



GUJARAT TECHNOLOGICAL UNIVERSITY

Program Name: Bachelor of Engineering

Level: UG

Branch: Chemical Engineering

Subject Code: BE05005011

Subject Name: Instrumentation and Process Control

w.e.f. Academic Year:	2024-25
Semester:	5
Category of the Course:	Professional Core Courses

Prerequisite:	Material and Energy Balance Calculations, Basics of differential equations.
Rationale:	The course introduces the fundamentals of process control and instrumentation with practical applications. It introduces transfer function based mathematical modeling of single-loop systems, dynamic response analysis of open- and closed-loop systems, stability in time and frequency domains. The course also emphasizes process instrumentation, including principles of measuring temperature, level, pressure, flow, along with transmitters, transducers, control valves, and digital/analog components used in PLC, DCS, and SCADA systems.

Course Outcome:

After Completion of the Course, Students will be able to:

No	Course Outcomes
01	Develop mathematical models of first and second order systems using Laplace transforms and transfer functions for stable and resource-efficient process control.
02	Analyze transient and frequency response and evaluate stability for safe, energy-efficient, and environmentally compliant operation.
03	Select and implement P, PI, PD, and PID controllers with appropriate final control elements for stable and sustainable process performance.
04	Select and evaluate process measurement instruments (temperature, pressure, level, flow) considering accuracy, dynamics, safety, and environmental compliance.

Teaching and Examination Scheme:

Teaching/Learning Scheme in hrs/semester					Total Credits	Assessment Pattern and Marks					Total Marks
L	T	P	PBL*	TH	TH/30	Theory		Practical			
						ESE (E)	PA (M)	PA (I)	PBL(I)	ESE (V)	
60	0	30	30	120	4	70	30	20	30	50	200

Where L = Lecture, T= Tutorial, P= Practical, TW/SL = Term-Work / Self-Learning, TH = Total Hours, ESE = End-Semester Examination, PA = Progressive Assessment



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Problem Based Learning (PBL) aims to accommodate learning beyond syllabus as per clause 9.4 of NBA manual.

Course Content:

Unit No.	Content	No. of Hours	% of Weightage
1	Introduction of Process Control: Need for control and automation, Steady state and dynamic system, control logic, servo and regulatory, control, block diagrams, control structures (feedback vs. feedforward), Sustainable plant operation using feedback systems	3	5
2	Laplace Transforms: Definition, Transforms of simple functions, Ramp functions, Sine functions, Solutions of differential equations. Inversions of transform function by partial fractions, qualitative nature of solutions, Final value and initial value theorems, Translation of transforms, Transforms of unit impulse functions, Transforms of integral	4	7
3	Response of First Order Systems: Mercury thermometer, Transient response of step functions, Sinusoidal input, Impulse functions. Physical Examples of First Order Systems: Liquid level, Mixing process, linearization. First Order System in Series: Non interacting system of liquid level, Generalization of several non-interacting systems in series, Interacting systems.	6	10
4	Second Order Systems: Development of transfer functions, Damped vibrator, Liquid manometer, Thermometer in thermo-pocket, Step response & impulse response, Overshoot, Decay ratio, Rise time, Response time, Period of oscillation, Natural period of oscillation, Sinusoidal response, Transportation lag.	4	7
5	The Control Systems: Block diagram, Standard block diagram symbols, Negative and positive feedback, Servo problem v/s regulator problems, Development of block diagrams, Process measuring element, Controller, Final control element. Closed Loop Transfer Functions: Sustainable control loop design, Block diagram reduction, Overall transfer function for single loop system, Overall transfer function for change in load, Overall transfer function for multi loop control system, process and instrumentation diagrams, parts of control system.	5	8
6	Controllers and Final Control Elements: Actual v/s Ideal controller, Pneumatic controller mechanism of proportional control, Proportional integral (PI) control, Proportional derivative (PD) control, Proportional integral derivative (PID) control. Control valve, Control valve characteristics. Transfer functions of P, On-off, PI, PD, and PID control, Motivation for addition of integral and derivative modes, Block diagram of chemical reactor control system.	5	8



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7	Transient Response of Simple Control Systems: Proportional control for Set point change (Servo Problem), Proportional control for load change (Regulator Problem), Proportional integral control for load change, Proportional Integral control for set point change, Proportional control for system with measurement lag.	4	7
8	Stability: Concept of stability, Definition of stability (linear system), Stability criterion, Characteristic equation, Routh test for stability, Routh array, Method of Root Locus for stability analysis, Nyquist stability criterion.	5	8
9	Frequency Response analysis: Fortunate circumstances, Transportation lag, First order system, First order system in series, Bode diagrams, Bode stability criterion, Graphical rules for Bode diagrams. Transient response phase margin, magnitude ratio, phase shift, open loop bode diagrams of various controllers.	4	7
10	Introduction of Process Measurement: Elements of instruments, Parts of instruments, Static and dynamic characteristics.	3	5
11	Temperature Measurement: Scales, Expansion thermometers like constant volume gas, Mercury in glass, Bimetallic, Filled system thermometer like pressure spring thermometer, Static accuracy of thermometer, Dip effect in thermometer, Errors in thermometer of liquid and gas filled type like cross ambient effect, Head effect, Methods of compensation, Thermoelectric temperature measurement: Thermo couples, Pyrometers: Radiation pyrometer, Photo electric pyrometers, Optical pyrometers, Errors in optical pyrometers.	5	8
12	Pressure Measurement: Liquid column manometer, Enlarged leg manometer, Inclined tube manometer, Ring manometer, Tilting U tube manometer, Bourdon gauge, Bellows, Bellows differential pressure gauge, Vacuum Measurement: Ionization gauge, Pirani vacuum gauge, Thermocouple vacuum gauge, McLeod gauge,	3	5
13	Liquid Level Measurement: Direct measurement, Float and tap, Float and shaft, Hydraulic remote transmission, Bubbler system, Diaphragm & air trap system, Differential pressure manometer, Float and spring pneumatic balance, Displacement float, Magnetic float gauge.	3	5
14	Flow Measurement: Head flow meter, Orifice plate, Flow nozzle, Venturi tube, Pitot tube, Differential pressure meter, Electric type head flow meter, Bellows type meter, Rota meter, Piston type area meter and Positive displacement meter, Flow control actuators: different types of valves.	3	5
15	Introduction to advance topics I- Electrical and pneumatic signal conditioning and transmission, Computer process control, PLC, DCS, and SCADA, Use of Artificial Intelligence in plant automation.	3	5
	Total	60	100



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Sustainability alignment: This course addresses SDG7 (Affordable and Clean Energy), SDG 9 (Industry, Innovation and Infrastructure) with the help of industrial automation and control strategies efficient plant operation can be carried out.

Suggested Specification table with Marks (Theory):

Distribution of Theory Marks					
R Level	U Level	A Level	N Level	E Level	C Level
10	20	15	10	10	5

Legends: R: Remembrance; U: Understanding; A: Application, N: Analyze; E: Evaluate and C: Create and above Levels (Revised Bloom's Taxonomy)

Note: This specification table shall be treated as a general guideline for students and teachers. The actual distribution of marks in the question paper may vary slightly from above table.

References/Suggested Learning Resources:

(a) Books:

1. Coughanowr, D. R., LeBlanc, S. "Process Systems Analysis and Control", 3rd edition, McGraw-Hill (2008).
2. Stephanopoulos, G. "Chemical Process Control: An Introduction to Theory and Practice", Pearson Education (1984)
3. Seborg, D.E., Edgar, T.F., Mellichamp, D.A. "Process Dynamics and Control", 2nd edition, John Wiley (2003)
4. William C. Dunn, Fundamentals of Industrial Instrumentation and Process Control, McGrawHill (2005)..
5. S.K. Singh, Industrial Instrumentation and Control, 3rd edition, McGraw-Hill (2008)
6. R. P. Vyas, "Process Control and Instrumentation", Denett & Co.
7. Donald .P. Eckman, "Industrial Instrumentation", John Wiley & Sons Inc, New York.

(b) Open source software and website:

1. Scilab Xcos open source software can be used for process control modelling and analysis.
2. Students can refer to video lectures available on the websites including NPTEL
3. Students can refer website of "The International Federation of Automatic Control (IFAC)" <https://www.ifac-control.org/> for international conference proceedings.



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Problem based learning activity can include the following:

Sr. No.	Description	No. Of hours	Total Hrs.
1	Project based on control strategy for controlling parameters (Temp./Pressure/Flow/Composition) in any unit process / unit operation used in chemical industry	Select one process (tank level / heat exchanger / CSTR / flow loop)2h Develop mathematical model.2h Identify controlled variables, manipulated variables, disturbance variables.2h Introduce PID controller for automation with control strategy suggesting improvements for controlling parameters for the above process.2h Prepare technical report (10–15 pages).2h	10
2	Industrial visit to chemical plant control room and submit report	Observe PID tuning parameters used in real plant. 2h Identify control loops: temperature, pressure, level, flow control systems.2h Understand alarm management system. Prepare block diagram of one real control loop (e.g., steam temperature control).2h Report should include: loop description, sensor used, controller type, control valve action.4h	10
3	Case study on industrial control failure (e.g., reactor runaway or any industrial accident)	Analyze Bhopal Gas Tragedy or any other chemical industry accident from control and instrumentation perspective. 3 h Report should include: Major cause due to which accident took place and preventive measures to avoid these type of accidents from control and instrumentation perspective 2 h	05
4	MATLAB/Scilab based modeling of process control system	Model first-order system/second order system 2h Simulate step response and impulse response 2h Analyze overshoot, rise time, settling time.2h Implement PID controller and compare P, PI, PD responses2h Plot Bode and Nyquist diagrams.2h	10
5	Online certification course (NPTEL)	Complete NPTEL course on Process Dynamics & Control.5h Submit learning summary of 5 modules.5h	10
6	Poster/Presentation on Process Control systems/ Automation	Poster/Chart/Powerpoint preparation 5h and presentation (any one topic to be considered)5h	10



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strategy for Temperature/Flow/Pressure control for any unit process		
Max. Hours to be allotted		30

- Above activities are suggestive, faculty can choose any of these activities. However, project at sr.no 1 is compulsory
- The number of hour is suggestive. Faculty can sub-divide the number of hours based on the activity. However, the total number of hours is fixed.
- All records pertaining to the evaluation and assessment of self-learning activities must be properly maintained and preserved at the institute level. These records should be made available to the university upon request.
- Institutes are encouraged to utilize digital platforms, such as Microsoft Teams, for effective record keeping and to ensure transparency in the evaluation and assessment of problem based learning.

List of Experiments: (Minimum 10 experiments to be performed)

1. Response of first order system: thermometer
2. Response of first order liquid level system
3. Response of mixing process
4. Responses of second order system: U-tube manometer or damped vibrator
5. Response of Interacting tanks
6. Response of Non-interacting tanks
7. Calibration of thermos couple test rig.
8. Characteristics of flow control valves
9. Temperature and pressure measuring devices
10. Level measuring devices (Bubble system)
11. Viscosity and pH measuring devices (pH Control trainer)
12. Transmitters and transducers
13. Open loop systems: lagged thermometer
14. Temperature, level, flow, and pressure control trainers
15. Flow-level cascade control

Major Equipment:

Interacting and Non-Interacting Tank System Setup, Control Valve Setup with Positioner, PID Controller Trainer Kit, DCS/SCADA Simulation for any unit process, Level Measurement Setup(Bubbler system / Differential pressure type), Flow Measurement Setup



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(Orifice meter / Venturi meter / Rotameter), Temperature Measurement Setup (Thermocouple, RTD, Bimetallic thermometer)

Suggested Activities for Students: Preparation of power-point slides, which include videos, animations, pictures, graphics for better understanding theory and practical work – The faculty will allocate chapters/ parts of chapters to groups of students so that the entire syllabus be covered. The power-point slides should be put up on the web-site of the College/ Institute, along with the names of the students of the group, the name of the faculty, Department and College on the first slide.
