

|                              |                                                                              |
|------------------------------|------------------------------------------------------------------------------|
| <b>Branch Name:</b>          | Electrical Engineering                                                       |
| <b>Program Code:</b>         | ET109                                                                        |
| <b>Course Name:</b>          | Department Elective-IV: Advanced Control Systems                             |
| <b>Course Code:</b>          | 1ET1090805                                                                   |
| <b>Pre-requisite Course:</b> | Fundamental Knowledge of Elements of Electrical Engineering, Control Theory. |

### Course Objectives:

1. This course provides detailed concepts of feedback control design.
2. This course provides detailed concepts of state-space approach.
3. This course provides detailed concepts of non linear system analysis and overview of control techniques.

### Teaching and Examination Scheme:

| Teaching Scheme (Hours per week) |          |           |        | Evaluation Scheme (Marks) |      |                       |      |                       |      |                       |      |       |
|----------------------------------|----------|-----------|--------|---------------------------|------|-----------------------|------|-----------------------|------|-----------------------|------|-------|
| Lecture                          | Tutorial | Practical | Credit | Theory                    |      |                       |      | Practical             |      |                       |      | Total |
|                                  |          |           |        | University Assessment     |      | Continuous Assessment |      | University Assessment |      | Continuous Assessment |      |       |
|                                  |          |           |        | Min.                      | Max. | Min.                  | Max. | Min.                  | Max. | Min.                  | Max. |       |
| 3                                | -        | -         | 3      | 28                        | 70   | 12                    | 30   | -                     | -    | -                     | -    | 100   |

### Course Contents:

| Sr. No. | Topic                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | Total Hours | Weightage (%) |
|---------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------|---------------|
| 1       | <b>Mathematical Background – Matrices:</b><br>Definition of Matrices; Matrix Algebra; Matrix Multiplication and Inversion; Rank of a Matrix; Differentiation and Integration of Matrices.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | 4           | 5%            |
| 2       | <b>State Space Analysis of Control Systems:</b><br>State Variables; State-Space Representation of Electrical, Mechanical and Electromechanical Systems; State Space Representation of nth Order Linear Differential Equation; Transformation to Phase Variable Canonical Form; Relationship Between State Equations and Transfer Functions; Characteristic Equation; Eigen Values and Eigen Vectors; Transformation to Diagonal Canonical Form; Jordan Canonical Form; Controllability Canonical Form; Observability Canonical Form; Decomposition of Transfer Function-Direct, Cascade and Parallel Decomposition; State Diagram; Solution of the Time-Invariant State Equation; State Transition Matrix and its Properties; Transfer Matrix; Transfer Matrix of Closed Loop Systems | 18          | 35%           |
| 3       | <b>Controllability and Observability:</b><br>Concept of Controllability and Observability; Kalman's Theorems on Controllability and Observability, Alternative Tests (Gilbert's Method) of Controllability and Observability; Principle of Duality; Relationship among Controllability, Observability and Transfer Function.                                                                                                                                                                                                                                                                                                                                                                                                                                                          | 10          | 20%           |

|   |                                                                                                                                                                                                                                                                                                                                                                |    |     |
|---|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----|-----|
| 4 | <b>Liapunov Stability Analysis :</b><br>Stability of Equilibrium State in the Sense of Liapunov; Graphical Representation of Stability; Asymptotic Stability and Instability; Sign-Definiteness of Scalar Function; Second Method of Liapunov; Stability Analysis of Linear Systems; Krasovski's Theorem; Liapunov Function Based on Variable Gradient Method. | 12 | 25% |
| 5 | <b>State Feedback Control Design:</b><br>Design of Robust Control Systems; State Feedback Control-Pole Placement Design, State Feedback with Integral Control.                                                                                                                                                                                                 | 08 | 15% |

#### Reference Books:

1. Modern Control Engineering, Fourth Edition, Prentice Hall, 2001- Katsuhiko Ogata.
2. Automatic Control Systems, High Education Press, 2003- B. C. Kuo.
3. Control Systems Engineering, Fifth Edition, New Age International Publishers, 2007- L. J. Nagrath & M. Gopal.
4. Modern Control Systems, Sixth Edition, Addison-Wesley, 1993- Rich.

#### List of Open Source Software/learning website:

1. MATLAB Software.
2. Control System Tutorials by University of Michigan

**Course Learning Outcomes (CLO):** On completion of this course, the students will be able to:

| CLO  | Description                                                                                                                                    | Bloom's Taxonomy Level |
|------|------------------------------------------------------------------------------------------------------------------------------------------------|------------------------|
| CLO1 | To know about Mathematical Background – Matrices:                                                                                              | 1 Remembering          |
| CLO2 | Understand how the state space system representation provides an internal description of the system including possible internal instabilities. | 2 Understanding        |
| CLO3 | To analyze Controllability and Observability                                                                                                   | 4 Analyze              |
| CLO4 | To derive place closed loop poles at desirable locations.                                                                                      | 4 Analyze              |
| CLO5 | To derive the describing function for different types of non-linearity.                                                                        | 4 Analyze              |
| CLO6 | To understand the various power system stability limits .                                                                                      | 2 Understanding        |

#### Mapping of CLOs with POs & PSOs

| Course Learning Outcomes | Program Outcomes (POs) |     |     |     |     |     |     |     |     |      |      |      | Program Specific Outcomes(PSOs) |      |      |      |
|--------------------------|------------------------|-----|-----|-----|-----|-----|-----|-----|-----|------|------|------|---------------------------------|------|------|------|
|                          | PO1                    | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 | PSO1                            | PSO2 | PSO3 | PSO4 |
| CLO1                     |                        |     | L   |     |     | M   |     |     |     | L    | M    |      | L                               |      | L    |      |
| CLO2                     |                        | L   | H   |     | L   |     | M   |     |     |      |      | M    |                                 | L    |      |      |

|      |   |  |   |   |   |   |   |   |  |   |   |   |   |   |   |   |
|------|---|--|---|---|---|---|---|---|--|---|---|---|---|---|---|---|
| CLO3 |   |  |   | L | H |   |   | L |  |   | M |   |   |   |   | L |
| CLO4 |   |  |   |   |   | L |   |   |  |   |   | L |   |   | L |   |
| CLO5 | L |  | M |   |   |   |   | L |  | M |   |   | M | L |   |   |
| CLO6 |   |  |   |   | L |   | L |   |  |   |   |   | L |   |   |   |

H: High, M: Medium, L: Low