinkhorn algorithm. Characterization of (extremal) bi-stochastic matrices: perfect bipartite matchings and permutation matrices. • Matroids and the greedy algorithm. Introduction, motivation, examples. Maximal vs. maximum sets. Cheating the greedy algorithm. Sublclusion and the exchange property:matroids. Characterization of matroids: Rado's Theorem. Examples (uniform matroid, graphical matroid, vector matroid). Matroid representability: vector vs. graphic matroid. • Approximation algorithms. Introduction to deterministic approximation algorithms. Approximation ratio, polynomial-time approximation schemes. Example 1: TSP. Double tree algorithm. Christofides' (1/2)-approximation algorithm for the metric TSP. Example 2: Knapsack 01. A utility-based dynamic programming algorithm. Complexity. Scaling coefficients: a fully polinomial-time approximation scheme. Implicit enumeration algorithms. Search by split. Enumeration tree for COPs. Relations between ILP and LP. Bounds by LP and their use in a branch-and-bound method. First example of a branch-and-bound method: 01-knapsack. Computing the LP bound. Branching on fractional variables. Example: 01 Knapsack. Combinatorial bounds. Example: TSP.

SEMESTER 3 - CINVESTAV - SPECIALIZATION E

<table>
<tr><th colspan="3">Computer Vision</th></tr>
<tr><td>Credits</td><td>7.5 ECTS</td><td rowspan="5">Semester 3
CINVESTAV</td></tr>
<tr><td>Lectures</td><td>60 h</td></tr>
<tr><td>Tutorials</td><td>4 h</td></tr>
<tr><td>Exam</td><td>4 h</td></tr>
<tr><td>Total</td><td>68 h</td></tr>
<tr><td colspan="2">Instructor</td><td></td></tr>
<tr><td colspan="2">Objectives</td><td>This course aims to provide students with a comprehensive understanding of computer vision techniques, algorithms, and applications. Students will learn fundamental image processing methods, feature extraction, object detection, and deep learning-based vision techniques. By the end of the course, students will be able to develop and implement computer vision systems for real-world applications.</td></tr>
<tr><td colspan="2">Content</td><td>
Module 1: Introduction to Computer Vision (5 Hours)

Overview and applications of computer vision
Basics of image formation and representation
Digital image processing fundamentals

Module 2: Image Processing Techniques (7 Hours)

Image filtering (smoothing, sharpening)
Histogram equalization and thresholding
Morphological operations (erosion, dilation, opening, closing)
Module 3: Feature Extraction and Keypoint Detection (6 Hours)
Edge detection (Sobel, Canny)
Corner detection (Harris, Shi-Tomasi)
Feature descriptors (SIFT, SURF, ORB)

Module 4: Image Segmentation (5 Hours)

Threshold-based segmentation
Contour detection and shape analysis
Region-based segmentation (Watershed, GrabCut)

Module 5: Object Detection and Recognition (7 Hours)

Template matching
Feature-based object detection (HOG, Viola-Jones)
Introduction to deep learning for object detection

Module 6: Deep Learning for Computer Vision (8 Hours)

Basics of Convolutional Neural Networks (CNNs)
Pretrained models (AlexNet, VGG, ResNet)
Transfer learning and fine-tuning

Module 7: Motion Analysis and Object Tracking (6 Hours)

Background subtraction techniques
Optical flow methods (Lucas-Kanade, Farneback)
Object tracking (Kalman Filter, DeepSORT)

Module 8: 3D Vision and Depth Estimation (4 Hours)

Stereo vision and depth perception
Structure from Motion (SfM)

</td></tr>
</table>

	• Point clouds and 3D reconstruction **Module 9: Final Project and Applications (2 Hours)** • Real-world applications in robotics, healthcare, and autonomous systems • Implementation of a small computer vision project

Neural nets techniques for EV control		
Credits	7.5 ECTS	**Semester 3** **CINVESTAV**
Lectures	60 h	
Tutorials	4 h	
Exam	4 h	
Total	68 h	
Instructor		
Objectives		This course aims to provide an in-depth understanding of neural network techniques applied to electric vehicles (EVs). It covers the fundamentals of artificial neural networks (ANNs), deep learning models, and their applications in EV power management, battery state estimation, motor control, and autonomous driving. By the end of the course, students will be able to design and implement neural network models for various EV-related tasks using simulation tools like MATLAB and Python.
Content		**Module 1: Introduction to Neural Networks and Electric Vehicles (5 Hours)** • Overview of electric vehicles and key components • Introduction to artificial neural networks (ANNs) • Types of neural networks (feedforward, convolutional, recurrent) • Role of AI and neural networks in EV technology **Module 2: Fundamentals of Machine Learning for EVs (6 Hours)** • Supervised vs. unsupervised learning • Activation functions and loss functions • Backpropagation and gradient descent • Neural network architectures for EV applications **Module 3: Battery Management Using Neural Networks (7 Hours)** • Importance of battery state estimation • Neural networks for State of Charge (SoC) estimation • State of Health (SoH) prediction using deep learning • Battery fault detection and anomaly prediction **Module 4: Neural Networks for EV Motor Control (6 Hours)** • Basics of motor control in EVs • Neural networks for torque estimation and efficiency optimization • Predictive control using deep learning • Fault diagnosis in electric motors **Module 5: Energy Management and Optimization (7 Hours)** • Power consumption prediction using ANNs • Smart charging strategies with deep learning • Energy optimization in hybrid and electric powertrains • Reinforcement learning for real-time energy management

	Module 6: Neural Networks in Autonomous Electric Vehicles (7 Hours) • Object detection and recognition for autonomous EVs • Path planning using deep reinforcement learning • Sensor fusion techniques with neural networks • End-to-end learning for self-driving applications **Module 7: Implementation and Simulation (6 Hours)** • Introduction to MATLAB, Python (TensorFlow, PyTorch) for EV simulations • Training and testing neural networks for EV applications • Case studies on EV performance enhancement with AI • Hands-on project: Implementing a neural network model for an EV system **Module 8: Challenges, Future Trends, and Final Project (6 Hours)** • Challenges of AI in electric mobility • Ethical considerations and safety concerns • Emerging trends in AI-driven electric vehicle technology • Final project: Develop and present a neural network-based EV solution

AI techniques for EV mobility		
Credits	7.5 ECTS	**Semester 3** **CINVESTAV**
Lectures	60 h	
Tutorials	4 h	
Exam	4 h	
Total	68 h	
Instructor		
Objectives		This course aims to provide a comprehensive understanding of Artificial Intelligence (AI) techniques applied to electric vehicle (EV) mobility. It covers machine learning (ML), deep learning (DL), reinforcement learning (RL), and optimization techniques for improving EV performance, energy efficiency, battery management, and autonomous driving. By the end of the course, students will be able to design and implement AI models to solve key challenges in EV mobility using Python, TensorFlow, MATLAB, and simulation tools.
Content		**Module 1: Introduction to AI in Electric Vehicle Mobility (5 Hours)** • Overview of electric vehicle mobility and key challenges • Role of AI in EV mobility (efficiency, sustainability, autonomy) • Introduction to AI techniques: Machine Learning (ML), Deep Learning (DL), Reinforcement Learning (RL) • Overview of AI tools and platforms (Python, MATLAB, TensorFlow, PyTorch) **Module 2: Machine Learning for EV Powertrain and Battery Management (7 Hours)** • Basics of machine learning (supervised, unsupervised, and reinforcement learning) • Predictive maintenance for electric powertrains using AI

	• Battery state estimation (State of Charge (SoC), State of Health (SoH), Remaining Useful Life (RUL)) • Fault detection in electric powertrains and battery packs • Module 3: AI-Based Energy Management for EVs (7 Hours) • Smart charging strategies using AI • AI-based energy optimization for hybrid and electric powertrains • Grid integration and Vehicle-to-Grid (V2G) optimization • Demand forecasting for charging infrastructure using AI **Module 4: AI for Electric Vehicle Routing and Traffic Optimization (6 Hours)** • AI-based route planning and navigation for EVs • Traffic flow prediction using deep learning • Optimization of EV fleet management using AI • Reinforcement learning for adaptive traffic control **Module 5: AI Techniques for Autonomous Electric Vehicles (7 Hours)** • AI-based perception for autonomous EVs (object detection, lane tracking) • Path planning and trajectory optimization using deep learning • Sensor fusion techniques for autonomous EVs (LIDAR, radar, cameras) • Deep reinforcement learning for autonomous driving decision-making **Module 6: AI in Connected and Smart Mobility (6 Hours)** • Internet of Vehicles (IoV) and AI-driven vehicle communication • AI for predictive maintenance in smart mobility systems • Smart cities and AI-driven EV mobility solutions • AI-powered fleet management and ride-sharing optimization **Module 7: AI for EV Market and Policy Analysis (6 Hours)** • AI in EV adoption forecasting and policy planning • Market trends analysis using machine learning • AI-driven consumer behavior analysis for EV adoption • Ethical and environmental implications of AI in EV mobility **Module 8: Implementation, Case Studies, and Final Project (6 Hours)** • AI model development using Python, TensorFlow, MATLAB • Case studies on real-world AI applications in EV mobility • Final project: Develop an AI-powered EV mobility solution

<table>
<tr><th colspan="3">Machine learning with application to EV’s</th></tr>
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<tr><td>Total</td><td>68 h</td></tr>
<tr><td colspan="2">Instructor</td><td></td></tr>
<tr><td colspan="2">Objectives</td><td>This course provides an in-depth understanding of machine learning (ML) techniques and their applications in electric vehicle (EV) mobility. Students will explore ML algorithms for battery management, energy optimization, predictive maintenance, autonomous driving, and smart transportation. By the end of the course, students will be able to implement ML models to address real-world challenges in EV mobility using Python, TensorFlow, and MATLAB.</td></tr>
<tr><td colspan="2">Content</td><td>Module 1: Introduction to Machine Learning for Electric Vehicles (5 Hours)

Overview of electric vehicles and mobility challenges
Introduction to machine learning (supervised, unsupervised, reinforcement learning)
Applications of ML in EV mobility
ML tools and frameworks (Python, TensorFlow, MATLAB, Scikit-Learn)

Module 2: Data Acquisition and Processing for EV Systems (6 Hours)

EV data sources (sensors, GPS, battery management systems)
Data preprocessing techniques (normalization, feature selection, outlier detection)
Time-series data analysis for EV performance monitoring
Handling missing and noisy data in EV dataset

Module 3: Machine Learning for Battery Management and Optimization (7 Hours)

Battery health prediction using regression models
State of Charge (SoC) and State of Health (SoH) estimation with ML
Predictive maintenance using ML algorithms
Optimization of battery charging and discharging cycles

Module 4: ML-Based Energy Management and Smart Charging (6 Hours)

Predictive analytics for EV energy consumption
Smart charging station placement using ML clustering techniques
Demand forecasting for charging stations using time-series analysis
Reinforcement learning for real-time energy management

Module 5: Machine Learning for EV Traffic and Route Optimization (7 Hours)

Traffic prediction using deep learning (LSTMs, CNNs)
Route optimization for electric vehicle fleets using ML algorithms
Adaptive cruise control and eco-driving using ML
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</table>

	• Reinforcement learning for traffic congestion reduction **Module** 6: ML for Autonomous Driving in Electric Vehicles (7 Hours) • Object detection and classification using ML (YOLO, Faster R-CNN) • Lane detection and path planning for autonomous EVs • Sensor fusion for perception in autonomous EVs • Reinforcement learning for self-driving decision-making **Module 7: Predictive Maintenance and Fault Diagnosis in EVs (6 Hours)** • Fault detection in power electronics and drivetrains using ML • Anomaly detection in EV motors and controllers • AI-driven diagnostics for vehicle performance issues • Case studies on predictive maintenance in electric fleet **Module 8: AI-Powered Fleet Management and Smart Mobility (6 Hours)** • Machine learning for ride-sharing optimization • Predicting EV fleet demand and usage patterns • ML applications in vehicle-to-grid (V2G) optimization • Case studies on AI-driven fleet management **Module 9: Case Studies, Implementation, and Final Project (6 Hours)** • Case studies on ML applications in EVs • Hands-on implementation using Python and MATLAB • Final project: Develop an ML-based solution for an EV mobility challenge