School of Engineering

6312ELE/6412ELE: Process Control

Coursework

Control system design and simulation for a chemical process

Module Name:	Process control
Module Code:	6312ELE/6412ELE
Level:	**6**
Credit Rating:	20
Weighting:	**3**0% (exam worth 70%)
Lecturer:	Dr J B Gomm, Prof D Yu
Contact:	If you have any issues with this coursework you may contact your lecturer. Contact details are: Email: D.Yu@LJMU.AC.UK Tel: 0151 231 2033 Room: 502A (James Parson Building, Byrom Street)
Issue Date:	Monday 4 March 2024
Submission Deadline:	Friday 19 April 2024 – uploading to Canvas.
Feedback:	Feedback will be given on the marked coursework.
Programmes:	BEng Electrical and Electronics Engineering

Introduction

This coursework is to be carried out individually. It includes some questions and is designed to meet the Learning Outcomes of this module, as presented in the module proforma, i.e.

Learning Outcomes:

LO1 Identify the principles of cascade, feed-forward and ratio control of process plants, with typical applications
LO2 Appraise typical components in process systems and develop process models for analysis and controller design
LO3 Characterise strategies for controlling systems possessing dead-time, inverse response and interaction properties
LO4 Use computer based software packages for analysis, design and simulation of process control systems

Additional learning outcomes:

1. Knowledge and understanding of scientific principles and methodology necessary to underpin their education in their engineering discipline, to enable appreciation of its scientific and engineering context, and to support their understanding of historical, current, and future developments and technologies
2. Ability to apply and integrate knowledge and understanding of other engineering disciplines to support study of their own engineering discipline
3. Understanding of engineering principles and the ability to apply them to analyse key engineering processes
4. Ability to identify, classify and describe the performance of systems and components through the use of analytical methods and modelling techniques
5. Ability to apply quantitative methods and computer software relevant to their engineering discipline, in order to solve engineering problems
6. Understanding of and ability to apply a systems approach to engineering problems

Coursework Specification and Marking Scheme

A concentration control loop in an industrial chemical process can be represented by a second order dynamics with a long transmission delay. The two time constants of the second order dynamics are T_1 = 4 min and T_2 = 6 min respectively. The steady state gain is 5 and the dead time is 12 min. The loop is to be controlled to achieve a desired dynamics of first order with time constant T_d = 2 min and zero steady-state offset for a step reference. Produce solutions to the following questions.

(i) Identify the plant transfer function. Then, design a feedback control system with the controller designed using Direct Synthesis method, where the time-delay is approximated using the first-order Taylor expansion. Implement the controller with a standard industrial PID controller.
Simulate the designed control system for 100 minutes using a unity step input as the reference signal. Display the output and the set-point in the top figure, and the corresponding control variable u(t) in the bottom figure.

[20 marks]

(ii) Design a feedback PID control system for the given plant, where the PID controller is designed using the closed-loop Ziegler-Nichols empirical method. The Simulink model used in the experiment to obtain the sustained oscillatory output curve should be displayed, and the output curve should also be displayed. The controller design procedure should be presented. Do the same simulation and display the results as in (i).

[20 marks]

(iii) Design a Smith Predictor control system for the given plant with the controller designed using the Direct Synthesis method. A block diagram should be shown to demonstrate the control system structure. The design details are also required. The designed controller should be implemented using a PID controller. Do the same simulation as in (i).

[20 marks]

(iv) Construct a Simulink model with three sub-models with each for a control system designed in the above. Run the simulation and display the results with three outputs and the set-point in the top figure, and the three control signals in the bottom figure. Compare the performance of the designed three control systems and comment on the performance.

[20 marks]

(v) Write a formal report to present the design, simulations and the results. The report should have a content list, a brief introduction, description of the process to be controlled, presentation of the control system design using each method, simulation models, control systems outputs and corresponding control variables, and finally the comparison, comments and conclusion.
The report should be written logically, clearly and completely. Mathematical expressions would be presented using Microsoft Equation. All figures would have title, labels, units for variables and legends as appropriate.

[20 marks]

Recommended Reading

References

Course Material Book

Author: Seborg, Edgar and Mellichamp

Publishing Year: 2011

Title: Process dynamics and control

Subtitle:

Edition: 3rd

Publisher: McGraw-Hill

ISBN: 978-0-470-64610-6

Author: Ogata, K.

Publishing Year: 1997

Title: Modern Control Engineering

Subtitle:

Edition: 3rd

Publisher: Prentice Hall International

ISBN: 0-13-261389-1

Guide to Performance Criteria **(The Module Leader is advised to delete sections not applicable to the coursework set and if necessary modify the criteria accordingly)**

70% and above:
Your work must be of outstanding quality and fully meet the requirements of the coursework specification and learning outcomes stated. You must show independent thinking and apply this to your work showing originality and consideration of key issues. There must be evidence of wider reading on the subject.

Key words which may describe a coursework at this level include: *appraises, compares, concludes, contrasts, criticizes, critiques, defends, discriminates, evaluates, explains, interprets, justifies, relates, supports.*

60% - 70%:
Your work must be of good quality and meet the requirements of the coursework specification and learning outcomes stated. You must demonstrate some originality in your work and show this by applying new learning to the key issues of the coursework. There must be evidence of wider reading on the subject.

Key words which may describe a coursework at this level include: *categorizes, combines, compiles, creates, devises, generates, modifies, reconstructs, identifies, illustrates, outlines, synthesizes.*

50% - 60%:
Your work must be comprehensive and meet all of the requirements stated by the coursework specification and learning outcomes. You must show a good understanding of the key concepts and be able to apply them to solve the problem set by the coursework. There must be enough depth to your work to provide evidence of wider reading.

Key words which may describe a coursework at this level include: *demonstrates, changes, applies, operates, produces, predicts, shows, solves, uses, translates, comprehends, converts, generalizes.*

40% - 50%:
Your work must be of a standard that meets the requirements stated by the coursework specification and learning outcomes. You must show a reasonable level of understanding of the key concepts and principles and you must have applied this knowledge to the coursework problem. There should be some evidence of wider reading.

Key words which may describe a coursework at this level include: *comprehends, defines, describes, identifies, knows, labels, lists, matches, outlines, recalls, recognizes, reproduces, selects, states, rewrites.*

Below 40%:
Your work is of poor quality and does not meet the requirements stated by the coursework specification and learning outcomes. There is a lack of understanding of key concepts and knowledge and no evidence of wider reading.

Plagiarism

Plagiarism is considered as academic misconduct. The University takes cases of plagiarism very seriously and all alleged cases of academic misconduct will be investigated thoroughly by a School Investigatory Panel. Students are advised to ensure that any coursework submitted is their own work or, where the work of others is referred to (this includes **any** third-part material e.g. text, images, diagrams, drawings), it is correctly referenced. The University defines plagiarism in the following way:

- The representation of the work, written or otherwise, of any other person, from any source whatsoever, as the candidate's own. Examples of plagiarism may be as follows:
- The verbatim copying of another's work without clear identification and acknowledgement – including the downloading of materials from the internet without proper referencing and acknowledgement
- The close paraphrasing of another's work by simply changing a few words or altering the order of presentation, without clear identification and acknowledgement.
- Unidentified and unacknowledged quotation of phrases from another's work.
- The deliberate and detailed presentation of another's concept as one's own.

For more information you are directed to following the university websites:

- Information regarding ***plagiarism***: http://www.ljmu.ac.uk/StudentServices/81924.htm
- Information on ***study skills***: http://www.ljmu.ac.uk/lea/78126.htm
- Information regarding ***referencing***: http://www.ljmu.ac.uk/lea/78127.htm