1. **Course title:** PRACTICAL IMPLEMENTATION OF CONTROL ALGORITHMS

2. **Course code**

3. **Validity of course description:** 2012/2013

4. **Level of studies:** BA, BSc programme / MA, MSc programme lub 1st cycle / 2nd cycle of higher education

5. **Mode of studies:** intramural studies / extramural studies

6. **Field of study:** AUTOMATIC CONTROL AND ROBOTICS (FACULTY SYMBOL) AEI

7. **Profile of studies:** AUTOMATICS

8. **Programme:**

9. **Semester:** 2

10. **Faculty teaching the course:**

11. **Course instructor:** dr hab. inż Jacek Czeczot, Prof. Pol. Śl.

12. **Course classification:**

13. **Course status:** compulsory / elective

14. **Language of instruction:** English

15. **Pre-requisite qualifications:** Numerical methods, Process dynamics, Introduction to automatic control, Introduction to control theory, Process identification. It is assumed that the participants have the background in deriving the first principle process models (both static and dynamic), linearization and representation in the form of the equivalent transfer functions. It is also assumed that the participants have the background in the practical identification of the simple static and dynamic process models based on the approximation and interpolation methods and they have the basic knowledge about the elementary control structures, the properties and tuning methods of the conventional PID controller and they know the basic methods of quantifying the control performance.

16. **Course objectives:** The goal of this course is to present the complex control structures and the advanced control algorithms including the safety functionalities. It is discussed how to use the measurement data for the controller tuning. Apart from the conventional controllers (PID, on-off, step controller, etc.), the other selected advanced model-based controllers are presented. Additionally, the other functionalities available for the professional function blocks accessible for implementing the control algorithms in PLC devices are presented and discussed.

17. **Description of learning outcomes:**

<table>
<thead>
<tr>
<th>Nr</th>
<th>Learning outcomes description</th>
<th>Method of assessment</th>
<th>Teaching methods</th>
<th>Learning outcomes reference code</th>
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<tbody>
<tr>
<td>1.</td>
<td>The significance of the elements of the practical control system and their influence on the control performance are known.</td>
<td>SP, OS</td>
<td>WT, L</td>
<td>K_W2/1; W6/2; W20/1; W21/1;</td>
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<tr>
<td>2.</td>
<td>The methods of the identification of the parameters of the simplified static and dynamic models are known. The possibilities of improving the control performance by applying such models are known.</td>
<td>SP, CL, OS</td>
<td>WT, L</td>
<td>K_W10/2; W11/1; W13/2;</td>
</tr>
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<td>3.</td>
<td>The methods of improvement of the control performance by applying more complex control structures and/or advanced controllers are known.</td>
<td>SP, CL, OS</td>
<td>WT, L</td>
<td>K_W3/2; W10/3; W14/3; W17/2</td>
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<td>4.</td>
<td>The additional functionalities of the practical controllers required for their application to the industrial control systems are known, jointly with the functionalities required for reliable safety-based applications.</td>
<td>CL, OS</td>
<td>WT, L</td>
<td>K_W22/2</td>
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<tr>
<td>5.</td>
<td>It is known how to define the conditions of the practical identification experiment and how to determine the input-output characteristic and the dynamical properties of the controlled process.</td>
<td>SP, CL, OS</td>
<td>WT, L</td>
<td>K_U1/2; U2/2; U3/2; U14/1</td>
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</tbody>
</table>
6. It is known how to choose the appropriate control structure and the controller with its tunings.
   SP, CL, OS  WT, L  K_U23/2

7. It is known how to quantify the control performance of the real control system, how to distinguish the potential sources of the performance deterioration and how to manage these problems.
   CL, OS  WT, L  K_U7/2; U23/2; U25/2

8. It is known how to implement both the conventional and the advanced control algorithms in PLC devices.
   CL  WT, L  K_U7/2; U9/1

9. It is known how to choose the best possible solutions for the practical implementation of the real control systems.
   CL, OS  WT, L  K_K1/1; K2/1; K4/2; K6/1;

10. It is known how to present and discuss the proposed solutions.
    OS, CL  L  K_K2/1; K7/2

18. Teaching modes and hours
Lecture / BA / MA Seminar / Class / Project / Laboratory
Lectures: 30 h, Laboratory: 30 h

19. Syllabus description:
Lectures
1. Introduction to the course.
2. Classification of the control systems, selection of the manipulating variable.
3. Adaptation, self-tuning, complex control structures: cascade control, ratio control, feedforward control, MIMO control.
4. Limitations for the control system resulting from the static and dynamic properties of the process and of the actuator.
5. Conventional controllers: on-off, PWM, PID, etc.
6. Practical aspects of the application of the conventional controllers (P, PI, PID, on-off, etc.): different structures of the conventional PID controller; practical methods of tuning the controllers.
7. Discrete form of the PID controller; implementation of the output limitation, anti-windup, bumpless switching, etc.
8. Design of the experiments for the identification of the dynamic properties of the process, impact of the measurement noise, influence of the uncertainty on the measurement data, influence of the dynamics of the actuator.
9. Approximation and interpolation of the static and dynamic characteristics of the process based on the measurement data collected by the identification experiments.
10. Practical aspects of implementing the gain scheduling technique based on the static and dynamic characteristics of the process.
11. Practical aspects of the synthesis of the linear and nonlinear controllers, open loop control based on the first principle process model.
12. Review of the selected functionalities available in the commercial PID function blocks (SIPART DR24, SIMATIC S7, etc.).
13. Introduction to the simplified first principle modelling, affine form of the model, nonstationary form as the potential possibility of describing the nonlinearities.
15. Introduction to the predictive control: reference trajectory, prediction horizon, control horizon, the repetition rule.
16. Practical implementation of the simple model-based controllers: PMBC (Process Model-Based Control), linearizing control, PFC (Predictive Functional Control). Limitations and advantages.
17. Adaptation and integration of the control error as two methods for rejecting the offset for the model-based controllers: GMC (Generic Model Control) and B-BAC (Balance-Based Adaptive Control).
18. Perspectives for development of the advanced control algorithms, limitations resulting from their practical implementation.

Laboratory exercises
The laboratory exercises are the illustration for the problems discussed during the lectures. They are dedicated to the most important aspects of the practical implementation of the simple and complex control systems.
The laboratory exercises are spread into 4 blocks. Each block consists of 3 meetings and is dedicated to one laboratory setup, which gives 12 meetings for each laboratory group. Each block starts with a short introduction to the laboratory setup. The participants should be prepared for the exercises based on the lectures and the laboratory instruction.
The list of laboratory blocks:
1. Control of the pH process (identification of the static and dynamic characteristic, implementation of the PID controller as a function block in the dedicated PLC device, implementation of the gain scheduling technique, implementation of the GMCController)
2. Control of the heating process, part 1 (identification of the static and dynamic characteristic, implementation of the simple feedback control structure, tuning of the P and PI controllers, nonlinear correctors, implementation of the B-BACController).
3. Control of the hydraulic system (identification of the static and dynamic characteristic, implementation of the nonlinear control system, tuning of the controller for the integrating systems, implementation of the gain scheduling technique, control of the valve).
4. Control of the heating process, part 2 (implementation of the PFC controller, its tuning and correction from the measurable
For each block, the work is organized according to the same schedule:

a) Introduction to the laboratory setup and the control problem, collecting the measurement data for the process identification.
b) Implementation of the selected control algorithms and their tuning.
c) Validation of the control performance based on the measurement data.
d) Considering the potential possibilities of improving the control performance by applying more advanced control solutions.
e) Preparing and discussing the report.

20. Examination: NO

21. Primary sources:

22. Secondary sources:

23. Total workload required to achieve learning outcomes

<table>
<thead>
<tr>
<th>Lp.</th>
<th>Teaching mode</th>
<th>Contact hours / Student workload hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Lecture</td>
<td>30/0</td>
</tr>
<tr>
<td>2</td>
<td>Classes</td>
<td>0/0</td>
</tr>
<tr>
<td>3</td>
<td>Laboratory</td>
<td>30/30</td>
</tr>
<tr>
<td>4</td>
<td>Project</td>
<td>0/0</td>
</tr>
<tr>
<td>5</td>
<td>BA/ MA Seminar</td>
<td>0/0</td>
</tr>
<tr>
<td>6</td>
<td>Other</td>
<td>0/0</td>
</tr>
<tr>
<td></td>
<td>Total number of hours</td>
<td>60/30</td>
</tr>
</tbody>
</table>

24. Total hours: 90

25. Number of ECTS credits: 3

26. Number of ECTS credits allocated for contact hours: 2

27. Number of ECTS credits allocated for in-practice hours (laboratory classes, projects): 2

26. Comments:

Approved:

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(date, Instructor’s signature)                                                 (date, the Director of the Faculty Unit signature)