



# GUJARAT TECHNOLOGICAL UNIVERSITY

Program Name: Bachelor of Engineering

Level: UG

Branch: Electrical Engineering

Subject Code: BE05009011

Subject Name: Control Systems

|                        |                          |
|------------------------|--------------------------|
| W.E.F. Academic year   | 2024-25                  |
| Semester               | 5                        |
| Category of the Course | Professional Core Course |

|                      |                                                                                                                                                                                                                                                                                                                                                                             |
|----------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Prerequisite:</b> | Basic knowledge of Signals and Systems.                                                                                                                                                                                                                                                                                                                                     |
| <b>Rationale:</b>    | Automatic control of industrial processes is essential for increasing the output and in turn the profit of an industry. As a result, most of the companies are using automatic control of the machineries and processes. As an engineer, a student must know the basics of automatic control system. This subject is intended to supplement the basic skill of an engineer. |

## Course outcomes:

| Sr No                                                                    | CO statement                                                                                                                                             | Weightage% |
|--------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------|------------|
| <b>On successful completion of this course student will be able to :</b> |                                                                                                                                                          |            |
| CO1                                                                      | Develop mathematical models and representations of control systems using transfer functions, block diagram reduction, and signal flow graphs.            | 20         |
| CO2                                                                      | Analyse the behaviour in transient as well as steady state of an LTI system in time domain.                                                              | 20         |
| CO3                                                                      | Understand control system stability using BIBO stability, Routh stability criterion, and root locus techniques.                                          | 20         |
| CO4                                                                      | Analyse control system stability and performance using frequency response techniques, including polar plots, Bode plots, and Nyquist stability criteria. | 20         |
| CO5                                                                      | Explain the basic principles of controllers, compensation techniques, and state space analysis in control systems.                                       | 20         |

## Teaching and examination scheme:

| Teaching-Learning scheme in<br>(Hours per semester) |   |    |     |     | Total<br>credits=<br>TH/30 | Assessment Pattern and marks |           |                    |            |            | Total<br>marks |
|-----------------------------------------------------|---|----|-----|-----|----------------------------|------------------------------|-----------|--------------------|------------|------------|----------------|
| L                                                   | T | P  | PBL | TH  |                            | Theory                       |           | Tutorial/Practical |            |            |                |
|                                                     |   |    |     |     |                            | ESE<br>(E)                   | PA<br>(M) | PA<br>(I)          | PBL<br>(I) | ESE<br>(V) |                |
| 45                                                  | 0 | 30 | 45  | 120 | 4                          | 70                           | 30        | 20                 | 30         | 50         | 200            |

Where L = Lecture, T= Tutorial, P= Practical, TH = Total Hours, ESE = End Semester Examination, PA = Progressive Assessment.

**\*Problem based learning (PBL) aims to accommodate learning beyond syllabus as per clause 9.4 of NBA manual.**



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## Content:

| Sr no | Content                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | Total hours | Weightage% |
|-------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------|------------|
| 1     | <b>Introduction and modelling of control system:</b><br>Brief history of control systems, Open and close loop systems- its elements and comparison. Concept of transfer function, mathematical modelling of mechanical (translational and rotational) and electrical system, 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.<br>Concept of block diagram representation, block diagram reduction techniques and its application, Signal flow graph representation, Mason's formula and its application.                                        | 8           | 20         |
| 2     | <b>Time Response analysis:</b><br>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 damping ratio and undamped natural frequency of oscillation.<br>Concept of steady state error, static error constants, its formulas and determination for Type 0, 1 and 2 systems. | 8           | 20         |
| 3     | <b>Concept of stability and Root locus techniques:</b><br>Concept of BIBO stability, necessary condition for stability, Routh stability criterion, its special cases, concept of relative stability in reference to Routh criterion.<br>The root locus concept, rules to construct root locus plot and its application to sketch root locus plots.                                                                                                                                                                                                                                                                                                                                                     | 8           | 20         |
| 4     | <b>Frequency response analysis:</b><br>Concept and advantages of frequency response, frequency domain plots, procedure to sketch polar plot, phase margin, gain margin from polar plot, 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.                                                                                                                                                                                                                                                                                | 9           | 20         |
| 5     | <b>Basics of controllers and compensation techniques:</b><br>Proportional, Integral and Derivative control actions, effects of P,PI,PD and PID controllers, Types of compensation techniques, Phase lead and lag compensation and its effects.                                                                                                                                                                                                                                                                                                                                                                                                                                                         | 6           | 10         |



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|          |                                                                                                                                                                                                                                                                                                                                                                                                              |          |           |
|----------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------|-----------|
| <b>6</b> | <b>Introduction to State space analysis:</b><br>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. | <b>6</b> | <b>10</b> |
|----------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------|-----------|

## Suggested Specification table with Marks (Theory):

| Distribution of theory marks |         |         |         |         |         |
|------------------------------|---------|---------|---------|---------|---------|
| R Level                      | U Level | A Level | N Level | E Level | C Level |
| 15                           | 30      | 30      | 15      | 10      | ==      |

**Legends: R: Remembrance; U: Understanding; A: Application, N: Analyse and 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 above table.

The syllabus of Control system directly contributes to following Sustainable Development Goals.

|               |                                                                                                                                                                                                                                                                                                                                                                                                         |
|---------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>SDG 7</b>  | <b>Affordable and Clean Energy:</b><br>Control system forms the basis for optimization of renewable energy sources(e.g. solar trekking), Electrical system stabilization, Smart grid management etc.                                                                                                                                                                                                    |
| <b>SDG 9</b>  | <b>Industry, Innovation and Infrastructure</b> Control systems theory (PID controllers, stability analysis, state space method) is fundamental to industrial automation, process control, robotics, smart manufacturing, and resilient infrastructure. The syllabus equips learners to develop and optimize automated systems, directly supporting inclusive and sustainable industrial infrastructure. |
| <b>SDG 11</b> | <b>Sustainable Cities and Communities:</b> Traffic and building automation, Smart infrastructures and contemporary urban systems are enabled through PID actions, Stability and frequency response studies etc.                                                                                                                                                                                         |
| <b>SDG 12</b> | <b>Responsible Consumption and Production:</b> The syllabus contains controllers and compensation techniques for steady state error mitigation and transient response optimisation which eventually helps engineers to minimize waste and energy losses in industrial processes.                                                                                                                        |
| <b>SDG 13</b> | <b>Climate Action:</b> The reduction in energy losses, waste, emissions in industrial processes helps in climate control.                                                                                                                                                                                                                                                                               |



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## Reference books:

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

## Suggested list of experiments:

1. To prepare a Simulink model for an armature controlled dc servomotor.
2. To generate standard test signals for control system using 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 root locus of 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 effect of P, PD, PI, PID controller on second order control systems.
9. To prepare a design of Lag and lead compensator using root locus techniques.
10. To study state space model representation using MATLAB.

**Major equipment:** MATLAB/Simulink software with control system toolbox.

**Open-source software:** Scilab ( <https://scilab.org/>) - open source alternative to MATLAB.

## List of learning website:

1. NPTEL open courseware.
2. Virtual labs by IITs (<https://vlab.co.in/>) – Simulations and experiments related to control system.
3. Reputed research journal website.

## Activities suggested under Problem based Learning (PBL) component:

| Sr No | PBL category         | Name of the activity                                                                                                                     | No of hours | Suggested evaluation criteria                                  |
|-------|----------------------|------------------------------------------------------------------------------------------------------------------------------------------|-------------|----------------------------------------------------------------|
| 1     | Video based learning | Technical videobased learning (NPTEL lectures) (Suggested: Introduction to control engineering by Dr Ramkrishna Pasumarthy, IIT Madras.) | 20 hours    | Submit Presentation/report of the content and modules learned. |



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|   |                                                            |                                                                                                          |                                                                                                                                          |                                                                                          |
|---|------------------------------------------------------------|----------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------|
| 2 | Assignment /Technical writing/Research writing.            | Problem solving based assignments is preferable. /Technical article writing.                             | 20 Hours. (One Assignment per module should be given with minimum 10 question per module. The difficulty level should be medium to hard. | Assignment submission, assess accuracy, clarity of steps, and coverage of problem types. |
| 3 | Group discussion/Quiz/ Simulation                          | Off line quiz practices involving solution of GATE Exam questions/ Online technical quizzes/ discussion. | 10 Hours                                                                                                                                 | Based on performance and score obtained.                                                 |
| 4 | Case study analysis/ Mini project targeting relevant SDGs. | (Case studies of Real-world Applications addressing Sustainable Development Goals.)                      | 10 hours                                                                                                                                 | Submit a brief page report.                                                              |
| 5 | Research paper review/analysis                             | Discussion on research paper based on relevant subject                                                   | Max 20 hours. (4 hours for each paper)                                                                                                   | Summarize research paper and evaluation critical parameters.                             |
| 6 | Poster/Chart/Power point presentation                      | Poster/chart/power point preparation on technical topics_                                                | 6 hours                                                                                                                                  | Based on poster/chart preparation and presentation skills                                |
| 7 | Micro Project                                              | Simulation of controller design based on root locus/bode plots to be solved and simulated.               | 5 hours.                                                                                                                                 | Based on solution and simulation results.                                                |
| 8 | Other                                                      | Study of standards for energy efficient servomotors.                                                     | (4) hours.                                                                                                                               | Prepare brief report on the topic.                                                       |
| 9 | Other                                                      | Study of standards for PLCs.                                                                             | (4 hours)                                                                                                                                | Prepare brief report on IS14254                                                          |

Note:

1. In alignment with Outcome-Based Education(OBE) and NBA accreditation requirements, the subject control system incorporates;
  - Mini project- 10 marks
  - Micro project- 5 marks.

These activities are incorporated as integral PBL components. These activities are designed to foster experimental learning, encouraging innovation and strengthen problem-solving skills by engaging students in practical applications of control system principles. The inclusion of PBL ensures that



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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 no. of PBL hours and marks.

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