320129 - ACSEP - Applications and Control of Power Electronic Systems

Coordinating unit: 205 - ESEIAAT - Terrassa School of Industrial, Aerospace and Audiovisual Engineering
Teaching unit: 710 - EEL - Department of Electronic Engineering
Academic year: 2018
Degree: BACHELOR’S DEGREE IN INDUSTRIAL ELECTRONICS AND AUTOMATIC CONTROL ENGINEERING (Syllabus 2009). (Teaching unit Optional)
ECTS credits: 6
Teaching languages: Catalan

Teaching staff
Coordinator: Antoni Arias

Prior skills
Students might have passed the courses of Control Engineering (Q6) and Power Electronics (Q5, Q6).

Degree competences to which the subject contributes

Transversal:
1. SELF-DIRECTED LEARNING - Level 2: Completing set tasks based on the guidelines set by lecturers. Devoting the time needed to complete each task, including personal contributions and expanding on the recommended information sources.
2. EFFICIENT ORAL AND WRITTEN COMMUNICATION - Level 2. Using strategies for preparing and giving oral presentations. Writing texts and documents whose content is coherent, well structured and free of spelling and grammatical errors.
3. TEAMWORK - Level 2. Contributing to the consolidation of a team by planning targets and working efficiently to favor communication, task assignment and cohesion.
4. EFFECTIVE USE OF INFORMATION RESOURCES - Level 2. Designing and executing a good strategy for advanced searches using specialized information resources, once the various parts of an academic document have been identified and bibliographical references provided. Choosing suitable information based on its relevance and quality.

Teaching methodology
In the theory sessions, the teacher will introduce the theoretical basis. The exposition of the concepts and their implementation should be made clearly and concisely all illustrating examples to facilitate understanding. Students will work and adapt the examples theory for application sessions in order to do lab sessions. In the laboratory, students must achieve the concepts covered in the theory sessions and implementation. Students will use Matlab-Simulink software as a laboratory tool.

Learning objectives of the subject
The student should be able to understand, analyze and design control for applications where actuators are power electronic converters. The course is marked as a challenge to link knowledge and subjects of Engineering Control and Industrial Electronics and Power.
### Study load

<table>
<thead>
<tr>
<th>Total learning time:</th>
<th>Hours large group:</th>
<th>45h</th>
<th>30.00%</th>
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<tbody>
<tr>
<td></td>
<td>Hours medium group:</td>
<td>0h</td>
<td>0.00%</td>
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<tr>
<td></td>
<td>Hours small group:</td>
<td>15h</td>
<td>10.00%</td>
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<tr>
<td></td>
<td>Guided activities:</td>
<td>0h</td>
<td>0.00%</td>
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<tr>
<td></td>
<td>Self study:</td>
<td>90h</td>
<td>60.00%</td>
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## Content

### TOPIC 1: Presentation of the course

**Learning time:** 1h  
Theory classes: 1h

**Description:**
- Presentation of course content and its program (Theory, Application, and Lab Activities Directed).
- Assessment Regulations.
- Basic and complementary bibliography. Tool and computer-aided design (Matlab-Simulink).
- State of the art.
- Matlab / Simulink as a basic tool for modeling and simulation for the various applications

### TOPIC 2: Tools for modelling power electronics converters

**Learning time:** 13h  
Theory classes: 6h  
Practical classes: 3h  
Laboratory classes: 4h

**Description:**
- Models converters.
  Switching.
  Averages of large signal and small signal.
- Three phase transformations.
  Clarke (\(\_\_\_\)).
  Park (d-q).
  Model three-phase inverter connected to the network  
  Coordinates a-b-c and d-q.
  Small signal
- Modeling of permanent magnet synchronous machine.
  Characteristics.
  Electrical part in coordinates (a, b, c), (\(\_\_\_\)) and (dq).
  Mechanical part

**Related activities:**
- Simulation model of a permanent magnet synchronous machine.
- Simulation model of a three-phase inverter connected to the grid
TOPIC 3: Control applications with electric machines

Learning time: 24h
- Theory classes: 11h
- Practical classes: 6h
- Laboratory classes: 7h

Description:
- Vector Control (FOC: Field Oriented Control) in four quadrants. (2hT has +1)
  - Analogy to the DC motor.
  - Tuning controllers running through the root locus.
  - PI pre-filter or IP.
  - Matlab Sisotool and Control toolbox
- Feedforward terms
  - Anti wind up.
- DTC: Direct Torque Control into four quadrants.
  - Control of hysteresis comparators.
- External velocity and position loops.
  - Tuning controllers using root locus
  - Feedforward control for changes in load torque.
  - Matlab Sisotool and Control toolbox.
- Introduction to DSP implementation
  - Step controller in continuous time to discrete time. Sampling periods for current loops and speed or position.
  - Programming the controller.
  - DSP / FPGA Architectures.
- Applications in Renewable Energy, Electric Vehicle, Industrial Drives and Mechatronics.
- State of the art industry.
  - Commercial products based on FOC (Emerson, Eurotherm, etc...) and DTC (ABB)
- State of the art research.
  - Control in state space.
  - The challenge of Sensorless Control.
- Estimators, observers and tracking techniques.
  - Research laboratories. Testing.

Related activities:
- Model simulation of vector control of permanent magnet motor with external loop speed and / or position
  - In continuous time.
  - Discrete-time and three-phase inverter.
  - With speed and position estimator (Sensorless).
- Simulation model of direct torque control of a permanent magnet motor with external speed loop and / or position.
### TOPIC 4: Applications of investors connected to the network

**Learning time:** 16h  
Theory classes: 8h  
Practical classes: 4h  
Laboratory classes: 4h

<table>
<thead>
<tr>
<th>Description</th>
<th>Related activities</th>
</tr>
</thead>
<tbody>
<tr>
<td>· Duality FIRE - VOC DTC - DPC</td>
<td>· Model-oriented simulation of a control voltage (VOC).</td>
</tr>
</tbody>
</table>
| · VOC-Voltage Oriented Control  
  Internal loop active and reactive currents. Power Factor Control. Synchronization with the network.  
  External loop voltage. | · Simulation model of a direct power control (DPC). |
| · DPC Direct Power Control  
  Control of hysteresis comparators. | |
| · Applications in renewable energy, electric vehicles, energy storage, HVDC transmission | |
| · State of the art industry  
  Commercial products. | |
| · State of the art research  
  Multilevel converters.  
  Feedforward control, predictive, multivariate, etc..  
  Research laboratories. | |

**Description:**

- VOC-Voltage Oriented Control  
  Internal loop active and reactive currents. Power Factor Control. Synchronization with the network.  
  External loop voltage.

- DPC Direct Power Control  
  Control of hysteresis comparators.

- Applications in renewable energy, electric vehicles, energy storage, HVDC transmission

- State of the art industry  
  Commercial products.

- State of the art research  
  Multilevel converters.  
  Feedforward control, predictive, multivariate, etc..  
  Research laboratories.
### TOPIC 5: Renewable Energy applications and others

<table>
<thead>
<tr>
<th>Learning time: 15h</th>
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<tbody>
<tr>
<td>Theory classes: 6h</td>
</tr>
<tr>
<td>Practical classes: 3h</td>
</tr>
<tr>
<td>Guided activities: 6h</td>
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**Description:**
- Generation of wind power.
- Fixed speed
- Variable speed. Operation modes.
- Wind generator system based on permanent magnets.
- Back to back connection. Crowbar by the DC bus.

- Generating solar energy.
  - Modeling of photovoltaic panels.
  - Maximum power tracking techniques.
  - Photovoltaic systems autonomous and connected to the grid.

- Other energies: navy, etc. ...

- Electric vehicles and other drives.

**Related activities:**
- Adaptation of previous models to a particular application (chosen by students).

### Qualification system

- 1st Exam: 25%
- 2nd Exam: 25%
- Lab: 25%
- AD: 25%

### Bibliography

**Basic:**

**Complementary:**