GUJARAT TECHNOLOGICAL UNIVERSITY (GTU)

Competency-focused Outcome-based Green Curriculum-2021 (COGC-2023)

Semester - VI

Course Title: **Advance Process Control**

(Course Code: 4361703)

Diploma programme in which this course is offered	Semester in which offered
Instrumentation and Control Engineering	Sixth

1. RATIONALE

This course lays a strong foundation in process control, covering history, basics, closed-loop control and advanced process control. Advanced process control is based on the need to address the complexities and challenges present in sophisticated industrial processes. As industries evolve and become more technologically advanced, there is a growing demand for specialized control strategies and techniques. Students gain hands-on experience in controller synthesis, advanced strategies, and intelligent systems, developing a holistic grasp of automation in diverse industries. The structured progression—from basics to innovations—prepares students for the ever-evolving tech landscape in this dynamic field.

2. COMPETENCY

The purpose of this course is to help the student to attain the following industry identified competency through various teaching learning experiences:

- **Understand, implement, analyze, design and simulate various advanced process control strategies.**

3. COURSE OUTCOMES (COs)

The practical exercises, the underpinning knowledge and the relevant soft skills associated with this competency are to be developed in the student to display the following COs:

a) Describe advanced process control concepts.
b) Analyze the performance of closed loop control system for various controller configuration.
c) Describe the basics of digital control systems.
d) Implement advanced control strategies for various process control.
e) Describe the basics of Artificial Neural Network and fuzzy logic system.

4. TEACHING AND EXAMINATION SCHEME

Teaching Scheme (In Hours)			Total Credits (L+T+P/2)	Examination Scheme				
				Theory Marks		Practical Marks		Total Marks
L	T	P	C	CA*	ESE	CA	ESE	
3	0	2	4	30*	70	25	25	150

(*): Out of 30 marks under the theory CA, 10 marks are for assessment of the micro-project to facilitate integration of COs and the remaining 20 marks is the average of 2 tests to be taken during the semester for the assessing the attainment of the cognitive domain UOs required for the attainment of the COs.

***Legends: L**-Lecture; **T** – Tutorial/Teacher Guided Theory Practice; **P** -Practical; **C** – Credit, **CA** - Continuous Assessment; **ESE** -End Semester Examination.*

5. SUGGESTED PRACTICAL EXERCISES

The following practical outcomes (PrOs) that are the subcomponents of the COs.*Some ofthe **PrOs** marked **'*'** are compulsory, as they are crucial for that particular CO at the 'Precision Level' of Dave's Taxonomy related to 'Psychomotor Domain'*.

S. No.	Practical Outcomes (PrOs)	Unit No.	Approx. Hrs. Require
1	Design and Simulate a closed-loop control system for a given process, considering stability and performance.	1	2
2	Design and Simulate a PID controller for temperature regulation in a simulated system.	2	2
3	Compare the performance of a proportional, integral, and derivative controller in a practical setup.	2	2
4	Set up a basic DDC system for monitoring and controlling a simple process.	3	2
5	Design and implement a DDC system for heating application, considering efficiency and user comfort.	3	2
6	Develop a machine learning algorithm for predicting variations in a controlled process.	3	2
7	Design and Simulate a cascade control system.	4	2
8	Design and Simulate a feedback control system.	4	2
9	Design and Simulate a feed forward control system.	4	2

10	Design and Simulate a ratio control system.	4	2
11	Design and Simulate a selective control system.	4	2
12	Design and Simulate an adaptive control system.	4	2
13	Compare any two control System with practical setup.	4	2
14	Train an Artificial Neural Network to predict the behavior of a complex system.	5	2
15	Apply fuzzy logic to a control system, considering imprecise or uncertain variables.	5	2
	Total		30

Note

*i. More **Practical Exercises** can be designed and offered by the respective course teacher to develop the industry relevant skills/outcomes to match the COs. The above table is only a suggestive list**.***

*ii. The following are some **sample** 'Process' and 'Product' related skills (more may be added/deleted depending on the course) that occur in the above listed **Practical Exercises** of this course required which are embedded in the COs and ultimately the competency..*

Sr. No.	**Sample Performance Indicators for the PrOs**	**Weightage in %**
1	Prepare of experimental setup/simulation circuit	20
2	Operate the equipment setup or execute simulation circuit	20
3	Follow safe practices measures	10
4	Record observations correctly	20
5	Interpret the result and conclude	30
Total		**100**

6. MAJOR EQUIPMENT/ INSTRUMENTS REQUIRED

This major equipment with broad specifications for the PrOs is a guide to procure them by the administrators to usher in uniformity of practicals in all institutions across the state.

i. Computer System.
ii. Simulation Software.

7. AFFECTIVE DOMAIN OUTCOMES

The following ***sample*** Affective Domain Outcomes (ADOs) are embedded in many of the above mentioned COs and PrOs. More could be added to fulfil the development of this competency.

a) Work as a leader/a team member.
b) Follow safety practices while using electrical appliances.
c) Practice environmental friendly methods and processes. (Environment related)

The ADOs are best developed through the laboratory/field based exercises. Moreover, the level of achievement of the ADOs according to Krathwohl's 'Affective Domain Taxonomy' should gradually increase as planned below:

i. 'Valuing Level' in 1st year
ii. 'Organization Level' in 2nd year.
iii. 'Characterization Level' in 3rd year.

8. UNDERPINNING THEORY

Only the major Underpinning Theory is formulated as higher level UOs of *Revised Bloom's taxonomy* in order development of the COs and competency is not missed out by the students and teachers. If required, more such higher level UOs could be included by the course teacher to focus on attainment of COs and competency.

Unit	Unit Outcomes (UOs) (4 to 6 UOs at Application and above level)	Topics and Sub-topics
Unit – I Introduction to Process Control	1. Define process and process control. 2. Enlist types of process. 3. List benefits, difficulties and Requirements of Process Control Implementation. 4. Classify process variables. 5. Compare Open-loop vs. Closed-loop Systems. 6. Compare Servo vs. Regulatory Control. 7. Compare Feedback and Feedforward Control Configuration. 8. List Steps followed in Synthesis of a Control System.	1.1 Introduction. 1.2 Evolution of Process Control. 1.3 Concept, Definition, and Types of Process. 1.4 Benefits, Difficulties, and Requirements of Process Control Implementation. 1.5 Classification of Process Variables. 1.6 Open-loop vs. Closed-loop Systems. 1.7 Servo vs. Regulatory Control. 1.8 Feedback and Feedforward Control Configuration. 1.9 Steps in Synthesis of a Control System.

Unit – II Closed-loop Response	1. Derive transfer functions of Closed Loop. 2. Explain P controller. 3. Explain PI controller. 4. Explain PD controller. 5. Explain PID controller. 6. Discuss response of controller for step, pulse, ramp, sinusoid. 7. Compare Various Controller Configurations. 8. Discuss Controller Tuning procedure.	2.1 Transfer Functions of Closed Loop control system. 2.2 Proportional Controller in Closed Loop. 2.3 Integral Controller in Closed Loop. 2.4 PI Controller in Closed Loop. 2.5 PD Controller in Closed Loop. 2.6 PID Controller in Closed Loop. 2.7 Controller response for different test inputs. 2.8 Integral Windup and Anti-windup. 2.9 Comparison of Various Controller Configurations. 2.10 Controller tuning methods: Process Reaction Curve, Ziegler –Nichols. Evaluation Criteria- IAE, ISE, ITAE.
Unit– III Digital Controllers	1. Define key parts of Direct Digital Control system. 2. Explain DDC operation and communication flow. 3. Apply DDC benefits in varied scenarios for efficiency and scalability. 4. Design digital controller for specific applications using discrete domain analysis. 5. Evaluate system stability, critique various DDC configurations in discrete domain. 6. Discuss DDC application in brief. 7. Analyze trends in DDC like IoT integration, machine learning, and analytics.	3.1 Introduction to DDC. 3.2 Components and working of DDC. 3.3 Benefits of DDC. 3.4 Digital Controller Realization. 3.5 Discrete Domain Analysis. 3.6 Application of DDC • DDC of air heater. • DDC of DC motor speed control. 3.7 Future Trends and Innovations • IoT Integration • Machine Learning in DDC • Advanced Analytics
Unit– IV Advance Control Strategies	1. Explain cascade control. 2. Explain Feedforward control. 3. Explain Feedforward-feedback Control Configuration. 4. Explain Ratio Control with an examples. 5. Explain Selective Control. 6. Explain Adaptive Control. 7. Compare Selective Control v/s Adaptive Control. 8. Draw and explain Adaptive	4.1 Cascade Control: Features, Cascade control of Jacketed CSTR and boiler drum level, and advantages of Cascade Control. 4.2 Feedforward Control: Feedforward control of distillation column, heat exchanger, and drum boiler, advantages and disadvantages of Feedforward Control. 4.3 Ratio Control. 4.4 Selective Control: Override control, protection of a drum boiler, protection of steam

	Control Configuration.	distribution system, and prevention of flooding in distillation column, Split-range control. 4.5 Adaptive Control. 4.6 Adaptive Control Configuration: Programmed adaptive control, Self-adaptive controller, Model Reference adaptive controller, and self-tuning Regulator.
Unit– V Introduction to Neural-Fuzzy system	1. Define Artificial Neural Network (ANN). 2. Classify Artificial Neural Network (ANN). 3. List Applications of ANN. 4. Define Fuzzy Logic. 5. List Applications of Fuzzy Logic. 6. Compare Fuzzy vs. ANN.	5.1 Introduction Artificial Neural Network (ANN). 5.2 Perceptron Model for ANN. 5.3 Classification of ANN. 5.4 Introduction of fuzzy logic. 5.5 Crisp vs. Fuzzy Logic. 5.6 Fuzzy Logic vs. Probability. 5.7 Applications of Fuzzy Logic and ANN.

***Note**: The UOs need to be formulated at the 'Application Level' and above of Revised Bloom's Taxonomy' to accelerate the attainment of the COs and the competency.*

9. SUGGESTED SPECIFICATION TABLE FOR QUESTION PAPER DESIGN

Unit No.	Unit Title	Teaching Hours	Distribution of Theory Marks			
			R Level	U Level	A Level	Total Marks
I	**Introduction to Process Control**	6	4	4	2	10
II	**Closed-loop Response**	8	4	6	2	12
III	**Digital Controllers**	8	6	5	3	14
IV	**Advance Control Strategies**	14	10	8	6	24
V	**Introduction to Neural-Fuzzy system**	6	4	4	2	10
Total		**42**	**28**	**27**	**15**	**70**

***Legends:** R=Remember, U=Understand, A=Apply and above (Revised Bloom's taxonomy)*

***Note**: This specification table provides general guidelines to assist students for their learning and to teachers to teach and question paper designers/setters to formulate test items/questions assess the attainment of the UOs. The actual distribution of marks at different taxonomy levels (of R, U and A) in the question paper may vary slightly from the above table.*

10. SUGGESTED STUDENT ACTIVITIES

Other than the classroom and laboratory learning, following are the suggested student-related ***co-curricular*** activities which can be undertaken to accelerate the attainment of the various outcomes in this course: Students should conduct following activities in group and prepare reports of about 5 pages for each activity, also collect/record physical evidences for their (student's) portfolio which will be useful for their placement interviews:

i. Industrial visit should be arranged by department for students so that students can have exposure to the real industrial realm.
ii. Department should arrange a workshop/seminar where students can have interaction with industry personnel.
iii. Faculty guided self-learning activities, Course/library/internet/lab based mini projects, industrial visit etc.
iv. Students should deliver a seminar in groups on advances/latest trends in advanced control system.

11. SUGGESTED SPECIAL INSTRUCTIONAL STRATEGIES (if any)

These are sample strategies, which the teacher can use to accelerate the attainment of the various outcomes in this course:

a) Massive open online courses (***MOOCs***) may be used to teach various topics/ subtopics.
b) Guide student(s) in undertaking micro-projects.
c) ***'L' in section No. 4***means different types of teaching methods that are to be employed by teachers to develop the outcomes.
d) About ***20% of the topics/sub-topics*** which are relatively simpler or descriptive in nature is to be given to the students for ***self-learning***, but to be assessed using different assessment methods.
e) With respect to ***section No.11***, teachers need to ensure to create opportunities and provisions for ***co-curricular activities***.
f) Guide students on how to address issues on environment and sustainability
g) Guide students for using data manuals.

12. SUGGESTED MICRO-PROJECTS

Only one micro-project is planned to be undertaken by a student that needs to be assigned to him/her in the beginning of the semester. In the first four semesters, the micro-project are group-based. However, in the fifth and sixth semesters, it should be preferably be ***individually*** undertaken to build up the skill and confidence in every student to become problem solver so that s/he contributes to the projects of the industry. In special situations where groups have to be formed for micro-projects, the number of students in the group should ***not exceed three.***

The micro-project could be industry application based, internet-based, workshop-based, laboratory-based or field-based. Each micro-project should encompass two or more COs which are in fact, an integration of PrOs, UOs and ADOs. Each student will have to maintain a dated work diary consisting of individual contributions in the project work and give a seminar presentation of it before submission. The total duration of the micro-project should not be less than ***16 (sixteen) student engagement hours*** during

the course. The student ought to submit a micro-project by the end of the semester to develop the industry oriented COs.

A suggestive list of micro-projects is given here. This has to match the competency and the COs.Similar micro-projects could be added by the concerned course teacher:

i. Simulation Models of control system.
ii. Chart / Model Preparation
iii. Prepare Presentation

13. SUGGESTED LEARNING RESOURCES

S. No.	Title of Book	Author	Publication with place, year and ISBN
1	PROCESS CONTROL: PRINCIPLES AND APPLICATIONS	Surekha Bhanot	**1. 978-0195693348** 2. **9780195693348**
2	Introduction to Process Control	Jose A. Romagnoli and Ahmet Palazoglu	
3	Dynamic Simulation of Electric Machinery: Using MATLAB/SIMULINK	Chee-Mun Ong	
4	Direct Digital Control Systems: Application · Commissioning	Sam Nazarian	
5	Direct Digital Control: A Guide to Distributed Building Automation	Lawrence J. Swanson	
6	Digital Control System: Identification, design and implementation	Ioan D. Landau and Gianluca Zito	

14. SOFTWARE/LEARNING WEBSITES

1. MATLAB/Simulink
2. LabVIEW
3. Honeywell UniSim Design Suite
4. DeltaV
5. Coursera - Control of Mobile Robots
6. ISA - International Society of Automation
7. Scilab

15. PO-CO MPETENCY - CO MAPPING

Semester VI	ADVANCE PROCESS CONTROL (Course Code: 4361703)						
	Pos						
Competency & Course Outcomes	PO 1 Basic & Discipline specific knowledge	PO 2 Problem Analysis	PO 3 Design/ development of solutions	PO 4 Engineering Tools, Experimentation & Testing	PO 5 Engineering practices for society, sustainability & environment	PO 6 Project Management	PO 7 Life-long learning
Competency:- •Understand, implement, analyze, design and simulate various advanced process control strategies.							
Describe advanced process control concepts.	3	-	-	-	-	-	1
Analyze the performance of closed loop control system for various controller configuration.	3	2	1	2	-	2	1
Describe the basics of digital control systems.	3	1	1	1	-	1	
Implement advanced control strategies for various process control.	3	2	2	2	1	1	1
Describe the basics of Artificial Neural Network and fuzzy logic system.	3	-	-	-	-	-	1

Legend: '**3**' for high, '**2**' for medium, '**1**' for low or '**-**' for the relevant correlation of each competency, CO, with PO/ PSO

16. COURSE CURRICULUM DEVELOPMENT COMMITTEE

Member – Board of Studies (GTU), Electrical and Allied branches

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