240EQ013 - Process Control

Coordinating unit: 295 - EEBE - Barcelona East School of Engineering
Teaching unit: 707 - ESAII - Department of Automatic Control
Academic year: 2018
Degree: MASTER'S DEGREE IN CHEMICAL ENGINEERING (Syllabus 2012). (Teaching unit Compulsory)
MASTER'S DEGREE IN CHEMICAL ENGINEERING (Syllabus 2012). (Teaching unit Compulsory)
ECTS credits: 4,5
Teaching languages: Catalan, Spanish

Teaching staff
Coordinator: JORDI SOLÀ SOLER
Others: ABEL TORRES CEBRIÁN

Opening hours
Timetable: Teachers will let students know their questions schedule during the first lecture.

Prior skills
Basic mathematical knowledge (linear algebra, elementary calculus, complex variable and linear differential equations) and basic control knowledge.

Requirements
None.

Degree competences to which the subject contributes

Specific:
1. Apply knowledge of mathematics, physics, chemistry, biology and other natural sciences, obtained through study, experience, and practice, critical reasoning to establish economically viable solutions to technical problems.

2. Conceptualize engineering models; apply innovative methods in problem solving and applications suitable for the design, simulation, optimization and control of processes and systems.

3. Ability to solve problems that are unfamiliar, incompletely defined, and have competing specifications, considering the possible methods of solution, including the most innovative, selecting the most appropriate, and to correct implementation, evaluating the different solutions Design.

Generical:
4. Ability to apply the scientific method and the principles of engineering and economics, to formulate and solve complex problems in processes, equipment, facilities and services, in which the material changes its composition, state or energy content, characteristic of chemical industry and other related sectors which include the pharmaceutical, biotechnology, materials, energy, food or environmental.

5. Conceive, design, calculate, and design processes, equipment, manufacturing and service facilities in the field of chemical engineering and related industrial sectors in terms of quality, safety, economy, rational and efficient use of natural resources and conservation environment.

6. Possess independent learning skills to maintain and enhance the competencies of chemical engineering to enable the continued development of their profession.

7. Know how to establish and develop mathematical models using appropriate informatics, scientific and technological basis for the design of new products, processes, systems and services, and for other already developed optimization.

8. Ability to analyze and synthesize to the continued progress of products, processes, systems and services using
The main objective of the course is to progress in the knowledge of control systems analysis and design techniques and in the fundamental aspects required for the implementation of these control systems to the chemical processes.

The specific objectives are:
- To settle the bases of basic theory for continuous time linear systems dynamics through the study of the main tools for the analysis and design of these kind of systems
- To introduce the basic control structures in closed loop and in open loop
- To present the state space representation as a different way to model the dynamic systems which introduces new tools for the analysis and the design of the controllers
- To generalise the transfer function concept to systems with multiple inputs and multiple outputs and introduce tools for the analysis and design of this kind of systems
- To present the digital control as the necessary formulation to implement computer based controllers
- To study the z transform, its properties and its use in the analysis and design of computer based control systems
- To introduce advanced control techniques used in the chemical industry
- To study the main actuators and sensors found in the chemical processes as well as the technological chain that includes data acquisition, data processing, generation of the control actions and actuation.

### Transversal:
9. EFFECTIVE USE OF INFORMATION RESOURCES: Managing the acquisition, structuring, analysis and display of data and information in the chosen area of specialisation and critically assessing the results obtained.

### Teaching methodology
The lessons are organised in theoretical sessions and practical sessions. The theoretical sessions include the explanation of the theoretical concepts, the presentation of examples and the resolution of exercises and problems. The teacher induces the students to participate actively in during the class. The practical sessions consist in the development of different practical works at the laboratory, with the support of informatic programs specially oriented to the analysis and design of control systems.

### Learning objectives of the subject
The main objective of the course is to progress in the knowledge of control systems analysis and design techniques and in the fundamental aspects required for the implementation of these control systems to the chemical processes.

### Study load

<table>
<thead>
<tr>
<th>Total learning time: 112h 30m</th>
<th>Hours large group:</th>
<th>27h</th>
<th>24.00%</th>
</tr>
</thead>
<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>13h 30m</td>
<td>12.00%</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>72h</td>
<td>64.00%</td>
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</tbody>
</table>
### Content

<table>
<thead>
<tr>
<th>Basic theory of the control of linear systems</th>
<th>Learning time: 30h</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Theory classes: 8h</td>
</tr>
<tr>
<td></td>
<td>Laboratory classes: 4h</td>
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<tr>
<td></td>
<td>Self study: 18h</td>
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</tbody>
</table>

**Description:**
Overview of the basic theory of control of the linear systems in continuous-time (analog) with external representation. Presentation of examples and problems in the field of chemical processes.

**Related activities:**
Two practical sessions in the lab dedicated to the design, analysis and simulation of controllers

**Specific objectives:**
- Modelization of the systems with external representation (transfer function, block diagram)
- Time response of the first and second degree systems (stability, dynamic characteristics)
- Feedback control, (PID design, cascade connection)
- Analysis in the frequency domain

<table>
<thead>
<tr>
<th>Internal representation</th>
<th>Learning time: 15h</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Theory classes: 4h</td>
</tr>
<tr>
<td></td>
<td>Laboratory classes: 2h</td>
</tr>
<tr>
<td></td>
<td>Self study: 9h</td>
</tr>
</tbody>
</table>

**Description:**
Present the internal representation with a different formulation to the external representation from which new tools derive for the analysis of the linear systems and a whole family of techniques for the design of controllers.

**Related activities:**
A practical session devoted to the use of MATLAB for the analysis and design of controllers by internal representation

**Specific objectives:**
- Definition of state space
- Equivalences and differences between internal and external representations
- Solution of the state equation
- Reachability and observability
- Design of controllers by pole placement
- Design of observers
### Introduction to digital (discrete-time) control

**Learning time:** 21h  
Theory classes: 6h  
Laboratory classes: 2h  
Self study: 13h

**Description:**  
Basic knowledge about mathematical modelling of dynamic systems in discrete time and about study methods of its performance.  
Introduction to Digital Control by the study of the main analysis and synthesis methods of computer control systems.

**Related activities:**  
A practical session devoted to the use of MATLAB for digital controller design

**Specific objectives:**  
- Architecture of a digital control system  
- Sampling and digitalisation of signals  
- Transfer function in z  
- Analysis in the time domain  
- Design of digital controllers

### Advanced controllers

**Learning time:** 21h  
Theory classes: 6h  
Laboratory classes: 2h  
Self study: 13h

**Description:**  
Overview about the different techniques of advanced control and assessment of their suitability in different types of chemical plants.

**Related activities:**  
A practical session devoted to the use of MATLAB for advanced controller design

**Specific objectives:**  
- Modifications on the basic PID  
- Wind-up effect in the integrator  
- Limitation of the derivative gain  
- Process models and tuning methods  
- Digital implementation of a PID
| -Multivariable control | Learning time: 13h  
Theory classes: 4h  
Laboratory classes: 1h  
Self study: 8h |
|---|---|
| **Description:**  
Generalise the concept of transfer function for systems with multiple inputs and outputs and introduce analysis and design tools for this type of systems  
**Related activities:**  
Half practical session will be dedicated to the use of MATLAB for the analysis of dynamic systems  
**Specific objectives:**  
- External description of the multivariable systems  
- Analytical tools for multivariable systems  
- Design tools of controllers for multivariable systems |

| -Measure and instrumentation in chemical processes | Learning time: 9h 30m  
Theory classes: 2h  
Laboratory classes: 1h  
Self study: 6h 30m |
|---|---|
| **Description:**  
Study of the own instrumentation of the chemical industry and introduction to data acquisition and signal processing  
**Related activities:**  
Half lab session  
**Specific objectives:**  
- General characteristics of sensors and actuators  
- Sensors and actuators of the chemical industry |
## Planning of activities

| PRACTICE 1 | Hours: 5h  
Laboratory classes: 2h  
Self study: 3h |
<table>
<thead>
<tr>
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<tbody>
<tr>
<td><strong>Description:</strong></td>
<td>Study and usage of MATLAB tools for the analysis and simulation of a chemical system</td>
</tr>
<tr>
<td><strong>Support materials:</strong></td>
<td>Computer with MATLAB</td>
</tr>
</tbody>
</table>

| PRACTICE 2 | Hours: 5h  
Laboratory classes: 2h  
Self study: 3h |
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<tbody>
<tr>
<td><strong>Description:</strong></td>
<td>Analysis of the response and stability of systems in open loop and closed loop in the time and frequency domains</td>
</tr>
<tr>
<td><strong>Support materials:</strong></td>
<td>Computer with MATLAB</td>
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</tbody>
</table>

| PRACTICE 3 | Hours: 5h  
Laboratory classes: 2h  
Self study: 3h |
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<tbody>
<tr>
<td><strong>Description:</strong></td>
<td>Analysis, modelling and design of a classic controller for a thermal system</td>
</tr>
<tr>
<td><strong>Support materials:</strong></td>
<td>Thermal system of the lab and associated control system</td>
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</tbody>
</table>

| PRACTICE 4 | Hours: 5h  
Laboratory classes: 2h  
Self study: 3h |
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<tbody>
<tr>
<td><strong>Description:</strong></td>
<td>Study and use of the MATLAB tools for the analysis and design of controllers through internal representation and multivariable systems</td>
</tr>
<tr>
<td><strong>Support materials:</strong></td>
<td>Computer with MATLAB</td>
</tr>
</tbody>
</table>

| PRACTICE 5 | Hours: 5h  
Laboratory classes: 2h  
Self study: 3h |
PRACTICE 6

Description:
Implementation of the advanced concepts of control applied to the lab systems

Support materials:
Thermal system of the lab and associated control systems

Qualification system
The final mark is calculated through four evaluations: two partial exams, the evaluation of the practical works and the mark of classroom exercises, according to the following weights:

Applied exercises 10%
Laboratory marks 20%
First partial exam (P1) 35%
First partial exam (P2) 35%

Students who don't pass the subject during the course may do a re-assessment exam (RA). This exam will contain conceptual questions and problems about the whole contents of the subject. It will allow to make up 70% of the final mark, according to the formula max{0.35P1+0.35P2, 0.7RA}.

Regulations for carrying out activities
To do the exams, students can have one sheet of notes (two pages DIN A4), the s and z transform tables, and a calculator.
Bibliography

Basic:


Complementary:


