Process Control and Instrumentation - Web course

COURSE OUTLINE

The first course in control engineering generally introduces the fundamental concepts, principles and application of control theory and controller design to the undergraduate students of chemical engineering.

This course " Process Control and Instrumentation " goes deeper into the various aspects of control engineering along with bringing out the theories and practical knowledge of control engineering.

Each topic will be developed in logical progression with up-to-date information.

The topics cover introductory concepts, modeling considerations, dynamic behavior of chemical processes, stability aspects and design of feedback controller.

Other topics which will be covered are control strategies such as feed-forward controller, cascade control structure, ratio control, split-range control, selective control and preliminary concepts of adaptive control.

Even though the course is on first course of control engineering, the topics on multi-loop multivariable control will also be presented for completeness.

Instrumentation part will consist of valve characteristics, various measuring devices, instrumentation symbols and introduction to P&ID.

The course material will be very useful to undergraduate students, teachers and control practitioners.

A number of chosen problems will be solved to illustrate the concepts clearly.

Contents:

Introductory concepts; first principles model development of chemical processes, steady state and dynamic behaviour; linearization of nonlinear processes, Laplace Transform, initial and final value theorems.

Transfer function of chemical processes, poles and zeros of a transfer function; stability issues, unstable and non-minimum phase behavior; dynamics of first, second and higher order linear systems.

Frequency response analysis - Bode and Nyquist plot; introduction to feedback control, elements of control loop, servo and regulatory problems; P, PI, PID controllers.

Routh-Hurwitz criteria, root-locus analysis; design of feedback controller - performance criteria, controller tuning methods, Cohen-Coon method, 1/4th decay ratio method, direct synthesis methods, gain and phase margins, Ziegler-Nichols method, Bode & Nyquist stability criteria, robustness analysis.

Feed forward controller, cascade control structure, ratio control, split range control, selective control, override control, auctioneering control; adaptive and inferential control; multi loop multivariable control.

Final Control Elements; measuring devices, instrumentation symbols introduction to process flow diagram (PFD) and piping & instrumentation diagram (P&ID)

COURSE DETAIL

NP-TEL

NPTEL

http://nptel.iitm.ac.in

Chemical Engineering

Coordinators:

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S.No	Topics	No. of Hours
1	**Introductory Concepts:** a. Representative process control problems -Liquid Surge Tank, Blending Process. b. Incentives for Chemical Process Control. c. Classification of variables and design elements of a control system.	1
2	**Modeling Considerations:** a. Rationale for process modeling. b. General modeling principles; balance equations - mass, energy, momentum; Thermodynamics and reaction kinetics; degrees of freedom analysis. c. State variables, State equations; input-output models. d. Lumped and distributed parameter systems. e. Steady state and dynamic behavior. f. Examples – liquid serge tank, isothermal chemical reactor.	3
3	**Dynamic behavior of Chemical Processes:** a. Solving algebraic equations and integration of ODEs. b. Concept of nonlinearity; linearization of nonlinear processes; deviation variables. c. Concept of Laplace Transform (LT); the LT of basic functions - step, impulse, pulse, ramp, exponential, integral, derivative, time delay; initial and final value theorems. d. Solution of differential equation using LT techniques - Partial fraction expansion, direct division. e. Transfer function of Single Input Single Output (SISO) process; Transfer function matrix of Multi Input Multi Output (MIMO) process. f. Properties of transfer function; Poles and Zeros of a transfer function; stability issues, unstable and non-minimum phase behavior. g. Dynamic response of a first order process, first order plus dead time process, second order process, pure capacitive process, pure dead time, higher order process; inverse response; Padé approximation. h. Interacting and non-interacting processes. i. Development of Empirical model - Model development using linear and nonlinear regression, fitting first and second order models using step test results. j. Frequency response analysis - Bode and Nyquist plot.	12

4	**Feedback controller:** a. Introduction to feedback control. b. Elements of Control loop - controller, measuring device, final control element, transmission lines, transducers, transmitters, block diagram. c. Concept of servo and regulatory problems. d. Selection of measured, manipulated and controlled variables. e. Types of controller - P, PI, PID, on-off. f. Effects of proportional, integral and derivative actions. g. Notion of stability - characteristic equation, Routh-Hurwitz criteria, root-locus analysis. h. Design of feedback controller - performance criteria, controller tuning methods, Cohen-Coon method, 1/4th 12 decay ratio method, direct synthesis methods, gain and phase margins, Ziegler-Nichols method, Bode & Nyquist stability criteria, robustness analysis. i. Compensation for large dead time and inverse response, Smith Predictor.	12
5	**Other control strategies:** a. Feed forward controller - design with steady state model, design with dynamic model, combination of feed forward-feedback structure. b. Cascade control structure - analysis and design. c. Ratio control, split range control, selective control, override control, auctioneering control. d. Concepts of adaptive and inferential control.	5
6	**Multi loop multivariable control:** a. Process and control loop interaction. b. Singular Value Decomposition (SVD), Relative Gain Array (RGA), I/O pairing. c. Sensitivity to model uncertainty; failure sensitivity. d. Decoupling and design of non-interacting control loops. e. Example - Design of controller and control structure for a 4 input x 4 output Distillation Column.	4
7	**Instrumentation:** a. Final Control Elements - Valve characteristics, thyristors. b. Measuring Devices for flow, temperature, pressure and level. c. Instrumentation symbols.	5

	d. Introduction to Process Flow Diagram (PFD) and Piping & Instrumentation Diagram (P&ID).	
	Total	42

References:

1. Stephanopoulos, G., " Chemical Process Control: An Introduction to Theory and Practice ", Prentice-Hall, New Jersey, 1984.
2. Coughanowr, D. R. and L. B. Koppel, " Process systems Analysis and Control ", Mc-Graw-Hill, 2nd. Ed., 1991.
3. Luyben, W. L.," Process Modelling Simulation and Control for Chemical Engineers ", McGraw Hill, 1990.