GUJARAT TECHNOLOGICAL UNIVERSITY

Program Name: Bachelor of Engineering
Level: UG
Branch: Power Electronics
Subject Code: BE05024031
Subject Name: Control System Engineering

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

Prerequisite:	**Mathematics**
Rationale:	Automatic control of industrial processes plays a crucial role in enhancing productivity, efficiency, and overall profitability. With the increasing adoption of automation across industries, control systems have become an integral part of modern engineering applications. This importance is further amplified in the context of Industry 4.0, where intelligent and interconnected systems rely heavily on precise and reliable control mechanisms. In this context, it is essential for engineering students to develop a strong foundation in control systems. This course is designed to provide a comprehensive understanding of the principles of automatic control. It covers classical control techniques, analysis and design tools for Linear Time-Invariant (LTI) systems, and introduces the fundamentals of modern control theory, including state-space representation and controller design. The knowledge gained through this course will enable students to analyze, design, and implement control systems effectively in real-world engineering applications

Course Outcomes:

Sr.No.	**CO statement**	**Marks% weightage**
CO1	Develop mathematical models and representations of LTI control systems using transfer functions, block diagram reduction, signal flow graphs and state-space methods.	20
CO2	Analyze the effects of feedback on control system performance, including sensitivity reduction, disturbance rejection, and stability characteristics.	10
CO3	Analyze the behaviour in the transient as well as the steady state LTI systems in the time domain.	15
CO4	Assess control system stability using BIBO stability, Routh stability criterion, and root locus techniques.	20
CO5	Analyze control system stability and performance using frequency response techniques, including polar plots, Bode plots, and Nyquist stability criteria	15
CO6	Explain the basic principles of controllers, compensation techniques and state space analysis of control systems.	20

Teaching and Examination Scheme:

Teaching / Learning Scheme (in Hours per semester)					**Total Credits**	**Assessment Pattern and Marks**					**Total Marks**
						Theory		**Tutorial / Practical**			
L	**T**	**P**	**PBL***	**Total no of hours per semester**		**ESE (E)**	**PA / CA (M)**	**PA/CA (I)**	**PBL (I)**	**ESE (V)**	
45	0	30	15	90	3	70	30	20	30	50	200

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

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

Content:

Sr. No.	Content	Total Hrs
1	**Introduction and modelling of the control system:** Brief history of control systems, Open and closed loop systems- their elements and comparison. Concept of transfer function, mathematical modelling of mechanical and electrical systems, analogous system, force voltage and force current analogy, mechanical equivalent network, transfer function of some basic components like gear trains, armature and field-controlled DC servomotor, etc. Concept of block diagram representation, block diagram reduction techniques and their application, Signal flow graph representation, Mason's gain formula and its application.	6
2	**Feedback Characteristics of Control Systems:** Feedback and non-feedback systems, Effects of feedback on parameter variation reduction, system dynamics, disturbance signals, etc., Linearizing effect of feedback, Regenerative feedback,	7
3	**Time Response analysis:** Introduction to transient and steady state response, standard test signals, concept of "Order" and "Type" of system, time response of first and second order system for standard test input signals, concept of underdamped, undamped, critically damped and over damped system, transient response specifications for second order underdamped system such as rise time, peak time, settling time, max overshoot etc, their concept, derivation and application.Significance of the damping ratio and the undamped natural frequency of oscillation. Concept of steady state error, static error constants, their formulas and determination for Type 0,1 and 2 systems.	6
4	**Concept of stability and Root Locus Techniques:** Concept of BIBO stability, necessary condition for stability, Routh stability criterion, its special cases, concept of relative stability in reference to Routh criterion. The root locus concept, rules to construct root locus plot and its application to sketch root locus plots.	10
5	**Frequency response analysis:** Concept and advantages of frequency response, frequency domain plots, procedure to sketch a polar plot, phase margin, gain margin from polar plot, and Nyquist stability criterion. Bode plots of minimum and non-minimum phase systems, determination of gain margin, phase margin, stability and static error constants from Bode plots. Frequency response of a closed-loop system.	6
6	**Introduction to State Space Analysis:** Advantages of state space analysis, terminology related to state space analysis, State space representation of basic electrical and mechanical systems, Correlation of state space with transfer function, State transition matrix, its properties and computation methods, solution of state equations, basic concept of controllability and observability.	5
7	**Basics of controllers and compensation techniques** Compensation, Types of compensation techniques, and their effects, Phase lead and lag compensation, Proportional, Integral and Derivative control actions, effects of P,PI,PD and PID controllers	5
	TOTAL	**45**

SuggestedSpecificationtablewithMarks(Theory):(ForB.E.only)

Distribution ofTheoryMarks					
RLevel	ULevel	ALevel	NLevel	ELevel	CLevel
15	30	25	15	10	05

R: Remembrance; U: Understanding; A: Application, N: Analyzeand E: Evaluate; 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 the above table.

The course Control System Engineering is directly aligned with SDGs 7, 9, and 13 through its focus on feedback control, stability, and controller design, enabling efficient energy systems and industrial automation. It is indirectly aligned with SDGs 3, 8, 11, and 12, as these principles support smart infrastructure, resource efficiency, and economic growth..

SDG 3	Good Health and Well-being – Indirect linkage Stability and control principles are vital in safety-critical applications such as medical devices, biomedical systems, and life-support equipment. Proper system design prevents failures and ensures reliable operation, directly contributing to human safety and well-being.
SDG 7	Affordable & Clean Energy – Direct linkage Concepts such as feedback systems, stability analysis, and controllers (PID) are essential for regulating voltage, frequency, and power in renewable energy systems and smart grids.
SDG 8	Decent Work and Economic Growth — Indirect Alignment Knowledge of **control system design, modelling, and industrial controllers (PID, state-space)** enhances employability in automation, manufacturing, aerospace, and energy sectors.
SDG 9	Industry, Innovation & Infrastructure – Direct linkage Topics like transfer function modelling, PID controllers, root locus, and state-space analysis are fundamental to designing stable and efficient industrial automation, robotics, and infrastructure control systems.
SDG 11	Sustainable Cities & Communities – Indirect linkage Application of closed-loop control, feedback systems, and dynamic response analysis supports smart traffic systems, elevators, HVAC systems, and urban automation.
SDG12	Responsible Consumption & Production– Direct linkage Concepts like system optimization, error minimization, and compensation techniques (lead/lag) ensure efficient system performance, reducing energy wastage and improving resource utilization.
SDG 13	Climate Action — Direct Alignment Efficient control using stability analysis, frequency response (Bode/Nyquist), and optimized controllers (PI/PID) minimizes energy losses and improves the performance of low-carbon technologies like EVs and renewable systems.

Reference Books:

1. I. J. Nagrath, M. Gopal, Textbook of Control System Engineering, New Age International (I) Ltd.
2. Norman S. Nise, " Nise's Control Systems Engineering" Wiley India edition.
3. S. Hasan Saeed, "Automatic control systems (With Matlab Programs)" S.K.Kataria& sons.
4. K. Ogata, Textbook of Modern Control Systems, Prentice Hall of India, New Delhi.
5. B. S. Manke "Linear Control Systems", Khanna Publishers.

List of Experiments: Suggested Experiment

1. Block diagram reduction using MATLAB
2. To generate standard test signals for the control system using the MATLAB program and display them simultaneously.
3. To study and analyse time responses of first and second-order control systems using MATLAB.
4. To study and analyse steady state errors for different "types" of systems using Simulink.
5. To plot the root locus of the given transfer function using MATLAB.
6. To study frequency response analysis by sketching Bode plots using MATLAB.
7. To study frequency response analysis and study relative stability by sketching Nyquist plots using MATLAB.
8. To study the effect of P, PD, PI, and PID controllers on second-order control systems.
9. To design a Lag and lead compensator using root locus techniques.
10. To study state space model representation using MATLAB.

Major Equipment:

Computer systems (minimum i5 / 8 GB RAM recommended), Software (Mandatory) MATLAB with Simulink, Control System Toolbox, Signal Processing Toolbox, Optional: Data acquisition board for hardware integration (if required)

List of Open-SourceSoftware:

1. Open Modellica
2. GNU Octave
3. Scilab

List of learning websites:

1. MIT OpenCourseWare (https://ocw.mit.edu/courses/electrical-engineering-and-computer-science/)
2. NPTEL
3. Coursera
4. edX
5. Reputed Research Journal Website

List of suggested activities for Problem-based Learning (PBL):

Sr.No.	PBL Category	Name of the activity	No. of hours	Evaluation Criteria
1	Industry / Research Laboratory Visit	Industry/Research laboratory Visit	Visit = 5hrs, Report preparation = 5hrs Total = 10hrs	Based on the report submitted. Report should contain observations and calculations based on industry/ lab data.
2	Video-Based Learning	Technical Video-based learning related to the subject	Duration of video = 5hrs Report preparation = 5hrs	Report /presentation based on the video learning outcomes.

Sr.No.	PBL Category	Name of the activity	No. of hours	Evaluation Criteria
		(MOOC/NPTEL Video)	Total = 10hrs	
		Self-learning online course	The minimum duration of the course should be 10 hours.	Examination-based assessment at the end of the course. Based on the certificate produced.
		Annotated Video Explanation of Concept/Problem	10hrs (Preparation + Recording + Submission)	Based on the accuracy of explanation, clarity, and presentation style.
3	Assignment/ Technical Writing / Research Writing	Assignment writing. Numerical-based assignment is preferable.	5 assignments of 2 hours each. Total = 10hrs	Based on the assignment submitted.
		Blog or Technical Article Writing	10hrs (Research – 6hrs, Writing – 4hrs)	Based on originality, technical content, references cited, and clarity of communication.
4	Complex Problem-Solvingtargeting relevant SDGs. / Mini Project	Complex problem solving	Maximum 2 problems. Study of the problem and solution finding, Total = 15 hrs	Based on the depth of the solution submitted.
5	Research Paper Review / Analysis	Discussion on a research paper based on a relevant subject (SCOPUS Index/any reputed Journal)	5 research paper = 20 hrs	Summarize research paper and the evaluation of critical parameters
6	Poster/ Chart/ Power point presentation	Poster/chart/power point preparation on technical topics	Duration = 6 hrs	Based on poster/chart preparation and presentation skills
7	MicroProject	Working/non-working model on technical topics	Working = 10hrsnon-working = 10hrs	Based on inter-department/external evaluation
8	Group Discussion / Quiz / Simulation	Group Discussion on emerging/trending technical topics based on the subject	Duration = 1 hrs each	Based on performance in group discussion, technical depth,knowledge etc.
		Online Technical Quizzes/Simulations	Multiple quizzes summing up to 10 hours	Based on quiz scores and the reflection report after each quiz.
9	Case Study Analysis / Seminar	Real-world case studies-based learning	Duration of data collection/study = 5hrs Report preparation = 5hrs Total = 10hrs	Based on an in-depth study, technical depth, data collected, fact-finding, etc.
10	Other	Patent Search and Innovation Gap Identification	10hrs (Search + Report)	Based on the number of relevant patents analyzed and the identification of innovation scope.

Note:

1. In alignment with Outcome-Based Education (OBE) and NBA accreditation requirements, the subject **Control System Engineering** incorporates;
   - Mini Project – 10 Marks
   - Micro Project – 5 Marks

These activities are incorporated as integral components of PBL. These activities are designed to foster experiential learning, encourage innovation, and strengthen problem-solving skills by engaging students in practical applications of power converter design, simulation, and analysis. The inclusion of PBL ensures that learners develop higher-order cognitive abilities mapped to Bloom's taxonomy, while simultaneously enhancing teamwork, communication, and research competencies essential for professional engineering practice.

2. The hours allocated to specific activities should be proportionate to the total number of PBL hours and marks.

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