# Course Curriculum

*for*

# Bachelor of Technology (BTech) Programme

in

# Electrical and Electronics Engineering

*in the department of*

# Electrical and Electronics Engineering

at

http://www.nitgoa.ac.in


**राष्ट्रीय प्रौद्योगिकी संस्थान गोवा**

**NATIONAL INSTITUTE OF TECHNOLOGY GOA**

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# Module 1

# Credits Distribution : BTech (EEE)

## 1.1 Programme Structure Summary

| Sl No | Classifications | Course Type | Credits For CGPA | Courses |
|---|---|---|---|---|
| 1. | Basic Sciences | BS | 21 | MA → 11, PH → 5, CY → 5 |
| 2. | Basic Engineering Sciences and Technical Arts | ES | 21 | EM → 3, BMC → 3, BES → 6 CPPS → 4, ED → 3, WP → 2 |
| 3. | Humanities and Social Sciences | HU & HS | 7 | PC → 4, ECO → 3 |
| 4. | Indian Knowledge Systems | IKS | 5 | HH → 2, OE → 3 |
| 5. | Others: Liberal Arts, Innovation & Entrepreneurship | OT | 2 | LA → 1, IE → 1 |
| 6. | Mandatory Learning Courses | MLC | 2 | PE → 0, ES → 1, PEHV → 1 |
| 7. | Department Core | DC | 83 - 86 | Core Theory and Lab courses, Comprehensive Examination → 1 Seminar → 1, Summer Internship → 1 Project Work → 5 |
| 8. | Department Elective: (including MOOCs or any other as approved by the Institute) | DE | 21 - 27 | 7-9 Electives |
| 9. | Open Elective: (including MOOCs or any other as approved by the Institute) | OE | 0 - 6 | Upto 2 Open Electives |
| **Total Credits** | | | **168** | |
| 10. | Minor Program | MR | 18 | |

## 1.2 Semester-wise Credits Distribution

| Sl No. | Year | Semester-wise Credit | | Year-wise Credit |
|---|---|---|---|---|
| | | Semester | Credits | |
| 1. | First Year | I | 23 | 46 |
| | | II | 23 | |
| 2. | Second Year | III | 22 | 45 |
| | | IV | 23 | |
| 3. | Third Year | V | 23 | 46 |
| | | VI | 23 | |
| 4. | Fourth Year | VII | 19 | 31 |
| | | VIII | 12 | |
| **Total Credits** | | | | **168** |

## 1.3 Overall Scheme of B. Tech. Programme (EEE)

Table 1.1: Four-Year BTech (EEE) Scheme

| **First Year** | | | | **Second Year** | | | | **Third Year** | | | | **Fourth Year** | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Odd (I) Semester | | Even (II) Semester | | Odd (III) Semester | | Even (IV) Semester | | Odd (V) Semester | | Even (VI) Semester | | Odd (VII) Semester | | Even (VIII) Semester | |
| Subject Name | C | Subject Name | C | Subject Name | C | Subject Name | C | Subject Name | C | Subject Name | C | Subject Name | C | Subject Name | C |
| Matrices and Advanced Calculus | 4 | Differential Equations and Vector Calculus | 4 | Probability, Statistics and Complex Analysis | 3 | Innovation and Entrepreneurship | 1 | Environmental Studies | 1 | Professional Ethics and Human Values | 1 | Industrial Economics | 3 | Elective - VIII | 3 |
| Engineering Physics | 3 | Engineering Chemistry | 3 | Circuit Theory | 4 | Signals and Systems | 3 | Power Electronics | 3 | Electrical System Design | 3 | Elective - IV | 3 | Elective - IX | 3 |
| Basics of Electrical Engineering | 2 | Basics of Electronics Engineering | 2 | Electromagnetic Fields | 3 | Electrical Machines - I | 3 | Electrical Machines - II | 3 | Electrical Drives | 3 | Elective - V | 3 | Elective-X | 3 |
| Engineering Mechanics | 3 | Professional Communication | 4 | Analog and Integrated Circuits | 3 | Digital Systems | 3 | Power Systems - I | 4 | Power Systems - II | 4 | Elective - VI | 3 | | |
| Computer Programming and Problem Solving | 3 | Basics of Mechanical and Civil Engineering | 3 | Electrical and Electronic Measurement | 3 | Control Systems | 4 | Microprocessor and Microcontroller | 3 | Elective - II (IKS) | 3 | Elective - VII | 3 | | |
| Liberal Arts | 1 | Health and Happiness | 2 | | | Computational Methods | 3 | Elective - I | 3 | Elective - III | 3 | | | | |
| Engineering Physics Laboratory | 2 | Engineering Chemistry Laboratory | 2 | Simulation Lab | 2 | Electrical Machine Laboratory - I | 2 | Electrical Machine Laboratory - II | 2 | Power Electronics and Drives Laboratory | 2 | Major Project - I | 2 | Major Project - II | 3 |
| Basics of Electrical Engineering Lab. | 1 | Basics of Electronics Engineering Lab. | 1 | Electrical and Electronic Measurement Lab | 2 | Analog and Digital Circuit Laboratory | 2 | Microprocessor Lab. | 2 | Power System Laboratory | 2 | Summer Project or Industrial Training | 1 | | |
| Engineering Drawing | 3 | Workshop Practices | 2 | Tinkering Lab - I | 2 | Control System Laboratory | 2 | Tinkering Lab - II | 1 | Electrical and Electronic Design Laboratory | 2 | Comprehensive Examination | 1 | | |
| Computer Programming Lab | 1 | Physical Education | 0 | | | | | Seminar | 1 | | | | | | |
| Total Credits | 23 | Total Credits | 23 | Total Credits | 22 | Total Credits | 23 | Total Credits | 23 | Total Credits | 23 | Total Credits | 19 | Total Credits | 12 |
| **Total Credits : 168** | | | | | | | | | | | | | | | |

## 1.4 Second Year B. Tech. Programme

Table 1.2: Third Semester Course

| Sl No | Course Code | Course Name | Course Type | Nature of Course | L - T - P | Credit |
|---|---|---|---|---|---|---|
| 1 | MA203 | Probability, Statistics and Complex Analysis | BS | Theory | 2-1-0 | 3 |
| 2 | EE200 | Circuit Theory | DC | Theory | 3-1-0 | 4 |
| 3 | EE201 | Electromagnetic Fields | DC | Theory | 3-0-0 | 3 |
| 4 | EE202 | Analog and Integrated circuits | DC | Theory | 3-0-0 | 3 |
| 5 | EE203 | Electrical and Electronics Measurements | DC | Theory | 3-0-0 | 3 |
| 6 | EE204 | Simulation Lab | DC | Practical | 0-0-3 | 2 |
| 7 | EE205 | Electrical and Electronics Measurements Lab | DC | Practical | 0-0-3 | 2 |
| 8 | EE206 | Tinkering Lab - 1 | DC | Practical | 0-0-3 | 2 |
| Total Credits | | | | | | 22 |

Table 1.3: Fourth Semester Course

| Sl No | Course Code | Course Name | Course Type | Nature of Course | L - T - P | Credit |
|---|---|---|---|---|---|---|
| 1 | IE250 | Innovation & Entrepreneurship | OT | Theory | 1-0-0 | 1 |
| 2 | EE250 | Signals and Systems | DC | Theory | 3-0-0 | 3 |
| 3 | EE251 | Electrical Machines - I | DC | Theory | 3-0-0 | 3 |
| 4 | EE252 | Digital Systems | DC | Theory | 3-0-0 | 3 |
| 5 | EE253 | Control Systems | DC | Theory | 3-1-0 | 4 |
| 6 | EE254 | Computational Methods | DC | Theory cum Practical | 2-0-2 | 3 |
| 7 | EE255 | Electrical Machines - I Lab | DC | Practical | 0-0-3 | 2 |
| 8 | EE256 | Analog and Digital circuit Lab | DC | Practical | 0-0-3 | 2 |
| 9 | EE257 | Control System Lab | DC | Practical | 0-0-3 | 2 |
| Total Credits | | | | | | 23 |

## 1.5 Third Year B. Tech. Programme

Table 1.4: Fifth Semester Course

| Sl No | Course Code | Course Name | Course Type | Nature of Course | L - T - P | Credit |
|---|---|---|---|---|---|---|
| 1 | ES300 | Environmental Studies | MLC | Theory | 1-0-0 | 1 |
| 2 | EE300 | Power Electronics | DC | Theory | 3-0-0 | 3 |
| 3 | EE301 | Electrical Machines -II | DC | Theory | 3-0-0 | 3 |
| 4 | EE302 | Power Systems - I | DC | Theory | 3-1-0 | 4 |
| 5 | EE303 | Mircroprocessor and Microcontroller | DC | Theory | 3-0-0 | 3 |
| 6 | YY5XX | Elective - I | OE/DE* | Theory | 3-0-0 | 3 |
| 7 | EE304 | Electrical Machine Lab - II | DC | Practical | 0-0-3 | 2 |
| 8 | EE305 | Microprocessor Lab | DC | Practical | 0-0-3 | 2 |
| 9 | EE306 | Tinkering Lab - II | DC | Practical | 0-0-2 | 1 |
| 10 | EE307 | Seminar | DC | Practical | 0-0-1 | 1 |
| Total Credits | | | | | | 23 |

Table 1.5: Sixth Semester Course

| Sl No | Course Code | Course Name | Course Type | Nature of Course | L - T - P | Credit |
|---|---|---|---|---|---|---|
| 1 | HU350 | Professional Ethics and Human Values | HU & HS | Theory | 1-0-0 | 1 |
| 2 | EE350 | Electrical System Design | DC | Theory | 3-0-0 | 3 |
| 3 | EE351 | Electrical Drives | DC | Theory | 3-0-0 | 3 |
| 4 | EE352 | Power Systems - II | DC | Theory | 3-1-0 | 4 |
| 5 | YY5XX | Elective - II | IKS | Theory | 3-0-0 | 3 |
| 6 | YY5XX | Elective - III | OE/DE* | Theory | 3-0-0 | 3 |
| 7 | EE353 | Power Electronic and Drives Lab | DC | Practical | 0-0-3 | 2 |
| 8 | EE354 | Power System Lab | DC | Practical | 0-0-3 | 2 |
| 9 | EE355 | Electrical and Electronic Design Lab | DC | Practical | 0-0-3 | 2 |
| Total Credits | | | | | | 23 |

## 1.6 Fourth Year B. Tech. Programme

Table 1.6: Seventh Semester Course

| Sl No | Course Code | Course Name | Course Type | Nature of Course | L - T - P | Credit |
|---|---|---|---|---|---|---|
| 1 | EE400 | Major Project -1 | DC | Project | 0-0-3 | 2 |
| 2 | EE401 | Summer Project / Industrial Training | DC | Project/Training | 0-0-2 | 1 |
| 3 | EE402 | Comprehensive Examination | DC | - | - | 1 |
| 4 | HS350 | Industrial Economics | HU & HS | Theory | 3-0-0 | 3 |
| 5 | | Elective - IV | OE/DE* | Theory | 3-0-0 | 3 |
| 6 | | Elective - V | OE/DE* | Theory | 3-0-0 | 3 |
| 7 | | Elective - VI | OE/DE* | Theory | 3-0-0 | 3 |
| 8 | | Elective - VII | OE/DE* | Theory | 3-0-0 | 3 |
| Total Credits | | | | | | 19 |

Table 1.7: Eighth Semester Course

| Sl No | Course Code | Course Name | Course Type | Nature of Course | L - T - P | Credit |
|---|---|---|---|---|---|---|
| 1 | EE450 | Major Project - II | DC | Project | 0-0-6 | 3 |
| 2 | | Elective - VIII | OE/DE* | Theory | 3-0-0 | 3 |
| 3 | | Elective - IX | OE/DE* | Theory | 3-0-0 | 3 |
| 4 | | Elective - X | OE/DE* | Theory | 3-0-0 | 3 |
| Total Credits | | | | | | 12 |

*** Note:** A student is allowed to register for only one **Open Elective (OE) per semester**, with a maximum of **two OEs throughout the entire B.Tech curriculum**. This limit excludes the ***Indian Knowledge System (IKS)*** course offered in the **sixth semester**. As the IKS course is a mandatory OE, students are not permitted to register for any other OE during that semester (i.e., **sixth semester**) .

## 1.7 List of Departmental Electives

| Sl No | Course Code | Course Name | Course Type | Nature of Course | L - T - P | Credit |
|---|---|---|---|---|---|---|
| 1 | EE500 | Selected Topics in Electrical Engineering | DE | Theory | 3-0-0 | 3 |
| 2 | EE501 | Electrical Safety: Standards and Protocols | DE | Theory | 3-0-0 | 3 |
| 3 | EE502 | Electricity Markets | DE | Theory | 3-0-0 | 3 |
| 4 | EE503 | Energy Auditing | DE | Theory | 3-0-0 | 3 |
| 5 | EE504 | Utilization of Electrical Energy & Illumination | DE | Theory | 3-0-0 | 3 |
| 6 | EE505 | Building Management Systems | DE | Theory | 3-0-0 | 3 |
| 7 | EE510 | Power System Protection | DE | Theory | 3-0-0 | 3 |
| 8 | EE511 | Advanced Power System Protection | DE | Theory | 3-0-0 | 3 |
| 9 | EE512 | Power System Operation and Control | DE | Theory | 3-0-0 | 3 |
| 10 | EE513 | Power Quality | DE | Theory | 3-0-0 | 3 |
| 11 | EE514 | Smart Electric Grids | DE | Theory | 3-0-0 | 3 |
| 12 | EE515 | Microgrid Operation and Control | DE | Theory | 3-0-0 | 3 |
| 13 | EE516 | HVDC and FACTS | DE | Theory | 3-0-0 | 3 |
| 14 | EE517 | Power Distribution Systems | DE | Theory | 3-0-0 | 3 |
| 15 | EE518 | High Voltage Engineering | DE | Theory | 3-0-0 | 3 |
| 16 | EE520 | Advanced Power Electronics | DE | Theory | 3-0-0 | 3 |
| 17 | EE521 | Power Electronic Converters for Renewable Energy | DE | Theory | 3-0-0 | 3 |
| 18 | EE522 | Advanced Electric Drives | DE | Theory | 3-0-0 | 3 |
| 19 | EE523 | Electrical Machine Design | DE | Theory | 3-0-0 | 3 |
| 20 | EE524 | Special Electric Machines | DE | Theory | 3-0-0 | 3 |
| 21 | EE530 | Renewable Energy Systems | DE | Theory | 3-0-0 | 3 |
| 22 | EE531 | Electric Vehicles | DE | Theory | 3-0-0 | 3 |
| 23 | EE532 | Autonomous Vehicles and Drones | DE | Theory | 3-0-0 | 3 |
| 24 | EE533 | Robotics and Automation | DE | Theory | 3-0-0 | 3 |
| 25 | EE534 | Energy Storage Systems | DE | Theory | 3-0-0 | 3 |

| Sl No | Course Code | Course Name | Course Type | Nature of Course | L - T - P | Credit |
|---|---|---|---|---|---|---|
| 26 | EE540 | Advanced Control System | DE | Theory | 3-0-0 | 3 |
| 27 | EE541 | Embedded Systems Design | DE | Theory | 3-0-0 | 3 |
| 28 | EE542 | Embedded Control System | DE | Theory | 3-0-0 | 3 |
| 29 | EE543 | Digital Signal Processing | DE | Theory | 3-0-0 | 3 |
| 30 | EE544 | Digital Image Processing | DE | Theory | 3-0-0 | 3 |
| 31 | EE545 | FPGA based Digital Design | DE | Theory | 3-0-0 | 3 |
| 32 | EE550 | Applied Linear Algebra for Electrical Engineers | DE | Theory | 3-0-0 | 3 |
| 33 | EE551 | Intelligent Systems in Electrical Engineering | DE | Theory | 3-0-0 | 3 |
| 34 | EE552 | Optimization Techniques for Electrical Engineering | DE | Theory | 3-0-0 | 3 |
| 35 | EE553 | Soft Computing | DE | Theory | 3-0-0 | 3 |
| 36 | EE554 | Internet of Things (IoT) in Electrical Engineering | DE | Theory | 3-0-0 | 3 |
| 37 | EE555 | IoT, IoV, IoD and IIoT Applications in Electrical Engineering | DE | Theory | 3-0-0 | 3 |
| 38 | EE556 | Cyber Physical Systems | DE | Theory | 3-0-0 | 3 |
| 39 | EE557 | Cyber Security in Electrical Grids | DE | Theory | 3-0-0 | 3 |
| 40 | EE558 | AI and ML Applications in Electrical Engineering | DE | Theory | 3-0-0 | 3 |
| 41 | EE559 | Evolutionary Computation for Electrical Engineering | DE | Theory | 3-0-0 | 3 |
| 42 | EE560 | VLSI Technology | DE | Theory | 3-0-0 | 3 |
| 43 | EE561 | Multimedia Systems | DE | Theory | 3-0-0 | 3 |
| 44 | EE562 | Reliability Engineering | DE | Theory | 3-0-0 | 3 |

## 1.8 List of Open Electives offered by EEE Department

| Sl No | Course Code | Course Name | Course Type | Nature of Course | L - T - P | Credit |
|---|---|---|---|---|---|---|
| 1 | EE900 | Electrical System Design for Buildings | OE | Theory | 3-0-0 | 3 |
| 2 | EE901 | General Aspects of Electrical Safety | OE | Theory | 3-0-0 | 3 |
| 3 | EE902 | Introduction to Non-Conventional Energy | OE | Theory | 3-0-0 | 3 |
| 4 | EE903 | Electric Vehicle Technology | OE | Theory | 3-0-0 | 3 |

# Part I

# Course Content : Core Courses

# Module 2

# Third Semester Courses:

## 2.1 Probability, Statistics and Complex Analysis

| Course Code | Courses Name | Course Type | L - T - P | Credits | Total Hours |
|---|---|---|---|---|---|
| MA203 | Probability, Statistics and Complex Analysis | Theory | 2 - 1 - 0 | 3 | 42 |

### 2.1.1 Objectives:

The objectives of studying this course are,

1. to provide a comprehensive grasp of probability, random variables, statistics and complex analysis.
2. to help to develop a deep understanding of applied mathematics.
3. to correlate the knowledge with its real time applications.

### 2.1.2 Course Outcome:

At the completion of this course, the student shall acquire knowledge and ability

1. CO1 : to grasp a solid comprehension of probability distributions and apply them to address challenging engineering problems.
2. CO2 : to comprehend the significance and analytical solving methods for statistical and their applications in communication engineering problems.
3. CO3 : to grasp the fundamentals of complex variables, complex functions, and the processes of complex differentiation and integration.

### 2.1.3 CO - PO Mapping:

| **Relationship of Course Outcomes to Program Outcomes** | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **CO ↓** | **PO** | | | | | | | | | | | |
| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
| CO1 | H | H | H | M | M | | | L | L | M | | H |
| CO2 | H | H | H | H | H | | | L | L | M | | H |
| CO3 | H | H | H | H | H | | | L | L | M | | H |
| **H = High correlation; M = Medium correlation; L = Low correlation** | | | | | | | | | | | | |

### 2.1.4 Syllabus:

**Module 1:** **Elements of Probability:** Introduction to Probability, Sample Space and Events, Probabilities Defined on Events, Conditional Probabilities, Independent Events; Total Probability, Bayes' Formula.

**Module 2:** **Random Variables and Distribution:** Random Variables: Concept of Random Variables, Distribution and Density Function, Jointly Distributed Random of Variables, Conditional and Joint Density Distribution function, Function of Random Variables, Expected Value: Mean, Variance and moments of random variable, Joint moments, conditional expectation, covariance and correlation, Some special distributions: Uniform and Gaussian distributions, Bernoulli, Binomial, and Poisson distributions.

**Module 3:** **Statistics:** The Sample Mean, The Central Limit Theorem, The Sample Variance, Sampling Distributions from a Normal Population, Sampling from a Finite Population, Parameter Estimation, Maximum Likelihood Estimators, Interval Estimates; Estimating the Difference in Means of Two Normal Populations, Hypothesis Testing, Significance Levels, Tests Concerning the Mean of a Normal Population, Testing the Equality of Means of Two Normal Populations, Hypothesis Tests Concerning the Variance of a Normal Population, Hypothesis Tests in Bernoulli Populations, Tests Concerning the Mean of a Poisson Distribution, Regression (Basic concepts only).

**Module 4:** **Complex Analysis:** Complex Numbers, geometric representation, powers and roots of complex numbers, Functions of a complex variable, Analytic functions, Cauchy-Riemann equations; elementary functions, Conformal mapping (for linear transformation); Contours and contour integration, Cauchy's theorem, Cauchy integral formula; Power Series and properties, Taylor series, Laurent series, Zeros, singularities, poles, essential singularities, Residue theorem, Evaluation of real integrals and improper integrals.

### 2.1.5 Learning Resources:

#### 2.1.5.1 Text Books:

1. E Kreyszig, "Advanced engineering mathematics", Wiley India Pvt. Ltd., 2006 ($8^{th}$ Ed.)

#### 2.1.5.2 Reference Books:

1. S M Ross, "Stochastic Processes", Wiley India Pvt. Ltd., 1995 ($2^{th}$ Ed.)

2. S M Ross, "Introduction to Probability and Statistics for Engineers and Scientists", Academic Press, 2021 ($6^{th}$ Ed.)

3. S M Ross, "Introduction to Probability Models", Academic Press, 2014 ($11^{th}$ Ed.)

4. R V Churchill and J W Brown, "Complex variables and applications", McGraw Hill Higher Education, 2003 ($7^{th}$ Ed.)

## 2.2 Circuit Theory

| Course Code | Courses Name | Course Type | L - T - P | Credits | Total Hours |
|---|---|---|---|---|---|
| EE200 | Circuit Theory | Theory | 3 - 1 - 0 | 4 | 56 |

### 2.2.1 Objectives:

The objectives of studying this course are,

1. to understand and analyse electrical circuits in both time and frequency domain.
2. to apply techniques learned in pure science courses (physics and mathematics) for solving electrical circuits.
3. to understand the similarity between electrical circuits with other linear systems.
4. to evaluate circuits using appropriate techniques based on the nature of the problem.
5. to get introduced with circuits used in engineering applications.

### 2.2.2 Course Outcome:

At the completion of this course, the student shall acquire knowledge and ability

1. CO1 : to analyse dynamic and steady state response of electrical circuits in time domain.
2. CO2 : to analyse dynamic and steady state response of electrical circuits in frequency domain.
3. CO3 : to apply circuit analysis techniques in different engineering systems.
4. CO4 : to evaluate electrical circuits using appropriate techniques based on the nature of problem.

### 2.2.3 CO - PO Mapping:

| **Relationship of Course Outcomes to Program Outcomes** | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **CO ↓** | **PO** | | | | | | | | | | | |
| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
| CO1 | H | M | | | L | | | | | M | | |
| CO2 | H | M | | | L | | | | | M | | |
| CO3 | H | M | M | | L | | | | | | | L |
| CO4 | H | M | M | | L | | | | | | | L |
| **H = High correlation; M = Medium correlation; L = Low correlation** | | | | | | | | | | | | |

### 2.2.4 Syllabus:

**Module 1:** **Analysis of circuits and two port networks:** Review of circuits, Circuits with Linear Dependent Sources: nodal analysis and mesh analysis – super node and supermesh - effect on the symmetry of nodal admittance matrix and mesh impedance matrix- Two Port Networks: characterization and inter relationships among parameter sets- Interconnection of Two port networks – Applications: feedback systems, transmission lines etc.

**Module 2:** **Steady-state analysis of three-phase circuits:** Review of network theorems for ac circuits, Polyphase working - 3 phase a.c systems - balanced and unbalanced system - Power concepts in three phase systems– symmetrical transformation – sequence components – power in sequence components. Dependent source equivalent circuits for coupled coils – steady-state analysis of coupled coils – two-winding transformer.

**Module 3:** **Circuit Analysis in Time-domain and s-domain:** Time Domain Analysis of Circuits: Solution of circuits by differential equation method - Determination of initial conditions– Laplace Transform and its properties - Solution of Differential Equations – s-domain Analysis of Circuits - Solution of circuits with mutual inductance. Generalization of Circuit theorems – Input and transfer immittance functions - Transfer functions - Impulse response and Transfer function- Poles and Zeros - Pole Zero plots – Stability and poles.

**Module 4:** **Sinusoidal Steady - State Frequency Response:** Frequency response: Properties - frequency response from s-domain transfer functions - Frequency response of first order circuits – filters, integrator, differentiator, signal coupling circuit etc. – frequency response for second order functions. Fourier series-Fourier Coefficients and its determination-Waveform Symmetry-Exponential Fourier Series - Discrete Amplitude and Phase Spectra – Applications: LC filters in Power Systems and power supplies, parallel RLC circuit in Communication circuits.

### 2.2.5 Learning Resources:

#### 2.2.5.1 Text Books:

1. M E Van Valkenburg, "Network Analysis," Pearson Education, India, 2010 ($3^{rd}$ Ed.)
2. W H Hayt, J E Kemmerly, S Durbin and J Phillips, "Engineering Circuit Analysis," McGraw Hill Education, 2012 ($6^{th}$ Ed.)
3. C K Alexander and M N O Sadiku, "Fundamentals of Electric Circuits," McGraw Hill Education, 2022 ($7^{th}$ Ed.)

#### 2.2.5.2 Reference Books:

1. J D Ryder, "Networks, Lines and Fields," Prentice Hall India, 1989 ($2^{nd}$ Ed.)
2. R C Dorf and J A Svoboda, "Introduction to Electric Circuits," John Wiley & Sons, 2004 ($6^{th}$ Ed.)

## 2.3 Electromagnetic Fields

| Course Code | Courses Name | Course Type | L - T - P | Credits | Total Hours |
|---|---|---|---|---|---|
| EE201 | Electromagnetic Fields | Theory | 3 - 0 - 0 | 3 | 42 |

### 2.3.1 Objectives:

The objectives of studying this course are,

1. to learn the fundamental concepts in electromagnetic field.
2. to understand the Maxwell's equations and its applications.
3. to apply the principles of electromagnetic field theory for the design and analysis of power transmission lines.

### 2.3.2 Course Outcome:

At the completion of this course, the student shall acquire knowledge and ability

1. CO1 : to familiarize with the electromagnetic field and its applications in electrical engineering.
2. CO2 : to understand the basic concept on electromagnetic field.
3. CO3 : to apply knowledge of vector calculus to describe Electric and Magnetic fields.
4. CO4 : to analyse the time varying fields using Maxwell's equations.
5. CO5 : to develop the concept behind Electrical machines and transmission lines.

### 2.3.3 CO - PO Mapping:

| **Relationship of Course Outcomes to Program Outcomes** | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **CO ↓** | **PO** | | | | | | | | | | | |
| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
| CO1 | H | H | H | | | | | | | | | |
| CO2 | H | H | H | | | | | | | | | |
| CO3 | H | H | H | | | | | | | | | |
| CO4 | H | H | H | M | M | | | | | | | |
| CO5 | H | H | H | M | | | | | | | | L |
| **H = High correlation; M = Medium correlation; L = Low correlation** | | | | | | | | | | | | |

### 2.3.4 Syllabus:

**Module 1:** **Electrostatics:** Charge and Electric Forces, Electric Fields, Electric Dipoles, Continuous Charge Distributions, Gauss's Law, Electric Potential Difference, Work and Potential Energy, Conductors and Insulators, Dielectrics and Capacitors, Capacitors in Circuits.

**Module 2:** **Magnetic Fields and Forces:** Magnetic Fields and the Lorentz Equation, Biot-Savart and Force on a Wire, Magnetic Dipoles, Force and Torque on Magnetic Dipoles, Ampere's Law, Symmetries for Using Ampere's Law.

**Module 3:** **Maxwell's Equations:** Faraday's Law, Lenz's Law, Induced Electric Field, Inductors, Energy in Inductors, Displacement Current, Solution to Maxwell's Equations, Maxwell's Equations in Differential Form, Poynting Vector, Radiation Pressure, Momentum, and Power.

**Module 4:** **Transmission Lines:** Equations of current and voltage, Standing waves and impedance transformation, Power transfer on a transmission line, Loss-less and low-loss transmission lines, Discontinuity, Bounce diagram and Digital transmission lines.

### 2.3.5 Learning Resources:

#### 2.3.5.1 Text Books:

1. W H Hayt, J A Buck and M J Akhtar, "Engineering Electromagnetics," McGraw Hill Education, 2017 ($8^{th}$ Ed.)
2. M Sadiku and S V Kulkarni, "Elements of Electromagnetics", Oxford University Press, 2015, ($6^{th}$ Ed.)

#### 2.3.5.2 Reference Books:

1. John Kraus and Daniel Fleisch, "Electromagnetics with Applications," McGraw Hill Education, 2017 ($5^{th}$ Ed.)
2. S M Ross and N N Rao, "Elements of Engineering Electromagnetics," Pearson Education, 2006 ($6^{th}$ Ed.)

## 2.4 Analog and Integrated Circuits

| Course Code | Courses Name | Course Type | L - T - P | Credits | Total Hours |
|---|---|---|---|---|---|
| EE202 | Analog and Integrated Circuits | Theory | 3 - 0 - 0 | 3 | 42 |

### 2.4.1 Objectives:

The objectives of studying this course are,

1. to analyze and design Circuits using MOSFET and op-amps.
2. to develop the applications using Op-Amps and special Integrated circuits.
3. to design and analyze various types of ADCs, DACs, and various applications using 555 timer.

### 2.4.2 Course Outcome:

At the completion of this course, the student shall acquire knowledge and ability

1. CO1 : to understand current mirrors, different MOSFET amplifier configurations and the frequency response of MOSFET.
2. CO2 : to describe the various ideal and practical characteristics of an op-amp.
3. CO3 : to design and analyze different op-amp circuits and other ICs for various applications.
4. CO4 : to analyse and design various types of ADCs and DACs and develop various application circuits using 555 timer.

### 2.4.3 CO - PO Mapping:

| **Relationship of Course Outcomes to Program Outcomes** | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **CO ↓** | **PO** | | | | | | | | | | | |
| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
| CO1 | H | H | M | M | M | L | | | | | | M |
| CO2 | H | H | M | L | | | | | | | | M |
| CO3 | H | H | H | M | M | L | | | | | | M |
| CO4 | H | H | M | M | M | | | | | | | M |
| **H = High correlation; M = Medium correlation; L = Low correlation** | | | | | | | | | | | | |

### 2.4.4 Syllabus:

**Module 1:** **MOSFET Amplifiers:** Analysis and design of different configurations, thermal runway in MOS amplifiers, cascade stages and current mirrors, MOS differential pair, small and large signal analysis, differential pair with active loads, feedback amplifier, Oscillators.

**Module 2:** **Operational amplifiers:** Ideal and practical op-amps, concept of negative feedback and virtual ground, parameters of op-amps, inverting and non-inverting configurations, voltage to current converter, current to voltage converter, summing amplifier, differential amplifier, instrumentation amplifier.

**Module 3:** **Applications of op-amps:** Schmitt trigger, comparators, integrators, differentiators, peak detectors, sample and hold circuit, precision rectifier, generation of sine wave, triangular wave, sawtooth wave, Active filters.

**Module 4:** **Other Integrated circuits:** Timer circuits, IC 555 timer and its applications, astable and monostable multivibrator, saw-tooth wave generator, voltage regulators, VCO, phase locked loop, A/D and D/A converters, Oscillators.

### 2.4.5 Learning Resources:

#### 2.4.5.1 Text Books:

1. Sergio Franco, "Design with Operational Amplifiers and Analog Integrated Circuits," McGraw Hill Education, 2017 ($3^{rd}$ Ed.)

#### 2.4.5.2 Reference Books:

1. Ramakanth A. Gayakwad, "Op-Amps and Linear Integrated Circuits," Pearson Education, 2015 ($4^{th}$ Ed.)

2. A S Sedra, K C Smith and Arun N. Chandorkar, "Microelectronic Circuits: Theory And Applications", Oxford University Press, 2017 ($7^{th}$ Ed.)

3. Thomas L. Floyd, "Electronic Devices", Pearson Education Limited, 2013 ($9^{th}$ Ed.)

4. Behzad Razavi, "Fundamentals of Microelectronics", John Wiley & Sons, 2021 ($3^{rd}$ Ed.)

## 2.5 Electrical and Electronics Measurement

| Course Code | Courses Name | Course Type | L - T - P | Credits | Total Hours |
|---|---|---|---|---|---|
| EE203 | Electrical and Electronics Measurement | Theory | 3 - 0 - 0 | 3 | 42 |

### 2.5.1 Objectives:

The objectives of studying this course are,

1. to understand the analog and digital measuring instruments.
2. to study principles, working, mathematical relation characteristics, advantages and limitations of various sensors and transducers.
3. to select appropriate sensor/transducer for specific application.

### 2.5.2 Course Outcome:

At the completion of this course, the student shall acquire knowledge and ability

1. CO1 : to understand the working principle of analog and digital measuring instruments.
2. CO2 : to define, list and analyse performance characteristic of different sensors and transducers for various applications.
3. CO3 : to analyze the operation and usage of oscilloscopes, detectors, alarms/annunciators for practical applications.
4. CO4 : to develop prototype for effective implementation of Instrumentation based system at zero level.

### 2.5.3 CO - PO Mapping:

| **Relationship of Course Outcomes to Program Outcomes** | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **CO ↓** | **PO** | | | | | | | | | | | |
| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
| CO1 | H | H | M | M | L | L | L | L | L | L | L | M |
| CO2 | H | H | H | H | M | L | L | L | L | L | L | M |
| CO3 | H | H | H | M | L | L | L | L | L | L | L | M |
| CO4 | H | H | H | H | M | L | L | L | L | L | M | M |
| **H = High correlation; M = Medium correlation; L = Low correlation** | | | | | | | | | | | | |

### 2.5.4 Syllabus:

**Module 1:** **Measuring Instruments:** Introduction to measurement system, block diagram of measurement system, Static and dynamic characteristics of an instrument, selection criteria for instruments, error and error analysis in measurements, Measurement standards, Classification, Electromechanical Instruments–deflecting, control and damping torques–Ammeters and Voltmeters– PMMC, moving iron type instruments, electrodynamometer type instruments.

**Module 2:** **Measurement of RLC, Power and Energy:** Measurement of resistance, inductance and capacitance using DC and AC bridges, Q meter, Dynamometer and induction instruments, kVAh and kVARh meters, Instrument transformers – Current and Potential transformers, Potentiometers.

**Module 3:** **Electronic Instruments:** Electronic multimeter, Digital voltmeters, ramp type voltmeter, quantization error, digital frequency meter/timer, distortion meter, wavemeter and spectrum analyzer, Digital Storage Oscilloscopes.

**Module 4:** **Sensors and Transducers:** Calibration and standards, classification, selection criterion, measurement of temperature, flow, pressure, level, displacement, specifications of transducers, optical sensors, opto-couplers, Hall effect sensor, LEM Current and Voltage Sensors, Rogowski coil, leak detector, flame detector, smoke detector, humidity, sound sensors, signal conditioning, Introduction to alarms and annunciators.

**Module 5:** **Smart and MEMS sensors:** Principles of smart sensing, classification and terminology of smart sensors. MEMS (Piezoresistive, capacitive, conductive, optical), Introduction to sensor modelling, IC based sensors, Case study on Instrumentation System Design with any one transducer.

### 2.5.5 Learning Resources:

#### 2.5.5.1 Text Books:

1. A K Sawhney, "Electrical and Electronic Measurements and Instrumentation", Dhanpath Rai & Co., 2023
2. E O Doebelin, "Measurement Systems", McGraw Hill, 1990 ($4^{th}$ Ed.)

#### 2.5.5.2 Reference Books:

1. E W Golding, "Electrical Measurements & Measuring Instruments", Reem Publications, 2019 ($6^{th}$ Ed.)
2. Kalsi H S, "Electronic Instrumentation", Tata McGraw Hill, 2019 ($4^{th}$ Ed.)
3. David A. Bell, "Electronic Instrumentation and Measurements" Oxford University Press, 2013 ($3^{rd}$ Ed.)
4. Bowens A J, "Digital Instrumentation", Tata McGraw Hill, 1996.
5. Cooper, "Electronic Instrumentation And Measurement Techniques", Prentice Hall, 1985
6. Rangan C S, "Instruments Devices And System", Tata McGraw Hill, 1998
7. V K Aatre, G K Ananthasuresh, K J Vinoy, S Gopalakrishnan, K N Bhat , "Micro and Smart Systems", Willey India Publiser, 2010

## 2.6 Simulation Laboratory

| Course Code | Courses Name | Course Type | L - T - P | Credits | Total Hours |
|---|---|---|---|---|---|
| EE204 | Simulation Laboratory | Theory | 0 - 0 - 3 | 2 | 42 |

### 2.6.1 Objectives:

The objectives of studying this course are,

1. to understand basic block sets of different simulation platform used in electrical/electronic circuit design.
2. to understand use and coding in different software tools used in electrical/ electronic circuit design.
3. to understand the simulation of electric/electronic circuits for performance analysis.

### 2.6.2 Syllabus:

**Module 1:** **Introduction:** Introduction to basic matrix operations and generation of various signals & sequences using a suitable Simulation Platform.

**Module 2:** Using the suitable simulation platform,

1. Verify Mesh and Nodal analysis to find branch voltages and currents.
2. Verify various network theorems.
3. Analyse single–phase series and parallel AC circuits using R-L, R-C and R -L-C elements.
4. Simulate transient response of RLC Circuit to an input (i) Step, (ii) Pulse and (iii) Sinusoidal signals.
5. Simulate half wave and full wave bridge rectifiers with R-L, R-C and R-L-C Loads.
6. Verify the truth tables of basic gates.
7. Design the NAND and NOR gates as universal logic gates.
8. Simulate the Integrator and Differentiator circuits using OP-AMP.
9. Design and verify the truth tables of Half and Full adder circuits.
10. Design and verify the truth tables of Half and Full subtractor circuits.

## 2.7 Electrical and Electronics Measurement Lab

| Course Code | Courses Name | Course Type | L - T - P | Credits | Total Hours |
|---|---|---|---|---|---|
| EE205 | Electrical and Electronics Measurement Lab | Theory | 0 - 0 - 3 | 2 | 42 |

### 2.7.1 Objectives:

The objectives of studying this course are,

1. to To be familiar with basic control configurations and also to be competent in mathematical modelling of physical systems and analyze their time and frequency response.
2. to understand the tools for the stability analysis of the closed loop system.
3. to understand the tuning of P, PI and PID controller.

### 2.7.2 Syllabus:

**Module 1:**

1. (a) Loading effects of Potentiometer.
   (b) Calibration of Voltmeters and Ammeters using Potentiometers.
2. (a) Measurement of Low Resistance by Kelvin's Double Bridge Method.
   (b) Measurement of resistance by Wheatstone bridge method.
3. Measurement of Self Inductance and Capacitance using Bridges.
4. Measurement of Power and Power Factor using wattmeter method.
5. Study of DSO control panel, its specifications. Find time constant of a relay using DSO.

**Module 2: (Any Three)**

6. (a) Measurements using proximity sensors.
   (b) Characterize the Hall Effect sensor.
   (c) Characterize the temperature sensors (RTD, Thermocouple).
7. (a) Measurement of level in a tank using capacitive type level probe.
   (b) Measurement of pressure and displacement.
   (c) Measurement of strain and torque using strain gauges.
8. (a) Study of Opto-coupler using photoelectric transducers.
   (b) Characteristics of Micro pressure and Micro accelerometer sensing device.
9. (a) Study of Detectors (leak detector, flame detector, smoke detector etc.).
   (b) Study of smart transmitters.
   (c) Design of alarms and annunciators.
10. Signal Conditioning for any one transducer.

**Module 3:**

11. PCB design for any one signal conditioning application.
12. Enclosure design for circuit and measurement.
13. Simulation of Instrumentation System Design Using real-time suitable software.

## 2.8 Tinkering Lab - I

| Course Code | Courses Name | Course Type | L - T - P | Credits | Total Hours |
|---|---|---|---|---|---|
| EE206 | Tinkering Lab - I | Practical | 0 - 0 - 3 | 2 | 42 |

### 2.8.1 Objectives:

The objectives of studying this course are,

1. to encourage the spirit of curiosity and innovation among young minds.
2. to gain hands-on experience by Do-It-Yourself (DIY) mode, learn from failures and acquire new skills.
3. to do studio projects based on the latest technology-based applications.

### 2.8.2 Syllabus:

**Module 1:** **Introduction:** Workshop attire briefing. Electric safety rules and unsafe practices. Precautions and first aid practices. Introduction to tools, electrical materials, meters, symbols and abbreviations

**Module 2:** 1. Basic Wiring

2. Control a fan using electronic regulator/calling bell/ buzzer/ alarm

3. Meter board for lighting installation using energy meter, fuse, Main Circuit Breaker (MCB), Double Pole (DP) switch, Earth-leakage circuit breaker (ELCB), open circuit, short circuit, polarity, insulation resistance and earth fault and indicator

4. Preparing an electrical extension board

5. Soldering exercise.

6. PCB Design.

7. UPS/Inverter Wiring.

8. Winding an Inductor of specified rating.

9. Earthing analysis .

10. Testing of Motors, Cables, Power Capacitors, Batteries, etc.

11. Arduino based projects .

12. Studio projects on state-of-art technologies. Ex: Drones, IoT applications, Robotics, Mobile technology, etc

# Module 3

# Fourth Semester Courses:

## 3.1 Innovation & Entrepreneurship

| Course Code | Courses Name | Course Type | L - T - P | Credits | Total Hours |
|---|---|---|---|---|---|
| IE250 | Innovation & Entrepreneurship | Theory | 1 - 0 - 0 | 1 | 14 |

### 3.1.1 Objectives:

The objectives of studying this course are,

1. to introduce to a project-based learning approach from Ideation to Innovation and Entrepreneurship will be the key process considered here.
2. to learn the essential concepts of innovation and entrepreneurship through hands-on activities and the best and most relevant practical examples.
3. to provide the tools necessary for starting independent innovation and businesses.
4. give students practical experience in market survey, commercialization, IPR and proactively work in projects in risky market environments.

### 3.1.2 Course Outcome:

At the completion of this course, the student shall acquire knowledge and ability

1. CO1 : to comprehend the basic theories and concepts that underlie a survey study of Innovation, Entrepreneurship and Social Business or Entrepreneurship.
2. CO2 : to understand how to generate good large company or startup business ideas or societal ideas, and refine these ideas, to substantially increase chances for success in the marketplace.
3. CO3 : to get exposed to the thoughts and strategies of some very effective real-life innovators and entrepreneurs through videos and small cases.
4. CO4 : to understand about IPR, prototyping and financial management.

### 3.1.3 CO - PO Mapping:

| **Relationship of Course Outcomes to Program Outcomes** | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **CO ↓** | **PO** | | | | | | | | | | | |
| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
| CO1 | L | H | L | H | M | H | H | L | H | H | H | H |
| CO2 | L | H | L | H | H | H | H | L | H | H | H | H |
| CO3 | L | H | L | H | H | H | H | L | M | H | H | H |
| CO4 | L | H | L | H | H | H | H | H | L | L | H | H |
| **H = High correlation; M = Medium correlation; L = Low correlation** | | | | | | | | | | | | |

### 3.1.4 Syllabus:

**Module 1:** **Introduction:** Creative thinking, blocks to creativity, factors that influence creative design, engineering design and creative design, influence of society, market pull & technology push, attribute of a creative person Three levels of Design - Viceral, Behavioral and Reflective design. Qualities and skills required for entrepreneurship, Functions of an entrepreneur, Importance of entrepreneur in economic development

**Module 2:** **Ideas for Entrepreneurship:** Need or identification of a problem, market survey, data collection, review & analysis, problem definition, challenge statement, problem statement initial specifications, Brain storming, analogy technique or Synectic, check list, trigger words, morphological method, interaction matrix method, analysis of interconnected decision making.

**Module 3:** **Theory of Inventive Problem Solving (TRIZ):** 20 key TRIZ principles – multifunction, compensation, nested doll, blessing in disguise, segmentation, separation, symmetry change, opaque & porous, inflate and deflate, recycle & recover, phase transformation, energy, imaging, environment, composition, economical, surface response, static & dynamic, continuous & intermittent, dimensions.

**Module 4:** **Product Design, IPR & Finance:** Detail design, prototyping, product deployment, useful life assessment and recycling and sustainability; patent act, patent laws, Types of entrepreneurs- Based on type of business, based on use of technology, based on motivation, based on stages of development, based on motive, Based on capital ownership, Business Plan, Finance and Funding.

### 3.1.5 Learning Resources:

#### 3.1.5.1 Text Books:

1. C B Gupta and N P Srinivasan, "Entrepreneurial Development", Sultan Chand and Sons, 2020

#### 3.1.5.2 Reference Books:

1. Floyd Hurt, "Rousing Creativity: Think New Now", Crisp Publications Inc., 1999
2. Kalevi Rantanen and Ellen Domb, "Simplified TRIZ", Auerbach Publications, Taylor & Francis Group, 2010 ($2^{nd}$ Ed.)
3. John Adair, "The Art of Creative Thinking", Kogan Page Publication, 2011

## 3.2 Signals and Systems

| Course Code | Courses Name | Course Type | L - T - P | Credits | Total Hours |
|---|---|---|---|---|---|
| EE250 | Signals and Systems | Theory | 3 - 0 - 0 | 3 | 42 |

### 3.2.1 Objectives:

The objectives of studying this course are,

1. to understand the characteristics of both continuous-time and discrete-time signals and systems.
2. to analyse electrical network in both the time and transform domains.
3. to provide the foundation to other courses that deal with signals and systems theory.

### 3.2.2 Course Outcome:

At the completion of this course, the student shall acquire knowledge and ability

1. CO1 : to understand the mathematical description and representation of continuous-time and discrete-time signals and to classify systems based on properties.
2. CO2 : to analyze the spectral characteristics of continuous-time and discrete-time periodic and aperiodic signals using Fourier analysis.
3. CO3 : to analyse system properties based on impulse response and Fourier analysis in continuous-time and discrete-time domain.
4. CO4 : to convert a continuous time signal into discrete time signal and reconstruct the continuous time signals back from its samples.
5. CO5 : to apply the Laplace transform and Z- transform respectively for the analysis of continuous time and discrete-time signals.

### 3.2.3 CO - PO Mapping:

| **Relationship of Course Outcomes to Program Outcomes** | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **CO ↓** | **PO** | | | | | | | | | | | |
| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
| CO1 | H | H | M | M | L | | | | | | | M |
| CO2 | H | H | H | H | L | | | | | | | M |
| CO3 | H | H | H | M | L | | | | | | | M |
| CO4 | H | H | H | H | L | | | | | | | M |
| CO5 | H | H | H | H | L | | | | | | | M |
| **H = High correlation; M = Medium correlation; L = Low correlation** | | | | | | | | | | | | |

### 3.2.4 Syllabus:

**Module 1:** **Introduction to CT Signals and Systems:** Continuous-time signals, transformation of independent variables, some signals of importance: unit step, unit impulse, sinusoid, complex exponential etc., Classification of signals, Operations on Signals, Systems and its properties (linearity, shift-invariance, causality, stability etc.) with examples.

**Module 2:** **Analysis of CT signals and Systems in Time-domain:** Impulse response and step response of continuous-time linear time invariant systems, Convolution integral, characterization of causality and stability of linear time-invariant systems, system representation using differential equations with electrical networks, Analysis of Electrical circuits (First order and Second Order Circuits) using Laplace transform, state space representation in Laplace transform.

**Module 3:** **Analysis of CT signals and Systems in Frequency-domain:** Fourier Transform and its properties, magnitude and phase response computation for electrical networks, Fourier domain duality, harmonic analysis of simple electrical networks.

**Module 4:** **Sampling and Reconstruction:** Sampling theorem, Aliasing, Quantization, reconstruction of band limited signals, discrete-time signals and systems, difference equation, convolution sum, auto-correlation and cross-correlation.

**Module 5:** **Analysis of DT signals and systems in Frequency domain:** Z-transform and inverse Z-transform for some typical signals, solution of difference equation, stability analysis in z-domain. Discrete-time Fourier series and its properties, Discrete-time Fourier transform and its properties, applications of signals and system theory.

### 3.2.5 Learning Resources:

#### 3.2.5.1 Text Books:

1. Alan V Oppenheim, Alan S Willsky and S Hamid Nawab, "Signals and Systems", Prentice Hall, 1983

2. Simon Haykin and Barry van Veen, "Signals and Systems", John Wiley and Sons (Asia) Private Limited, 1998

#### 3.2.5.2 Reference Books:

1. M E Van Valkenberg, "Network Analysis", PHI Learning Publications, 2014 ($3^{rd}$ Ed.)

2. B P Lathi, "Signal Processing and Linear Systems", Oxford University Press, 1998

## 3.3 Electrical Machines - I

| Course Code | Courses Name | Course Type | L - T - P | Credits | Total Hours |
|---|---|---|---|---|---|
| EE251 | Electrical Machines - I | Theory | 3 - 0 - 0 | 3 | 42 |

### 3.3.1 Objectives:

The objectives of studying this course are,

1. to review the concepts of magnetic circuit fundamentals.
2. to have a comprehensive idea on electromechanical energy conversion.
3. to understand the working of transformers , DC and induction machines
4. to analyze the equivalent circuit model and performance characteristics of the electrical machines.

### 3.3.2 Course Outcome:

At the completion of this course, the student shall acquire knowledge and ability

1. CO1 : to familiarize the application of magnetic circuit fundamentals in the working of electrical machines.
2. CO2 : to understand the electromechanical energy conversion phenomenon in electrical machines.
3. CO3 : to understand how the transformers and rotating machines work.
4. CO4 : to analyze the equivalent circuit model of the machines.
5. CO5 : to analyze the performance characteristics of the machines.

### 3.3.3 CO - PO Mapping:

| **Relationship of Course Outcomes to Program Outcomes** | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **CO ↓** | **PO** | | | | | | | | | | | |
| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
| CO1 | M | | | | | | | | | | | |
| CO2 | M | | L | | | | | | | | | |
| CO3 | H | H | | | | | | | | | | |
| CO4 | M | H | | M | M | | | | | | | |
| CO5 | M | H | | M | | | | | | | | L |
| **H = High correlation; M = Medium correlation; L = Low correlation** | | | | | | | | | | | | |

### 3.3.4 Syllabus:

**Module 1:** **Basic Concepts:** Review of Magnetic Circuits, Flux, MMF, EMF, Force, exciting current, Hysteresis and eddy current loss, Sinusoidal excitation- Review of three phase AC circuits-Concept of Field energy and Co energy, Mechanical force in electromagnetic system- Linear and rotational, Rotating machines, Cylindrical machines, Concentrated and Distributed Winding – Winding factors-MMF distribution in windings, Pulsating and Rotating magnetic field, space and time harmonics, EMF generation, Torque Production.

**Module 2:** **DC Machines:** Classification of DC machines, Armature windings, EMF, Armature Reaction, Electromagnetic torque, Characteristic curves for DC machines, Losses and Efficiency , Speed control of DC motors, Braking of DC motors, PMDC motors

**Module 3:** **Transformer:** Single phase: Working principle, Ideal and practical transformer, Per unit concept Equivalent circuit and phasor diagrams, Determination of Equivalent circuit parameters, Voltage regulation, losses and efficiency, Tests on Transformer, Auto transformer, Distribution transformers. Three phase: Three phase winding connections, Vector grouping, Three winding transformers, Tap changing of transformers.

**Module 4:** **Induction Machines:** Introduction ,Modes of operation, Equivalent circuit model, Analysis of equivalent circuit- Torque-slip and Power slip characteristics, Determination of equivalent circuit parameters, Performance characteristics, Powerflow, Circle diagram, Starting methods of Induction motors, Speed control of induction motors

### 3.3.5 Learning Resources:

#### 3.3.5.1 Text Books:

1. A E Fitzgerald, C Kingsley and S D Umans, "Electrical Machinery," Tata McGraw Hill, 2003 ($6^{th}$ Ed.).

2. AE Clayton and NN Hancock, "Performance & Design Of DC Machines," CBS, 2001 ($3^{rd}$ Ed.).

3. P C Sen, "Principles of Electric Machines," Wiley India Pvt Ltd., 2020 ($3^{rd}$ Ed.).

#### 3.3.5.2 Reference Books:

1. S J Chapman, "Electric Machinery Fundamentals," McGraw Hill, 2010 ($4^{th}$ Ed.).

2. I J Nagarath and D P Kothari, "Electric Machines," Tata McGraw Hill, 2010 ($4^{th}$ Ed.).

3. P S Bimbhra, "Electrical Machinery," Khanna Publishers, 2008 ($7^{th}$ Ed.).

## 3.4 Digital Systems

| Course Code | Courses Name | Course Type | L - T - P | Credits | Total Hours |
|---|---|---|---|---|---|
| EE252 | Digital Systems | Theory | 3 - 0 - 0 | 3 | 42 |

### 3.4.1 Objectives:

The objectives of studying this course are,

1. to design combinational and sequential digital circuits.
2. to study state machines for the design of digital systems.
3. to familiarize the Verilog concept for the development of digital circuits.

### 3.4.2 Course Outcome:

At the completion of this course, the student shall acquire knowledge and ability

1. CO1 : to apply the knowledge of Boolean algebra and other minimization schemes to deduce optimal digital circuits.
2. CO2 : to design combinational and sequential circuits for a given problem / case studies related to digital circuits.
3. CO3 : to analyse and develop digital networks using a state diagram.
4. CO4 : to code combinational and sequential circuits using Verilog HDL.

### 3.4.3 CO - PO Mapping:

| **Relationship of Course Outcomes to Program Outcomes** | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **CO ↓** | **PO** | | | | | | | | | | | |
| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
| CO1 | H | H | M | M | | L | | | | | | M |
| CO2 | H | H | H | H | | L | | | | | | M |
| CO3 | H | H | H | M | | L | | | | | | M |
| CO4 | H | M | M | M | H | | | | M | | | M |
| **H = High correlation; M = Medium correlation; L = Low correlation** | | | | | | | | | | | | |

### 3.4.4 Syllabus:

**Module 1:** Review of Number systems-representation-conversion, error detecting and correcting codes, review on Boolean algebra and logic gates, simplification of logic functions using Karnaugh map, Quine–McCluskey method.

**Module 2:** Combinational logic Circuits: Adders, subtractors, parallel adder, BCD adder, binary multiplier, magnitude comparator, decoders, BCD to 7-segment decoder driver, encoders, priority encoders, code converters, parity generator/checker, multiplexers and de-multiplexers, implementation of logical functions using multiplexers.

**Module 3:** Sequential circuits, latches and flip-flops: SR-latch, D-latch, D flip-flop, JK flip-flop, T flip-flop, timing hazards and races, edge-triggered flip-flops, register, shift register, universal shift register; application of shift register: ring counter, Johnson counter, sequence generator and detector, up- and down counter, asynchronous ripple counter, synchronous counters, counter design using flip flops, counter design with asynchronous reset or preset; applications of counters.

**Module 4:** Canonical model of a state machine, types of state machines, state diagram, state table, state assignment, Moore and Mealy model, state minimization, timing a digital circuit, fundamentals of timing analysis, setup and hold time, Read-only memory, read/write memory – SRAM, DRAM, PLAs, PALs, ADC, DACs

**Module 5:** Introduction to VLSI design-Basic gate design, Design of general Boolean circuits using CMOS gates, Verilog concepts.

### 3.4.5 Learning Resources:

#### 3.4.5.1 Text Books:

1. M. Morris Mano and Michael D. Ciletti, "Digital Design: With an Introduction to Verilog HDL", Pearson Education India, 2013 ($5^{th}$ Ed.)
2. Wakerly J F, "Digital Design: Principles and Practices", Prentice-Hall, 2022 ($2^{nd}$ Ed.)
3. D. D. Givone, "Digital Principles and Design", Tata Mc-Graw Hill, New Delhi, 2003

#### 3.4.5.2 Reference Books:

1. Stephen Brown and Zvonko Vranesic, "Fundamentals of Digital Logic with VHDL Design", McGraw Hill Education, 2017 ($3^{rd}$ Ed.)
2. Ronald J. Tocci, Neal S. Widmer, Gregory L. Moss, "Digital Systems: Principles and Applications", Pearson Education, 2009 ($10^{th}$ Ed.)
3. Herbert Taub and Donald Schilling, "Digital Integrated Electronics", McGraw Hill Education, 2017
4. T. L. Floyd and Jain, "Digital Fundamentals", Pearson Education, 2003 ($8^{th}$ Ed.)

## 3.5 Control Systems

| Course Code | Courses Name | Course Type | L - T - P | Credits | Total Hours |
|---|---|---|---|---|---|
| EE253 | Control Systems | Theory | 3 - 1 - 0 | 4 | 56 |

### 3.5.1 Objectives:

The objectives of studying this course are,

1. to be familiar with basic control configurations and also to be competent in mathematic modelling of physical systems and analyze their time and frequency response.
2. to understand the tools for the stability analysis of the closed loop system.
3. to understand the tuning of P, PI and PID controller.

### 3.5.2 Course Outcome:

At the completion of this course, the student shall acquire knowledge and ability

1. CO1 : to develop mathematical model for electrical and mechanical systems.
2. CO2 : to compute and analyze the transient and steady state behaviour of the system.
3. CO3 : to analyze the stability of closed loop systems using various tools.
4. CO4 : to design the classical controllers such as P, PI, etc., for electrical systems.

### 3.5.3 CO - PO Mapping:

| **Relationship of Course Outcomes to Program Outcomes** | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **CO ↓** | **PO** | | | | | | | | | | | |
| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
| CO1 | H | M | M | L | L | L | L | L | L | L | L | M |
| CO2 | H | H | H | M | L | L | L | L | L | L | L | M |
| CO3 | H | H | H | M | L | L | L | L | L | L | L | M |
| CO4 | H | H | H | M | L | L | L | L | L | L | L | M |
| **H = High correlation; M = Medium correlation; L = Low correlation** | | | | | | | | | | | | |

### 3.5.4 Syllabus:

**Module 1:** **Mathematical Modelling:** Open loop and closed loop systems, mathematical modelling of physical systems, transfer functions, block diagram and Signal flow graph representation and Analysis of System, feedback characteristics of closed loop system. Control system components, Stepper motors, Tacho-generators, DC and AC Servomotors.

**Module 2:** **Time Response Analysis:** Standard test signals, time response of first and second order systems, steady-state errors and dynamic error coefficients, effect of addition of poles and zeros on response of system.

**Module 3:** **Concept of stability:** Routh-Hurwitz criterion, Root locus, gain margin and phase margin, effect of addition of poles and zeros on root locus.

**Module 4:** **Frequency domain Analysis:** Frequency response specifications, frequency and time domain correlation, Bode plot, Polar plot, Nyquist criterion, Compensation Techniques: Response of P, PI, PID controllers, Design of Lead, Lag, Lead-Lag Compensation.

**Module 5:** **State Space Analysis:** State space model, transfer function from the state space model, Eigen values, Eigen vector and diagonalisation of the state matrix, Jordan canonical form, Computation of state transition matrix, Transformation to phase to variable canonical form, The state diagram, decomposition of digital system, Concept of controllability and observability.

### 3.5.5 Learning Resources:

#### 3.5.5.1 Text Books:

1. Katsuhiko Ogata, "Modern Control Engineering", PHI, 5th Edition, 2020
2. M. Gopal, "Control Systems, Principles and Design", Tata McGraw Hill, 2020

#### 3.5.5.2 Reference Books:

1. I. J. Nagrath M. Gopal, "Control Systems Engineering", New Age Int., 7th Edition,2021
2. Norman S. Nise, "Control System Engineering", John Wiley and Sons, Inc, 2018

## 3.6 Computational Methods

| Course Code | Courses Name | Course Type | L - T - P | Credits | Total Hours |
|---|---|---|---|---|---|
| EE254 | Computational Methods | Theory cum Practical | 2 - 0 - 2 | 3 | 56 |

### 3.6.1 Objectives:

The objectives of studying this course are,

1. to offer a thorough understanding of numerical methods.
2. to emphasize essential concepts, including numerical solutions for algebraic, transcendental, and differential equations, and explores their practical applications.

### 3.6.2 Course Outcome:

At the completion of this course, the student shall acquire knowledge and ability

1. CO1 : to gain expertise in numerical solving techniques for single-variable equations and systems of equations, and then apply these principles to address intricate engineering challenges.
2. CO2 : to understand the significance of curve fitting, interpolation, numerical differentiation and integration.
3. CO3 : to foster a deep comprehension of the importance of numerically solving ordinary and partial differential equations (ODEs) and explore their wide-ranging applications across diverse fields.
4. CO4 : to develop a profound understanding of the significance of employing numerical methods through the utilization of diverse programming languages.

### 3.6.3 CO - PO Mapping:

**Relationship of Course Outcomes to Program Outcomes**

| **CO ↓** | **PO** | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
| CO1 | H | H | H | M | M | | | L | L | M | | H |
| CO2 | H | H | H | H | H | | | L | L | M | | H |
| CO3 | H | H | H | H | H | | | L | L | M | | H |
| CO4 | H | H | H | H | H | | | L | L | M | | H |

**H = High correlation; M = Medium correlation; L = Low correlation**

### 3.6.4 Syllabus:

**Module 1:** **Numerical solution of equations and systems:** Equations in one variable: The Bisection method, Fixed point iteration method; Secant method; Regular-Falsi method; Newton's method and its extensions; Convergence of Newtons's method. System of equations: Jacobi and Gauss-Seidel iterative methods; Sufficient conditions for convergence; Power method to find the dominant eigen value and eigenvector.

**Module 2:** **Interpolation, Numerical Differentiation and Integration:** Interpolation and Curve fitting: The Lagrange polynomial; Divided differences; Method of least square approximations. Numerical integration: Open and closed Newton-Cotes formula; Gaussian quadrature formula.

**Module 3:** **Numerical Methods for Differential Equations:** Ordinary Differential Equations: Euler's method; Euler's modified method; Taylor's method and Runge-Kutta method; Multistep methods. Elliptic partial differential equations: Finite difference method for two dimensional equations. Parabolic partial differential equations: Forward difference method, backward difference method and the Crank-Nicolson method for one dimensional equations. Hyperbolic partial differential equations: Central difference method for one dimensional equations.

**Module 4:** **Lab Experiments: 2 hrs per week**

1. Introduction on a standard simulation platform.
2. Program to solve one variable equation using Bisection, Fixed point, Newton Raphson, Regula-Falsi and Secant methods.
3. Program to solve system of equations using Gauss-Jacobi and Gauss-Seidal Method
4. Program to find dominant eigenvalue using the Power Method
5. Program to fit a curve using method of least square.
6. Program to interpolate using the Lagrange polynomial method.
7. Program to evaluate differentiation and integration.
8. Programs to solve ordinary differential equations using Euler's Method, Taylor's method, R-K method of order four, multistep methods.
9. Programs to solve elliptic equations using the finite difference method.
10. Programs to solve parabolic and hyperbolic equations using the finite difference method.

### 3.6.5 Learning Resources:

#### 3.6.5.1 Text Books:

1. M K Jain, S R K Iyengar and R K Jain, "Numerical Methods for Scientific and Engineering Computation", New Age Publishers, 2012 ($6^{th}$ Ed.)

#### 3.6.5.2 Reference Books:

1. E Kreyszig, "Advanced engineering mathematics", Wiley India Pvt. Ltd., 2010 ($8^{th}$ Ed.)
2. R L Burden and J D Faires, "Numerical Analysis", Brooks/Cole, 2012 ($9^{th}$ Ed.)
3. G D Smith, "Numerical solution of Partial Differential Equations", Oxford University Press, 1985, ($3^{rd}$ Ed.)
4. M B Patil, M C Chandorkar, V Ramanarayanan and V T Ranganathan, "Simulation of Power Electronic Circuits", Narosa, 2009, ($1^{st}$ Ed.)

## 3.7 Electrical Machine Lab - I

| Course Code | Courses Name | Course Type | L - T - P | Credits | Total Hours |
|---|---|---|---|---|---|
| EE255 | Electrical Machine Lab - I | Practical | 0 - 0 - 3 | 2 | 42 |

### 3.7.1 Objectives:

The objectives of studying this course are,

1. to provide an insight into the constructional details of dc machines and transformers with a view for better understanding of their working principles.
2. to test and evaluate the performance of various dc machines, tansformer and induction machines by conducting appropriate experiments.

### 3.7.2 Syllabus:

1. Determination of B-H curve for ferromagnetic core.
2. Performance Characteristics of DC generator.
3. Performance Characteristics of DC Motor.
4. Speed control of DC shunt Motor.
5. Open circuit and Short circuit test of 1-ph and 3-ph transformer.
6. Direct load test on 1-ph and 3-ph transformer.
7. No Load and Block rotor test on three phase Induction motor.
8. Performance Characteristics of three phase Induction motor.
9. Speed control of Slip ring Induction motor.

## 3.8 Analog and Digital Circuits Lab

| Course Code | Courses Name | Course Type | L - T - P | Credits | Total Hours |
|---|---|---|---|---|---|
| EE256 | Analog and Digital Circuits Lab | Practical | 0 - 0 - 3 | 2 | 42 |

### 3.8.1 Objectives:

The objectives of studying this course are,

1. to demonstrate the knowledge of analog and digital circuits.
2. to design various analog and digital circuits.

### 3.8.2 Syllabus:

1. Characteristics of MOSFET in different configurations.
2. Characteristics of RC oscillator.
3. Adder and subtractor circuits.
4. Multiplexer and Demultiplexer.
5. Counters/registers using flip-flops.
6. Linear applications of op-amps.
7. Non-linear applications of op-amps.
8. Second order low pass, high pass, band pass filters implementation.
9. Monostable, Astable, and bistable multivibrators.
10. Phase locked loop.
11. ADCs and DACs.
12. Verilog/VHDL programming to realize logic gates, sequential and combinational circuits.

## 3.9 Control System Lab

| Course Code | Courses Name | Course Type | L - T - P | Credits | Total Hours |
|---|---|---|---|---|---|
| EE257 | Control System Lab | Practical | 0 - 0 - 3 | 2 | 42 |

### 3.9.1 Objectives:

The objectives of studying this course are,

1. to demonstrate the knowledge of simulation tools for control system design.
2. to develop the mathematical model of a given physical system by conducting appropriate experiments.
3. to analyse the performance and stability of physical systems using classical and advanced control approaches.
4. to design controllers for physical systems to meet the desired specifications.

### 3.9.2 Syllabus:

1. Simulation of various control systems tools using suitable software.
2. Study of DC servo motors and Synchro pairs.
3. Study of rectilinear motion.
4. DC and AC position Control Systems.
5. (a) Closed-loop P, PI, PD, and PID controllers.
   (b) Design and validation of PID controller for speed and position control.
6. (a) Temperature Control Systems.
   (b) Two tank water Level Control Systems.
7. Study of Inverted Pendulum System.
8. (a) Study of 2-DoF ball on beam.
   (b) Study of Cascade Control using 3-DoF gyroscope.
9. Study and develop the ladder programs using PLC for different applications.
10. Study of Magnetic Levitation.
11. Microcontroller based Control System with any one application.

# Module 4

# Fifth Semester Courses:

## 4.1 Environmental Studies

| Course Code | Courses Name | Course Type | L - T - P | Credits | Total Hours |
|---|---|---|---|---|---|
| ES300 | Environmental Studies | Theory | 1 - 0 - 0 | 1 | 14 |

### 4.1.1 Objectives:

The objectives of studying this course are to,

1. Understand the environment and its key components.
2. Learn the importance of environment for life and ecosystems.
3. Study human activities and their environmental impacts.
4. Explore climate change and related global initiatives.
5. Promote awareness and action for environmental conservation.

### 4.1.2 Course Outcome:

At the completion of this course, the student shall acquire knowledge and ability to,

1. CO1: Understand in-depth knowledge on natural processes and resources that sustain life.
2. CO2: Understand the effect of human interference on the web of life, economy, and quality of human life.
3. CO3: Develop critical thinking for shaping strategies for environmental protection, conservation of biodiversity, environmental equity, and sustainable development.
4. CO4: Acquire values and attitudes towards understanding complex environmental economic- social challenges, and active participation in solving current environmental problems and preventing the future ones.
5. CO5: Adopt sustainability as a practice in life, society, and industry.

### 4.1.3 CO - PO Mapping:

| **Relationship of Course Outcomes to Program Outcomes** | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **CO ↓** | **PO** | | | | | | | | | | | |
| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
| CO1 | - | L | L | H | | H | H | H | H | L | L | H |
| CO2 | - | H | H | M | L | H | H | H | H | L | L | H |
| CO3 | - | H | H | L | | H | H | H | M | L | L | H |
| CO4 | - | L | L | L | | L | H | H | L | L | L | H |
| CO5 | - | H | H | M | M | M | H | H | H | L | M | H |
| **H = High correlation; M = Medium correlation; L = Low correlation** | | | | | | | | | | | | |

### 4.1.4 Syllabus:

**Module 1:** **Introduction:** Environment, interaction organism, scale of interaction, types of environment, Human interference, environmental ethics, environmental problems, sustainable society, ecological foot prints.

**Module 2:** **Ecosystem:** current status, Role of organism, species, Life supporting system, Factors sustaining life, Components of ecosystem, Ecological efficiency, Matters in ecosystem, Major chemical cycles, Role of Species, Classification of species.

**Module 3:** **Biodiversity and species interaction:** Biodiversity and Ecosystem, Species interaction, Natural selection, population growth, factor limiting population growth, Population dynamics, Species and reproductive pattern, Biodiversity, Population and Economy, Food and nutrition.

### 4.1.5 Learning Resources:

#### 4.1.5.1 Text Books:

1. Erach Bharucha, "Textbook for environmental studies for undergraduate courses of all branches of higher education (Online book-UGC website)," University Grants Commission, India

2. Daniel B. Botkin, and Edward A. Keller, "*Environmental science: Earth as a living planet*", John Wiley & Sons, Inc., 2013 $8^{th}$ Ed., ISBN 978-0-470-52033-8.

3. G. Tyler Miller, Jr., Scott Spoolman, Brooks/Cole, "*Environmental science: Problems, concepts, and solutions*", $16^{th}$ Ed., ISBN-13: 978-0-495-55671-8.

#### 4.1.5.2 Reference Books:

1. William P. Cunningham, Mary Ann Cunningham, "Principles of environmental science: Inquiry & application," Mcgraw-Hill, ($7^{th}$ Ed.) ISBN 978–0–07–353251–6

2. William P. Cunningham, Mary Ann Cunningham, "Environmental science: A global concern," Mcgraw-Hill, ($12^{th}$ Ed.) ISBN 978–0–07–338325–5.

## 4.2 Power Electronics

| Course Code | Courses Name | Course Type | L - T - P | Credits | Total Hours |
|---|---|---|---|---|---|
| EE300 | Power Electronics | Theory | 3 - 0 - 0 | 3 | 42 |

### 4.2.1 Objectives:

The objectives of studying this course are to,

1. Understand the fundamentals and switching characteristics of power semiconductor devices.
2. Analyze and design rectifiers, DC-DC converters, inverters, and AC voltage controllers.
3. Study modulation techniques for power conversion and control.
4. Explore the applications of power electronics in industrial drives, renewable energy, and electric vehicles.
5. Introduce modern trends in power electronics, including digital control, wide-bandgap devices, and smart grids.

### 4.2.2 Course Outcome:

At the completion of this course, the student shall acquire knowledge and ability to

1. CO1 : Understand the fundamentals of power electronics devices, their characteristics, and control requirements.
2. CO2 : Analyze and compare different types of AC-DC and DC-AC converters and their applications.
3. CO3 : Design and evaluate DC-DC converter topologies under various modes of operation.
4. CO4 : Investigate switching strategies and multilevel-inverter techniques for efficient power conversion.
5. CO5 : Apply power converters in real-world systems like UPS, battery chargers, and renewable energy systems.

### 4.2.3 CO - PO Mapping:

| **Relationship of Course Outcomes to Program Outcomes** | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **CO ↓** | **PO** | | | | | | | | | | | |
| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
| CO1 | H | M | L | L | M | L | L | L | L | L | L | M |
| CO2 | H | H | M | L | M | L | L | L | L | L | L | M |
| CO3 | H | M | H | M | H | L | M | L | L | L | L | M |
| CO4 | H | H | H | M | H | L | M | L | M | M | M | H |
| CO5 | H | M | H | M | H | M | H | M | M | M | M | H |
| **H = High correlation; M = Medium correlation; L = Low correlation** | | | | | | | | | | | | |

### 4.2.4 Syllabus:

**Module 1:** **Introduction to Power Electronics Systems and Applications:** Review of Basic Electric and magnetic concepts, Power Electronic Devices: Operation and characteristics, ratings, Control and protective mechanism, Recent trends in power electronics.

**Module 2:** **Line frequency Converter:** Uncontrolled rectifiers, phase controlled rectifiers and inverters, Applications.

**Module 3:** **DC-DC switched mode Converter:** Principle of operation, isolated and non-isolated converters, Continuous and discontinuous mode of operation, Applications.

**Module 4:** **DC-AC switched mode Converter:** Principle of operation, topologies, modulation schemes, introduction to multilevel-inverters, unity power factor converters, Applications.

**Module 5:** **Design & Applications:** Practical converter design consideration, few applications of power electronic systems, such as Battery Chargers, Uninterruptible Power Supplies, Renewable Energy Systems, Power Adaptors, etc

### 4.2.5 Learning Resources:

#### 4.2.5.1 Text Books:

1. Ned Mohan, Undeland and P Robin, "*Power Electronics Converters, Applications and Design*", John Wiley & Sons, 3rd Edition, 2007
2. M. H. Rashid, "*Power Electronics: Circuits, Devices, and Applications*", PHI, 2013 $4^{th}$ Ed.).
3. Daniel W. Hart, "*Power Electronics*", McGraw-Hill Education, 2010.

#### 4.2.5.2 Reference Books:

1. Robert W. Erickson and Dragan Maksimović, "Fundamentals of Power Electronics," Springer, 2002 $3^{rd}$ Ed.)
2. John G. Kassakian, Martin F. Schlecht, and George C. Verghese, "Principles of Power Electronics," Cambridge University Press, 2021 ($2^{nd}$ Ed.)
3. M. B. Patil, V. Ramanarayanan, and V. T. Ranganathan, "Simulation of Power Electronic Circuits", Narosa Publishing House, 2013

## 4.3 Electrical Machines-II

| Course Code | Courses Name | Course Type | L - T - P | Credits | Total Hours |
|---|---|---|---|---|---|
| EE301 | Electrical Machines-II | Theory | 3 - 0 - 0 | 3 | 42 |

### 4.3.1 Objectives:

The objectives of studying this course are to,

1. Understand the construction, operation, and performance of synchronous machines.
2. Analyze control strategies for synchronous motors including power factor and speed control.
3. Study types, starting methods, and applications of single-phase AC machines.
4. Explore working principles and characteristics of special machines like BLDC, SRM, and stepper motors.
5. Apply knowledge of machines in practical and industrial applications.

### 4.3.2 Course Outcome:

At the completion of this course, the student shall acquire knowledge and ability to

1. CO1 : Explain the operating principles and characteristics of synchronous machines, including performance under various loading and control conditions.
2. CO2 : Analyze voltage regulation methods, parallel operation, and power-angle characteristics of synchronous generators.
3. CO3 : Describe the types, construction, starting methods, and applications of single-phase AC motors.
4. CO4 : Examine the working principles and performance of special machines such as BLDC, stepper, and linear motors.
5. CO5: Apply the knowledge of electrical machines to evaluate their suitability for specific industrial and commercial applications.

### 4.3.3 CO - PO Mapping:

| **Relationship of Course Outcomes to Program Outcomes** | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **CO ↓** | **PO** | | | | | | | | | | | |
| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
| CO1 | H | M | L | L | M | L | L | L | L | M | L | M |
| CO2 | H | H | M | M | M | L | L | L | L | M | L | M |
| CO3 | H | M | L | L | M | L | L | L | M | M | L | L |
| CO4 | H | M | M | M | H | L | L | L | L | M | M | M |
| CO5 | M | M | H | M | H | M | L | L | M | H | M | H |
| **H = High correlation; M = Medium correlation; L = Low correlation** | | | | | | | | | | | | |

### 4.3.4 Syllabus:

**Module 1:** **Synchronous Machines:** Synchronous generators-concept of infinite bus–Equivalent circuit model of synchronous machine-Methods to determine voltage regulation-EMF, MMF, ZPF, Power- angle characteristics, capability curves, Parallel operation of Synchronous generators, Salient pole synchronous machines-Determination of $X_d$ and $X_q$ , Synchronous motors – starting methods, Torque-speed characteristics , V-curves , Power factor control , Speed control of synchronous motors ,Permanent magnet synchronous motors.

**Module 2:** **Single Phase AC machines:** Fractional kilowatt motors-Equivalent circuit- starting-classification-Characteristics and applications-design of starting winding, Working principle, characteristics and application of -Series (Universal) motors, Synchronous motors - Reluctance motors, Hysteresis motors.

**Module 3:** **Special Machines:** Working principle, characteristics and application of Servo motors, BLDC motors , Linear Induction motor, Linear synchronous motors, Switched Reluctance motors, Synchros, Stepper motors.

### 4.3.5 Learning Resources:

#### 4.3.5.1 Text Books:

1. P C Sen, "Principles of Electric Machines," Wiley India Pvt Ltd., 2020 ($3^{rd}$ Ed.).
2. I J Nagarath and D P Kothari, "Electric Machines," Tata McGraw Hill, 2010 ($4^{th}$ Ed.).

#### 4.3.5.2 Reference Books:

1. A E Fitzgerald, C Kingsley and S D Umans, "Electrical Machinery," Tata McGraw Hill, 2003 ($6^{th}$ Ed.).
2. Theodore Wildi , "Electrical Machines, Drives, and Power Systems," Pearson Education Limited
3. S J Chapman, "Electric Machinery Fundamentals," McGraw Hill, 2010 ($4^{th}$ Ed.).

## 4.4 Power Systems-I

| Course Code | Courses Name | Course Type | L - T - P | Credits | Total Hours |
|---|---|---|---|---|---|
| EE302 | Power Systems-I | Theory | 3 - 1 - 0 | 4 | 56 |

### 4.4.1 Objectives:

The objectives of studying this course are to,

1. Provide a comprehensive understanding of power system structure, transmission line performance, and mechanical aspects of overhead lines and underground cables.
2. Introduce circuit breakers, grounding techniques, fault analysis, and stability considerations in power systems.
3. Emphasize modern protection schemes, power system reliability, and safety measures.

### 4.4.2 Course Outcome:

At the completion of this course, the student shall acquire knowledge and ability

1. CO1 : Describe the structure and components of power systems, including bulk grids, microgrids, and distributed energy resources.
2. CO2 : Analyse transmission line performance using ABCD parameters, voltage regulation, and compensation techniques.
3. CO3 : Evaluate mechanical aspects of overhead lines and underground cables, including sag calculations and insulation resistance.
4. CO4 : Understand different types of circuit breakers, their ratings, operating principles, and neutral grounding techniques.
5. CO5 : Apply protection schemes for generators, transformers, busbars, and transmission lines, including modern relays and overvoltage protection.

### 4.4.3 CO - PO Mapping:

| **Relationship of Course Outcomes to Program Outcomes** | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **CO ↓** | **PO** | | | | | | | | | | | |
| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
| CO1 | H | M | M | M | L | L | H | L | L | L | L | M |
| CO2 | H | H | H | H | M | L | H | L | L | L | M | M |
| CO3 | H | H | H | H | M | L | H | L | L | L | M | M |
| CO4 | H | H | H | H | M | L | H | L | L | L | M | M |
| CO5 | H | H | H | H | M | H | H | L | L | L | M | M |
| **H = High correlation; M = Medium correlation; L = Low correlation** | | | | | | | | | | | | |

### 4.4.4 Syllabus:

**Module 1:** **Power System Structure:** Evolution of power systems. Traditional Vs. modern grids, Bulk power grids and microgrids: Features, challenges, and benefits. Conventional Vs. renewable energy sources and their integration, Distributed Energy Resources (DERs) and their impact on system stability. Energy storage technologies: Role in grid regulation and reliability. Synchronous Vs. asynchronous grid interconnections.

**Module 2:** **Transmission Line Performance:** Classification: Short, medium, and long transmission lines. ABCD parameters, voltage regulation, and efficiency analysis. Compensation techniques: Shunt and series compensation. Effects on transmission lines: Skin effect, proximity effect, Ferranti effect, and corona discharge.

**Module 3:** **Mechanical Aspects of OH Lines and Underground Cables:** Insulators, insulator types, and string efficiency. Sag and Tension calculations for Equal & Unequal heights of supports. Underground cables: Classification, insulation resistance, grading techniques, and thermal performance.

**Module 4:** **Circuit Breakers and Grounding Techniques:** Circuit breakers: Arc Phenomenon, Interruption methods, types of CB (Oil, Air, SF6, vacuum, and hybrid). Ratings, selection criteria, and auto-reclosing mechanisms. Neutral grounding: Ungrounded vs. grounded systems, resistance, reactance, and resonant grounding. Impact of grounding on system protection and fault mitigation.

**Module 5:** **Protection:** Protective relays: Electromagnetic, static, digital, and adaptive relays. Protection schemes for generators, transformers, busbars, and transmission lines. Overvoltage protection: Lightning arresters, insulation coordination, and surge protection.

### 4.4.5 Learning Resources:

#### 4.4.5.1 Text Books:

1. D P Kothari and I J Nagrath, "Power System Engineering," Tata Mcgraw-Hill, 2008 ($2^{nd}$ Ed.)
2. J. J. Grainger & W. D. Stevenson Jr., "Power System Analysis", McGraw-Hill.
3. C. L. Wadhwa, "Electrical Power Systems," New Age Int. Publishers, 2022 ($X^{th}$ Ed.)

#### 4.4.5.2 Reference Books:

1. Sunil S Rao, "Switch gear and protection," Khanna publishers, 1997 ($X^{nd}$ Ed.)
2. A. R. Warrington, "Electrical Power System Protection", Wiley.
3. Y. G. Paithankar & S. R. Bhide, "Fundamentals of Power System Protection", PHI Learning.
4. Prabha Kundur, "Power System Stability and Control", McGraw-Hill.

## 4.5 Microprocessor and Microcontroller

| Course Code | Courses Name | Course Type | L - T - P | Credits | Total Hours |
|---|---|---|---|---|---|
| EE303 | Microprocessor and Microcontroller | Theory | 3 - 0 - 0 | 3 | 42 |

### 4.5.1 Objectives:

The objectives of studying this course are to,

1. Understand the architecture and organization of microcomputers, focusing on 80x86 microprocessors and 8051 microcontrollers.
2. Learn the principles of interfacing peripherals with microprocessors and microcontrollers.
3. Develop programming skills for 80x86 processors and 8051 microcontrollers.
4. Explore the architecture and functionalities of advanced processors like ARM and PIC.
5. Gain insights into the practical applications and system design using microcontrollers and high-end processors.

### 4.5.2 Course Outcome:

At the completion of this course, the student shall acquire knowledge and ability to

1. CO1 : Understand the architecture, data handling, and arithmetic operations in microcomputers and processors.
2. CO2: Apply instruction sets and addressing modes to program and interface 80x86 processors with memory and peripherals.
3. CO3: Analyze the architecture and programming of 8051 microcontrollers and their interfacing techniques.
4. CO4: Design and develop microcontroller-based systems using serial or parallel interfaces and peripherals.
5. CO5: Explore high-end processors (ARMx, Raspberry Pi, PIC) and their application in embedded systems.

### 4.5.3 CO - PO Mapping:

| **Relationship of Course Outcomes to Program Outcomes** | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **CO ↓** | **PO** | | | | | | | | | | | |
| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
| CO1 | H | M | L | L | M | L | L | L | L | L | L | M |
| CO2 | H | H | H | M | M | L | L | L | L | L | L | M |
| CO3 | H | H | H | M | H | L | L | L | L | L | L | M |
| CO4 | M | H | H | M | H | L | L | L | M | M | M | H |
| CO5 | H | M | M | M | H | L | L | L | M | M | M | H |
| **H = High correlation; M = Medium correlation; L = Low correlation** | | | | | | | | | | | | |

### 4.5.4 Syllabus:

**Module 1:** Organization of microcomputer: Von Neumann and Harvard architecture, Instruction set architectures, data transfer operations and their hardware implementation, addressing schemes, instruction set design, general purpose register organization, basic operational concepts of CPU and GPU, multiprocessors, multicore processors, fixed point and floating point arithmetic, overview on assembly language.

**Module 2:** Arithmetical algorithms, pipelining, 80x86 Architecture, programming models, segmentation, addressing modes of 80x86, instructions sets of 80x86, I/O addressing in 80x86, programming with 80x86, interfacing with 80x86: interfacing with RAMs, ROMs, peripheral ICs and key-boards, use of 80x86 in electrical engineering.

**Module 3:** Intel 8051 Microcontroller-Architecture, Assembly language of 8051, programmable keyboard/display interface, interface programmable peripheral interface, programmable communication interface, serial and parallel bus (RS232,IEEE488), use of 8051 in electrical engineering, overview of architecture of 8096 16-bit microcontroller.

**Module 4:** Introduction to High end Processors: ARMx processors, ARMx Architecture, registers and internal modules, JTAG, GPIO, ADC in ARMx processors, overview on Raspberry Pi/PIC microcontroller.

### 4.5.5 Learning Resources:

#### 4.5.5.1 Text Books:

1. M. Morris Mano, "Computer System Architecture", Pearson Education
2. Sivarama P. Dandamudi, "Introduction to Assembly Language Programming: From 8086 to Pentium Processors", Springer.
3. Muhammad Ali Mazidi, Janice G. Mazidi, Rolin D Mckinlay," 8051 Microcontroller and Embedded systems", Pearson Education
4. Krishna Kant, "Microprocessors and Microcontrollers, Architecture, Programming, and System Design-8085,8086,8051,8096" Publication,

#### 4.5.5.2 Reference Books:

1. Barry B. Brey, "The Intel Microprocessors: Architecture, Programming and Interface", PHI
2. Felipe. Neves," Hands-On Embedded System Design: Leverage The Power Of Arm Processors, FPGAs, ASIP And ASICS For Building Effective Embedded System Design, PACKT Publishing Limited

## 4.6 Electrical Machine-II Laboratory

| Course Code | Courses Name | Course Type | L - T - P | Credits | Total Hours |
|---|---|---|---|---|---|
| EE304 | Electrical Machine-II Laboratory | Practical | 0 - 0 - 3 | 2 | 42 |

### 4.6.1 Objectives:

The objectives of studying this course are to,

1. Provide hands-on experience with synchronous machines, $1-\phi$ AC machines, and special electrical machines.
2. Understand the performance characteristics, operational behavior, and control strategies of various machines.
3. Reinforce theoretical knowledge through practical experimentation.
4. Familiarize students with real-world applications and modern machine technologies.

### 4.6.2 Syllabus:

1. Determine synchronous impedance and voltage regulation using the EMF method.
2. Determination of Voltage regulation of Alternator by ZPF method.
3. Operating Characteristics of Alternator.
4. Determination of V-Curve and Inverted V-Curve of Synchronous Motor.
5. Determination of $X_d$ and $X_q$ of salient pole synchronous machine.
6. Performance analysis of Permanent Magnet Synchronous Motor.
7. Performance analysis of BLDC Motor.
8. Performance characteristics of Single-Phase Induction Motor.
9. Study the torque characteristics and commutation principles of SRM.
10. Analysis of speed-torque characteristics and performance of Universal Motor under AC and DC supplies.

## 4.7 Microprocessor Lab

| Course Code | Courses Name | Course Type | L - T - P | Credits | Total Hours |
|---|---|---|---|---|---|
| EE305 | Microprocessor Lab | Practical | 0 - 0 - 3 | 2 | 42 |

### 4.7.1 Objectives:

The objectives of studying this course are to,

1. Understand and differentiate between various types of microprocessors and microcontrollers.
2. Gain practical knowledge of microprocessor and microcontroller architectures and operations.
3. Develop programming skills for different microprocessor/microcontroller platforms.
4. Explore interfacing techniques for connecting peripherals to microprocessors and microcontrollers.
5. Design, implement, and test microprocessor/microcontroller-based systems for real-world applications.

### 4.7.2 Syllabus:

1. Arithmetic operations using 80x86.
2. Waveform generations using 80x86.
3. Interfacing using 80x86.
4. Arithmetic operations and waveform generation using 8051.
5. Interfacing of Stepper motor/DC motor control using 8051.
6. Programming timers, serial communications, interrupts using 8051.
7. Interfacing using ARMx.
8. Basic Verilog programming for implementation of digital logics.
9. Mini Projects.

# 4.8 Tinkering Lab - II

| Course Code | Courses Name | Course Type | L - T - P | Credits | Total Hours |
|---|---|---|---|---|---|
| EE306 | Tinkering Lab - II | Practical | 0 - 0 - 3 | 1 | 42 |

## 4.8.1 Objectives:

The objectives of studying this course are to,

1. Enable students to integrate concepts from various subjects—machines, power systems, control strategies, and more—into a unified, practical solution.
2. Guide students in designing and analyzing electrical systems, considering performance metrics, efficiency, and reliability.
3. Encourage students to tackle real-world engineering problems, fostering creativity and innovation in developing solutions.
4. Equip students with the skills to incorporate emerging technologies, tools, and control techniques into their projects.
5. Promote collaboration, time management, and effective communication to successfully complete a project from concept to implementation.

## 4.8.2 Syllabus:

The entire class will be divided into a few groups. Based on the knowledge gained so far, each group is required to conceptualize, design, and complete a project, applying their understanding of the subjects they have learned, along with performance analysis and control strategies, to address a practical problem or develop an innovative solution.

# Module 5

# Sixth Semester Courses:

## 5.1 Electrical System Design

| Course Code | Courses Name | Course Type | L - T - P | Credits | Total Hours |
|---|---|---|---|---|---|
| EE350 | Electrical System Design | Theory | 3 - 0 - 0 | 3 | 42 |

### 5.1.1 Objectives:

The objectives of studying this course are,

1. To provide a structured approach to electrical system design, covering key aspects from specifications to performance evaluation.
2. To develop proficiency in selecting components, designing circuits, and implementing protection mechanisms.
3. To enhance understanding of control strategies for efficient and reliable system operation.
4. To ensure compliance with industry standards, safety regulations, and best practices.
5. To integrate modern technological advancements for optimized system performance and sustainability.

### 5.1.2 Syllabus:

Consider an electrical system and design it using a structured, step-by-step methodology. This process should encompass essential aspects, including defining system specifications, selecting appropriate components, designing circuits, implementing protection mechanisms, developing control strategies, and evaluating performance. The focus is on adhering to industry standards, optimizing efficiency, ensuring safety, and incorporating modern technological advancements for improved system reliability and effectiveness.

### 5.1.3 Learning Resources:

#### 5.1.3.1 Text Books:

1. The books suggested by the course instructor.

#### 5.1.3.2 Reference Books:

1. The books suggested by the course instructor.

## 5.2 Electrical Drives

| Course Code | Courses Name | Course Type | L - T - P | Credits | Total Hours |
|---|---|---|---|---|---|
| EE351 | Electrical Drives | Theory | 3 - 0 - 0 | 3 | 42 |

### 5.2.1 Objectives:

The objectives of studying this course are to,

1. Understand the fundamental principles and dynamics of electric drives.
2. Analyze various types of DC and AC motor drives and their control techniques.
3. Develop knowledge of converter-fed motor drives and closed-loop control systems.
4. Explore modern control strategies including vector control and direct torque control.
5. Introduce special drives and emerging applications in industrial and renewable energy systems.

### 5.2.2 Course Outcome:

At the completion of this course, the student shall acquire knowledge and ability to,

1. CO1: Explain the fundamental concepts, components, and dynamics of electric drives under various operating conditions.
2. CO2: Analyze and implement control strategies for chopper-fed and closed-loop DC drives.
3. CO3: Evaluate different AC drive techniques including V/f, vector control, and DTC for various motor types.
4. CO4: Illustrate the operation and control of special drives including SRM, stepper motors, and linear drives.
5. CO5: Assess modern trends in electric drives applications in Industry 4.0, electric vehicles, and renewable energy systems.

### 5.2.3 CO - PO Mapping:

| **Relationship of Course Outcomes to Program Outcomes** | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **CO ↓** | **PO** | | | | | | | | | | | |
| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
| CO1 | H | M | L | L | M | L | L | L | L | L | L | M |
| CO2 | H | H | M | M | H | L | L | L | L | M | L | M |
| CO3 | H | H | H | M | H | L | L | L | L | M | L | M |
| CO4 | H | M | M | M | M | L | L | L | M | M | L | M |
| CO5 | M | M | M | M | M | M | H | M | M | M | M | H |
| **H = High correlation; M = Medium correlation; L = Low correlation** | | | | | | | | | | | | |

### 5.2.4 Syllabus:

**Module 1:** **Fundamentals of Electric Drives:** Definition of electric drive, Components, Advantages, type of drives; Speed-torque characteristic of driven unit/loads and motors; Classification and components of load torque; Dynamics of Electric Drives: Steady-state and Transient Conditions, Estimation of Drive Motor Rating.
Review of power converters used in drives, multi-quadrant operation of electric drive, Dynamics of Electric Drives: Steady-state and Transient Conditions.

**Module 2:** **DC Drives:** Review of DC Motors and Their Characteristics, Chopper fed DC Drives: Principle of operation and control techniques, Closed Loop Control of DC Drives.

**Module 3:** **AC Drives:** Induction Motor Characteristics and Speed Control Methods, Stator Voltage Control and Variable Frequency Control (V/f Control), constant flux operation and controlled current operation. Current source inverter fed drives, Introduction to direct torque control and Vector control of induction machines, Synchronous Motor Basics and Control Strategies, Permanent Magnet Synchronous Motor (PMSM) Drives, BLDC Motor Drives, Control Techniques for PMSM and BLDC Drives.

**Module 4:** **Special Drives:** Switched Reluctance Motor (SRM) Drives, Linear Electric Drives and Stepper Motors, Industrial Applications of Electric Motor Drives, Industry 4.0 and Smart Electric Drives, Future Trends in Electrification of Transportation, integration of Electric Drives with Renewable Energy Systems.

### 5.2.5 Learning Resources:

#### 5.2.5.1 Text Books:

1. Dubey G. K., “Fundamentals of Electric Drives,” Narosa Publishing House, 2007 ($2^{nd}$ Ed.).
2. Bose B. K., “Power Electronics and Variable Frequency Drives”, IEEE Press, 2001. ($1^{st}$ Ed.).
3. R. Krishnan, “Electric Motor Drives: Modeling, Analysis, and Control”, Pearson Education, 2001, ($1^{st}$ Ed.).
4. I. Boldear and S. A. Nasar, “Electric Drives,” CRC Press, Boca Raton, FL, 1999

#### 5.2.5.2 Reference Books:

1. Mikhail Chilikin, “Electric Drive”, Mir Publishers, 1976, ($1^{st}$ Ed.).

## 5.3 Power Systems-II

| Course Code | Courses Name | Course Type | L - T - P | Credits | Total Hours |
|---|---|---|---|---|---|
| EE352 | Power Systems-II | Theory | 3 - 1 - 0 | 4 | 56 |

### 5.3.1 Objectives:

The objectives of studying this course are to,

1. Provide a rigorous understanding of power system modeling, load flow analysis, fault analysis, and stability assessment.
2. Equip students with analytical and computational techniques for power system operation, fault detection, and stability enhancement.
3. Introduce modern simulation and numerical methods for power system analysis and protection.

### 5.3.2 Course Outcome:

At the completion of this course, the student shall acquire knowledge and ability to,

1. CO1 : Model and analyse power system components using per-unit representation, impedance, and admittance matrices.
2. CO2 : Perform load flow analysis using numerical methods and compare their efficiency.
3. CO3 : Conduct symmetrical and unsymmetrical fault analysis, determining system response and protection needs.
4. CO4 : Develop sequence networks and apply digital methods for fault detection and system protection.
5. CO5 : Assess power system stability using swing equations, equal area criteria, and numerical techniques.

### 5.3.3 CO - PO Mapping:

| **Relationship of Course Outcomes to Program Outcomes** | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **CO ↓** | **PO** | | | | | | | | | | | |
| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
| CO1 | H | H | H | H | L | L | M | L | L | L | L | M |
| CO2 | H | H | H | H | M | L | M | L | L | L | M | M |
| CO3 | H | H | H | H | L | L | M | L | L | L | M | M |
| CO4 | H | H | H | H | L | L | M | L | L | L | M | M |
| CO5 | H | H | H | H | M | H | M | L | L | L | M | M |
| **H = High correlation; M = Medium correlation; L = Low correlation** | | | | | | | | | | | | |

### 5.3.4 Syllabus:

**Module 1:** **Power System Component Modelling:** Representation of power system components. Single-phase equivalent and per-unit system representation. Single-line diagrams, impedance and reactance diagrams. Steady-state modelling of synchronous machines, power transformers, and loads. Formulation of bus admittance and impedance matrices.

**Module 2:** **Load Flow Analysis:** Network model formulation for power flow analysis. Load flow problem formulation. Solution techniques: Gauss-Seidel, Newton-Raphson, and Fast Decoupled methods. Performance comparison of different load flow methods. Computational efficiency and convergence considerations.

**Module 3:** **Symmetrical Fault Analysis:** Transients in transmission lines. Short circuit analysis of synchronous machines. Fault analysis using impedance matrices. Circuit breaker ratings and selection criteria. Current limiting reactors and fault current mitigation.

**Module 4:** **Unsymmetrical Fault Analysis:** Symmetrical components and sequence networks. Sequence impedances of synchronous machines, transmission lines, and transformers. Analysis of LG, LL, LLG, and open circuit faults using sequence components. Digital computational techniques for fault analysis.

**Module 5:** **Power System Stability Analysis:** Dynamics of synchronous machines and power angle equations. Swing equation and equal area criterion. Steady-state and transient stability assessment. Multi-machine stability analysis. Numerical solutions for transient stability improvement.

### 5.3.5 Learning Resources:

#### 5.3.5.1 Text Books:

1. W. D. Stevenson Jr. “Elements of Power System Analysis”, McGraw, Hill, 1968.
2. C. L. Wadhwa, “Electrical Power Systems,” New Age Int. Publishers, 2022 ($X^{th}$ Ed.)
3. I J Nagrath and D P Kothari, ”Modern Power System Analysis,” Tata Mcgraw-Hill, 2011 ($4^{th}$ Ed.)
4. Prabha Kundur, “Power System Stability and Control”, McGraw Hill

#### 5.3.5.2 Reference Books:

1. J. D. Glover, M. S. Sarma, T. Overbye, “Power System Analysis and Design”, Cengage Learning
2. C. L. Wadhwa, “Electrical Power Systems,” New Age Int. Publishers, 2022 ($X^{th}$ Ed.)
3. P. M. Anderson, “Faulted Power System Analysis”, IEEE Press
4. A. R. Bergen & V. Vittal, “Power System Analysis”, Pearson

## 5.4 Power Electronics and Drive Lab

| Course Code | Courses Name | Course Type | L - T - P | Credits | Total Hours |
|---|---|---|---|---|---|
| EE353 | Power Electronics and Drive Lab | Practical | 0 - 0 - 3 | 2 | 42 |

### 5.4.1 Objectives:

The objectives of studying this course are to,

1. Provide hands-on experience with power semiconductor devices and converters.
2. Demonstrate the working principles of rectifiers, choppers, inverters, and AC voltage controllers.
3. Implement control strategies for DC and AC motor drives.
4. Develop practical skills in analyzing power electronic circuits and drive performance.
5. Understand modern techniques used in industrial motor control systems.

### 5.4.2 Syllabus:

1. Characteristics of Semiconductor Devices such as, BJT, IGBT, MOSFET, etc.
2. Performance analysis of uncontrolled rectifiers - single phase and three-phase rectifier
3. Performance analysis of SCR rectifiers - single phase and three-phase rectifier.
4. Simulation and hardware implementation of DC-DC converters with duty cycle control.
5. Performance analysis of 1-$\phi$ & $3-\phi$ inverter output voltage with square wave, quasi-square wave, and PWM control.
6. Closed-loop speed control of DC motor using chopper circuits.
7. V/f control of three-phase induction motor using a PWM inverter.
8. Implementation of slip control and rotor resistance control of induction motor.
9. BLDC/PMSM/SRM motor control.

## 5.5 Power System Lab

| Course Code | Courses Name | Course Type | L - T - P | Credits | Total Hours |
|---|---|---|---|---|---|
| EE354 | Power System Lab | Practical | 0 - 0 - 3 | 2 | 42 |

### 5.5.1 Objectives:

The objectives of studying this course are to,

1. Understand the role of power systems in ensuring efficient and reliable power transfer from generation to load.
2. Simulate transmission lines to analyze performance under different operating conditions.
3. Measure sequence impedance and current parameters to evaluate system behavior during balanced and unbalanced faults.
4. Understand protection systems and their role in safeguarding power networks against faults and disturbances.
5. Perform high voltage testing to study insulation performance and breakdown characteristics.
6. Develop coding skills and learn to use appropriate software tools for conducting power system analysis and simulations.

### 5.5.2 Syllabus:

**Module - 1: Hardware Experiments (any Six)**

1. Transmission Line studies using simulator: a. ABCD Paraments b. Ferranti Effect, c. Voltage regulation, d. Compensation methods
2. Measurement of sequence impedances and currents.
3. Numerical relay characteristics - Over current relay, IDMT, Over Voltage/Under Voltage, etc
4. Testing of Current Transformer and Potential Transformer.
5. Study of circuit breakers.
6. Study of any two protection schemes:a. Earth fault protection of a generator, b. Transformer differential protection , c. Working of Buchholz relay, d. Over Current protection of Transmission Line, e. Over Voltage /Under Voltage protection of Transmission Line
7. Study of Digital Energy Meter.
8. Study of Solar Photo Voltaic (SPV) systems.
9. High Voltage testing: a. Impulse and Flashover testing, b. Partial Discharge, c. Earth Resistance Tester, d. Transformer oil testing, e. String Insulators

**Module - 2: Software simulations**

10. Formation of Y$BUS$ and Z$_{BUS}$.
11. Load Flow Analysis using Gauss Seidal (GS) Method.
12. Load Flow Analysis using Newton-Raphson (NR) Method.
13. Load Flow Analysis using Fast Decoupled (FD) Method.
14. To obtain Swing Curve and to determine Critical Clearing Time, angle, Regulation, Inertia Constant, etc

# 5.6 Electrical & Electronic Design Lab

| Course Code | Courses Name | Course Type | L - T - P | Credits | Total Hours |
|---|---|---|---|---|---|
| EE355 | Electrical & Electronic Design Lab | Practical | 0 - 0 - 3 | 2 | 42 |

## 5.6.1 Objectives:

The objectives of studying this course are to,

1. Apply the theoretical knowledge gained from the Electrical System Design course to create practical, functioning electrical systems.
2. Develop the ability to define system requirements and select appropriate components based on performance, cost, and safety considerations.
3. Design and construct electrical circuits, ensuring they meet industry standards for reliability, efficiency, and performance.
4. Analyze system performance using relevant metrics and refine designs to improve efficiency, stability, and overall functionality.
5. Work collaboratively in teams to manage design projects from concept to completion, fostering communication, planning, and problem-solving skills.

## 5.6.2 Syllabus:

Based on the concepts and methodologies learned in the **"Electrical System Design"** course, students are required to apply their knowledge to complete a comprehensive design project. This project will involve integrating key aspects such as system specifications, component selection, circuit design, protection mechanisms, control strategies, and performance evaluation, demonstrating their ability to design a functional and efficient electrical system.

# Module 6

# Seventh Semester Courses:

## 6.1 Industrial Economics

| Course Code | Courses Name | Course Type | L - T - P | Credits | Total Hours |
|---|---|---|---|---|---|
| HS350 | Industrial Economics | Theory | 3 - 0 - 0 | 3 | 42 |

### 6.1.1 Objectives:

The objectives of studying this course are to,

1. Identify and analyse the behaviour of a firm under different market situations systematically.
2. Understand and assimilate the issues related to strategic behaviour in firms, R & D and innovation.
3. Have a comprehensive coverage of firms & profitability and efficiency measurements, with applications to India's industrial structure.
4. To understand the rich complexities and paradox of fourth industrial revolution.

### 6.1.2 Course Outcome:

At the completion of this course, the student shall acquire knowledge of,

1. CO1: Market structure, conduct and performance
2. CO2: Strategic behaviour in firms
3. CO3: Innovation, R & D and the market
4. CO4: Industrial efficiency and its applications for the Indian economy.

### 6.1.3 CO - PO Mapping:

| **Relationship of Course Outcomes to Program Outcomes** | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **CO ↓** | **PO** | | | | | | | | | | | |
| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
| CO1 | H | H | M | M | M | M | M | M | M | M | L | M |
| CO2 | M | H | H | M | M | H | M | M | H | M | M | M |
| CO3 | M | M | H | H | H | M | M | M | H | M | M | M |
| CO4 | H | M | M | M | L | L | H | H | M | M | M | H |
| **H = High correlation; M = Medium correlation; L = Low correlation** | | | | | | | | | | | | |

### 6.1.4 Syllabus:

**Module 1:** Introduction to Economics - introduction to Industrial economics - nature and scope - concept of firm and industry- types of firms - structure, conduct and performance.

**Module 2:** Standard forms of market structure - pricing strategies and output determination of firms - profit maximization, sales maximization (William J. Baumol), utility maximization (Oliver E. Williamson), growth maximization (George K. Yarrow) - equilibrium of firms under perfect competition, monopoly, monopolistic competition and oligopoly – optimum, price and output - economies of scale.

**Module 3:** Price and non-price competition - strategic behaviour of firms - collusion and mergers - game theory - market failures and information asymmetry - advertising and product differentiation - market entry and exit - concentration and diversification.

**Module 4:** Patents and technological change- the economics of patent-innovation and diffusion measures of concentration.

**Module 5:** Research and Development (R & D) and market structure – product and process innovation- R & D and patent race-licensing and incentive to innovate.

**Module 6:** Economics of the fourth Industrial Revolution – Industrial revolution past, present and Future, Internet Artificial Intelligence- Blockchain technologies

### 6.1.5 Learning Resources:

#### 6.1.5.1 Text Books:

1. Donald A. Hay, Derek J. Morris, Industrial Economics: Theory and Evidence, Oxford University Press, 1979
2. Carton, D. and J. Perloff. Modern Industrial Organization (Reading, Massachusetts: AddisonWesley), 1999.
3. Lall, Sanjaya. Competitiveness, Technology and Skills (Cheltenham: Edward Elgar), 2001.
4. Shy, O. (1996). Industrial organization: Theory and applications. MIT Press.

#### 6.1.5.2 Reference Books:

1. A. Singh and A.N. Sandhu, Industrial Economics, Himalaya Publishing House, Bombay, 1988.
2. Ferguson, Paul R. and Glenys J. Ferguson, (1994), Industrial Economics - Issues and Perspectives, Macmillan, London.
3. Stephen Martin, Advanced Industrial Economics, Oxford, UK Blackwell Publisher, 2002.
4. R. R. Barthwal, Industrial Economics: An Introductory Textbook, New Age International Publishers, 2007.
5. Hay, Donald A. and Derek J. Morris. Industrial Economics and Organization: Theory and Evidence, 2nd Edition (Oxford: Oxford University Press), 1991.
6. Schmalensee, R., Inter-industry studies of Structure and Performance, in Schmalensee, R. and R. D.Willig (eds.): Handbook of Industrial Organization [Amsterdam: North-Holland] Vols. 2 Chapter 16, pp. 951-1009, 1989.
7. Siddharthan, N. S. and Y.S. Rajan. Global Business, Technology and Knowledge Sharing: Lessons for Developing Country Enterprises (New Delhi: Macmillan), 2002.
8. Tirole, Jean. The Theory of Industrial Organization (Cambridge, MA: The MIT Press), 1988.

# Part II

# Course Content : Elective Courses

# Module 7

# Elective Courses:

## 7.1 Selected Topics in Electrical Engineering

| Course Code | Courses Name | Course Type | L - T - P | Credits | Total Hours |
|---|---|---|---|---|---|
| EE500 | Selected Topics in Electrical Engineering | Theory | 3 - 0 - 0 | 3 | 42 |

### 7.1.1 Syllabus:

The syllabus will be designed based on current research trends and specific academic or industry requirements.

### 7.1.2 Learning Resources:

#### 7.1.2.1 Text Books:

1. The books suggested by the course instructor.

#### 7.1.2.2 Reference Books:

1. The books suggested by the course instructor.

## 7.2 Electrical Safety: Standards and Protocols

| Course Code | Courses Name | Course Type | L - T - P | Credits | Total Hours |
|---|---|---|---|---|---|
| EE501 | Electrical Safety: Standards and Protocols | Theory | 3 - 0 - 0 | 3 | 42 |

### 7.2.1 Objectives:

The objectives of studying this course are to,

1. Provide a comprehensive understanding of electrical hazards, safety protocols, and compliance with international and national standards.
2. Emphasize risk assessment, protective equipment, and safe operation and maintenance of electrical systems.
3. Explore advanced safety strategies using AI, IoT, and automation for enhanced safety in industries, smart grids, and renewable energy systems.

### 7.2.2 Course Outcome:

At the completion of this course, the student shall acquire knowledge and ability

1. CO1 : Identify electrical hazards and implement safety measures in power systems.
2. CO2 : Apply safe operation and maintenance practices for electrical equipment.
3. CO3 : Understand and comply with national and international electrical safety standards.
4. CO4 : Assess and mitigate electrical risks in power grids, industries, and smart grids.
5. CO5 : Implement AI-based predictive safety monitoring and risk mitigation strategies.

### 7.2.3 CO - PO Mapping:

| **Relationship of Course Outcomes to Program Outcomes** | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **CO ↓** | **PO** | | | | | | | | | | | |
| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
| CO1 | H | H | M | M | L | H | M | L | L | L | L | M |
| CO2 | H | H | H | H | H | L | H | L | L | L | M | H |
| CO3 | H | H | H | H | M | L | M | L | L | L | M | M |
| CO4 | H | H | H | H | M | L | H | L | L | L | M | H |
| CO5 | H | H | H | H | H | H | H | L | L | L | M | H |
| **H = High correlation; M = Medium correlation; L = Low correlation** | | | | | | | | | | | | |

### 7.2.4 Syllabus:

**Module 1:** **Fundamentals of Electrical Safety:** Electrical Hazards: Shock, Arc Flash, Arc Blast, Fire, and Explosions. Effects of Electric Shock on Humans (Physiological impact). Safety in Electrical Installations: Earthing, Insulation, Isolation Techniques. Personal Protective Equipment (PPE) for Electrical Safety. Arc Flash Incident Analysis in Industrial Plants. Hazard Identification & Risk Assessment in Power Plants.

**Module 2:** **Safe Operation & Maintenance of Electrical Systems:** Safe Operating Procedures for Switchgear, Transformers & Generators. Lockout/Tagout (LOTO) Procedures for Maintenance Safety. Fire & Explosion Prevention in Electrical Installations. Safe Work Practices in Low & High Voltage Installations. Emergency Response Planning in Power Plants & Industries.

**Module 3:** **Electrical Safety Standards & Compliance:** Indian & International Electrical Safety Standards: Indian Standards (IS 732, IS 3043, IS 5216), IEC 60364, IEEE 1584 (Arc Flash Standards), OSHA, NFPA 70E. Electrical Safety in Industrial and Commercial Buildings. Regulations for Renewable Energy Systems. Regulatory Failures Leading to Electrical Accidents. Safety Audits & Electrical Inspection in Compliance with IS/IEC Standards.

**Module 4:** **Electrical Safety in Power Systems & Smart Grids:** Protection Against Overvoltage, Short Circuits & Lightning Surges. Fault Protection Systems: Relays, Circuit Breakers, Ground Fault Detection. Safety Considerations in Smart Grids & Distributed Generation. AI & IoT for Predictive Safety Monitoring in Power Systems. Smart Grid Cybersecurity & Electrical Safety Challenges. Design of Safe and Resilient Power Grids.

**Module 5:** **Emergency Preparedness, Risk Mitigation & Future Trends:** Electrical Safety in Disaster Management (Fire, Flood, Earthquake Scenarios). Risk Assessment & Root Cause Analysis of Electrical Failures. Safety Considerations in Electric Vehicles & Battery Storage Systems. Future Trends in Electrical Safety: AI, Automation, and Digital Twin-Based Safety Systems. Electrical Fire & Protection Strategies in Industrial Plants. Developing a Risk Mitigation Plan for an Electrical Installation.

### 7.2.5 Learning Resources:

#### 7.2.5.1 Text Books:

1. John Cadick, Mary Capelli-Schellpfeffer, Dennis Neitzel & Al Winfield, "Electrical Safety Handbook," McGraw Hill, 2012 ($4^{th}$ Ed.)
2. Ray A. Jones & Jane G. Jones, "NFPA 70E Handbook for Electrical Safety," NFPA, 2021
3. Maxwell Adams, "Electrical Safety: A Guide to the Causes and Prevention of Electrical Hazards," Butterworth-Heinemann, 2020

#### 7.2.5.2 Reference Books:

1. NFPA 70E Standard for Electrical Safety in the Workplace, National Fire Protection Association.
2. IEEE 1584 Guide for Performing Arc Flash Hazard Calculations, IEEE Standards Association.
3. Indian Standards (IS 732, IS 3043, IS 5216) and IEC 60364 for Electrical Safety Compliance.
4. IEEE Transactions on Electrical Safety & Compliance.

## 7.3 Electricity Markets

| Course Code | Courses Name | Course Type | L - T - P | Credits | Total Hours |
|---|---|---|---|---|---|
| EE502 | Electricity Markets | Theory | 3 - 0 - 0 | 3 | 42 |

### 7.3.1 Objectives:

The objectives of studying this course are to,

1. Understand the structure and operation of electricity market systems.
2. Examine key issues in electricity markets and explore how they are addressed globally.
3. Analyze market dynamics, pricing mechanisms, and power trading strategies.
4. Study various electricity market operational and control challenges.
5. Apply advanced mathematical models to solve market-related problems.
6. Explore emerging trends and innovations in modern electricity markets.

### 7.3.2 Course Outcome:

At the completion of this course, the student shall acquire knowledge and ability to,

1. CO1 : Grasp the basic principles of Electricity Market operation and effectively apply them to solve engineering problems.
2. CO2 : Analyse the significance of Electricity Markets and its wide-range of possibilities.
3. CO3 : Comprehend the fundamental concepts of electricity markets' evolution, generation, economics, open access, ancillary services, market operation and their practical applications.
4. CO4 : Evaluate various aspects of Electricity Markets.

### 7.3.3 CO - PO Mapping:

| **Relationship of Course Outcomes to Program Outcomes** | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **CO ↓** | **PO** | | | | | | | | | | | |
| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
| CO1 | H | H | H | M | M | M | H | H | H | M | M | H |
| CO2 | H | H | H | M | M | M | H | H | H | M | M | H |
| CO3 | H | H | H | M | M | M | H | H | H | M | M | H |
| CO4 | H | H | H | M | M | M | H | H | H | M | M | H |
| **H = High correlation; M = Medium correlation; L = Low correlation** | | | | | | | | | | | | |

### 7.3.4 Syllabus:

**Module 1:** **Introduction:** Vertically integrated Utility, Electricity Act-2003, key issues in centralized and decentralized power markets with suitable solutions. Independent Power Producer, Captive Power Producer, Independent/ Transmission System Operator: Functions and responsibilities, Indian and International Electricity market models of ex: California market, New England ISO, Midwest ISO, Nordic pool, China, etc.

**Module 2:** **Generation Economics and Market Reforms:** Economics of Power Generation, Economic Dispatch of Power Plants, electricity pricing and forecasting, price-based unit commitment design, Load frequency control and Automatic Generation Control. Smart Grid markets: Pool, bilateral & multilateral

**Module 3:** **Transmission Open access:** Open access, Open Access Transmission Systems, Transmission pricing in open access system, Available Transfer Capability (ATC) calculation, congestion management, Congestion pricing, Locational marginal pricing, FACTS in congestion management, coordination strategies, power wheeling transmission..

**Module 4:** **Market operation and Ancillary Services:** Indian power markets, Power trading, Day-ahead and Real-time Energy Markets, Capacity and Ancillary Services Markets, Spot Markets, Financial Transmission Rights and Hedging, Renewable Energy Management System, renewable energy markets, policies and regulations followed worldwide.
Reactive power as an ancillary service, Energy Storage System, Reliability analysis, Demand response, Potential benefits of demand response in smart grid, enabling smart technologies for demand response, Demand response for Electric Vehicles.

**Module 5:** **Indian Context:** Challenges and synergies for Indian markets, Indian Case studies, latest advancements.

### 7.3.5 Learning Resources:

#### 7.3.5.1 Text Books:

1. Loi Lei Lai, "Power System Restructuring and Deregulation", John Wiley & son LTD, New York, 2001.
2. D. Kirschen, G. Strbac, Fundamentals of Power System Economics, John Wiley & Sons, Ltd., , March 2010. ISBN: 978-0-470-84572-1

#### 7.3.5.2 Reference Books:

1. Mohammad Shahidehpour, HatimYamin, "Market operations in Electric power systems", John Wiley & son LTD, Publication, 2002.
2. Lorrin Philipson, H. Lee Willis, "Understanding Electric Utilities and Deregulation" Taylor & Francis, New York 2006.
3. Mohammad Shahidehpour, Muwaffaq Alomoush, "Restructured Electrical Power Systems", Marcel Dekker, INC., New York, 2001.
4. Relevant research articles.

## 7.4 Energy Auditing

| Course Code | Courses Name | Course Type | L - T - P | Credits | Total Hours |
|---|---|---|---|---|---|
| EE503 | Energy Auditing | Theory | 3 - 0 - 0 | 3 | 42 |

### 7.4.1 Objectives:

The objectives of studying this course are to,

1. Understand the fundamental principles of energy management and conservation.
2. Learn energy auditing techniques for assessing energy consumption in various systems.
3. Explore energy efficiency measures across industrial, commercial, and residential sectors.
4. Familiarize with tools and software for energy analysis and performance evaluation.
5. Develop strategies to optimize energy usage and reduce operational costs.
6. Understand the role of renewable energy and emerging technologies in energy management.

### 7.4.2 Course Outcome:

At the completion of this course, the student shall acquire knowledge and ability

1. CO1 : Grasp the basic principles of Energy Auditing and effectively apply them to solve engineering problems.
2. CO2 : Analyse the significance of Energy Auditing and its wide-range of possibilities/applications.
3. CO3 : Comprehend the fundamental concepts of energy auditing, management, economics, energy efficiency, sustainability, various case studies and their practical applications.
4. CO4 : Evaluate the techniques involved in energy auditing.

### 7.4.3 CO - PO Mapping:

| **Relationship of Course Outcomes to Program Outcomes** | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **CO ↓** | **PO** | | | | | | | | | | | |
| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
| CO1 | H | H | H | M | M | M | H | H | H | M | M | H |
| CO2 | H | H | H | M | M | M | H | H | H | M | M | H |
| CO3 | H | H | H | M | M | M | H | H | H | M | M | H |
| CO4 | H | H | H | M | M | M | H | H | H | M | M | H |
| **H = High correlation; M = Medium correlation; L = Low correlation** | | | | | | | | | | | | |

### 7.4.4 Syllabus:

**Module 1:** **Introduction to Energy Auditing:** : Definition, Understanding the energy scenario in India, Need and Importance of Auditing, Preliminary & Detailed Audits, Audit Instruments and their Applications, Energy Conservation and Management Principles, Role of Auditors and Energy Managers.

**Module 2:** **Energy Management and Economics:** Energy Planning and Implementation Strategies, Costing and Financial Analysis (Payback Period, NPV, IRR), Monitoring, Benchmarking, Performance Indicators and Metrics, National and state-level energy policies, Role of Bureau of Energy Efficiency (BEE).

**Module 3:** **Energy Efficiency in Electrical Systems:** Basics of Electrical Energy and Load Management, Power Factor Correction and Demand side Management, Transformers and Electric Motors: Efficiency and Optimization, Lighting Systems: Types and Energy-Saving Strategies, Harmonics and Power Quality Issues.

**Module 4:** **Renewable Energy and Sustainability:** Integration of Renewable Energy in Industries, Energy Storage Technologies, Energy Efficiency Measures, Waste Heat Recovery Techniques, Refrigeration and Air Conditioning Systems, Insulation and Heat Loss Reduction, Carbon Footprint and Greenhouse Gas reduction strategies.

**Module 5:** **Energy Audit Methodology and Case Studies:** Step-by-Step Energy Audit Procedure, Data Collection and Analysis Techniques, Use of Energy Audit Software and Tools, Case Studies of Industrial and Commercial Energy Audits, Report Preparation and Recommendations. Latest advancements.

### 7.4.5 Learning Resources:

#### 7.4.5.1 Text Books:

1. Bureau of Energy Efficiency, Govt. of India, "Energy Manager and Energy Auditor Guide Books," Vol. 1 - 4
2. Indian Energy Policy & Regulations, Ministry of Power, Govt. of India, 2023
3. W.R. Murphy and G. McKay, "Energy Management"

#### 7.4.5.2 Reference Books:

1. Albert Thumann & William J. Younger, "Industrial Energy Management and Auditing"
2. Bureau of Energy Efficiency, "Energy Efficiency in Electrical Utilities"
3. S. C. Tripathy, "Energy Conservation and Management".
4. Case Studies on Energy Efficiency published by TERI, CII, and PCRA
5. Relevant research articles.

## 7.5 Utilization of Electrical Energy & Illumination

| Course Code | Courses Name | Course Type | L - T - P | Credits | Total Hours |
|---|---|---|---|---|---|
| EE504 | Utilization of Electrical Energy & Illumination | Theory | 3 - 0 - 0 | 3 | 42 |

### 7.5.1 Objectives:

The objectives of studying this course are to,

1. Understand the concept of Electrical Energy Utilization across various applications.
2. Explore the principles and methods of electrical heating systems.
3. Analyze refrigeration systems powered by electrical energy.
4. Study the working and types of electric welding processes.
5. Understand the design and functioning of electrical illumination systems.
6. Evaluate the efficiency and performance of these electrical energy applications.

### 7.5.2 Course Outcome:

At the completion of this course, the student shall acquire knowledge and ability

1. CO1 : Grasp the basic principles of Utilization of Electrical Energy & Illumination and effectively apply them to solve engineering problems.
2. CO2 : Analyse the significance of Utilization of Electrical Energy & Illumination and its wide-range of possibilities/applications.
3. CO3 : Comprehend the fundamental concepts of electric traction, refrigeration & air conditioning, electric heating, utilization in electric vehicles, illumination, various case studies and their practical applications.
4. CO4 : Evaluate various aspects of Utilization of Electrical Energy & Illumination.

### 7.5.3 CO - PO Mapping:

| **Relationship of Course Outcomes to Program Outcomes** | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **CO ↓** | **PO** | | | | | | | | | | | |
| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
| CO1 | H | H | H | M | M | M | H | H | H | M | M | H |
| CO2 | H | H | H | M | M | M | H | H | H | M | M | H |
| CO3 | H | H | H | M | M | M | H | H | H | M | M | H |
| CO4 | H | H | H | M | M | M | H | H | H | M | M | H |
| **H = High correlation; M = Medium correlation; L = Low correlation** | | | | | | | | | | | | |

### 7.5.4 Syllabus:

**Module 1:** **Electric traction:** Requirements of an ideal traction system, systems of traction, power supply, traction drives, electric braking, tractive effort calculations and speed-time characteristics. Locomotives and train, recent trends in electric traction.

**Module 2:** **Refrigeration and Air Conditioning:** Domestic refrigerator and water coolers, Heating Ventilation and Air Conditioning (HVAC), Various types of air conditioning systems and their applications, smart air conditioning, Energy Efficient motors, Direct Savings and payback analysis, efficiency evaluation factor.

**Module 3:** **Electric Heating and Welding:** Advantages, classification of heating equipment's, Types of heating and applications, methods of heat transfer - induction, eddy current, dielectric. Industrial furnaces. Electric welding and sources of welding, Electrolytic processes: Faraday's laws of electrolysis, resistance welding, arc welding, electrometallurgy and electroplating.

**Module 4:** **Utilization of Electrical Energy in Electric Vehicles:** Electric Vehicle Technology, Types of EV and its Components, Energy loss in various drive cycles. Charging technologies and infrastructure used in electric vehicles, Grid Integration issues.

**Module 5:** **Illumination:** Definition and Terminologies, Laws of illumination, Photometry, lighting calculations. Different types of electrical lamps - LEDs and Energy-efficient lamps. Design of Energy efficient lighting schemes for - Interior lighting, Sports lighting, factory lighting, flood and street lighting. Controllers and sensors used in smart lighting, Recent advancements, Indian Standards and Policies.

### 7.5.5 Learning Resources:

#### 7.5.5.1 Text Books:

1. Partab H, "Art and Science of Utilization of Electrical Energy," Dhanpat Rai & Sons, Delhi, 2017 ($3^{rd}$ Ed.)

2. E. O. Taylor, "Utilization of Electric Energy,"

3. C. L Wadhwa, "Generation, Distribution and Utilization of Electrical Energy," New Age International, 2020 ($3^{rd}$ Ed.)

#### 7.5.5.2 Reference Books:

1. Dr. Uppal S.L. and Prof. S. Rao, "Electrical Power Systems," Khanna Publishers, New Delhi.

2. Gupta, J.B., "Utilisation of Electrical Energy and Electric Traction," S. K. Kataria and Sons.

3. S. M. Chaudhari, "Illumination Engineering," Nirali Prakashan, 2021

4. Amir Khajepour, Saber Fallah and Avesta Goodarzi, "Electric and Hybrid Vehicles Technologies, Modeling and Control: A Mechatronic Approach," John Wiley & Sons Ltd.

5. "Energy Efficiency in Electrical Utilities," BEE Guidebook.

6. Relevant research articles.

## 7.6 Building Management Systems

| Course Code | Courses Name | Course Type | L - T - P | Credits | Total Hours |
|---|---|---|---|---|---|
| EE505 | Building Management Systems | Theory | 3 - 0 - 0 | 3 | 42 |

### 7.6.1 Objectives:

The objectives of studying this course are to,

1. Provide an overview of essential building services in multistoried structures.
2. Understand the working principles, operation, and maintenance of HVAC systems.
3. Explore the design and functioning of firefighting systems and safety protocols.
4. Study the operation and maintenance of elevators, escalators, and other vertical transportation systems.
5. Analyze various building services, including water supply, electrical systems, and waste management.
6. Develop an understanding of cost estimation and planning for building services.

### 7.6.2 Course Outcome:

At the completion of this course, the student shall acquire knowledge and ability

1. CO1 : Grasp the basic principles of Building Management Systems and effectively apply them to solve engineering problems.
2. CO2 : Analyse the significance of Building Management Systems and its wide-range of possibilities/applications.
3. CO3 : Comprehend the fundamental concepts of Building Management Systems, sensors, actuators, lighting design, Smart Buildings, communication, networking and their practical applications.
4. CO4 :Evaluate various aspects of Building Management Systems.

### 7.6.3 CO - PO Mapping:

| **Relationship of Course Outcomes to Program Outcomes** | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **CO ↓** | **PO** | | | | | | | | | | | |
| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
| CO1 | H | H | H | M | M | M | H | H | H | M | M | H |
| CO2 | H | H | H | M | M | M | H | H | H | M | M | H |
| CO3 | H | H | H | M | M | M | H | H | H | M | M | H |
| CO4 | H | H | H | M | M | M | H | H | H | M | M | H |
| **H = High correlation; M = Medium correlation; L = Low correlation** | | | | | | | | | | | | |

### 7.6.4 Syllabus:

**Module 1:** **Introduction:** Overview of Building Management Systems (BMS), importance in modern days, Components of a BMS: hardware, software, and networking, applications and benefits. AI and machine learning applications in BMS, Smart grids and renewable energy integration, Digital twins and predictive maintenance.

**Module 2:** **Sensors and actuators:** Sensors and Actuators - Types and functions, Controllers and programmable logic controllers (PLCs), Communication networks: BACnet, Modbus, LonWorks, KNX, others, Integration with other systems: HVAC, lighting, fire safety, and security. Heating, ventilation, and air conditioning (HVAC) systems. Energy efficiency strategies in HVAC management.

**Module 3:** **Lighting and Smart Buildings:** Types of lighting, Lux calculations, Illumination schemes, Energy Efficiency Schemes, National Electrical Code. Intelligent lighting strategies, Integration with IoT and smart building technologies, Energy-saving strategies, optimizing energy usage with BMS. Electrical system design, estimation and costing for various buildings– domestic, commercial complex, hospitals, schools, cinema theatres, small industries, etc..

**Module 4:** **Communication Protocols and Networking:** Communication protocols, Wired vs. wireless networking systems, Cloud-based remote monitoring, Cybersecurity considerations, Alarm management and fault detection, Security, Access Control, and Fire Safety. The role of BMS in sustainable and green buildings, Net-zero and energy-positive buildings, Certifications & Policies. Case studies and real-world applications. Industry Standards and Regulations, Future Trends in Building Automation. Review of recent technologies..

### 7.6.5 Learning Resources:

#### 7.6.5.1 Text Books:

1. K B Raina & S K Bhattacharya, "Electrical Design, Estimating and Costing," New Age International(p) Ltd., 2021 ($2^{nd}$ Ed.)

2. Surjit Singh, "Electrical Estimating and Costing," Dhanpat Rai & Co., Delhi, 2018 ($9^{th}$ Ed.)

3. IS:732 National Electrical Code, BIS, 2011 (Amendments 2021)

#### 7.6.5.2 Reference Books:

1. G. Ramamurthy, Hand book of Electrical Power Distribution, Universities Press (India) Private Ltd., NewDelhi.

2. N Alagappan, S Ekambaram, Electrical estimating and Costing, McGraw-Hill.

3. Narang K.L., A Text Book of Electrical Engineering Drawing, Tech India Publications.

4. Er. V. K. Jain, Er. Amitabh Bajaj, Design of Electrical Installations, University Science Press.

5. Code of practice for Electrical wiring installations, (System voltage not exceeding 650 volts), Indian Standard Institution, IS: 732-1983.

6. Guide for Electrical layout in residential buildings, Indian Standard Institution, IS: 4648-1968.

7. Relevant research articles.

## 7.7 Power System Protection

| Course Code | Courses Name | Course Type | L - T - P | Credits | Total Hours |
|---|---|---|---|---|---|
| EE510 | Power System Protection | Theory | 3 - 0 - 0 | 3 | 42 |

### 7.7.1 Objectives:

The objectives of studying this course are to,

1. Provide a comprehensive understanding of power system protection, including fault analysis, relay operation, and switchgear mechanisms.
2. Emphasize digital protection techniques, smart grid applications, and transient overvoltage protection.
3. Explore real-world case studies and modern industry practices to enhance practical learning and industry readiness.

### 7.7.2 Course Outcome:

At the completion of this course, the student shall acquire knowledge and ability

1. CO1 : Elucidate the principles of power system protection and evaluate different protection schemes for transmission and distribution networks.
2. CO2 : Analyse fault characteristics and apply modern numerical techniques for fault detection and classification.
3. CO3 : Design and implement protection strategies using conventional and digital relays, including adaptive and AI-based protection.
4. CO4 : Assess the impact of transient over voltages and insulation coordination in power system protection.
5. CO5 : Explore real-world applications and case studies of modern protection schemes, including WAMS, IEC 61850, and cybersecurity in power system protection.

### 7.7.3 CO - PO Mapping:

| **Relationship of Course Outcomes to Program Outcomes** | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **CO ↓** | **PO** | | | | | | | | | | | |
| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
| CO1 | H | H | M | M | L | H | M | L | L | L | L | M |
| CO2 | H | H | H | H | M | L | M | L | L | L | M | M |
| CO3 | H | H | H | H | L | H | H | H | H | L | M | H |
| CO4 | H | H | H | H | M | L | H | M | M | L | M | H |
| CO5 | H | H | H | H | M | H | H | H | H | L | M | H |
| **H = High correlation; M = Medium correlation; L = Low correlation** | | | | | | | | | | | | |

### 7.7.4 Syllabus:

**Module 1:** **Fundamentals of Power System Protection:** Need for power system protection, zones of protection, reliability, and selectivity. Fault types: Symmetrical and unsymmetrical faults, per-unit system, fault calculations. Case Study: Blackout Analysis (E.g., 2012 India Blackout, 2003 North American Blackout).

**Module 2:** **Protective Relaying and Transmission Line Protection:** Classification of relays: Electromagnetic, static, digital, and adaptive relays. Zones of protection and protection coordination. Current-based relaying (overcurrent and directional relays), Distance relaying (impedance, reactance, and mho relays), Pilot relaying schemes (carrier-aided protection), Auto-reclosing strategies in transmission line protection. Case Study on Distance Relay Maloperation and Grid Instability Events.

**Module 3:** **Protection of Power System Components & Industry Applications:** Generator Protection: Differential protection, reverse power, loss of excitation. Transformer Protection: Percentage differential protection, Buchholz relay, REF protection. Busbar Protection: High and low impedance differential protection schemes. Motor Protection: Thermal overload, short circuit, phase unbalance protection. Industry Applications: Protection in Large Power Plants, Industrial Grids, and Renewable Energy Systems.

**Module 4:** **Overvoltage Protection & Smart Grid-Based Protection:** Causes of overvoltage: Lightning, switching surges, insulation coordination. Surge protection devices, ground wires, and surge arresters. Adaptive protection in smart grids: PMUs, WAMS, and AI-based protection. IEC 61850-based substation automation and communication protocols. Application: Cybersecurity in Power System Protection & Recent Cyberattack Case Studies.

### 7.7.5 Learning Resources:

#### 7.7.5.1 Text Books:

1. P. M. Anderson, "Power System Protection," Wiley-IEEE Press, 2018 ($2^{nd}$ Ed.)

2. A.R. Warrington, "Protective Relays – Their Theory and Practice," Wiley, Reprint 2013

3. Sunil S. Rao, "Switchgear and Protection," Khanna Publishers, 2021 ($14^{th}$ Ed.)

4. Badri Ram & D.N. Vishwakarma, "Power System Protection and Switchgear," McGraw Hill.

5. J. Lewis Blackburn & Thomas J. Domin, "Protective Relaying: Principles and Applications," CRC Press.

#### 7.7.5.2 Reference Books:

1. W.D. Stevenson Jr., Elements of Power System Analysis, McGraw Hill.

2. J.B. Gupta, Switchgear and Protection, S.K. Kataria & Sons.

3. D.P. Kothari & I.J. Nagrath, Modern Power System Analysis, McGraw Hill.

4. P.K. Dash & S. Samantaray, Adaptive Protection of Power Systems, Springer.

5. IEEE Standards (IEEE C37 series) and research papers on smart grid and AI-based protection techniques.

6. Reports from PowerGrid India, CEA on Blackout Analysis & Smart Grid Protection.

## 7.8 Advanced Power System Protection

| Course Code | Courses Name | Course Type | L - T - P | Credits | Total Hours |
|---|---|---|---|---|---|
| EE511 | Advanced Power System Protection | Theory | 3 - 0 - 0 | 3 | 42 |

### 7.8.1 Objectives:

The objectives of studying this course are to,

1. Provide an in-depth understanding of advanced power system protection, including digital relays, distance and differential protection, and AI-based techniques.
2. Address protection challenges in modern grids, including HVDC, FACTS, smart grids, and renewable energy integration.
3. Develop expertise in adaptive and wide-area protection schemes for enhanced grid reliability and resilience.

### 7.8.2 Course Outcome:

At the completion of this course, the student shall acquire knowledge and ability

1. CO1 : Analyze power system protection fundamentals, coordination, and modern challenges.
2. CO2 : Design relay coordination strategies using digital and numerical relays.
3. CO3 : Implement distance and differential protection schemes for various power system components.
4. CO4 : Evaluate protection challenges in HVDC, renewables, and industrial power systems.
5. CO5 : Apply AI-based protection techniques for smart grids and microgrids.

### 7.8.3 CO - PO Mapping:

| **Relationship of Course Outcomes to Program Outcomes** | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **CO ↓** | **PO** | | | | | | | | | | | |
| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
| CO1 | H | H | M | M | L | H | M | L | L | L | L | M |
| CO2 | H | H | H | H | H | L | M | L | L | L | M | H |
| CO3 | H | H | H | H | H | L | M | L | L | L | M | H |
| CO4 | H | H | H | H | M | L | H | L | L | L | M | H |
| CO5 | H | H | H | H | H | H | H | L | L | L | M | H |
| **H = High correlation; M = Medium correlation; L = Low correlation** | | | | | | | | | | | | |

### 7.8.4 Syllabus:

**Module 1:** **Fundamentals & Protection Philosophy:** Basics of protection: Zones, reliability, and selectivity. Overcurrent, distance, differential, and pilot protection schemes. Challenges in protecting modern grids with renewables, HVDC, and FACTS. Grid Failure in India (2012 Blackout) – Protection Perspective. Protection coordination in industrial plants, metro rail, renewable power plants.

**Module 2:** **Digital & Numerical Relays:** Conventional Vs modern digital relays. Relay coordination and setting calculations. PMU-Based Protection for Indian Smart Grids. Smart grid fault detection, Wide-Area Monitoring Systems (WAMS). Communication protocols: IEC 61850, GOOSE messaging.

**Module 3:** **Distance & Differential Protection:** Distance protection: Impedance, MHO, quadrilateral relays. Differential protection: Transformer, generator, busbar, transmission lines. Adaptive and AI-based fault detection techniques. Protection Failures in UHVDC & Renewable Energy Grids.

**Module 4:** **Protection of Special Power System Components:** Generator and motor protection: Faults and relaying schemes. HVDC system protection: Converter faults, DC line faults. Protection of Large-Scale Industrial Motors in Steel & Cement Plants. Protection of Industrial Loads, Nuclear & Thermal Power Plants.

**Module 5:** **Protection in Smart Grids & Microgrids:** Smart grid protection: AI/ML-based fault detection. Microgrid and renewable energy protection schemes. Protection Challenges in Indian Renewable Energy Integration. Fault-tolerant microgrid protection, AI-driven protection in smart cities.

### 7.8.5 Learning Resources:

#### 7.8.5.1 Text Books:

1. P. M. Anderson, "Power System Protection," Wiley-IEEE Press, 2018 ($2^{nd}$ Ed.)

2. Badri Ram & D. N. Vishwakarma, "Power System Protection and Switchgear," McGraw-Hill

3. J. Lewis Blackburn & Thomas J. Domin, "Protective Relaying: Principles and Applications," CRC Press, 2014 ($4^{th}$ Ed.)

#### 7.8.5.2 Reference Books:

1. C. Christopoulos & A. Wright, "Electrical Power System Protection," Springer.

2. Y. G. Paithankar & S. R. Bhide, "Fundamentals of Power System Protection," Prentice Hall.

3. IEEE Standards (IEEE C37 series) and research papers on smart grid and AI-based protection techniques.

4. Reports from PowerGrid India, CEA on Blackout Analysis & Smart Grid Protection.

5. IEC 61850 – Communication Networks and Systems in Substations, IEC, 2021 Ed.

6. IEEE Std C37.118 – Synchrophasor Measurement for Power Systems, IEEE, 2022 Ed.

## 7.9 Power System Operation and Control

| Course Code | Courses Name | Course Type | L - T - P | Credits | Total Hours |
|---|---|---|---|---|---|
| EE512 | Power System Operation and Control | Theory | 3 - 0 - 0 | 3 | 42 |

### 7.9.1 Objectives:

The objectives of studying this course are to,

1. Develop a deep understanding of power system operation, economic dispatch, and control strategies for frequency and voltage regulation.
2. Explore optimization techniques, smart grid operations, renewable energy integration, and grid security challenges.
3. Equip students with AI-based methodologies for modern power system stability, resiliency, and efficient energy management.

### 7.9.2 Course Outcome:

At the completion of this course, the student shall acquire knowledge and ability to,

1. CO1 : Analyse power system operation, load forecasting, and economic dispatch strategies.
2. CO2 : Apply optimization techniques for economic load dispatch, unit commitment, and OPF.
3. CO3 : Design frequency control strategies and AGC for stable power system operation.
4. CO4 : Implement voltage control, reactive power management, and FACTS applications.
5. CO5 : Evaluate smart grid technologies, renewable integration, and cybersecurity challenges.

### 7.9.3 CO - PO Mapping:

| **Relationship of Course Outcomes to Program Outcomes** | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **CO ↓** | **PO** | | | | | | | | | | | |
| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
| CO1 | H | H | M | M | L | H | M | L | L | L | L | M |
| CO2 | H | H | H | H | M | L | M | L | L | L | M | M |
| CO3 | H | H | H | H | L | H | H | H | H | L | M | H |
| CO4 | H | H | H | H | M | L | L | L | M | L | M | H |
| CO5 | H | H | H | H | M | H | H | H | H | L | M | H |
| **H = High correlation; M = Medium correlation; L = Low correlation** | | | | | | | | | | | | |

### 7.9.4 Syllabus:

**Module 1:** **Power System Structure & Operational Aspects:** Structure of Modern Power Systems: Generation, Transmission, and Distribution. Power System Operation & Control Hierarchy: Primary, Secondary, and Tertiary Control. Load Characteristics & Load Forecasting Techniques. Energy Management System (EMS) & SCADA in Power System Operation.

**Module 2:** **Economic Operation of Power Systems:** Economic Load Dispatch (ELD) Without & With Network Losses. Unit Commitment (UC): Constraints, Dynamic Programming & Lagrange Relaxation. Optimal Power Flow (OPF) Using Classical & AI-Based Methods. Security-Constrained Economic Dispatch (SCED) & Security-Constrained OPF (SCOPF). Economic Dispatch in Renewable Integrated Grids.

**Module 3:** **Frequency Control & Automatic Generation Control (AGC):** Concept of Load-Frequency Control (LFC) in Power Systems. Primary & Secondary Frequency Control, Area Control Error (ACE). AGC for Single & Multi-Area Systems. AGC in Renewable-Dominated Power Grids. AGC in Renewable-Rich Grids for Grid Stability.

**Module 4:** **Voltage Control, Reactive Power Management & FACTS:** Reactive Power Flow & Voltage Stability in Power Systems. Voltage Control Techniques: Synchronous Condensers, Tap-Changing Transformers, Shunt & Series Compensation. Flexible AC Transmission Systems (FACTS) for Voltage & Reactive Power Control. FACTS for Enhancing Power Transfer & Stability. AI & Optimization Algorithms for Voltage Control in Smart Grids.

**Module 5:** **Smart Grid Operations, Renewable Integration & Grid Security:** Integration of Renewable Energy into Power Systems. Grid Resiliency, Blackout Prevention & Restoration Techniques. Demand Response & AI-Based Grid Optimization. Cybersecurity Challenges & AI-Based Anomaly Detection in Power Systems. Microgrid Operation & Control Strategies. AI & Blockchain in Energy Trading & Demand-Side Management.

### 7.9.5 Learning Resources:

#### 7.9.5.1 Text Books:

1. P. Kundur, "Power System Stability and Control," McGraw-Hill, 2023 (Reprint)
2. D. P. Kothari & I. J. Nagrath, "Modern Power System Analysis," McGraw-Hill, 2022 ($5^{th}$ Ed.)
3. A. J. Wood, B. F. Wollenberg, & G. B. Sheblé, "Power Generation, Operation, and Control," Wiley, 2020 ($4^{th}$ Ed.)

#### 7.9.5.2 Reference Books:

1. J. D. Glover, M. S. Sarma, & T. J. Overbye, "Power System Analysis and Design," Cengage, 2022 ($6^{th}$ Ed.)
2. N. G. Hingorani & L. Gyugyi, "Understanding FACTS: Concepts and Technology of Flexible AC Transmission Systems, Wiley-IEEE.
3. H. Saadat, "Power System Analysis," PSA Publishing, 2022 ($3^{rd}$ Ed.)
4. Research papers on AI-based grid optimization, cybersecurity, and renewable integration (IEEE, CIGRÉ, ISGF Reports).

## 7.10 Power Quality

| Course Code | Courses Name | Course Type | L - T - P | Credits | Total Hours |
|---|---|---|---|---|---|
| EE513 | Power Quality | Theory | 3 - 0 - 0 | 3 | 42 |

### 7.10.1 Objectives:

The objectives of studying this course are to,

1. Develop a comprehensive understanding of power quality (PQ) issues, including voltage disturbances, harmonics, and transients in modern power systems.
2. Explore PQ monitoring, mitigation strategies, and the role of FACTS, custom power devices, and AI-based forecasting techniques.
3. Analyze PQ challenges in renewable energy integration, EV charging infrastructure, and industrial power systems.

### 7.10.2 Course Outcome:

At the completion of this course, the student shall acquire knowledge and ability to,

1. CO1 : Identify and analyse PQ disturbances such as sags, swells, flicker, harmonics, and transients.
2. CO2 : Apply mitigation strategies using filters, FACTS devices, and custom power solutions.
3. CO3 : Utilize PQ monitoring tools for data logging and real-time analysis.
4. CO4 : Assess PQ challenges in renewable energy integration and EV charging.
5. CO5 : Evaluate economic impacts and AI-based forecasting techniques for PQ improvement.

### 7.10.3 CO - PO Mapping:

| **Relationship of Course Outcomes to Program Outcomes** | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **CO ↓** | **PO** | | | | | | | | | | | |
| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
| CO1 | H | H | M | H | L | H | M | L | L | L | L | M |
| CO2 | H | H | H | H | H | L | M | L | L | L | M | M |
| CO3 | H | H | H | H | H | L | M | L | L | L | M | H |
| CO4 | H | H | H | H | M | L | H | L | L | L | M | H |
| CO5 | H | H | H | H | H | M | H | L | L | L | M | H |
| **H = High correlation; M = Medium correlation; L = Low correlation** | | | | | | | | | | | | |

### 7.10.4 Syllabus:

**Module 1: Introduction to Power Quality and Voltage Disturbances:** Power Quality Definitions & Global Standards (IEEE-519, IEC 61000, CEA guidelines for India). Power Quality Issues: Voltage Sag, Swell, Flicker, Interruptions. Causes & Effects : Industrial Load Switching, Motor Starting, Grid Events. PQ Challenges in Industrial Loads, Metro Rails, Data Centers.

**Module 2: Harmonics in Power Systems and Mitigation Strategies:** Introduction to Harmonics: Nonlinear Loads, Inverter-Based Resources (IBR). Harmonic Indices: Total Harmonic Distortion (THD), Selective Harmonic Elimination (SHE). Harmonic Effects on Power System Components (Transformers, Motors, Capacitors). Mitigation Strategies : Passive Filters, Active Filters, Hybrid Filters, Zig-Zag Transformers. Harmonic mitigation in EV Charging, Industrial Drives, and Renewable Energy Integration.

**Module 3: Power Quality Monitoring, Compensation, and FACTS Applications:** Power Quality Monitoring Techniques: PQ Analysers, Smart Meters, Data Logging. Reactive Power Compensation: Static Var Compensator (SVC), Static Synchronous Compensator (STATCOM). Custom Power Devices for PQ Improvement: UPQC, DVR, D-STATCOM. FACTS for PQ Improvement in Industrial Grids, Smart Cities, Railways.

**Module 4: Transient Overvoltages, Surge Protection, and AI-based PQ Forecasting:** Lightning Surges, Switching Surges, Fault Clearing Transients. Effects of Transients : Equipment Failure, Data Corruption, Grid Stability Issues. Mitigation Strategies: Surge Arresters, Snubber Circuits, Isolation Transformers. AI & IoT-Based PQ Monitoring: Predictive Analytics, IoT Sensors for PQ Data Logging. AI-driven PQ Solutions for Renewable Energy Integration & Smart Grids.

**Module 5: Economic Impact, PQ Challenges in EV Charging & Renewable Energy:** Economic Impact of Poor PQ: Production Losses, Equipment Damage, Financial Costs. PQ Issues in EV Charging Infrastructure. PQ Challenges in Solar and Wind Farm Integration. Role of Supercapacitors & Battery Energy Storage (BESS) for PQ.

### 7.10.5 Learning Resources:

#### 7.10.5.1 Text Books:

1. A Ghosh & G Ledwich, "Power Quality Enhancement Using Custom Power Devices," Springer, 2022 ($2^{nd}$ Ed.)
2. C. Sankaran, "Power Quality," CRC Press, 2023 ($2^{nd}$ Ed.)
3. Roger C. Dugan, Mark F. McGranaghan, Surya Santoso & H. Wayne Beaty, "Electrical Power Systems Quality," McGraw-Hill, 2023 ($4^{th}$ Ed.)

#### 7.10.5.2 Reference Books:

1. IEEE Standards (IEEE-519, IEEE-1159) and IEC 61000 Reports on Power Quality.
2. Ewald F. Fuchs & Mohammad A. S. Masoum, "Power Quality in Power Systems and Electrical Machines," Elsevier, 2022 ($3^{rd}$ Ed.)
3. Bollen Math H J, "Understanding Power Quality Problems," Wiley-IEEE, 2021 (Reprint)
4. Research papers on PQ issues in EV charging and renewable energy integration (IEEE Transactions, CEA Reports)

# 7.11 Smart Electric Grids

| Course Code | Courses Name | Course Type | L - T - P | Credits | Total Hours |
|---|---|---|---|---|---|
| EE514 | Smart Electric Grids | Theory | 3 - 0 - 0 | 3 | 42 |

## 7.11.1 Objectives:

The objectives of studying this course are to,

1. Understand the concept of Smart Grids and compare them with conventional grids.
2. Identify the opportunities and barriers associated with Smart Grid implementation.
3. Explore various Smart Grid technologies and their applications.
4. Gain insights into Smart Grid operation and control strategies.
5. Analyze the role of Smart Grids in enhancing energy efficiency and reliability.
6. Understand future trends and innovations driving Smart Grid evolution.

## 7.11.2 Course Outcome:

At the completion of this course, the student shall acquire knowledge and ability

1. CO1 : Grasp the basic principles of Smart Electric Grid and effectively apply them to solve engineering problems.
2. CO2 : Analyse the significance of Smart Electric Grid and its wide-range of possibilities/applications.
3. CO3 : Comprehend the fundamental concepts of smart grid evolution, transmission and distribution technologies, microgrids, monitoring and control, cyber security, various case studies and their practical applications.
4. CO4 : Evaluate various aspects of Smart Electric Grid.

## 7.11.3 CO - PO Mapping:

| **Relationship of Course Outcomes to Program Outcomes** | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **CO ↓** | **PO** | | | | | | | | | | | |
| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
| CO1 | H | H | H | M | M | M | H | H | H | M | M | H |
| CO2 | H | H | H | M | M | M | H | H | H | M | M | H |
| CO3 | H | H | H | M | M | M | H | H | H | M | M | H |
| CO4 | H | H | H | M | M | M | H | H | H | M | M | H |
| **H = High correlation; M = Medium correlation; L = Low correlation** | | | | | | | | | | | | |

### 7.11.4 Syllabus:

**Module 1:** **Introduction:** Evolution of Electric Grid, Difference between conventional & smart grid, Concept of Smart Grid, Definitions, Need, Functions of Smart Grid, Opportunities & Barriers, Drivers in India, Challenges, Smart Grid Vision & Roadmap for India, Concept of Resilient and Self-Healing Grid, Present development & International policies in Smart Grid, Smart Cities, Pilot and main projects in India.

**Module 2:** **Smart Grid Technologies:** Architecture of Smart Grid Design, Smart Transmission Technologies, Remote Terminal Unit (RTU), Intelligent Electronic Devices (IED), Phase Measurement Unit (PMU), Substation and Feeder Automation, Integration of renewable energy sources, Computational Intelligence Techniques.

**Module 3:** **Distribution Automation:** Advanced Metering Infrastructure (AMI), Peak Load Management (PLM), Power Quality Management (PQM), Outage Management System (OMS), Real Time Pricing, Demand Side Management (DSM). Smart Sensors, Smart Appliances, Smart Storage technologies, Home & Building Automation, Electric Vehicles, V2X technologies, Policies and incentives for EV adoption.

**Module 4:** **Microgrids:** Renewable energy sources and Distributed generation, Concept of Microgrid, AC and DC Microgrids, Droop, Centralized and Distributed Control of Microgrids, protection schemes, Islanding Detection Techniques, Grid Integration Issues with PV, Wind, EV, Storage technologies. Case Studies and Test beds for the Smart Grids, Smart Grids to the Smart Cities: New Paradigms for Future Networks.

**Module 5:** **System Monitoring and Control:** Supervisory Control and Data Acquisition (SCADA), Wide Area Measurement System (WAMS), Home Area Network (HAN), Neighbourhood Area Network (NAN), Wide Area Network (WAN). Bluetooth, ZigBee, GPS, Wi-Fi, Wireless Networks. Cloud Computing, Artificial Intelligence and Machine Learning applications, Blockchain and Cyber Security applications, Simulation of cyberattacks and case studies, other latest technologies in Smart Grids.

### 7.11.5 Learning Resources:

#### 7.11.5.1 Text Books:

1. Ali Keyhani, Mohammad N. Marwali, Min Dai "Integration of Green and Renewable Energy in Electric Power Systems," Wiley, 2022 ($2^{nd}$ Ed.)
2. C W Gellings, "The Smart Grid: Enabling Energy Efficiency & Demand Response," CRC Press, 2021 ($2^{nd}$ Ed.)
3. Janaka Ekanayake, Nick Jenkins, Kithsiri Liyanage, Jianzhong Wu, Akihiko Yokoyama, "Smart Grid: Technology and Applications", Wiley, 2023 ($2^{nd}$ Ed.)

#### 7.11.5.2 Reference Books:

1. Stuart Borlase, "Smart Grids-Infrastructure, Technology and Solutions," CRC Press, 2024 ($3^{rd}$ Ed.)
2. Janaka Ekanayake, Kithsiri Liyanage, Jianzhong Wu and Akihiko Yokoyama, "Smart GridT echnology and applications", Wiley, 2020 ($2^{nd}$ Ed.)
3. James Momoh, "Smart Grid-Fundamentals of design and analysis", Wiley.
4. Relevant research papers.

## 7.12 Microgrid Operation and Control

| Course Code | Courses Name | Course Type | L - T - P | Credits | Total Hours |
|---|---|---|---|---|---|
| EE515 | Microgrid Operation and Control | Theory | 3 - 0 - 0 | 3 | 42 |

### 7.12.1 Objectives:

The objectives of studying this course are to,

1. Understand the concept, structure, and components of microgrids.
2. Explore the operation and control strategies of microgrids in grid-connected and islanded modes.
3. Analyze energy management techniques for optimizing microgrid performance.
4. Study the integration of renewable energy sources, energy storage, and distributed generation in microgrids.
5. Understand microgrid protection, stability, and resilience challenges.
6. Explore the role of smart technologies and future trends in microgrid development.

### 7.12.2 Course Outcome:

At the completion of this course, the student shall acquire knowledge and ability

1. CO1 : Grasp the basic principles of Microgrid Operation and Control and effectively apply them to solve engineering problems.
2. CO2 : Analyse the significance of Microgrid Operation and Control and its wide-range of possibilities/applications.
3. CO3 : Comprehend the fundamental concepts of Microgrids, their Operation, Control, management, protection, security, storage systems, grid integration challenges and their practical applications.
4. CO4 : Evaluate various aspects of Microgrid Operation and Control.

### 7.12.3 CO - PO Mapping:

| **Relationship of Course Outcomes to Program Outcomes** | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **CO ↓** | **PO** | | | | | | | | | | | |
| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
| CO1 | H | H | H | M | M | M | H | H | H | M | M | H |
| CO2 | H | H | H | M | M | M | H | H | H | M | M | H |
| CO3 | H | H | H | M | M | M | H | H | H | M | M | H |
| CO4 | H | H | H | M | M | M | H | H | H | M | M | H |
| **H = High correlation; M = Medium correlation; L = Low correlation** | | | | | | | | | | | | |

### 7.12.4 Syllabus:

**Module 1:** **Introduction:** Concept and definition of microgrids, Components, types of microgrids and their operation, Benefits and challenges in operation, architecture and components. Indian and International Real-world case studies of microgrid implementations.

**Module 2:** **Operation, Control and Management:** Modes of operation: Grid-connected and islanded modes, Control strategies: Droop, Centralized and Distributed Control of Microgrids, islanding detection techniques, stability issues in microgrids. Demand-side management and load forecasting, Microgrid scheduling and energy trading, artificial intelligence (AI) and machine learning (ML) applications in energy management. Policies and regulations for microgrid implementation.

**Module 3:** **Protection and Security:** Protection schemes, Fault detection and isolation, Cybersecurity threats and mitigation strategies, Resilience and reliability of microgrid systems.

**Module 4:** **Integration of Renewable Energy and Grid Interaction:** Challenges in renewable integration, Grid synchronization and stability issues, Power flow control and optimization, Role of energy storage in renewable integration. Emerging trends in microgrid operation: Blockchain, IoT, digital twins, etc, Review of recent technologies.

### 7.12.5 Learning Resources:

#### 7.12.5.1 Text Books:

1. Papia Ray, and Monalisa Biswal, "Microgrid: Operation, Control, Monitoring and Protection," Springer Verlag, Singapore, 2020 ($1^{st}$ Ed.)

2. Hassan Bevrani, Bruno Francois, and Toshifumi Ise, "Microgrid Dynamics and Control", John Wiley & Sons, Inc., 2017 ($1^{st}$ Ed.)

#### 7.12.5.2 Reference Books:

1. Josep M. Guerrero (Editor), Ritu Kandari (Editor), "Microgrids: Modeling, Control, and Applications," Academic Press Inc, 2021.

2. Research papers

## 7.13 HVDC and FACTS

| Course Code | Courses Name | Course Type | L - T - P | Credits | Total Hours |
|---|---|---|---|---|---|
| EE516 | HVDC and FACTS | Theory | 3 - 0 - 0 | 3 | 42 |

### 7.13.1 Objectives:

The objectives of studying this course are to,

1. Provide a comprehensive understanding of HVDC and FACTS technologies, including system components, control strategies, and stability enhancement.
2. Explore applications of HVDC and FACTS in renewable energy integration, weak grid support, and smart grid technologies.
3. Analyse emerging trends such as hybrid AC-DC grids, superconducting DC transmission, and advanced grid modernization techniques.

### 7.13.2 Course Outcome:

At the completion of this course, the student shall acquire knowledge and ability to,

1. CO1 : Analyse HVDC and FACTS principles, components, and operational strategies.
2. CO2 : Design control strategies for HVDC links and FACTS devices to enhance grid stability.
3. CO3 : Evaluate the role of HVDC and FACTS in renewable energy integration and weak grid support.
4. CO4 : Assess economic aspects and planning considerations for HVDC and FACTS deployments.
5. CO5 : Explore emerging trends such as hybrid AC-DC grids, superconducting DC, and smart grid applications.

### 7.13.3 CO - PO Mapping:

| **Relationship of Course Outcomes to Program Outcomes** | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **CO ↓** | **PO** | | | | | | | | | | | |
| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
| CO1 | H | H | M | M | L | H | M | L | L | L | L | M |
| CO2 | H | H | H | H | H | L | M | L | L | L | M | H |
| CO3 | H | H | H | H | H | M | M | L | L | L | M | H |
| CO4 | H | H | H | H | M | L | H | L | L | L | M | H |
| CO5 | H | H | H | H | H | H | H | L | L | L | M | H |
| **H = High correlation; M = Medium correlation; L = Low correlation** | | | | | | | | | | | | |

### 7.13.4 Syllabus:

**Module 1:** **Introduction to HVDC and FACTS:** Overview of Power Transmission Systems: AC vs. DC Transmission, Challenges in AC Systems. HVDC Transmission: Evolution, Links (Monopolar, Bipolar, Multi-Terminal), Advantages & Limitations, Applications. FACTS: Need, Benefits, Classification, Role in Voltage Stability, Power Flow Control.

**Module 2:** **HVDC System Components, Control, and Applications:** HVDC Components: Converter Topologies (LCC, VSC, MMC), Transformers, Harmonic Filters. HVDC Control: Rectifier & Inverter Control, Power Flow & Voltage Regulation, Fault Handling. Applications: Offshore Wind Integration, Multi-Terminal & Hybrid AC-DC Grids.

**Module 3:** **FACTS Devices, Control, and Applications:** Shunt Compensation: SVC, STATCOM. Series Compensation: TCSC, SSSC. Combined Series-Shunt: UPFC, IPFC. FACTS Control: Power Flow, Voltage Regulation, Stability Enhancement. Applications: FACTS in Transmission Capacity & Renewable Integration. STATCOM for Weak Grid Integration in India.

**Module 4:** **HVDC and FACTS for Power System Stability and Grid Integration:** HVDC & Power System Stability: Transient, Dynamic, Frequency, and Voltage Stability. FACTS for Stability: Transient Stability, Wide-Area Control. Applications: HVDC for Unsynchronized Grids, FACTS for Grid Resilience. Green Energy Corridor in India.

**Module 5:** **Future Trends, Planning, and Economic Aspects of HVDC & FACTS:** Planning & Economics: HVDC Vs. HVAC, Cost-Benefit Analysis, Investment & Policy Considerations. Emerging Technologies: Superconducting DC, Wide-Area FACTS, Solid-State Transformers. Applications: HVDC for Large-Scale Renewables, FACTS for Smart Grids. India's Renewable Grid Performance with HVDC & FACTS.

### 7.13.5 Learning Resources:

#### 7.13.5.1 Text Books:

1. K. R. Padiyar, "HVDC Power Transmission Systems," New Age International, 2017 ($3^{rd}$ Ed.)
2. Narain G. Hingorani, Laszlo Gyugyi, Understanding FACTS: Concepts and Technology of Flexible AC Transmission Systems, Wiley-IEEE, US, 1999 ($1^{st}$ Ed.)

#### 7.13.5.2 Reference Books:

1. J. Arrillaga, "High Voltage Direct Current Transmission," IET, 1998 ($2^{nd}$ Ed.)
2. IEEE & CIGRÉ Reports on HVDC and FACTS Technologies
3. Case Studies from Indian HVDC/FACTS Projects (PowerGrid Reports, CEA Reports)

## 7.14 Power Distribution Systems

| Course Code | Courses Name | Course Type | L - T - P | Credits | Total Hours |
|---|---|---|---|---|---|
| EE517 | Power Distribution Systems | Theory | 3 - 0 - 0 | 3 | 42 |

### 7.14.1 Objectives:

The objectives of studying this course are to,

1. Understand the fundamentals of power distribution system planning and operation.
2. Learn to design and analyze distribution systems using forecasted data.
3. Evaluate distribution system performance and optimization strategies.
4. Explore modern advancements in smart grid technologies and their implementation.
5. Understand the principles of power system reliability and methods to enhance it.
6. Develop practical insights into sustainable and efficient distribution network design.

### 7.14.2 Course Outcome:

At the completion of this course, the student shall acquire knowledge and ability to,

1. CO1 : Grasp the basic principles of Power Distribution Systems and effectively apply them to solve engineering problems.
2. CO2 : Analyse the significance of Power Distribution Systems and its wide-range of possibilities/applications.
3. CO3 : Comprehend the fundamental concepts of distribution system planning, voltage & power calculations, distribution system automation & smart grid operation, auditing, management, economics, energy efficiency, sustainability, various case studies and their practical applications.
4. CO4 : Evaluate various aspects of Power Distribution Systems.

### 7.14.3 CO - PO Mapping:

| **Relationship of Course Outcomes to Program Outcomes** | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **CO ↓** | **PO** | | | | | | | | | | | |
| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
| CO1 | H | H | H | M | M | M | H | H | H | M | M | H |
| CO2 | H | H | H | M | M | M | H | H | H | M | M | H |
| CO3 | H | H | H | M | M | M | H | H | H | M | M | H |
| CO4 | H | H | H | M | M | M | H | H | H | M | M | H |
| **H = High correlation; M = Medium correlation; L = Low correlation** | | | | | | | | | | | | |

### 7.14.4 Syllabus:

**Module 1:** **Distribution System Planning & Load Forecasting:** Structure of electric power systems, Transmission vs. distribution systems, Distribution System Planning, Primary and Secondary Distribution, Types of distribution systems, key components. Load Characteristics, Planning and forecasting techniques, Load management, tariffs and metering of energy.

**Module 2:** **Voltage Drop and Power Loss Calculations:** Three phase distribution system design, Copper losses, feeder costs, Loss reduction techniques and Voltage improvement in rural networks. Capacitors in Distribution Systems, Power factor and its improvement, Distribution transformers and tap-changing, Voltage regulation methods.

**Module 3:** **Distribution Automation and Smart Grids:** Substation layout and components, Classification of substations- Indoor & Outdoor substations, Protective devices (circuit breakers, reclosers, etc), Phasor measurement unit, Supervisory Control and Data Acquisition and Wide area monitoring systems, Smart grid technologies, Smart meters and demand response programs.

**Module 4:** **Microgrids and Power Quality:** Distributed generation (DG), Integration of renewable energy sources, Microgrid operation and control, Harmonics and their effects, Voltage sags, swells, and interruptions, Mitigation techniques.

**Module 5:** **Reliability and Economics:** Reliability indices (SAIDI, SAIFI, CAIDI), Case studies of modern distribution networks, Emerging technologies in power distribution, hands on using suitable softwares.

### 7.14.5 Learning Resources:

#### 7.14.5.1 Text Books:

1. Juan M. Gers, "Distribution Systems Analysis and Automation," IET power series, 2020, ($2^{nd}$ Ed.)
2. Turan Gonen, "Electric Power Distribution Engineering," CRC Press, 2015 ($3^{rd}$ Ed.)
3. James Northcote-Green, Robert G. Wilson, "Control and Automation of Electrical Power Distribution Systems," Taylor & Fransis, 2006 ($1^{st}$ Ed.)

#### 7.14.5.2 Reference Books:

1. A. S. Pabla, "Electric Power Distribution," TMH, 2000 ($5^{th}$ Ed.)
2. Sallam A. A, & Malik O. P, "Electric Distribution Systems," Wiley-IEEE Press, 2018 ($2^{nd}$ Ed.)
3. B. Das, "Power Distribution Automation," IET Power and Energy Series, 2016
4. J. J. Burke, "Power Distribution Engineering: Fundamentals and Applications," CRC Press, 1994 ($1^{st}$ Ed.)
5. T. A Short, "Electric Power Distribution Handbook," CRC Press, 2018 ($2^{nd}$ Ed.)
6. Relevant research articles.

## 7.15 High Voltage Engineering

| Course Code | Courses Name | Course Type | L - T - P | Credits | Total Hours |
|---|---|---|---|---|---|
| EE518 | High Voltage Engineering | Theory | 3 - 0 - 0 | 3 | 42 |

### 7.15.1 Objectives:

The objectives of studying this course are to,

1. Understand the principles and dynamics of high voltage (HV) generation.
2. Explore HV transmission systems and their operational characteristics.
3. Learn various HV testing methods and standards for equipment and insulation.
4. Study techniques for accurate HV measurement and diagnostics.
5. Examine practical applications of HV technology across industries.
6. Develop insights into safety protocols and emerging trends in HV systems.

### 7.15.2 Course Outcome:

At the completion of this course, the student shall acquire knowledge and ability

1. CO1 : Grasp the basic principles of High Voltage Engineering and effectively apply them to solve engineering problems.
2. CO2 : Analyse the significance of High Voltage Engineering and its wide-range of applications.
3. CO3 : Comprehend the fundamental concepts of high voltage engineering, methods to generate high voltages and currents, measurement, testing and their practical applications.
4. CO4 : Evaluate various aspects of High Voltage Engineering.

### 7.15.3 CO - PO Mapping:

| **Relationship of Course Outcomes to Program Outcomes** | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **CO ↓** | **PO** | | | | | | | | | | | |
| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
| CO1 | H | H | H | M | M | M | H | H | H | L | M | H |
| CO2 | H | H | H | M | M | M | H | H | H | L | M | H |
| CO3 | H | H | H | M | M | M | H | H | H | L | M | H |
| CO4 | H | H | H | M | M | M | H | H | H | L | M | H |
| **H = High correlation; M = Medium correlation; L = Low correlation** | | | | | | | | | | | | |

### 7.15.4 Syllabus:

**Module 1:** **Introduction:** Causes of over voltages, types, effect of over voltages on power system components, Electric Field intensity, Electric strength, classification of Electric Fields, control of electric Field intensity, surge diverters, EMI and EMC protection against over voltages, insulation coordination.

**Module 2:** **Generation of High voltages and currents:** Generation of high AC and DC voltages, insulation protection, impulse and switching voltages, generation of high impulse currents, applications.
AC voltages: cascade transformers, series resonance circuits, Tesla coils.
DC voltages: Voltage doubler, cascade circuits, electrostatic machines
Impulse voltages: single stage and multistage circuits, wave shaping, tripping and control of impulse generators, Generation of switching surge voltage and impulse currents. Simulation of voltage doubler, Cockroft Walton voltage multiplier and Marx impulse voltage generation circuits.

**Module 3:** **Measurements:** High voltage transmission, ratings, protection mechanism, cost advantage. Measurement of high AC, DC, impulse voltages using sphere gaps, peak voltmeters, potential dividers, rod gap method, High speed CRO and digital techniques. Measurement of high currents. Dielectric breakdown - break down in gases, liquids and solids; partial discharges and corona discharges.

**Module 4:** **High Voltage testing:** High voltage testing of circuit breakers, insulators, bushings, power capacitors, power transformers, and surge diverters. Standards and specifications IEC, ANSI, IEEE and Indian standards for HV testing of electrical equipment. Non-destructive test techniques, high voltage Schering bridge, breakdown mechanism of gaseous liquid and solid insulating materials, Townsend's first ionization coefficient.

**Module 5:** **Applications:** Applications in Industries, Medical use, Scientific & Research purposes, Transportation & Automotives, Telecommunications.

### 7.15.5 Learning Resources:

#### 7.15.5.1 Text Books:

1. C.L. Wadhwa, "High Voltage engineering," Wiley Eastern Limited, New Delhi, 1994 ($2^{nd}$ Ed.)
2. M.S. Naidu, & V.Kamaraju, "High Voltage Engineering" Tata McGraw Hill Publishing Company, New Delhi, 2013 ($3^{rd}$ Ed.)

#### 7.15.5.2 Reference Books:

1. E Kuffel, & W.S. Zaengl "High Voltage Engineering Fundamentals," Pergamon press, Oxford, London, 2013 ($2^{nd}$ Ed.)
2. Ravindra Arora & Wolfgang Mosch, "High Voltage and Electrical Insulation Engineering," Wiley-IEEE Press, 2011 ($1^{st}$ Ed.)
3. Standard techniques for high voltage testing, IEEE Publication 1978.
4. Relevant research articles.

# 7.16 Advanced Power Electronics

| Course Code | Courses Name | Course Type | L - T - P | Credits | Total Hours |
|---|---|---|---|---|---|
| EE520 | Advanced Power Electronics | Theory | 3 - 0 - 0 | 3 | 42 |

## 7.16.1 Objectives:

The objectives of studying this course are to,

1. Understand the capabilities, trends and the developments happening in the field of power electronics.
2. Study, evaluate and design topologies which cater to different requirements.
3. Understand techniques used for modelling the non-linear power electronic systems.
4. Understand the process of design the controllers used in power electronic systems.
5. Understand the process of overall design and development of a power electronic system.

## 7.16.2 Course Outcome:

At the completion of this course, the student shall acquire knowledge and ability to,

1. CO1 : Enable the student to understand the requirements, capabilities, trends, and developments associated with power electronic systems.
2. CO2: Enable the student to understand the process of modelling power electronic systems thereby enabling the design of controllers used in such systems.
3. CO3: Enable the student to design and develop a complete power electronic system.

## 7.16.3 CO - PO Mapping:

| **Relationship of Course Outcomes to Program Outcomes** | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **CO ↓** | **PO** | | | | | | | | | | | |
| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
| CO1 | M | L | L | L | L | M | M | L | L | L | L | L |
| CO2 | H | M | H | M | M | L | L | L | L | L | L | H |
| CO3 | H | M | H | M | M | L | L | L | L | L | L | H |
| **H = High correlation; M = Medium correlation; L = Low correlation** | | | | | | | | | | | | |

### 7.16.4 Syllabus:

**Module 1:** **Switched mode power Converter Topologies:** Requirements of switched mode power supplies and need for isolation, Non-isolated and isolated power converters, High gain converters, Design of transformers and magnetics for switched mode power converters.

**Module 2:** **Controllers and its design:** Design of controllers for SMPS, Modulation techniques, Fixed and Variable frequency control methods, Design of controller using small-signal modelling and state-space averaging, Digital control and Mixed mode control.

**Module 3:** **Soft switched Converters:** Converters operating at higher switching frequency, Problems associated with hard switching, Introduction to soft switching, resonant tank circuits and locus diagrams, Soft switched converters, Range of soft switching applicable to converters, Applications where soft switching is involved.

**Module 4:** **Multi-level converters:** Topologies and Applications.

### 7.16.5 Learning Resources:

#### 7.16.5.1 Text Books:

1. N.Mohan, T.M. Undeland and W.P.Robbins, Power Electronics: Converter, Applications & Design, John Wiley & Sons, 2003 ($3^{rd}$ Ed.)
2. R. W. Erickson & D. Maksimovic, "Fundamentals of Power Electronics," Springer, 2020 ($3^{rd}$ Ed.)
3. M. H. Rashid, "Power Electronics: Circuits, Devices, and Applications", PHI, 2013 ($4^{th}$ Ed.)

#### 7.16.5.2 Reference Books:

1. P. T. Krein, "Elements of Power Electronics, Indian Edition," Oxford University Press, 2014 ($2^{nd}$ Ed.)

## 7.17 Power Electronic Converters for Renewable Energy

| Course Code | Courses Name | Course Type | L - T - P | Credits | Total Hours |
|---|---|---|---|---|---|
| EE521 | Power Electronic Converters for Renewable Energy | Theory | 3 - 0 - 0 | 3 | 42 |

### 7.17.1 Objectives:

The objectives of studying this course are to,

1. Understand the characteristics of renewable energy sources and the specific features of the loads or the utility grid to which the power is to be sourced.
2. Analyze challenges and opportunities arising from the transition to renewable-based power generation.
3. Study power electronic converters used in renewable energy systems.
4. Develop solutions to address the challenges which are specific to renewable energy sources using power electronics.

### 7.17.2 Course Outcome:

At the completion of this course, the student shall acquire knowledge and ability to,

1. CO1 : Enable the student to understand the specific requirements, benefits, and challenges associated with integrating alternate energy sources with utility grid
2. CO2: Enable the student to understand the requirements and operation of the power processing unit used in conjunction with the renewable power generator
3. CO3: Enable the student to design and develop a power processing unit taking into consideration the effect of the renewable source, storage system (if any), and the utility grid requirements

### 7.17.3 CO - PO Mapping:

| **Relationship of Course Outcomes to Program Outcomes** | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **CO ↓** | **PO** | | | | | | | | | | | |
| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
| CO1 | H | L | L | L | L | L | M | L | L | L | L | L |
| CO2 | M | M | H | L | M | L | M | L | L | L | L | H |
| CO3 | M | L | H | M | M | L | M | L | L | L | L | H |
| **H = High correlation; M = Medium correlation; L = Low correlation** | | | | | | | | | | | | |

### 7.17.4 Syllabus:

**Module 1:** **Introduction:** Overview of renewable energy sources: Solar, Wind, Charactristics, Need for power electronic converters in renewable energy systems , Power electronic challenges in renewable energy integration.

**Module 2:** **DC-DC converters for RE applications:** Non-isolated and isolated, Maximum Power Point Tracking (MPPT) techniques for solar PV systems, Interleaved and Multiphase DC-DC converters, Battery: Types, charging-discharging.

**Module 3:** **AC-DC converters for RE applications:** Classification: Voltage Source Inverters (VSI) and Current Source Inverters (CSI), Isolated and Non-Isolated topologies, Grid-connected inverters: Single-phase and three-phase topologies, Harmonics, THD, and filtering techniques. Wind Generators: DC generator with DC to AC converters; Induction generator with & without converter; Synchronous generator with back to back controlled/uncontrolled converter; Doubly fed induction generator with rotor side converter topologies; permanent magnet-based generators. Single-phase and three-phase rectifiers for wind applications.

**Module 4:** **Grid synchronization techniques:** PLL, Phase detection, Static VAr compensators and Reactive power control , Anti-islanding protection and power quality issues, Microgrid concept and control strategies, Standards and regulations for grid-connected renewable systems (IEEE 1547, IEC 61727).

### 7.17.5 Learning Resources:

#### 7.17.5.1 Text Books:

1. Remus Teodorescu, Marco Liserre & Pedro Rodriguez, "Grid Converters for Photovoltaic and Wind Power Systems," Wiley-IEEE Press, January 2011 ($1^{st}$ Ed.)
2. Suleiman M. Sharkh, Mohammad A. Abu-Sara, Georgios I. Orfanoudakis & Babar Hussain, "Power Electronic Converters for Microgrids," Wiley-IEEE Press, April 2014 ($1^{st}$ Ed.)
3. Fang Lin Luo & Hong Ye, "Advanced DC/AC Inverters: Applications in Renewable Energy," CRC Press, 2013 ($1^{st}$ Ed.)

#### 7.17.5.2 Reference Books:

1. Sudipta Chakraborty, Marcelo G. Simões & William E. Kramer, "Power Electronics for Renewable and Distributed Energy Systems," Springer 2013 ($1^{st}$ Ed.)

# 7.18 Advanced Electric Drives

| Course Code | Courses Name | Course Type | L - T - P | Credits | Total Hours |
|---|---|---|---|---|---|
| EE522 | Advanced Electric Drives | Theory | 3 - 0 - 0 | 3 | 42 |

## 7.18.1 Objectives:

The objectives of studying this course are to,

1. To understand fundamental principles of electromagnetic energy conversion and electric machine analysis.
2. To develop analytical skills using reference frame theory for modeling AC machines.
3. To introduce scalar and vector control techniques for induction and synchronous motor drives.
4. To study advanced control strategies such as Field-Oriented Control (FOC) and Direct Torque Control (DTC).
5. To explore sensorless control mechanisms and speed estimation methods for high-speed electric drives.

## 7.18.2 Course Outcome:

At the completion of this course, the student shall acquire knowledge and ability

1. CO1 : Explain the fundamentals of electromagnetic energy conversion and torque production in AC machines.
2. CO2 : Apply reference frame theory to develop dynamic models of AC machines.
3. CO3 : Design and analyze scalar and vector control schemes including FOC and DTC for electric drives.
4. CO4 : Evaluate the performance and applicability of sensorless control techniques in high-speed drives.
5. CO5 : Simulate and interpret dynamic behaviors of controlled electric machines using modern tools.

## 7.18.3 CO - PO Mapping:

| **Relationship of Course Outcomes to Program Outcomes** | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **CO ↓** | **PO** | | | | | | | | | | | |
| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
| CO1 | H | M | L | L | - | - | - | - | - | - | - | - |
| CO2 | H | H | M | M | M | - | - | - | - | - | - | M |
| CO3 | M | H | H | M | H | - | - | - | - | - | - | M |
| CO4 | M | M | M | H | H | - | - | - | - | - | - | H |
| CO5 | M | M | M | H | H | - | - | - | L | M | L | H |
| **H = High correlation; M = Medium correlation; L = Low correlation** | | | | | | | | | | | | |

### 7.18.4 Syllabus:

**Module 1:** **Basic principles of electric machine analysis:** Magnetically coupled circuits, Electro-magnetic (EM) energy conversion, Single and double excited systems. Machine windings and air-gap MMF, Winding inductances and voltage equations, Production of electromagnetic torque

**Module 2:** **Reference frame theory:** Equations of transformation, transformation between reference frames, variables observed from various frames. Theory of symmetrical induction machines: Voltage and torque expression, state-space model of Induction motor in'd-q-0' variables.

**Module 2:** **Advanced AC Drives:** Comparison of scalar and vector control, Field-Oriented Control (FOC) for Induction and Synchronous motors. Direct Torque Control (DTC)

**Module 3:** **Sensorless Control:** Estimation of position and speed. MRAS-based speed sensorless control for induction motor, Introduction to High-Speed Induction and Synchronous Machine Drives.

### 7.18.5 Learning Resources:

#### 7.18.5.1 Text Books:

1. P. C. Krause, O. Wasynczuk, and S. D. Sudhoff, Analysis of Electric Machines and Drive Systems, 2nd edition, Wiley-IEEE Press, New York, 2002.
2. P. Vas, Sensorless Vector and Direct Torque Control, Oxford University Press, New York, 1998
3. D. W. Novotny and T. A. Lipo, Vector Control and Dynamics of AC Drives, Clarendon Press, New York, 1996
4. Rik W. De Doncker, Duco W.J. Pulle, and André Veltman, Advanced Electrical Drives: Analysis, Modeling, Control, Springer, 2020, 2nd Edition.
5. Ned Mohan, Advanced Electric Drives: Analysis, Control, and Modeling Using MATLAB/Simulink, Wiley, 2014, 1st Edition.

#### 7.18.5.2 Reference Books:

1. Ali Emadi, Advanced Electric Drive Vehicles, CRC Press, 2017, 1st Edition.
2. Frede Blaabjerg (Ed.), Advanced and Intelligent Control in Power Electronics and Drives, Springer, 2014, 1st Edition.

## 7.19 Electrical Machine Design

| Course Code | Courses Name | Course Type | L - T - P | Credits | Total Hours |
|---|---|---|---|---|---|
| EE523 | Electrical Machine Design | Theory | 3 - 0 - 0 | 3 | 42 |

### 7.19.1 Objectives:

The objectives of studying this course are to,

1. Introduce fundamental principles and challenges involved in electrical machine design.
2. Analyze the design methodology and performance aspects of transformers.
3. Develop an understanding of AC machine design including induction and synchronous machines.
4. Study mechanical, thermal, and cooling aspects related to electrical machines.
5. Apply computer-aided design tools and optimization methods in electrical machine design.

### 7.19.2 Course Outcome:

At the completion of this course, the student shall acquire knowledge and ability to,

1. CO1: Explain material selection and key principles governing the electrical, magnetic, and thermal aspects of machine design.
2. CO2: Design the core, winding, and cooling system of single and three-phase transformers based on performance requirements.
3. CO3: Analyze and design various components of induction and synchronous machines using output equations and dimensional parameters.
4. CO4: Evaluate mechanical and thermal stress factors for reliable and efficient machine operation.
5. CO5: Apply modern design techniques such as FEM and optimization using CAD tools in electrical machine

### 7.19.3 CO - PO Mapping:

| **Relationship of Course Outcomes to Program Outcomes** | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **CO ↓** | **PO** | | | | | | | | | | | |
| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
| CO1 | H | M | M | L | L | L | L | L | L | L | L | M |
| CO2 | H | H | H | M | M | L | L | L | L | L | M | M |
| CO3 | H | H | H | M | M | L | L | L | M | L | M | M |
| CO4 | H | M | M | M | M | L | M | L | L | L | M | M |
| CO5 | M | M | H | H | H | L | M | L | M | M | M | H |
| **H = High correlation; M = Medium correlation; L = Low correlation** | | | | | | | | | | | | |

### 7.19.4 Syllabus:

**Module 1:** **Fundamentals of Machine Design:** Introduction to Electrical Machine Design - Importance, objectives, and challenges. Materials Used - Magnetic materials, materials used for conductor, type of insulation, cooling methods. Basic Design Principles - Magnetic circuits, Electrical loading and magnetic loading, Thermal loading, Estimation of losses and efficiency considerations.

**Module 2:** **Design of Transformers:** Output equations for single and three-phase transformers, Core and winding design, Cooling methods and mechanical considerations, Regulation, losses, and short-circuit impedance.

**Module 3:** **Design of AC Machines:** Induction Motors - Output equations and main dimensions, Design of stator, rotor (squirrel cage & wound rotor), Performance characteristics — torque, slip, efficiency, Ventilation and cooling systems. Synchronous Machines: Output equations and main dimensions, Stator and rotor design (cylindrical and salient pole type), Field winding design, Cooling methods and performance analysis.

**Module 4:** **Mechanical, Thermal, and Modern Design Techniques:** Mechanical and Thermal Design Considerations - Shaft design and mechanical stresses, Bearings, cooling systems, and ventilation, Heat dissipation, temperature rise, and thermal loading. Computer-Aided Machine Design (CAMD) - Introduction to CAD tools and software, Finite Element Method (FEM) in electrical machine analysis, Optimization techniques — cost, size, weight, performance, Case studies on modern electrical machine designs.

### 7.19.5 Learning Resources:

#### 7.19.5.1 Text Books:

1. A. K. Sawhney A course in Electrical Machine Design, Dhanpat Rai & Co., New Delhi. 2013, 6th Edition.
2. Juha Pyrhonen, Tapani Jokinen, Valeria Hrabovcova, Design of Rotating Electrical Machines, John Wiley & Sons, New Delhi, 2013.
3. M.K. Giridharan, Electrical Systems Design, I K International, 2015.
4. S.K. Sen, Principles of Electrical Machine Design with Computer Programs, Oxford & IBH Publishing Company Pvt. Limited, 2006, 2nd Edition.
5. K.G. Upadhyay, Design of Electrical Machines, New Age International Publishers, 2008, 1st Edition.

#### 7.19.5.2 Reference Books:

1. Alexander Gray, Electrical Machine Design, McGraw Hill, New York, 2008.
2. M. G. Say, Performance and Design of AC Machines, Pitman Pub, 2002.
3. E Clayton & N. N. Hancook, Performance and design of DC machines, CBSPub., 1998, 3rd Edition.

## 7.20 Special Electric Machines

| Course Code | Courses Name | Course Type | L - T - P | Credits | Total Hours |
|---|---|---|---|---|---|
| EE523 | Special Electric Machines | Theory | 3 - 0 - 0 | 3 | 42 |

### 7.20.1 Objectives:

The objectives of studying this course are to,

1. Introduce the concepts and classifications of special electrical machines and their applications.
2. Explain the construction, operation, and control of stepper and switched reluctance motors.
3. Impart knowledge on permanent magnet machines including BLDC and PMSM.
4. Analyze the principles and performance of synchronous reluctance and linear machines.
5. Explore the construction and applications of emerging machines such as hysteresis, repulsion, axial, and transverse flux motors.

### 7.20.2 Course Outcome:

At the completion of this course, the student shall acquire knowledge and ability to,

1. CO1: Classify different types of special machines and describe their unique features and uses.
2. CO2: Analyze the working principles, characteristics, and control of stepper motors and SRMs.
3. CO3: Explain the operation, comparison, and control strategies of BLDC and PMSM drives.
4. CO4: Evaluate the performance of synchronous reluctance and linear machines in advanced systems.
5. CO5: Demonstrate understanding of the construction and applications of hysteresis, repulsion, axial, and transverse flux machines.

### 7.20.3 CO - PO Mapping:

| **Relationship of Course Outcomes to Program Outcomes** | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **CO ↓** | **PO** | | | | | | | | | | | |
| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
| CO1 | H | M | L | - | - | - | - | - | - | L | - | M |
| CO2 | H | H | M | M | M | - | - | - | - | - | - | M |
| CO3 | H | H | M | M | H | - | - | - | - | - | - | M |
| CO4 | H | H | M | H | M | - | - | - | L | M | - | H |
| CO5 | H | M | L | - | L | - | M | M | L | M | - | M |
| **H = High correlation; M = Medium correlation; L = Low correlation** | | | | | | | | | | | | |

### 7.20.4 Syllabus:

**Module 1:** **Introduction:** Introduction to special machines, Limitations of conventional machines, types, differences, applications. Overview of operation and control of Permanent Magnet Synchronous Machines (PMSM).

**Module 2:** **Stepper Motors and Switched Reluctance Motors (SRM):** Stepper Motors - Construction, Working principles, Torque generation, Characteristics, Drive circuits, Applications in automation and robotics. Switched Reluctance Motors (SRM) - Construction, Principle of operation, Torque production, Characteristics, Control techniques, Applications in electric vehicles and industrial drives..

**Module 3:** **Permanent Magnet Machines:** BLDC Motors: Construction, Working, Characteristics, Control methods, Applications. Comparison between BLDC and PMSM drives.

**Module 4:** **Synchronous Reluctance and Linear Machines:** Synchronous Reluctance Machines: Construction, Operating principle, Torque production, Performance analysis, Advantages, and Applications. Linear Machines: Linear Induction Motors (LIM), Linear Synchronous Motors (LSM), Construction, Working principles, Applications in transportation systems (Maglev trains), actuators, and automation systems..

**Module 5:** **Other Special Machines:** Hysteresis Motors: Construction, Principle, Characteristics, Applications. Repulsion Motors: Types, Working, Characteristics, Applications. Axial Flux and Transverse Flux Machines: Construction, Principle, Performance characteristics, Applications in EVs and wind turbines.

### 7.20.5 Learning Resources:

#### 7.20.5.1 Text Books:

1. K. Venkataratnam, Special Electrical Machines, Universities Press, 2009, 1st Edition.
2. E.G. Janardanan, Special Electrical Machines, Prentice Hall India, 2014, 1st Edition.
3. T.J.E. Miller, Brushless Permanent-Magnet and Reluctance Motor Drives, Oxford University Press, 1989, 1st Edition.
4. R. Krishnan, Switched Reluctance Motor Drives: Modelling, Simulation, Analysis, Design, and Applications, CRC Press, 2001, 1st Edition.
5. R. Krishnan, Permanent Magnet Synchronous and Brushless DC Motor Drives, CRC Press, 2010, 1st Edition.

#### 7.20.5.2 Reference Books:

1. C. K. Sankaran, Special Electrical Machines and Applications, Yes Dee Publishing, 2017, 1st Edition.
2. E.G. Janardanan, Special Electrical Machines, Prentice Hall India, 2014, 1st Edition.

# 7.21 Renewable Energy Systems

| Course Code | Courses Name | Course Type | L - T - P | Credits | Total Hours |
|---|---|---|---|---|---|
| EE530 | Renewable Energy Systems | Theory | 3 - 0 - 0 | 3 | 42 |

## 7.21.1 Objectives:

The objectives of studying this course are to,

1. Understand the significance of renewable energy in the current energy landscape.
2. Explore various renewable energy sources and their technologies.
3. Analyse the integration of renewable energy into existing power systems.
4. Assess the environmental and economic impacts of renewable energy deployment.

## 7.21.2 Course Outcome:

At the completion of this course, the student shall acquire knowledge and ability to,

1. CO1 : Enable the student to design and evaluate a renewable power generator at system level
2. CO2: Enable the student to evaluate the feasibility of a particular renewable energy source based on resource availability and techno economic considerations
3. CO3: Enable the student identify the potential benefits and challenges associated with replacing a conventional energy source with an alternate source
4. CO4: Enable the student to understand the benefits and challenges associated with integrating renewable energy sources with utility grid

## 7.21.3 CO - PO Mapping:

| **Relationship of Course Outcomes to Program Outcomes** | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **CO ↓** | **PO** | | | | | | | | | | | |
| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
| CO1 | H | M | H | L | M | L | H | L | M | L | L | H |
| CO2 | H | M | M | L | M | L | H | L | L | L | H | M |
| CO3 | H | L | L | L | L | M | H | L | L | L | L | L |
| CO4 | H | L | L | L | L | M | H | L | L | L | L | L |
| **H = High correlation; M = Medium correlation; L = Low correlation** | | | | | | | | | | | | |

**Module 1:** **Introduction to Renewable Energy:** Global and national energy scenarios., Need for sustainable and renewable energy sources., Overview of different renewable energy technologies/ options.

**Module 2:** **Solar Energy:** Solar radiation principles and measurement, Solar thermal energy conversion systems, Photovoltaic (PV) cell fundamentals, materials, and technologies., Design and evaluation of PV power plants.

**Module 3:** **Wind Energy:** Wind characteristics and resource assessment, Aerodynamics of wind turbines, Wind turbine technologies and configurations, Integration of wind energy into the power grid.

**Module 4:** **Other energy sources:** Hydropower-Types of hydroelectric power plants, small and large-scale hydro systems, pumped hydro, Biomass Energy, Geothermal and Ocean Energy.

**Module 5:** **Energy Storage and Integration:** Importance of energy storage in renewable systems, Battery technologies and applications, Grid integration challenges and smart grid solutions.

**Module 6:** **Environmental and Economic Aspects:** Life cycle assessment of renewable energy systems, Economic evaluation and policy considerations, Environmental impacts and mitigation strategies.

## 7.21.4 Learning Resources:

### 7.21.4.1 Text Books:

1. S P Sukhatme & J K Nayak, "Solar Energy: Principles of thermal collection and Storage," McGraw Hill Education, 2008 ($3^{rd}$ Ed.)
2. Chetan Singh Solanki, "Solar Photovoltaics: fundamentals, Technologies and Applications," Prentice Hall of India, 2015 ($3^{rd}$ Ed.)
3. S N Bhadra, D Kastha & S Banerjee, "Wind Electric Systems," Oxford Publications, 2007 ($2^{nd}$ Ed.)

### 7.21.4.2 Reference Books:

1. Twidell, J. & Weir T., "Renewable Energy Resources," Taylor & Francis, 2015 ($3^{rd}$ Ed.)
2. D.Y. Goswami, F.Kreith & J.F. Kreider, "Principles of Solar Engineering," Taylor and Francis, Philadelphia, 2022 ($4^{th}$ Ed.)
3. Boyle G., "Renewable Energy: Power for a Sustainable Future," Oxford University Press, 2012 ($3^{rd}$ Ed.)

## 7.22 Electric Vehicles

| Course Code | Courses Name | Course Type | L - T - P | Credits | Total Hours |
|---|---|---|---|---|---|
| EE531 | Electric Vehicles | Theory | 3 - 0 - 0 | 3 | 42 |

### 7.22.1 Objectives:

The objectives of studying this course are to,

1. Understand the architecture and components of Electric Vehicles (EVs) and compare them with Internal Combustion Engine (ICE) vehicles.
2. Explore different types of EVs (BEVs, HEVs, FCEVs, PHEVs), their configurations, modes of operation, and EV-grid integration.
3. Study vehicle mechanics, design parameters, and dynamic equations governing EV performance and traction.
4. Learn the fundamentals of power electronic converters and their role in EV power management.
5. Analyze motor drive technologies used in EVs, including Induction Motors, Permanent Magnet Synchronous Motors (PMSM), and Switched Reluctance Motors (SRM).
6. Understand EV charging technologies, battery management systems, and their impact on performance and sustainability.

### 7.22.2 Course Outcome:

At the completion of this course, the student shall acquire knowledge and ability to,

1. CO1 : Understand the architecture and components of Electric Vehicles (EVs), and evaluate EV configurations, charging topologies, and grid integration.
2. CO2: Analyze vehicle dynamics, and evaluate propulsion & traction parameters across different EV modes.
3. CO3: Design and assess DC/DC and DC/AC power converters used in EVs, including battery charging and cell balancing systems.
4. CO4: Understand the operation of Battery Management Systems (BMS) and its role in EV energy systems.
5. CO5: Apply vector control and converter realization for electric drives, including IM, PMSM, and SRM drives.

### 7.22.3 CO - PO Mapping:

| **Relationship of Course Outcomes to Program Outcomes** | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **CO ↓** | **PO** | | | | | | | | | | | |
| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
| CO1 | H | M | M | M | M | L | H | M | L | L | L | H |
| CO2 | H | H | M | M | L | L | M | L | L | L | L | M |
| CO3 | H | M | H | H | H | L | M | L | L | M | M | H |
| CO4 | H | M | H | M | M | L | H | M | L | L | L | H |
| CO5 | H | H | H | M | H | L | M | L | L | M | M | H |
| **H = High correlation; M = Medium correlation; L = Low correlation** | | | | | | | | | | | | |

### 7.22.4 Syllabus:

**Module 1:** **EV Architecture and Technology:** Introduction to EV and its components -Comparison of EV with IC engine vehicles- Types of EV and configurations-modes of operation- Motor-drive technologies-Energy source technologies- Vehicle grid interface, EV charging topologies, impact of EV- grid integration.

**Module 2:** **Vehicle mechanics:** Vehicle design parameters-Vehicle dynamics- Propulsion power, Traction force, drive cycle, Traction force equation and vehicle dynamic equation in different modes of operation of EV.

**Module 3:** **Converters for EV:** Performance and controller design of DC/DC converters and DC/AC power converters, converters for on board charging and cell balancing, Battery Management system.

**Module 4:** **Drives for EV:** Power converter realization and vector control of Induction motor drives and PMSM drives, power converter realization and control of Switched Reluctance Motor Drive .

### 7.22.5 Learning Resources:

#### 7.22.5.1 Text Books:

1. Iqbal Husain, "Electric and Hybrid Vehicles, Design Fundamentals," CRC Press, 2010 ($2^{nd}$ Ed.)

2. Mehrdad Ehsani, Yimin Gao & Stefano Longo & Kambiz Ebrahimi, "Modern Electric, Hybrid Electric, and Fuel Cell Vehicles," CRC Press, 2018 ($3^{rd}$ Ed.)

3. James Larminie, "Electric Vehicle Technology Explained", John Wiley & Sons, 2012 ($2^{nd}$ Ed.)

4. Behrooz Mashadi & David Crolla, "Vehicle Powertrain Systems,“ John Wiley & Sons, 2012 ($1^{st}$ Ed.)

#### 7.22.5.2 Reference Books:

1. K Wang Hee Na, "AC Motor Control & Electrical Vehicle Application," CR Press, Taylor & Francis Group, 2020 ($2^{nd}$ Ed.)

2. Ali Elamadi, "Handbook of Automotive Power Electronics and Drives," CRC publishers, 2012.

## 7.23 Autonomous Vehicles and Drones

| Course Code | Courses Name | Course Type | L - T - P | Credits | Total Hours |
|---|---|---|---|---|---|
| EE532 | Autonomous Vehicles and Drones | Theory | 3 - 0 - 0 | 3 | 42 |

### 7.23.1 Objectives:

The objectives of studying this course are to,

1. Provide a comprehensive understanding of autonomous vehicles and drones, focusing on electrical systems, power electronics, motor control, and AI-driven decision-making.
2. Explore sensor fusion, localization, path planning, and regulatory frameworks for autonomous mobility and industrial applications.
3. Integrate cybersecurity, energy management, and communication technologies for safe and efficient autonomous systems.

### 7.23.2 Course Outcome:

At the completion of this course, the student shall acquire knowledge and ability to,

1. CO1 : Understand the electrical architecture, power systems, and control strategies of autonomous vehicles and drones.
2. CO2 : Implement perception and sensor fusion techniques for real-time decision-making.
3. CO3 : Apply motor control and power electronics concepts to autonomous mobility systems.
4. CO4 : Analyse cybersecurity, communication, and energy management in autonomous systems.
5. CO5 : Design, simulate, and prototype autonomous electric vehicles and UAVs for real-world applications.

### 7.23.3 CO - PO Mapping:

| **Relationship of Course Outcomes to Program Outcomes** | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **CO ↓** | **PO** | | | | | | | | | | | |
| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
| CO1 | H | H | M | M | L | L | L | L | L | L | L | M |
| CO2 | H | H | H | H | H | L | H | L | L | L | M | H |
| CO3 | H | H | H | H | M | M | H | L | L | L | M | H |
| CO4 | H | H | H | H | M | M | M | L | L | L | M | M |
| CO5 | H | H | H | H | H | H | H | L | L | L | H | H |
| **H = High correlation; M = Medium correlation; L = Low correlation** | | | | | | | | | | | | |

### 7.23.4 Syllabus:

**Module 1:** **Fundamentals of Autonomous Vehicles and Drones:** Evolution and classification of autonomous vehicles and UAVs. Electrical system architecture: Power distribution, battery management, motor control. Sensors and actuators: LiDAR, radar, cameras, GPS, and IMU. Case Study on Electrical architecture of *Tesla's Autopilot* and drone-based delivery systems.

**Module 2:** **Perception, Sensor Fusion, and Control:** Signal processing for autonomous systems. Sensor fusion techniques: Kalman filtering, particle filtering, and deep learning-based perception. Feedback control strategies: PID, Model Predictive Control (MPC), Adaptive Control. Case Study on Vision-based navigation in autonomous drones.

**Module 3:** **Localization, Mapping, and Path Planning:** SLAM (Simultaneous Localization and Mapping) in autonomous mobility. GPS-based and vision-based localization techniques. Path planning algorithms: A*, Dijkstra, RRT, and reinforcement learning-based path optimization. Case Study on Autonomous vehicle path planning in dynamic urban environments.

**Module 4:** **Power Electronics and Motor Control for Autonomous Systems:** Electric propulsion: BLDC, PMSM, induction motor drives for autonomous mobility. Motor controllers: Inverters, DC-DC converters, and regenerative braking. Battery management systems (BMS) and energy-efficient operation. Case Study on UAV power management and electric drivetrain efficiency in self-driving cars.

**Module 5:** **AI, Communication, and Cybersecurity in Autonomous Systems:** Artificial intelligence and reinforcement learning for decision-making. Vehicle-to-Everything (V2X) communication and networking. Cybersecurity risks and mitigation in autonomous mobility. Regulatory challenges: FAA, DGCA, UNECE, and ISO standards. Case Study on Secure V2G (Vehicle-to-Grid) communication in electric autonomous vehicles.

### 7.23.5 Learning Resources:

#### 7.23.5.1 Text Books:

1. Siegwart, Nourbakhsh & Scaramuzza, "Introduction to Autonomous Mobile Robots," MIT Press, 2010 ($2^{nd}$ Ed.)
2. Robert Bosch, "Automotive Handbook," John Wiley & Sons, 2022 ($11^{th}$ Ed.)
3. Sebastian Thrun, Wolfram Burgard & Dieter Fox, "Probabilistic Robotics," MIT Press, 2005
4. Bimal K. Bose, "Modern Power Electronics and AC Drives," Prentice Hall, 2001

#### 7.23.5.2 Reference Books:

1. Peter Corke, "Robotics, Vision & Control: Fundamental Algorithms in MATLAB," Springer, 2017 ($2^{nd}$ Ed.)
2. Richard Szeliski, "Computer Vision: Algorithms and Applications," Springer, 2022 ($2^{nd}$ Ed.)
3. Raj Madhavan, "Autonomous Ground Vehicles: Technology, Applications & Challenges," Springer, 2011
4. M. Santos & V. Kumar, "Drone Technology: Principles, Applications and Future Trends," John Wiley & Sons, 2023 ($1^{st}$ Ed.)
5. IEEE Transactions on Intelligent Vehicles (T-IV), Vehicular Technology, Intelligent Transportation Systems.

# 7.24 Robotics and Automation

| Course Code | Courses Name | Course Type | L - T - P | Credits | Total Hours |
|---|---|---|---|---|---|
| EE533 | Robotics and Automation | Theory | 3 - 0 - 0 | 3 | 42 |

## 7.24.1 Objectives:

The objectives of studying this course are to,

1. Understand the fundamentals of automation and robotics.
2. Learn the working principles of robots and their components.
3. Explore various applications of robots in industrial and service sectors.
4. Study the integration of automation in modern engineering systems.

## 7.24.2 Course Outcome:

At the completion of this course, the student shall acquire knowledge and ability to,

1. CO1 : Learn robot anatomy of robot, configuration of different robots, and Describe construction and working of different types robots
2. CO2. Understand actuator, feedback components and programming for robotics
3. CO3: Analyze Sensing and Vision Systems for Robotics:
4. CO4: Understand basic concepts of automation and various controls required for automation
5. CO5: Implement the sequential and distributed control systems for automation

## 7.24.3 CO - PO Mapping:

| **Relationship of Course Outcomes to Program Outcomes** | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **CO ↓** | **PO** | | | | | | | | | | | |
| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
| CO1 | H | H | M | M | M | M | L | L | L | L | L | M |
| CO2 | H | H | H | H | H | M | L | L | L | L | L | H |
| CO3 | H | H | H | H | H | M | L | L | L | L | L | H |
| CO4 | H | H | H | M | H | M | L | L | L | L | M | H |
| CO5 | H | H | H | H | M | M | L | L | L | L | M | H |
| **H = High correlation; M = Medium correlation; L = Low correlation** | | | | | | | | | | | | |

### 7.24.4 Syllabus:

**Module 1:** **Introduction to Robotics:** Definition of robot, basic concepts, robot configurations, basic robot motions, point to point control, continuous path control, Components and operations, basic actuation mechanisms, robot actuation and feedback, manipulators –director and inverse kinematics, coordinate transformation, brief robot dynamics. Types of robot and effectors, grippers, tools as end effectors, robot end - effort interface.

**Module 2:** **Sensors, actuators and vision system for Robotics:** Sensory equipment, range sensing, proximity sensing, touch sensing, force and torque sensing, signal conditioning equipment, encoders etc., Camera-based robotic sensing, robotic vision systems, robotic actuators, robot programming,, AI and robotics.

**Module 3:** **Automation:** Benefits and Impact of Automation on Manufacturing and Process Industries; Architecture of Industrial Automation Systems. Data Acquisition systems and PC based automation. PID Control, Controller Tuning, Special Control Structures, Feedforward and Ratio Control, Predictive Control, Control of Systems with Inverse Response, Cascade Control. Process and Instrumentation Diagrams.

**Module 4:** **Sequence Control:** Programmable Logic Controllers (PLCs) and Relay Ladder Logic, Scan Cycle, RLL Syntax, Structured Design Approach, Advanced RLL Programming, distributed control systems (DCS); Control of Machine tools, introduction to CNC Machines.

### 7.24.5 Learning Resources:

#### 7.24.5.1 Text Books:

1. R.K.Mittal and I.J.Nagrath, "Robotics and Control, Tata McGraw Hill, New Delhi, 2017.
2. John J Craig,"Introduction to Robotics Mechanics and Control," Pearson Education, 2009 ($3^{rd}$ Ed.)
3. K. S. Fu., R. C. Gonalez, C. S. G. Lee, "Robotics control sensing, Vision and Intelligence," McGraw Hill International Editions, 1987.
4. Michelle P. Groover, Mitchell Weiss, "Industrial Robotics, Technology, Programming, and Applications," McGraw Hill International Editions, 1986
5. B K Ghosh, "Control in Robotics and Automation: Sensor Based Integration," Allied Publishers, Chennai, 1998
6. R Kelly, D. Santibanez, LP Victor and Julio Antonio,"Control of Robot Manipulators in Joint Space," Springer, 2005.
7. R M Murray, Z. Li and SS Sastry, "A Mathematical Introduction to Robotic Manipulation," CRC Press, 1994

#### 7.24.5.2 Reference Books:

1. Frank. D, Petruzella, "Programmable Logic Controllers," McGraw Hill, 2019 ($5^{th}$ Ed.)
2. Ernest O. Doebelin, Dhanesh N. Manik, "Doebelin's Measurement Systems," McGraw Hill, 2019 ($7^{th}$ Ed.)
3. G. Stephanopoulous, "Chemical Process Control: An introduction to Theory and Practice", EEE
4. S. Mukhopadhyay, S. Sen and A. K. Deb, "Industrial Instrumentation, Control and Automation," Jaico Publishing House, 2012

## 7.25 Energy Storage Systems

| Course Code | Courses Name | Course Type | L - T - P | Credits | Total Hours |
|---|---|---|---|---|---|
| EE534 | Energy Storage Systems | Theory | 3 - 0 - 0 | 3 | 42 |

### 7.25.1 Objectives:

The objectives of studying this course are to,

1. Understand the fundamentals of various electrical energy storage systems.
2. Explore the working principles and classifications of energy storage technologies.
3. Analyze key performance parameters of different battery technologies.
4. Evaluate the applications of energy storage in power systems and renewable integration.
5. Understand battery management systems (BMS) and safety considerations.
6. Explore emerging trends in advanced energy storage technologies.

### 7.25.2 Course Outcome:

At the completion of this course, the student shall acquire knowledge and ability to,

1. CO1 : Grasp the basic principles of Energy Storage Systems and effectively apply them to solve engineering problems.
2. CO2 : Analyse the significance of Energy Storage Systems and its wide-range of possibilities/applications.
3. CO3 : Comprehend the fundamental concepts of Storage Systems, battery parameters, battery energy storage systems, protection aspects, grid integration challenges and their practical applications.
4. CO4 : Evaluate various aspects of Energy Storage Systems.

### 7.25.3 CO - PO Mapping:

| **Relationship of Course Outcomes to Program Outcomes** | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **CO ↓** | **PO** | | | | | | | | | | | |
| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
| CO1 | H | H | H | M | M | M | H | H | H | M | M | H |
| CO2 | H | H | H | M | M | M | H | H | H | M | M | H |
| CO3 | H | H | H | M | M | M | H | H | H | M | M | H |
| CO4 | H | H | H | M | M | M | H | H | H | M | M | H |
| **H = High correlation; M = Medium correlation; L = Low correlation** | | | | | | | | | | | | |

### 7.25.4 Syllabus:

**Module 1:** **Introduction:** Importance of energy storage in power systems, Classification of energy storage technologies, Introduction to various Energy Storage technologies – Electrochemical, Mechanical, Fly Wheel, Battery, Super/Ultra Capacitor, Thermal, Hydrogen, Fuel Cell, any other latest technologies. Applications of storage for grid stability, renewable energy integration, electric vehicles, etc.

**Module 2:** **Battery Storage:** Basic battery parameters and their estimation techniques -Cells & Batteries, Nominal voltage and capacity, C rate, State of Charge, State of Health, Energy and power density, series and parallel operation, Charging and Discharging Process, Overcharge and Undercharge, Modes of Charging, Equivalent-circuit models.

**Module 3:** **Battery Energy Storage System (BMS):** BESS Functionality, Voltage Sensing, Temperature Sensing, Current Sensing, High-voltage contactor control, Isolation sensing, Thermal control, Communication Interface, Range estimation, State-of-charge estimation, Cell Balancing, Cell total energy, cell total power. BESS Types - Centralized, Modular, Master-Slave, Distributed. Comparison of the different topologies.

**Module 4:** **Protection:** Protection of BESS, Thermal management system and its types, Impact of Thermal management on battery performance, Cell Balancing and its types, Communication systems in BESS.

**Module 5:** **Grid Integration:** BESS Integration with renewable energy sources, issues and solutions, Energy management strategies for on-grid and off-grid applications, Energy management strategies for vehicular applications, Charging infrastructure and protocols, Emerging Trends and Technologies. Review of recent technologies.

### 7.25.5 Learning Resources:

#### 7.25.5.1 Text Books:

1. Davide Andrea, "Battery Management Systems for Large Lithium-ion Battery Packs," Artech House, 2010
2. Plett, Gregory L, "Battery management systems, Volume I: Battery modeling," Artech House, 2015.
3. Plett, Gregory L, "Battery management systems, Volume II: Equivalent-circuit methods," Artech House, 2015.

#### 7.25.5.2 Reference Books:

1. Bergveld H.J., Kraits W.S., Notten P.H.L, "Battery Management Systems - Design by Modelling" Philips Research Book Series, 2002
2. Pop Valer, et al, "Battery management systems: Accurate state-of-charge indication for battery-powered applications," Vol. 9. Springer Science & Business Media, 2008.
3. Halil S. Hamut, Nader Javani, Ibrahim Dinçer "Thermal Management of Electric Vehicle Battery Systems" John Wiley & Sons, 2016.
4. Relevant research articles

## 7.26 Advanced Control System

| Course Code | Courses Name | Course Type | L - T - P | Credits | Total Hours |
|---|---|---|---|---|---|
| EE540 | Advanced Control System | Theory | 3 - 0 - 0 | 3 | 42 |

### 7.26.1 Objectives:

The objectives of studying this course are to,

1. Gain a comprehensive understanding of the description and stability of both linear and non-linear systems.
2. Examine conventional techniques used for the analysis of non-linear systems and their practical applications
3. Understand the state-space representation of continuous-time systems for effective modeling and analysis
4. Study various stability criteria and methods to assess the stability of linear and non-linear systems
5. Utilize mathematical and computational tools for analyzing and solving system dynamics.

### 7.26.2 Course Outcome:

At the completion of this course, the student shall acquire knowledge and ability to,

1. CO1 : Understand the basic properties of multivariable linear systems such as controllability, observability, and transfer functions.
2. CO2 : Demonstrate the solution of linear systems using state space approach.
3. CO3 : Design and Analyze controllers and Observers
4. CO4 : Describe and evaluate nonlinear dynamical systems and apply linearization techniques when appropriate.

### 7.26.3 CO - PO Mapping:

| **Relationship of Course Outcomes to Program Outcomes** | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **CO ↓** | **PO** | | | | | | | | | | | |
| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
| CO1 | H | H | M | M | M | M | L | L | L | L | L | M |
| CO2 | H | H | H | H | H | M | L | L | L | L | L | H |
| CO3 | H | H | H | H | H | M | L | L | L | L | L | H |
| CO4 | H | H | H | M | H | M | L | L | L | L | M | H |
| **H = High correlation; M = Medium correlation; L = Low correlation** | | | | | | | | | | | | |

### 7.26.4 Syllabus:

**Module 1:** **State Space Description:** State space representations of systems, state variable modelling of dynamical systems, transfer functions, solution of state equation, transient response, stability of linear systems, preliminary tools on stability analysis.

**Module 2:** **System Analysis:** controllability, observability, duality, equivalent systems, system decomposition, diagonal form, controllable and observable canonical forms, state space realizations and minimal realizations.

**Module 3:** **State Feedback Design:** Linear State variable feedback, pole placement for single and multi-variable systems, optimal control concept, solution of linear quadratic regulator problem, system decoupling, direct transfer function design procedures.

**Module 4:** **State Estimation and Servo Control:** State observer, reduced order observers, combined observer-controller system, integral control, asymptotic tracking and regulation, robust servo control design.

**Module 5:** **Nonlinear system Dynamics & Control:** State-plane analysis, principles of linearization, describing function methods, introduction to nonlinear control techniques: Sliding mode control, feedback linearization methods.

### 7.26.5 Learning Resources:

#### 7.26.5.1 Text Books:

1. K. Ogata, “Modern Control Engineering”, Pearson, 2010 ($6^{th}$ Ed.)
2. Gopal M., “Control Systems Principles and Design,” Tata McGraw Hill, 2012 ($4^{th}$ Ed.)
3. H.K. Khalil, “Nonlinear Systems”, Prentice Hall, NJ, 2002 ($3^{rd}$ Ed.)
4. R. C. Dorf and R. H. Bishop,“Modern Control Systems”, Prentice Hall, 2016 ($13^{th}$ Ed.)

#### 7.26.5.2 Reference Books:

1. S.H. Zak, “Systems and Control,” Oxford Univ. Press, 2003
2. Alberto Isidori, “Nonlinear Control Systems,” Springer Verlag, 1995
3. Jean-Jacques E. Slotine & Weiping Li, “Applied Nonlinear Control,” Prentice-Hall, NJ, 1991

## 7.27 Embedded Systems Design

| Course Code | Courses Name | Course Type | L - T - P | Credits | Total Hours |
|---|---|---|---|---|---|
| EE541 | Embedded Systems Design | Theory | 3 - 0 - 0 | 3 | 42 |

### 7.27.1 Objectives:

The objectives of studying this course are to,

1. Gain insights into the fundamentals, architecture, and applications of embedded systems.
2. Develop knowledge of the design, implementation, and testing of embedded systems.
3. Understand the principles, features, and functionalities of real-time operating systems.
4. Learn about microcontroller architecture, programming, and interfacing techniques for embedded applications.

### 7.27.2 Course Outcome:

At the completion of this course, the student shall acquire knowledge and ability to,

1. CO1 : Understand the architecture of Embedded Systems and its development life cycle
2. CO2: Interface and program sensors and actuators for embedded applications
3. CO3: Design and Analyse Real-time operating systems
4. CO4: Design and Analyse Embedded Networks for different applications

### 7.27.3 CO - PO Mapping:

| **Relationship of Course Outcomes to Program Outcomes** | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **CO ↓** | **PO** | | | | | | | | | | | |
| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
| CO1 | H | H | M | M | M | M | L | L | L | L | L | M |
| CO2 | H | H | H | H | H | M | L | L | L | L | L | H |
| CO3 | H | H | H | H | H | M | L | L | L | L | L | H |
| CO4 | H | H | H | M | H | M | L | L | L | L | M | H |
| **H = High correlation; M = Medium correlation; L = Low correlation** | | | | | | | | | | | | |

### 7.27.4 Syllabus:

**Module 1:** Embedded System Architectures - ARM processor and SHARC processor - architectural design - memory organization-data operation-bus configurations. System on-chip, scalable bus architectures, Design example: Alarm clock, hybrid architectures., Embedded Product development life cycle, program modelling concepts

**Module 2:** Sensor and Actuator I/O – ADC, DAC, timers, Servos, Relays, stepper motors, H-Bridge, CODECs, FPGA, ASIC, diagnostic port..

**Module 3:** Real time operating system: Introduction to RTOS, Comparison of Embedded RTOS, Consideration of RTOS for programming, System architecture of RTOS, Thread creation, thread management, synchronization mechanism for RTOS, Semaphores, message Queues, Pipes, Interrupts for RTOS.

**Module 4:** Embedded Networks – Distributed Embedded Architecture – Hardware and Software Architectures, Networks for embedded systems– I2C, CAN Bus, Ethernet, Internet, SPI, SCI (RS232, RS485), I2C, 10CAN, Field-bus (Profibus), USB (v2.0), Bluetooth, Zig-Bee Network-based design– Communication Analysis, system performance Analysis, Hardware platform design, Allocation and scheduling, Design Example: Elevator Controller.

**Module 5:** System Design – Specification, Requirements and Architectural design of PBX systems, Set-top box, Ink-jet printer, Laser printer, Personal digital Assistants.

### 7.27.5 Learning Resources:

#### 7.27.5.1 Text Books:

1. David Simon, "An Embedded Software Primer," Addison Wesley, 2000
2. Shibu K.V.: "Introduction to Embedded Systems," Tata McGraw Hill, 2013
3. Steve Heath, "Embedded Systems Design," Publisher Butterworth-Heinemann, 2003
4. Wyne Woff "Principles of Embedded computing system design," Morgan Koffman publication, 2001
5. GaIski D. Vahid F., Narayan S., "Specification and Design of Embedded Systems," Prentice Hall, 2000
6. C.M Krishna, Kang G. Shin, "Real time systems," McGraw Hill, 1997 ($3^{rd}$ Ed.)

#### 7.27.5.2 Reference Books:

1. J.W. Valvano, "Embedded Microcomputer System: Real Time Interfacing," Brooks/Cole, 2000
2. Qing Li, "Real Time Concepts for Embedded Systems," Elsevier, 2001
3. Herma K., "Real Time Systems: Design for Distributed Embedded Applications," Springer, 2001 ($2^{nd}$ Ed.)

# 7.28 Embedded Control System

| Course Code | Courses Name | Course Type | L - T - P | Credits | Total Hours |
|---|---|---|---|---|---|
| EE542 | Embedded Control System | Theory | 3 - 0 - 0 | 3 | 42 |

## 7.28.1 Objectives:

The objectives of studying this course are to,

1. Investigate various sensing, actuation units and other required accessories with embedded controller.
2. Build a complete modern embedded control system for intended applications.
3. Develop and select suitable smart sensors, actuators, with associated knowledge of interface electronics and signal conditioning for cutting-edge applications.
4. Implement smart integrated MEMS devices and renewable energy harvesting based self-powered embedded system.

## 7.28.2 Course Outcome:

At the completion of this course, the student shall acquire knowledge and ability to,

1. CO1 : Understand the significance of embedded sensors, actuators, and signal conditioning circuits for embedded control systems.
2. CO2: Implement interfacing techniques for resistive and capacitive sensors, considering linearization and error reduction methods.
3. CO3: Design and Analyse modern embedded control system
4. CO4: Design of smart sensors , actuators and MEMS devices
5. CO5: Apply embedded sensing and actuation concepts to real-world case studies in electrical engineering applications.

## 7.28.3 CO - PO Mapping:

| **Relationship of Course Outcomes to Program Outcomes** | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **CO ↓** | **PO** | | | | | | | | | | | |
| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
| CO1 | H | H | M | M | M | M | L | L | L | L | L | M |
| CO2 | H | H | H | H | H | M | L | L | L | L | L | H |
| CO3 | H | H | H | H | H | M | L | L | L | L | L | H |
| CO4 | H | H | H | M | H | M | L | L | L | L | M | H |
| CO5 | H | H | H | H | M | M | L | L | L | L | M | H |
| **H = High correlation; M = Medium correlation; L = Low correlation** | | | | | | | | | | | | |

### 7.28.4 Syllabus:

**Module 1:** Introduction to embedded control system; Significance of embedded sensors, various types of important embedded sensors, actuators: based on thermal, mechanical, electrical, magnetic, optical, chemical, smart material and meta material, Signal conditioning circuits; Serial Communication protocols for interfacing.

**Module 2:** Interfacing Schemes of Resistive/Capacitive Sensors: Resistive sensor examples; Non-idealities in basic interfacing circuits; Linearization techniques; Error reduction schemes due to environmental effects and remote communication, Interfacing Schemes of Capacitive sensor examples; Interfacing scheme for different capacitive sensor configurations, direct interfacing schemes.

**Module 3:** Advanced Schemes for Direct Interfacing of Resistive/Capacitive Sensors with Embedded controller: Embedded controller based excitation system; Direct interfacing schemes of various resistive sensors topologies to microcontrollers; Interfacing scheme for sensor array, interfacing circuit for lossy capacitive sensors: Lossy Capacitive sensor characteristics; Various advanced interfacing schemes for lossy capacitive sensor.

**Module 4:** Miniaturization Technology for Smart Sensors and Actuators: Background of miniaturization; Miniaturized device fabrication process technology for Smart sensors and actuators, Miniaturized Sensors, Actuators and their Interfacing Electronics: Various types of important MEMS sensors and actuators: Design and operation; Interfacing Electronics for MEMS Devices; System-on-Chip integration; Applications, Renewable Energy Harvesters to Develop Self-Powered Embedded System.

**Module 5:** Application Case Studies of Embedded Sensing, Embedded Controller, Actuation and Interfacing System in Electrical Engineering.

### 7.28.5 Learning Resources:

#### 7.28.5.1 Text Books:

1. Nathan Ida, “Sensors, Actuators, and their Interfaces,” SciTech Publishing, 2014 ($1^{st}$ Ed.)
2. Stuart R. Ball, “Analog Interfacing to Embedded Microprocessor Systems,” Elsevier, 2004.
3. B. George, J. Roy, V. Jagadeesh Kumar & S. C. Mukhopadhyay, “Advanced Interfacing Techniques for Sensors,” Springer, 2017 ($1^{st}$ Ed.)
4. J. G. Webster & Ramón Pallás-Areny, “Sensors and Signal Conditioning,” John Wiley & Sons, 2000 ($2^{nd}$ Ed.)
5. Marc Madou, “Fundamentals of Microfabrication and Nanotechnology,” CRC press, 2018 ($3^{rd}$ Ed.)

#### 7.28.5.2 Reference Books:

1. S. Nihtianov, A. Luque, “Smart Sensors and MEMS,” Elsevier, 2014 ($1^{st}$ Ed.)
2. Bela G Liptak, “Instrument Engineers Handbook,” CRC press, 2003 ($4^{th}$ Ed.)
3. W B Ribbens, “Understanding Automotive Electronics: An Engineering Perspective,” Elsevier, 2017 ($8^{th}$ Ed.)

#### 7.28.5.3 E-Learning Resources:

1. Prof. Banibrata Mukherjee, IIT Kharagpur online lecture series on “Embedded Sensing, Actuation and Interfacing Systems” $https://onlinecourses.nptel.ac.in/noc24_ee68/preview/$

## 7.29 Digital Signal Processing

| Course Code | Courses Name | Course Type | L - T - P | Credits | Total Hours |
|---|---|---|---|---|---|
| EE543 | Digital Signal Processing | Theory | 3 - 0 - 0 | 3 | 42 |

### 7.29.1 Objectives:

The objectives of studying this course are,

1. To develop a strong understanding of spectral analysis techniques for analyzing signals in the frequency domain.
2. To acquire in-depth knowledge of Digital Signal Processing (DSP) systems, including their design, implementation, and analysiss.
3. To learn the principles of designing Finite Impulse Response (FIR) and Infinite Impulse Response (IIR) filters for various applications.
4. To develop the ability to implement DSP algorithms using software tools and hardware platforms.
5. To evaluate the efficiency, stability, and real-time processing capabilities of DSP systems.
6. To explore the use of DSP in areas such as audio processing, communication systems, biomedical engineering, and control systems.

### 7.29.2 Course Outcome:

At the completion of this course, the student shall acquire knowledge and ability to,

1. CO1 : Interpret, represent and process discrete/digital signals and systems
2. CO2 : Thorough understanding of frequency domain analysis of discrete time signals.
3. CO3 : Design & analyse DSP systems like FIR and IIR Filters.
4. CO4 : Understand practical implementation issues such as computational complexity, hardware resource limitations as well as cost of DSP systems or DSP Processors.
5. CO5 : Understand basics on multirate signal processing.

### 7.29.3 CO - PO Mapping:

| **Relationship of Course Outcomes to Program Outcomes** | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **CO ↓** | **PO** | | | | | | | | | | | |
| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
| CO1 | H | H | M | M | M | M | L | L | L | L | L | M |
| CO2 | H | H | H | H | H | M | L | L | L | L | L | H |
| CO3 | H | H | H | H | H | M | L | L | L | L | L | H |
| CO4 | H | H | H | M | H | M | L | L | L | L | M | H |
| CO5 | H | H | M | M | M | M | L | L | L | L | M | H |
| **H = High correlation; M = Medium correlation; L = Low correlation** | | | | | | | | | | | | |

### 7.29.4 Syllabus:

**Module 1:** Review of LTI systems characterized by linear constant coefficients difference equation, LTI systems as frequency-selective filters, Inverse systems, discrete Fourier transform and computational aspects: orthogonal transforms, discrete Fourier transform (DFT), relationship of DFT to other transforms, properties of DFT, computation of DFT, fast computation of DFT (FFT Algorithms).

**Module 2:** Digital Filter Design: Design of linear phase FIR filters using windowing and frequency sampling methods. Design of IIR filters and different transformations, design of digital filters based on least-square methods, lattice filters. .

**Module 3:** Implementation of DSP algorithms: Structures for FIR and IIR systems, number representation and overflow, quantization process and errors, fixed and floating point numbers, sensitivity analysis to quantization of filter coefficients, round-off effects in digital filters.

**Module 4:** Multi-rate digital signal processing: Basics of sampling rate converter, decimator, interpolator, rational sampling rate conversion, wavelet, sub-band coding, applications.

### 7.29.5 Learning Resources:

#### 7.29.5.1 Text Books:

1. Alan V. Oppenheim and Ronald W. Schafer, "Discrete-Time Signal Processing," Prentice Hall, 2009 ($3^{rd}$ Ed.)
2. Sanjit K. Mitra, "Digital Signal Processing," Tata McGraw Hill, 2010 ($4^{th}$ Ed.)
3. John G. Proakis, D. G. Manolakis, "Digital Signal Processing: Principles, Algorithms and Applications," Prentice Hall, 2006 ($4^{th}$ Ed.)
4. B. Venkatramani and M. Bhaskar, "Digital Signal Processors: Architecture, Programming, and Applications," Tata McGraw Hill, 2003

#### 7.29.5.2 Reference Books:

1. E. C. Ifeachor and B. W. Jervis, "Digital Signal Processing," Pearson Education, 2002 ($2^{nd}$ Ed.)
2. Li Tan, Jean Jiang, "Digital Signal Processing fundamentals and Applications," Academic Press, 2013

## 7.30 Digital Image Processing

| Course Code | Courses Name | Course Type | L - T - P | Credits | Total Hours |
|---|---|---|---|---|---|
| EE544 | Digital Image Processing | Theory | 3 - 0 - 0 | 3 | 42 |

### 7.30.1 Objectives:

The objectives of studying this course are to,

1. Enable students to apply various image processing techniques across different domains.
2. Equip students with the skills to implement advanced image processing methods.
3. Prepare students for research and development in the field of image processing.

### 7.30.2 Course Outcome:

At the completion of this course, the student shall acquire knowledge and ability to,

1. CO1 : Review the fundamental concepts of a digital image processing system.
2. CO2 : Analyze images in the frequency domain using various transforms.
3. CO3 : Evaluate the techniques for image enhancement and image restoration.
4. CO4 : Categorize various compression techniques.
5. CO5: Interpret Image compression standards, segmentation and representation schemes.

### 7.30.3 CO - PO Mapping:

| **Relationship of Course Outcomes to Program Outcomes** | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **CO ↓** | **PO** | | | | | | | | | | | |
| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
| CO1 | H | H | M | M | M | M | L | L | L | L | L | M |
| CO2 | H | H | H | H | H | M | L | L | L | L | L | H |
| CO3 | H | H | H | H | H | M | L | L | L | L | L | H |
| CO4 | H | H | H | M | H | M | L | L | L | L | M | H |
| CO5 | H | H | H | H | M | M | L | L | L | L | M | H |
| **H = High correlation; M = Medium correlation; L = Low correlation** | | | | | | | | | | | | |

### 7.30.4 Syllabus:

**Module 1:** **Image formation and Sampling:** Image formation, HVS, Discrete images and image transforms, 2-D sampling and reconstruction, Image quantization, 2-D transforms and properties.

**Module 2:** **Image Enhancement:** Histogram modelling, equalization and modification. Image smoothing, Image Sharpening. Spatial filtering, Replication and zooming, Generalized cepstrum and homomorphic filtering.

**Module 3:** **Image Restoration:** Image observation models. Image degradation and restoration model, inverse and Wiener filtering. Filtering using image transforms. Constrained least-squares restoration. Generalized inverse, SVD and interactive methods. Recursive filtering. Maximum entropy restoration. Bayesian methods.

**Module 4:** **Image Coding:** Image data compression- sub sampling, Coarse quantization and frame repetition. Pixel coding - PCM, entropy coding, run length coding, Bit-plane coding. Predictive coding. Transform coding of images. Hybrid coding and vector DPCM.

**Module 5:** **Image analysis:** applications, Spatial and transform features. Edge detection, boundary extraction, AR models and region representation, Segmentation, Applications in electrical engineering.

### 7.30.5 Learning Resources:

#### 7.30.5.1 Text Books:

1. A. K. Jain, "Fundamentals of Digital Image Processing," Prentice-Hall of India, 1989
2. R. C. Gonzalez & R. E. Woods, "Digital Image Processing," Pearson, 2018 ($4^{th}$ Ed.)
3. J. C. Russ, "The Image Processing Handbook", CRC Press, 2015 ($7^{th}$ Ed.)
4. S. Jayaraman, S. Esakkirajan & T. Veerakumar, "Digital Image Processing," Tata McGraw Hill, 2011

#### 7.30.5.2 Reference Books:

1. Anil K Jain, "Fundamentals of Digital Image Processing," Pearson, 1989
2. A. C. Bovik, "The essential guide to image processing," Academic Press, 2009
3. William K. Pratt, "Digital Image Processing," Wiley-Interscience, 2007 ($4^{th}$ Ed.)

## 7.31 FPGA based Digital Design

| Course Code | Courses Name | Course Type | L - T - P | Credits | Total Hours |
|---|---|---|---|---|---|
| EE545 | FPGA based Digital Design | Theory | 3 - 0 - 0 | 3 | 42 |

### 7.31.1 Objectives:

The objectives of studying this course are to,

1. Enable students to simulate and implement digital systems using Verilog/VHDL.
2. Provide hands-on experience with FPGA-based digital system design.
3. Develop proficiency in hardware description languages for real-time applications.

### 7.31.2 Course Outcome:

At the completion of this course, the student shall acquire knowledge and ability to,

1. CO1 : Understand digital system design methodologies, behavioral modeling, and simulation techniques.
2. CO2: Develop combinational and sequential logic circuits using HDLs and analyze synthesis issues.
3. CO3: Explore FPGA architectures, including logic blocks, interconnects, and timing models for efficient design.
4. CO4: Implement digital systems on FPGA platforms, considering placement, routing, and power optimization.
5. CO5: Apply FPGA-based design techniques for embedded systems, DSP applications, and reconfigurable computing.

### 7.31.3 CO - PO Mapping:

| **Relationship of Course Outcomes to Program Outcomes** | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **CO ↓** | **PO** | | | | | | | | | | | |
| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
| CO1 | H | H | M | M | M | M | L | L | L | L | L | M |
| CO2 | H | H | H | H | H | M | L | L | L | L | L | H |
| CO3 | H | H | H | H | H | M | L | L | L | L | L | H |
| CO4 | H | H | H | M | H | M | L | L | L | L | M | H |
| CO5 | H | H | H | H | M | M | L | L | L | L | M | H |
| **H = High correlation; M = Medium correlation; L = Low correlation** | | | | | | | | | | | | |

### 7.31.4 Syllabus:

**Module 1:** **Introduction:** Digital system design options and trade-offs, Design methodology and technology overview, High Level System Architecture and Specification: Behavioural modelling and simulation.

**Module 2:** **Tool for logic Implementation:** Hardware description languages, combinational and sequential design, state machine design, synthesis issues, test benches. Overview of FPGA architectures and technologies: FPGA Architectural options, granularity of function and wiring resources, coarse vs fine grained, vendor specific issues (emphasis on Xilinx / Altera).

**Module 3:** **Implementation on FPGA:** Logic block architecture: FPGA logic cells, timing models, power dissipation I/O block architecture: Input and Output cell characteristics, clock input, Timing, Power dissipation, Programmable interconnect - Partitioning and Placement, Routing resources, delays.

**Module 4:** **Applications:** Applications - Embedded system design using FPGAs, DSP using FPGAs, Dynamic architecture using FPGAs, reconfigurable systems, application case studies. Simulation / implementation exercises of combinational, sequential and DSP kernels on Xilinx / Altera boards.

### 7.31.5 Learning Resources:

#### 7.31.5.1 Text Books:

1. M. Morris Mano, Michael D. Ciletti, "Digital Design: With an Introduction to Verilog HDL," Pearson Education India, 2013 ($5^{th}$ Ed.)
2. Stephen Brown, Zvonko Vranesic, "Fundamentals of Digital Logic with VHDL Design," McGraw Hill Education, 2017, ($3^{rd}$ Ed.)
3. Cem Unsalan, Bora Tar, "Digital System Design with FPGA Implementation Using Verilog and VHDL," McGraw Hill Education, 2017 ($1^{st}$ Ed.)
4. Vahid, "Digital Design, with RTL Design, VHDL, and Verilog," John Wiley and Sons Publishers, ($2^{nd}$ Ed.)

#### 7.31.5.2 Reference Books:

1. Harris, "Digital Design and Computer Architecture," Elsevier, ($2^{nd}$ Ed.)

## 7.32 Applied Linear Algebra for Electrical Engineers

| Course Code | Courses Name | Course Type | L - T - P | Credits | Total Hours |
|---|---|---|---|---|---|
| EE550 | Applied Linear Algebra for Electrical Engineers | Theory | 3 - 0 - 0 | 3 | 42 |

### 7.32.1 Objectives:

The objectives of studying this course are to,

1. Develop a strong foundation in linear algebra with applications to electrical engineering.
2. Understand matrix operations, vector spaces, and eigenvalues in engineering problems.
3. Apply linear algebra techniques in circuit analysis, signal processing, and control systems.

### 7.32.2 Course Outcome:

At the completion of this course, the student shall acquire knowledge and ability to,

1. CO1 : Understand fundamental concepts of linear algebra and its importance in Electrical engineering
2. CO2: Understand and apply concepts of Vector Spaces, Transformations, Eigenvalues and Eigenvectors, Orthogonality, Least Squares Methods etc. in solving engineering problems
3. CO3: Explore Advanced Matrix Factorization Techniques
4. CO4: Implement solutions based on Linear Algebra in Electrical Engineering Applications

### 7.32.3 CO - PO Mapping:

| **Relationship of Course Outcomes to Program Outcomes** | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **CO ↓** | **PO** | | | | | | | | | | | |
| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
| CO1 | M | L | L | L | L | L | L | L | L | L | L | L |
| CO2 | M | M | L | L | L | L | L | L | L | L | L | H |
| CO3 | H | H | L | L | M | L | L | L | L | L | L | H |
| CO4 | H | H | M | L | M | L | L | L | L | L | L | H |
| **H = High correlation; M = Medium correlation; L = Low correlation** | | | | | | | | | | | | |

### 7.32.4 Syllabus:

**Module 1:** **Fundamentals of Linear Algebra:** Introduction to Linear Algebra & Its Importance in Electrical Engineering, Vectors, Matrices, and Operations (Addition, Multiplication, Inversion), Systems of Linear Equations & Gaussian Elimination, Rank, Nullity, and Matrix Factorization.

**Module 2:** **Vector Spaces and Transformations:** Definition and Properties of Vector Spaces, Basis, Dimension, and Subspaces, Linear Independence and Span, Linear Transformations and Matrix Representation.

**Module 3:** **Eigenvalues and Eigenvectors:** Determinants and Characteristic Equations,Eigenvalues, Eigenvectors, and Their Significance in Electrical Engineering, Diagonalization and Jordan Form, Applications in Stability Analysis and Control Systems.

**Module 4:** **Orthogonality and Least Squares:** Inner Product, Norms, and Orthogonality, Gram-Schmidt Orthogonalization, QR Decomposition, Least Squares Approximation and Applications in Signal Processing.

**Module 5:** **Matrix Factorizations and Engineering Applications** Singular Value Decomposition (SVD), Principal Component Analysis (PCA), Pseudoinverse and Its Use in Control Systems, Fourier and Wavelet Transforms Using Linear Algebra.

**Module 6:** **Applications in Electrical Engineering:** Circuit Analysis Using Matrices (Nodal and Mesh Analysis), State-Space Representation of Systems, Markov Chains and Stability Analysis, .

### 7.32.5 Learning Resources:

#### 7.32.5.1 Text Books:

1. Gilbert Strang, "Linear Algebra and Its Applications," Cengage Learning, 2016 ($5^{th}$ Ed.)
2. Thomas S. Shores, "Applied Linear Algebra and Matrix Analysis," Springer, 2017
3. M. B. Patil, V. Ramanarayanan, and V. T. Ranganathan, "Simulation of Power Electronic Circuits," Narosa Publishing House, 2013

#### 7.32.5.2 Reference Books:

1. Daniel Norman, "Introduction to Linear Algebra for Science and Engineering" CRC Press, 2010

## 7.33 Intelligent Systems in Electrical Engineering

| Course Code | Courses Name | Course Type | L - T - P | Credits | Total Hours |
|---|---|---|---|---|---|
| EE551 | Intelligent Systems in Electrical Engineering | Theory | 3 - 0 - 0 | 3 | 42 |

### 7.33.1 Objectives:

The objectives of studying this course are to,

1. Introduce AI techniques, fuzzy logic, neural networks, and optimization methods for intelligent decision-making in electrical systems.
2. Explore AI-based fault diagnosis, predictive maintenance, and smart grid management.
3. Investigate AI and blockchain applications in energy trading, cybersecurity, and decentralized energy management.

### 7.33.2 Course Outcome:

At the completion of this course, the student shall acquire knowledge and ability

1. CO1 : Apply AI techniques for fault diagnosis and decision-making in electrical systems.
2. CO2 : Implement fuzzy logic and neural networks for power system optimization.
3. CO3 : Develop AI-based controllers for power electronics and smart grid applications.
4. CO4 : Utilize AI-driven predictive maintenance and optimization techniques.
5. CO5 : Analyse AI and blockchain applications in energy trading and cybersecurity.

### 7.33.3 CO - PO Mapping:

| **Relationship of Course Outcomes to Program Outcomes** | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **CO ↓** | **PO** | | | | | | | | | | | |
| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
| CO1 | H | H | H | H | L | H | M | L | L | L | L | M |
| CO2 | H | H | H | H | H | L | H | L | L | L | M | H |
| CO3 | H | H | H | H | M | M | H | L | L | L | M | H |
| CO4 | H | H | M | M | M | M | M | L | L | L | M | M |
| CO5 | H | H | H | H | H | H | H | L | L | L | M | H |
| **H = High correlation; M = Medium correlation; L = Low correlation** | | | | | | | | | | | | |

### 7.33.4 Syllabus:

**Module 1:** : **Introduction to Intelligent Systems & AI in Electrical Engineering:** Introduction to Intelligent Systems: AI, Expert Systems, Machine Learning. Knowledge-Based Systems in Electrical Engineering. Fundamentals of Expert Systems & Decision Support Systems. AI-Based Fault Diagnosis in Electrical Networks.

**Module 2:** **Fuzzy Logic and Neural Networks in Electrical Systems:** Introduction to Fuzzy Logic, Membership Functions & Rule-Based Systems. Fuzzy Logic Applications in Power System Control & Optimization. Fuzzy Logic-Based Voltage Regulation in Power Systems. Artificial Neural Networks (ANNs) for Load Forecasting & Energy Prediction. Deep Learning for Electrical Load Pattern Recognition. Smart Grid Load Forecasting Using Neural Networks.

**Module 3:** **Intelligent Control Systems in Power Electronics & Smart Grids:** AI-Based Controllers for Power Electronics & Drives. Reinforcement Learning for Inverter & Converter Optimization. Intelligent Load Management in Smart Grids using AI. AI-Based Demand Response & Energy Management Systems. AI-Optimized Inverter Control in Renewable Energy Grids.

**Module 4:** **Optimization & AI-Based Predictive Maintenance in Electrical Systems:** Genetic Algorithm (GA) & Particle Swarm Optimization (PSO) for Electrical Engineering. Predictive Maintenance Using AI & IoT in Electrical Networks. Quantum AI for Grid Stability & Energy Storage Optimization. AI-Based Fault Prediction in Renewable Energy Systems. Predictive Maintenance for Power Transformers & Solar Panels. AI-Based Fault Detection in Wind Turbines.

**Module 5:** **AI-Based Energy Trading, Blockchain & Industry Applications:** Blockchain & AI for Smart Grid Energy Trading. AI-Based Cybersecurity in Power Systems. Deep Learning for Grid Anomaly Detection & Cybersecurity. Multi-Agent Systems (MAS) for Distributed Energy Management. AI for Distributed Energy Resource Management & Trading. Blockchain-Based Energy Trading in Peer-to-Peer Grids.

### 7.33.5 Learning Resources:

#### 7.33.5.1 Text Books:

1. K. Warwick, A. Ekwue, & R. Aggarwal, "Artificial Intelligence Techniques in Power Systems," IET, 2004
2. J. M. Zurada, "Introduction to Artificial Neural Systems," West Publishing, 1992
3. P. Wang & L. Goel, "Artificial Intelligence Applications in Power Systems," Springer, 2017
4. S. Haykin, "Neural Networks and Learning Machines," Pearson, 2020 ($3^{rd}$ Ed.)

#### 7.33.5.2 Reference Books:

1. T. J. Ross, "Fuzzy Logic with Engineering Applications," Wiley, 2010 ($3^{rd}$ Ed.)
2. S. Rajasekaran & G. A. Vijayalakshmi Pai, "Neural Networks, Fuzzy Logic, and Genetic Algorithms: Synthesis and Applications," Prentice Hall, 2003
3. F. Milano, "AI and Machine Learning in Smart Grid Systems," Springer, 2020
4. IEEE Transactions & research papers on AI applications in power systems, smart grids, and energy trading.

## 7.34 Optimization Techniques for Electrical Engineering

| Course Code | Courses Name | Course Type | L - T - P | Credits | Total Hours |
|---|---|---|---|---|---|
| EE552 | Optimization Techniques for Electrical Engineering | Theory | 3 - 0 - 0 | 3 | 42 |

### 7.34.1 Objectives:

The objectives of studying this course are to,

1. Introduce mathematical, AI-based, and quantum optimization techniques for electrical engineering applications.
2. Explore classical and heuristic methods for solving power system, smart grid, and renewable energy optimization problems.
3. Apply optimization strategies in real-world scenarios, including FACTS placement, EV charging, and microgrid energy management.

### 7.34.2 Course Outcome:

At the completion of this course, the student shall acquire knowledge and ability to,

1. CO1 : Understand classical and AI-driven optimization techniques for electrical engineering.
2. CO2 : Apply heuristic methods like GA, PSO, and ACO to power system optimization.
3. CO3 : Solve multi-objective and stochastic optimization problems in grid operations.
4. CO4 : Utilize quantum and blockchain-based optimization for smart grids.
5. CO5 : Analyse real-world optimization challenges in renewable energy and EV charging.

### 7.34.3 CO - PO Mapping:

| **Relationship of Course Outcomes to Program Outcomes** | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **CO ↓** | **PO** | | | | | | | | | | | |
| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
| CO1 | H | H | M | M | L | H | M | L | L | L | L | M |
| CO2 | H | H | H | H | H | H | H | L | L | L | M | H |
| CO3 | H | H | H | H | M | H | H | L | L | L | M | H |
| CO4 | H | H | H | H | M | H | H | L | L | L | M | H |
| CO5 | H | H | H | H | H | H | H | L | L | L | M | H |
| **H = High correlation; M = Medium correlation; L = Low correlation** | | | | | | | | | | | | |

### 7.34.4 Syllabus:

**Module 1:** **Fundamentals of Optimization & Classical Techniques:** Introduction to Optimization & Problem Formulation, Single-Variable & Multivariable Optimization, Linear Programming (LP) & Simplex Method, Nonlinear Programming (NLP) & Lagrange Multipliers, Convex & Non-Convex Optimization. Economic Load Dispatch (ELD) in Power Systems. Optimal Scheduling of Power Plants.

**Module 2:** **AI-Based & Heuristic Optimization Techniques:** Genetic Algorithm (GA) for Power System Optimization. Particle Swarm Optimization (PSO) for Load Flow Studies. Ant Colony Optimization (ACO) for Network Routing. Artificial Neural Networks (ANN) for Predictive Optimization. Optimization of Electric Vehicle (EV) Charging Stations.

**Module 3:** **Multi-Objective & Stochastic Optimization:** Multi-Objective Optimization (MOO) – Pareto Front & Trade-Offs. Dynamic Programming & Stochastic Optimization. Robust & Fuzzy Optimization Techniques. FACTS Devices Optimization for Grid Stability. Optimal Placement of FACTS Devices in Indian Power Grids. MOO for Load Frequency Control (LFC).

**Module 4:** **Modern & Quantum Optimization Techniques:** Deep Reinforcement Learning (DRL) for Grid Operation. Quantum Optimization for Power Systems (QAOA & VQE Methods). Blockchain-Based Optimization for Energy Trading. Smart Grid Optimization Using AI & Blockchain. AI-Based Microgrid Optimization. Quantum-Inspired Optimization for Power Dispatch.

**Module 5:** **Applications & Industry ‘Implementation:** Power System State Estimation & Optimal Power Flow (OPF). Renewable Energy Integration & Storage Optimization. EV Fleet Charging Optimization & Demand Response. Real-Time Power Grid Operation & Blackout Prevention. Optimization of India’s Renewable Energy Grid Mix. Optimization of EV Charging in a Microgrid.

### 7.34.5 Learning Resources:

#### 7.34.5.1 Text Books:

1. S.S. Rao, ”Engineering Optimization: Theory & Practice,” New Age International, 2020 ($4^{th}$ Ed.)
2. D.P. Kothari & J.S. Dhillon, ”Power System Optimization,” PHI Learning.
3. Kalyanmoy Deb, ”Optimization for Engineering Design: Algorithms and Examples,” Prentice Hall of India.

#### 7.34.5.2 Reference Books:

1. J. A. Momoh, ”Electric Power System Applications of Optimization,” CRC Press, 2021 ($2^{nd}$ Ed.)
2. Xiao-Ping Zhang, ”Resilient Power Systems with Optimization and AI,” Wiley-IEEE Press.
3. A. P. Engelbrecht, ”Computational Intelligence: An Introduction,” Wiley.
4. IEEE Transactions on Power Systems & Smart Grids – Research on AI and optimization in power networks

## 7.35 Soft Computing

| Course Code | Courses Name | Course Type | L - T - P | Credits | Total Hours |
|---|---|---|---|---|---|
| EE553 | Soft Computing | Theory | 3 - 0 - 0 | 3 | 42 |

### 7.35.1 Objectives:

The objectives of studying this course are to,

1. Introduce soft computing techniques, including fuzzy logic, neural networks, and evolutionary algorithms.
2. Explore their applications in electrical engineering for optimization, control, and intelligent decision-making.
3. Investigate hybrid soft computing models for real-time applications in smart grids, renewable energy, and power electronics.

### 7.35.2 Course Outcome:

At the completion of this course, the student shall acquire knowledge and ability

1. CO1 : Understand soft computing techniques and their applications in electrical engineering.
2. CO2 : Design and implement fuzzy logic systems for intelligent control and decision-making.
3. CO3 : Apply artificial neural networks for power system forecasting, fault detection, and energy optimization.
4. CO4 : Utilize evolutionary algorithms for solving electrical engineering optimization problems.
5. CO5 : Develop hybrid soft computing models for real-time applications in smart grids, renewable energy, and power electronics.

### 7.35.3 CO - PO Mapping:

| **Relationship of Course Outcomes to Program Outcomes** | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **CO ↓** | **PO** | | | | | | | | | | | |
| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
| CO1 | H | H | M | M | L | L | L | L | L | L | L | M |
| CO2 | H | H | H | H | H | L | H | L | L | L | M | H |
| CO3 | H | H | H | H | M | M | H | L | L | L | M | H |
| CO4 | H | H | M | M | M | M | M | L | L | L | M | M |
| CO5 | H | H | H | H | H | H | H | L | L | L | M | H |
| **H = High correlation; M = Medium correlation; L = Low correlation** | | | | | | | | | | | | |

### 7.35.4 Syllabus:

**Module 1:** **Introduction to Soft Computing in Electrical Engineering:** Hard computing Vs. soft computing: Need for approximation and optimization. Components of soft computing: Fuzzy Logic, Neural Networks, Evolutionary Computing. Applications of soft computing in power systems, control systems, and electrical machines. Case Study on Smart grid fault diagnosis using soft computing techniques.

**Module 2:** **Fuzzy Logic and Applications in Electrical Systems:** Fuzzy sets, membership functions, and linguistic variables. Fuzzy logic operations, fuzzy inference systems (FIS), and defuzzification techniques. Fuzzy control applications in power electronics, voltage control, and energy management. Case Study on Fuzzy-based MPPT (Maximum Power Point Tracking) for solar PV systems.

**Module 3:** **Artificial Neural Networks (ANNs) for Power and Control Systems:** Biological neurons Vs. artificial neurons, perceptron model, activation functions. Multi-layer perceptron (MLP), backpropagation, and training algorithms. ANN applications in fault diagnosis, load forecasting, and power electronics control. Case Study on ANN-based short-term load forecasting for power grids.

**Module 4:** **Evolutionary and Swarm Intelligence Algorithms in Electrical Engineering:** Genetic Algorithms (GA): Operators, selection, crossover, mutation. Particle Swarm Optimization (PSO), Differential Evolution (DE), Ant Colony Optimization (ACO). Optimization applications in power systems, load dispatch, and renewable energy integration. Case Study on GA-based economic load dispatch in power systems.

**Module 5:** **Hybrid Soft Computing & Industry Applications:** Integration of fuzzy logic, neural networks, and evolutionary computing. Neuro-fuzzy systems, fuzzy-genetic algorithms, hybrid AI models. Applications in smart grids, renewable energy forecasting, power quality monitoring, and electric vehicle (EV) energy management. Case Study on AI-driven predictive maintenance for power transformers.

### 7.35.5 Learning Resources:

#### 7.35.5.1 Text Books:

1. Simon Haykin, "Neural Networks and Learning Machines," Pearson.
2. Timothy J. Ross, "Fuzzy Logic with Engineering Applications," Wiley.
3. Jang, Sun, & Mizutani, "Neuro-Fuzzy and Soft Computing," Pearson.

#### 7.35.5.2 Reference Books:

1. David E. Goldberg, "Genetic Algorithms in Search, Optimization, and Machine Learning," Pearson.
2. S. Rajasekaran & G.A. Vijayalakshmi Pai, "Neural Networks, Fuzzy Logic, and Genetic Algorithms," PHI, 2020 ($4^{th}$ Ed.)

## 7.36 Internet of Things (IoT) in Electrical Engineering

| Course Code | Courses Name | Course Type | L - T - P | Credits | Total Hours |
|---|---|---|---|---|---|
| EE554 | Internet of Things (IoT) in Electrical Engineering | Theory | 3 - 0 - 0 | 3 | 42 |

### 7.36.1 Objectives:

The objectives of studying this course are to,

1. Understand the fundamentals of the Internet of Things (IoT) and its architecture.
2. Explore the significance of IoT in electrical engineering applications.
3. Learn about IoT communication protocols and sensor technologies.
4. Gain hands-on experience with IoT platforms and data acquisition techniques.
5. Apply data analytics for monitoring and optimizing electrical systems.
6. Explore emerging trends in IoT for smart grids, automation, and energy management.

### 7.36.2 Course Outcome:

At the completion of this course, the student shall acquire knowledge and ability

1. CO1 : Grasp the basic principles of Internet of Things (IoT) in Electrical Engineering and effectively apply them to solve engineering problems.
2. CO2 : Analyse the significance of Internet of Things (IoT) in Electrical Engineering and its wide-range of possibilities/applications.
3. CO3 : Comprehend the fundamental concepts of Internet of Things (IoT), sensors, actuators, communication protocols, embedded systems, challenges, various case studies and their practical applications.
4. CO4 : Evaluate various aspects of Internet of Things (IoT) applications in Electrical Engineering.

### 7.36.3 CO - PO Mapping:

| **Relationship of Course Outcomes to Program Outcomes** | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **CO ↓** | **PO** | | | | | | | | | | | |
| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
| CO1 | H | H | H | M | M | M | H | H | H | M | M | H |
| CO2 | H | H | H | M | M | M | H | H | H | M | M | H |
| CO3 | H | H | H | M | M | M | H | H | H | M | M | H |
| CO4 | H | H | H | M | M | M | H | H | H | M | M | H |
| **H = High correlation; M = Medium correlation; L = Low correlation** | | | | | | | | | | | | |

### 7.36.4 Syllabus:

**Module 1:** **Introduction:** Definition and characteristics of IoT, IoT architecture: Perception, Network, and Application layers, Key enabling technologies: Sensors, Actuators, Communication Protocols, Applications in- Smart Cities, Agriculture, Security, Transport, Medical, Health, Industrial Automation, Energy Management, home automation, etc.

**Module 2:** **Sensors and Actuators:** Introduction, Sensor types and their Characteristics, Sensorial Deviations, Scalar sensing, Multimedia sensing, Hybrid sensing, Virtual sensing, Sensing Considerations. Function of Actuators, Electrical, Electronic and Mechanical Actuators and their Characteristics.

**Module 3:** **Communication Protocols:** Overview of communication technologies- Wired & Wireless, Protocols: MQTT, CoAP, HTTP, AMQP, etc; Wireless communication: Wi-Fi, Bluetooth, Zigbee, LoRa, NB-IoT.
Constrained nodes, Constrained Networks, Infrastructure Protocols, Discovery Protocols, Data Protocols, Identification Protocols, Device Management, Semantic Protocols.

**Module 4:** **Embedded Systems:** Understanding of Arduino, ESP32, Node MCU, Raspberry Pi, any latest devices and their programming tools. IoT Case Studies in - Irrigation, Vehicular technology, Crime assistance, transportation, Healthcare, Smart Grid, Smart Cities and Smart Homes, EV Connected Vehicles. Hands-on of IoT Projects.

**Module 5:** **Paradigms, Challenges, and the Future (Only Overview):** Evolution of New IoT Paradigms, Internet of energy (IoE), Internet of vehicles (IoV), Internet of battlefield things (IoBT), Internet of underwater things (IoUT), Internet of drones (IoD), Internet of space (IoSpace), Internet of services (IoS), Internet of people (IoP), Internet of nano things (IoNT), Internet of everything (IoE). Challenges associated with IoT, Mobility, Addressing - Power Heterogeneous connectivity, Communication range, Security, Device size, etc. Review of recent technologies.

### 7.36.5 Learning Resources:

#### 7.36.5.1 Text Books:

1. Sudip Misra, Anandarup Mukherjee and Arijit Roy, Introduction to IoT, Cambridge University Press, 2021.
2. Dimitrios Serpanos, Marilyn Wolf, Internet-of-Things (IoT) Systems - Architectures, Algorithms, Methodologies, Springer Publications, 2018.
3. Anandarup Mukherjee, Chandana Roy, Sudip Misra - Introduction to Industrial Internet of Things and Industry 4. 0-CRC Press, 2020.

#### 7.36.5.2 Reference Books:

1. Anuradha, J., Tripathy, B. K, Internet of things (IoT) technologies, applications, challenges and solutions, CRC Press, Taylor & Francis, 2018.
2. Mansaf Alam, Kashish Ara Shakil, Samiya Khan, Internet of Things (IoT) - Concepts and Applications, Springer Publications, 2020.
3. Ernest O. Doebelin, Dhanesh N. Manik, Doebelin's Measurement Systems, McGraw Hill, 2019, 7th Edition.

## 7.37 IoT, IoV, IoD and IIoT Applications in Electrical Engineering

| Course Code | Courses Name | Course Type | L - T - P | Credits | Total Hours |
|---|---|---|---|---|---|
| EE555 | IoT, IoV, IoD and IIoT Applications in Electrical Engineering | Theory | 3 - 0 - 0 | 3 | 42 |

### 7.37.1 Objectives:

The objectives of studying this course are to,

1. Explores the integration of IoT, IoV, IoD, and IIoT in electrical engineering, focusing on smart grids, energy management, EV infrastructure, and industrial automation.
2. It emphasizes real-time monitoring, AI-driven decision-making, and cybersecurity.
3. Students will gain hands-on experience in designing and implementing intelligent electrical systems using IoT technologies.

### 7.37.2 Course Outcome:

At the completion of this course, the student shall acquire knowledge and ability

1. CO1 : Understand the fundamentals of IoT, IoV, IoD, and IIoT in electrical engineering applications.
2. CO2 : Design and implement IoT-enabled smart grid and energy management systems.
3. CO3 : Apply IoV concepts for electric vehicle (EV) communication, fleet management, and V2G systems.
4. CO4 : Develop drone-based solutions for power line monitoring and predictive maintenance.
5. CO5 : Analyse cybersecurity challenges and AI-based solutions for secure and efficient IIoT applications.

### 7.37.3 CO - PO Mapping:

| **Relationship of Course Outcomes to Program Outcomes** | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **CO ↓** | **PO** | | | | | | | | | | | |
| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
| CO1 | H | H | M | M | L | L | L | L | L | L | L | M |
| CO2 | H | H | H | H | H | H | H | L | L | L | H | H |
| CO3 | H | H | H | H | M | M | H | L | L | L | M | H |
| CO4 | H | H | H | H | M | H | H | L | L | L | H | H |
| CO5 | H | H | M | M | H | M | M | L | L | L | M | M |
| **H = High correlation; M = Medium correlation; L = Low correlation** | | | | | | | | | | | | |

### 7.37.4 Syllabus:

**Module 1:** **Fundamentals of IoT, IoV, IoD, and IIoT :** Introduction to IoT, IoV, IoD, and IIoT: Concepts, architectures, and applications. Communication protocols: MQTT, CoAP, LoRa, Zigbee, 5G, V2X, UAV communication. IoT hardware: Microcontrollers (Arduino, ESP32, STM32), sensors, and actuators. Case Study on IoT-based remote monitoring of electrical substations.

**Module 2:** **IoT and IIoT in Smart Grids and Energy Management:** Smart grid architecture and IoT-enabled energy management. IoT-based fault detection, demand response, and real-time monitoring. Industrial IoT (IIoT) in power plants: SCADA, PLCs, and automation. Case Study on AI-driven IoT solutions for power quality monitoring.

**Module 3:** **IoV Applications in Electrical Engineering:** IoV architecture: V2G (Vehicle-to-Grid), V2X (Vehicle-to-Everything), fleet management. IoT for EV charging infrastructure: Smart charging and grid integration. Data analytics in IoV: Predictive maintenance and real-time diagnostics. Case Study on IoT-enabled V2G energy trading in smart grids.

**Module 4:** **IoD Applications in Power Systems:** Drone technology for electrical infrastructure monitoring. UAV-based predictive maintenance for power lines and substations. Drone communication protocols and real-time data analytics. Case Study on Drone-assisted fault detection in high-voltage transmission lines.

**Module 5:** **Security, AI, and Future Trends in IoT Applications:** IoT and IIoT security: Cyber threats, encryption, and authentication. AI and machine learning in IoT-enabled electrical systems. Blockchain for secure energy transactions and smart contracts. Case Study on AI-based cyber threat detection in smart grids.

### 7.37.5 Learning Resources:

#### 7.37.5.1 Text Books:

1. Ovidiu Vermesan & Peter Friess, Internet of Things: Converging Technologies for Smart Environments, River Publishers.
2. Rajkumar Buyya & Amir Vahid Dastjerdi, Internet of Things: Principles and Paradigms, Elsevier.
3. Al-Sakib Khan Pathan, Securing IoT in Industrial Applications, CRC Press.

#### 7.37.5.2 Reference Books:

1. Arshdeep Bahga & Vijay Madisetti, Internet of Things: A Hands-on Approach, Universities Press.
2. Robert Faludi, Building Wireless Sensor Networks, O'Reilly Media.
3. IEEE transactions on Industrial Electronics, Smart Grid, Vehicular Technology, Internet of Things, Robotics.

## 7.38 Cyber Physical Systems

| Course Code | Courses Name | Course Type | L - T - P | Credits | Total Hours |
|---|---|---|---|---|---|
| EE556 | Cyber Physical Systems | Theory | 3 - 0 - 0 | 3 | 42 |

### 7.38.1 Objectives:

The objectives of studying this course are to,

1. Understand the fundamentals of Cyber-Physical Systems (CPS) and their architecture.
2. Identify vulnerabilities, risks, and potential threats in CPS environments.
3. Explore communication protocols and data exchange mechanisms in CPS.
4. Analyze security challenges and strategies to protect CPS from cyberattacks.
5. Examine real-world applications of CPS in sectors like power systems, smart grids, and automation.
6. Understand emerging trends and innovations in CPS design, security, and resilience.

### 7.38.2 Course Outcome:

At the completion of this course, the student shall acquire knowledge and ability to,

1. CO1 : Grasp the basic principles of Cyber Physical Systems and effectively apply them to solve engineering problems.
2. CO2 : Analyse the significance of Cyber Physical Systems and its wide-range of possibilities/applications.
3. CO3 : Comprehend the fundamental concepts of Cyber Physical Systems, vulnerabilities, hardware, communication, network security, digital twins, case studies and their practical implementations.
4. CO4 : Evaluate various aspects of Cyber Physical Systems.

### 7.38.3 CO - PO Mapping:

| **Relationship of Course Outcomes to Program Outcomes** | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **CO ↓** | **PO** | | | | | | | | | | | |
| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
| CO1 | H | H | H | M | M | M | H | H | H | M | M | H |
| CO2 | H | H | H | M | M | M | H | H | H | M | M | H |
| CO3 | H | H | H | M | M | M | H | H | H | M | M | H |
| CO4 | H | H | H | M | M | M | H | H | H | M | M | H |
| **H = High correlation; M = Medium correlation; L = Low correlation** | | | | | | | | | | | | |

### 7.38.4 Syllabus:

**Module 1:** **Fundamentals of Cyber Physical Systems:** Evolution of Industry 4.0, Cyber Physical systems in the real world, Differences between CPS and embedded systems, Industrial Control Systems and Operations, Industrial Network Protocols, Vulnerabilities, Cyber Physical System Modeling, Plant Models and Anomaly Detection Models, Auto SAR and Industrial Internet of Things (IIoT).

**Module 2:** **Hardware platforms:** Processors, Sensors, Actuators, CPS Network: Wireless Hart, CAN, Automotive Ethernet, CPS Software stack: Real-Time Operating Systems (RTOS), Scheduling, Overview of CPS Software components and their mapping to Electronic Control Units (ECUs), Field network and its protocols (profibus, DNP3 etc), ICS/SCADA Security, IoT Security, Legal and Privacy Aspects, CPS: Risk Management. Industry standards.

**Module 3:** **Communication:** Communication networks and protocols, Development of an IoT system, User requirements and specifications, Adaptive Embedded systems, Concept of Digital twins, Role of digital twins in Industrial IoT and Manufacturing Process, Digital twins for complex real time embedded systems, Integration levels and Computing.

**Module 4:** **Applications:** Intelligent CPS, Robot motion control, Autonomous Vehicle control, Smart Grid Demand Response, Building Automation, Applications of CPS on Critical Infrastructures - healthcare, aerospace, industrial automation, Power Grid, Railways Systems, Transportation Systems, Water/Sewage Systems and their automation architecture, Past Cases of Cyber Security Compromises and Trends. Latest case studies and attacks. Applications in Building Automation and Medical CPS. Review of recent technologies.

### 7.38.5 Learning Resources:

#### 7.38.5.1 Text Books:

1. Edward A. Lee and Sanjit A. Seshia, Introduction to Embedded Systems, A Cyber-Physical Systems Approach, Second Edition, MIT Press.

2. Rajeev Alur, Principles of Cyber-Physical Systems, MIT Press.

3. T. D. Lewis, Network Science: Theory and Applications, Wiley.

#### 7.38.5.2 Reference Books:

1. Ranjan Ganguli, Sondipon Adhikari, Souvik Chakraborty, Mrittika Ganguli, Digital Twin: A Dynamic System and Computing Perspective, CRC Press.

2. Suh, Sang C., U. John Tanik, John N. Carbone, and Abdullah Eroglu, eds. Applied cyber-physical systems. Springer New York

3. Relevant research articles

## 7.39 Cyber Security in Electrical Grids

| Course Code | Courses Name | Course Type | L - T - P | Credits | Total Hours |
|---|---|---|---|---|---|
| EE557 | Cyber Security in Electrical Grids | Theory | 3 - 0 - 0 | 3 | 42 |

### 7.39.1 Objectives:

The objectives of studying this course are to,

1. Understand the fundamentals of cybersecurity and its importance in electrical grids.
2. Identify potential cyber threats, vulnerabilities, and attack scenarios in power systems.
3. Explore cybersecurity strategies for safeguarding grid infrastructure and critical assets.
4. Study intrusion detection, risk assessment, and response mechanisms for grid resilience.
5. Understand regulatory frameworks, standards, and best practices in power grid cybersecurity.
6. Analyze emerging trends, including AI-driven cybersecurity and smart grid protection.

### 7.39.2 Course Outcome:

At the completion of this course, the student shall acquire knowledge and ability to,

1. CO1 : Grasp the basic principles of Cyber Security in Electrical Grids and effectively apply them to solve engineering problems.
2. CO2 : analyse the significance of Cyber Security in Electrical Grids and its wide-range of possibilities/applications.
3. CO3 : Comprehend the fundamental concepts of cyber security, vulnerabilities, network security, cyber laws, case studies and their practical implementations.
4. CO4 : Evaluate various aspects of Cyber Security in Electrical Grids.

### 7.39.3 CO - PO Mapping:

| **Relationship of Course Outcomes to Program Outcomes** | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **CO ↓** | **PO** | | | | | | | | | | | |
| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
| CO1 | H | H | H | M | M | M | H | H | H | M | M | H |
| CO2 | H | H | H | M | M | M | H | H | H | M | M | H |
| CO3 | H | H | H | M | M | M | H | H | H | M | M | H |
| CO4 | H | H | H | M | M | M | H | H | H | M | M | H |
| **H = High correlation; M = Medium correlation; L = Low correlation** | | | | | | | | | | | | |

### 7.39.4 Syllabus:

**Module 1:** **Introduction:** Evolution of Industry 4.0, Cyber Physical Systems, Critical Information Infrastructure, Overview of Cyber Security, types of Cyber Threats, Cyber Warfare, Cyber Crime, Cyber terrorism, Cyber Espionage, Comprehensive Cyber Security Policy and Nodal Authority, International Cyberspace, Internet Governance – Challenges and Constraints, Cybersecurity Standards and Regulations. Real-World Case studies of Cyber Attacks on Electrical Grids.

**Module 2:** **Cyber Security Vulnerabilities:** Cyber physical systems - Energy, Oil and gas, transportation, telecommunication, water - An overview on them, System and software level vulnerabilities, network/communication level vulnerabilities, management level vulnerabilities, application-level vulnerabilities, data/information level vulnerabilities. Security threat, attack models and management of the critical information infrastructure.

**Module 3:** **Network Security in Power Systems:** Access control, Audit, Authentication, Biometrics, Cryptography, Deception, Ethical Hacking, Firewalls, Intrusion Detection Systems (IDS), and Intrusion Prevention Systems (IPS), Response, Scanning, Security policy, Virus/malware detection, network security protocols and standards. Communication Protocols - DNP3, Modbus, IEC 61850, MQTT, etc; Securing Web Application, Services and Servers. Cybersecurity in Wireless Sensor Networks (WSN) and IoT Devices.

**Module 4:** **Cyber Laws and Case Studies:** Cybersecurity Risks in Power Grids and Smart Grids, International Cybersecurity Policies for Electrical Systems, Role of International Law. Industrial Control Systems (ICS) & Supervisory Control and Data Acquisition (SCADA) Systems. Cyber-attacks on SCADA systems, smart grids, electric vehicles, etc.
Indian Context: Indian Cyberspace, National Cyber Security Policy, research challenges and open problems. Best Practices and Future Trends. Review of recent technologies.

### 7.39.5 Learning Resources:

#### 7.39.5.1 Text Books:

1. Computer Forensics and Cyber Crime: An Introduction (3rd Edition) by Marjie T. Britz, 2013.
2. Twenty Critical Security Controls for Effective Cyber Defense: Consensus Audit Guidelines (CAG), Version 3.1 October 3, 2011.
3. United States General Accounting office- Technology assessment report, Cybersecurity for Critical Infrastructure Protection, May 2004.

#### 7.39.5.2 Reference Books:

1. Mini S. Thomas, John Douglas McDonald, ‘Power System SCADA and Smart Grids’, CRC Press
2. Yongge Wang and Bei-Tseng Chu, SCADA: Securing SCADA Infrastructure Communications, August 5, 2004.
3. Andrew Hildick-Smith, Security for Critical Infrastructure SCADA Systems, February 23, 2005.
4. John D. Moteff, Critical Infrastructures: Background, Policy, and Implementation, July 11, 2011
5. Relevant research papers.

## 7.40 AI and ML Applications in Electrical Engineering

| Course Code | Courses Name | Course Type | L - T - P | Credits | Total Hours |
|---|---|---|---|---|---|
| EE558 | AI and ML Applications in Electrical Engineering | Theory | 3 - 0 - 0 | 3 | 42 |

### 7.40.1 Objectives:

The objectives of studying this course are to,

1. Introduce AI and ML techniques for power system automation, optimization, and security.
2. Explore AI-driven solutions for renewable energy forecasting, EV energy management, and grid resilience.
3. Investigate AI's role in cybersecurity, decentralized energy trading, and emerging trends in power networks.

### 7.40.2 Course Outcome:

At the completion of this course, the student shall acquire knowledge and ability to,

1. CO1 : Understand AI and ML fundamentals and their applications in power systems.
2. CO2 : Apply deep learning for renewable energy forecasting and power system stability.
3. CO3 : Utilize reinforcement learning for EV charging and smart grid optimization.
4. CO4 : Implement AI-driven cybersecurity techniques for energy networks.
5. CO5 : Analyze future AI trends in decentralized power systems and energy trading.

### 7.40.3 CO - PO Mapping:

| **Relationship of Course Outcomes to Program Outcomes** | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **CO ↓** | **PO** | | | | | | | | | | | |
| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
| CO1 | H | H | M | M | L | L | L | L | L | L | L | M |
| CO2 | H | H | H | H | H | L | H | L | L | L | M | H |
| CO3 | H | H | H | H | M | M | H | L | L | L | M | H |
| CO4 | H | H | H | H | M | M | M | L | L | L | M | H |
| CO5 | H | H | H | H | H | H | H | L | L | L | M | M |
| **H = High correlation; M = Medium correlation; L = Low correlation** | | | | | | | | | | | | |

### 7.40.4 Syllabus:

**Module 1:** **Fundamentals of AI & ML for Electrical Engineers:** AI Vs Traditional Control & Optimization Methods. ML Basics: Supervised, Unsupervised, and Reinforcement Learning. Mathematical Foundations: Feature Engineering, Probability, Neural Networks. AI-Based Smart Grid Load Balancing. AI in fault detection, power system stability, and control.

**Module 2:** **AI & Deep Learning for Power Systems and Smart Grids:** AI for Power System State Estimation & Fault Prediction. Deep Learning for Renewable Energy Forecasting (CNNs, RNNs, LSTMs). AI in Energy Market Prediction & Demand Response. Deep Learning-Based Solar & Wind Energy Forecasting in Indian Grids. AI in renewable energy forecasting, dynamic pricing, and blackout prevention.

**Module 3:** **Reinforcement Learning in Power Electronics, EVs & Smart Grids:** Reinforcement Learning (RL) for Power Systems & Grid Optimization. AI for Battery Management Systems (BMS) & EV Energy Optimization. Deep Q-Learning for Smart Charging Infrastructure. AI for energy storage, fast charging, V2G integration. Reinforcement Learning for EV Smart Charging Optimization.

**Module 4:** **AI-Driven Cybersecurity for Electrical Networks:** Cyber-security Risks in AI-Integrated Power Systems. AI for Intrusion Detection in Smart Grids. AI-Based Attack Prevention & Anomaly Detection. Cybersecurity Challenges in AI-Powered Indian Smart Grids. AI for grid resilience, cyber-attack mitigation in energy networks. Anomaly Detection in Smart Grids using AI & ML Algorithms.

**Module 5:** **Future Trends & AI in Decentralized Power Systems:** Federated Learning for Decentralized Energy Systems. AI in Peer-to-Peer Energy Trading. Quantum AI for Power System Optimization. Blockchain & AI-Based Energy Trading in India. AI in distributed energy systems, next-gen energy markets. AI for Blockchain-Based Smart Energy Trading.

### 7.40.5 Learning Resources:

#### 7.40.5.1 Text Books:

1. James Momoh, Smart Grid: Fundamentals of Design and Analysis, Wiley-IEEE Press.
2. Trevor Hastie, Robert Tibshirani, & Jerome Friedman, The Elements of Statistical Learning, Springer.
3. M. Negnevitsky, Artificial Intelligence: A Guide to Intelligent Systems, Pearson.

#### 7.40.5.2 Reference Books:

1. S. Haykin, Neural Networks and Learning Machines, Pearson.
2. P. S. R. Murty, Operation and Control in Power Systems, BS Publications.
3. Ian Goodfellow et al., Deep Learning, MIT Press
4. IEEE Transactions on AI in Power Systems & Cybersecurity
5. Industry Reports on AI-Driven Smart Grids & Cybersecurity by NITI Aayog

## 7.41 Evolutionary Computation for Electrical Engineering

| Course Code | Courses Name | Course Type | L - T - P | Credits | Total Hours |
|---|---|---|---|---|---|
| EE559 | Evolutionary Computation for Electrical Engineering | Theory | 3 - 0 - 0 | 3 | 42 |

### 7.41.1 Objectives:

The objectives of studying this course are to,

1. Introduce evolutionary computation techniques such as genetic algorithms, swarm intelligence, differential evolution, and artificial immune systems.
2. Explore their applications in power system stability, smart grid optimization, load forecasting, and cybersecurity.
3. Develop hybrid AI-EC approaches for solving advanced electrical engineering challenges in real-world scenarios.

### 7.41.2 Course Outcome:

At the completion of this course, the student shall acquire knowledge and ability

1. CO1 : Apply evolutionary algorithms for optimization in electrical engineering problems.
2. CO2 : Utilize genetic algorithms for load forecasting and power system planning.
3. CO3 : Implement swarm intelligence techniques for smart grid control and demand response.
4. CO4 : Analyse differential evolution and artificial immune systems for system stability and cybersecurity.
5. CO5 : Explore hybrid AI and EC approaches for advanced energy applications.

### 7.41.3 CO - PO Mapping:

| **Relationship of Course Outcomes to Program Outcomes** | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **CO ↓** | **PO** | | | | | | | | | | | |
| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
| CO1 | H | H | H | H | L | H | M | L | L | L | L | M |
| CO2 | H | H | H | H | H | L | H | L | L | L | M | H |
| CO3 | H | H | H | H | M | M | H | L | L | L | M | H |
| CO4 | H | H | M | M | M | M | M | L | L | L | M | M |
| CO5 | H | H | H | H | H | H | H | L | L | L | M | H |
| **H = High correlation; M = Medium correlation; L = Low correlation** | | | | | | | | | | | | |

### 7.41.4 Syllabus:

**Module 1:** **Introduction to Evolutionary Computation and Its Role in Electrical Engineering:** Introduction to Optimization in Electrical Engineering. Fundamentals of Evolutionary Computation (EC) & Bio-Inspired Algorithms. Comparison of EC with Traditional Optimization Methods. Types of Evolutionary Algorithms (EA): Genetic Algorithms, Evolutionary Programming, Evolutionary Strategies. Optimization of Power Flow in Smart Grids Using Evolutionary Algorithms.

**Module 2:** **Genetic Algorithms and Applications in Electrical Engineering:** Basic Structure of Genetic Algorithms (Selection, Crossover, Mutation). Real-Coded Genetic Algorithms and Constraint Handling Techniques. Multi-Objective Optimization Using GA. Hybrid GA with Neural Networks & Reinforcement Learning. GA-Based Load Forecasting for Indian Power Grid.

**Module 3:** **Swarm Intelligence – Particle Swarm Optimization (PSO) & Ant Colony Optimization (ACO):** Concept of Swarm Intelligence & Self-Organizing Systems. PSO Algorithm: Velocity & Position Update, Convergence Characteristics. Variants of PSO: Adaptive PSO, Multi-Objective PSO (MOPSO). Ant Colony Optimization (ACO) & Bee Colony Optimization (BCO). Optimization of Smart Grid Demand Response using PSO. PSO-Based Load Frequency Control in Power Systems.

**Module 4:** **Differential Evolution & Artificial Immune Systems for Electrical Engineering:** Differential Evolution (DE) Algorithm: Mutation, Crossover & Selection Strategies. DE Variants: Adaptive DE, Multi-Objective DE (MODE). Artificial Immune Systems (AIS) for Anomaly Detection in Electrical Systems. Clonal Selection Algorithm (CSA) & Negative Selection Algorithm (NSA). Hybrid DE with Deep Learning for Smart Grid Applications. DE for Voltage Stability Assessment in Power Systems. AIS for Cybersecurity in Smart Grids & Renewable Energy Networks.

**Module 5:** **Advanced Evolutionary Computation & Real-World Applications in Electrical Engineering:** Memetic Algorithms and Neuro-Evolution. Co-Evolutionary & Hybrid Evolutionary Algorithms. AI-Based Hyperparameter Optimization Using EC. EC in Quantum Computing & Blockchain-Based Energy Trading. Real-World Applications of EC in Electrical Engineering, Robotics & Cybersecurity. Neuro-Evolution in Energy Market Forecasting. Blockchain-Based Smart Grid Optimization using EC. Neuro-Evolution for Fault Detection in Indian Power Grids.

### 7.41.5 Learning Resources:

#### 7.41.5.1 Text Books:

1. X.-S. Yang, Nature-Inspired Optimization Algorithms, Elsevier.
2. D. E. Goldberg, Genetic Algorithms in Search, Optimization, and Machine Learning, Addison-Wesley
3. James Kennedy & R. Eberhart, Swarm Intelligence, Morgan Kaufmann

#### 7.41.5.2 Reference Books:

1. Kenneth A. De Jong, Evolutionary Computation: A Unified Approach, MIT Press.
2. A. P. Engelbrecht, Computational Intelligence: An Introduction, Wiley.
3. M. H. Rashid, Power Electronics Handbook: Devices, Circuits, and Applications, Academic Press.
4. IEEE Transactions & research papers on evolutionary computation applications in power systems, smart grids, and cybersecurity.

## 7.42 VLSI Technology

| Course Code | Courses Name | Course Type | L - T - P | Credits | Total Hours |
|---|---|---|---|---|---|
| EE560 | VLSI Technology | Theory | 3 - 0 - 0 | 3 | 42 |

### 7.42.1 Objectives:

The objectives of studying this course are to,

1. Understand basic Flow of VLSI design
2. Familiar with VLSI design and Technology.
3. Link knowledge of CAD tools with VLSI system designs
4. Have the ability to formulate problems, problem solving skills.
5. Analyze CMOS cells used in larger system design application

### 7.42.2 Course Outcome:

At the completion of this course, the student shall acquire knowledge and ability to,

1. CO1 : Describe the fabrication process and properties of MOS devices.
2. CO2: Analyze the impact of scaling on MOS circuit
3. CO3:Comprehend the need of hardware description language and its features.
4. CO4: Explain various modeling styles of architecture declaration
5. CO5: Familiar with EDA tools and physical design of IC
6. CO6: Perform design validation and verification using DRC, LVS, ERC, and formal verification methodologies to ensure reliability.

### 7.42.3 CO - PO Mapping:

| **Relationship of Course Outcomes to Program Outcomes** | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **CO ↓** | **PO** | | | | | | | | | | | |
| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
| CO1 | H | H | M | M | M | M | L | L | L | L | L | M |
| CO2 | H | H | H | H | H | M | L | L | L | L | L | H |
| CO3 | H | H | H | H | H | M | L | L | L | L | L | H |
| CO4 | H | H | H | M | H | M | L | L | L | L | M | H |
| CO5 | H | H | H | H | M | M | L | L | L | L | M | H |
| CO6 | H | H | H | H | M | M | L | L | L | L | M | H |
| **H = High correlation; M = Medium correlation; L = Low correlation** | | | | | | | | | | | | |

### 7.42.4 Syllabus:

**Module 1:** Application of Electronics in various applications and various fields of engineering. Electronic devices: active, passive, and interconnects. Classification of circuits Digital, Analog RF. Typical VLSI devices, Processor and Memories .

**Module 2:** VLSI fabrication technology, Miniaturization of devices, Foundry concept, the economy of the batch fabrication. Concepts of yield and reliability The figure of merit of VLSI devices, Area. Power, Delay.

**Module 3:** Overview of VLSI design flow, EDA tools, synthesis, placement, routing, layout. Design optimization. Design rules, IP Design Methodology, SoC Physical Design Methodology Design for Testability (DFT), Design-for-Manufacturability (DFM).

**Module 4:** Design implementation, Logic synthesis, RTL modeling, and simulation. Electronic circuits modeling and simulation by using SPICE. CMOS circuits' inverters, and design of basic gates. Examples and Hands-on experiments with RTL simulation circuit simulation.

**Module 5:** Design validation, functional testing, formal verification Physical Design Verification, Design Rule Checking (DRC) Layout-Versus-Schematic (LVS) Verification, Electrical Rule Checking (ERC), Lithography Process Checking (LPC), DRC Waivers.

### 7.42.5 Learning Resources:

#### 7.42.5.1 Text Books:

1. Neil H. E. Weste and David Money Harris, “CMOS VLSI design: A Circuits and Systems Perspective”, Pearson Publications

2. Thomas Dillinger, “VLSI Design Methodology development”, Pearson Publications

3. Sneh Saurabh, “Introduction to VLSI Design Flow”

#### 7.42.5.2 Reference Books:

1. Jan M. Rabaey, “Digital Integrated Circuits: A design perspective”, Pearson Publications

2. Morris M. Mano and M. D. Cilettil, “Digital Design”, Pearson

## 7.43 Multimedia Systems

| Course Code | Courses Name | Course Type | L - T - P | Credits | Total Hours |
|---|---|---|---|---|---|
| EE561 | Multimedia Systems | Theory | 3 - 0 - 0 | 3 | 42 |

### 7.43.1 Objectives:

The objectives of studying this course are to,

1. Understand the role of hardware accelerators in embedded systems.
2. Learn design methodologies for implementing hardware accelerators.
3. Explore optimization techniques for performance enhancement.
4. Gain hands-on experience in integrating accelerators with embedded platforms.

### 7.43.2 Course Outcome:

At the completion of this course, the student shall acquire knowledge and ability to,

1. CO1 : Analyze the key components of multimedia technologies including text, graphics, voice, video and animation and the broad principles associated with multimedia concepts used in computer graphics.
2. CO2: Understand different lossy and lossless compression algorithms.
3. CO3: Understand the various transforms required to compress images and critically analyze their advantages and limitations.
4. CO4: Analyze different audio, image and video compression standards and their advance features.
5. CO5: Understand different protocols of multimedia communication networking and their applications

### 7.43.3 CO - PO Mapping:

| **Relationship of Course Outcomes to Program Outcomes** | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **CO ↓** | **PO** | | | | | | | | | | | |
| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
| CO1 | H | H | M | M | M | M | L | L | L | L | L | M |
| CO2 | H | H | H | H | H | M | L | L | L | L | L | H |
| CO3 | H | H | H | H | H | M | L | L | L | L | L | H |
| CO4 | H | H | H | M | H | M | L | L | L | L | M | H |
| CO5 | H | H | H | H | M | M | L | L | L | L | M | H |
| **H = High correlation; M = Medium correlation; L = Low correlation** | | | | | | | | | | | | |

### 7.43.4 Syllabus:

**Module 1:** **Multimedia Application:** An extensive overview of state-of-the-art techniques, traditional development flows and algorithms on multimedia, image and multimedia processing, audio processing and highlight their limitations in the light of performance, power, and memory requirements. Programmable and custom architectures and algorithms, advanced video memories hierarchies and specialized (multi-/many-core) hardware processor architectures and design methods (e.g., Pipelined MPSoCs, Stream Processors, and Stochastic Processors).

**Module 2:** **Algorithms and Embedded systems:** Review of various architecture types, design consideration, memory reuse mechanisms, sub-task scheduling, architecture evaluation, resource sharing; High performance architectures, wavelet VLSI architectures; DCT architectures; lossless coders, Advanced arithmetic architectures and design methodologies: division and square root; finite field arithmetic; cordic algorithms and architectures for fast and efficient vector-rotation implementation; advanced systolic design; low power design; power estimation approaches; system exploration for custom low power data storage and transfer; hardware description and synthesis of DSP systems.

**Module 3:** **Architectures for multimedia CODEC module:** Design and analysis of several light-weight multimedia and image processing algorithms and computation management techniques. Study of various architectures for motion estimation, Intra prediction, Integer discrete cosine transform, motion compensation , deblocking filter, entropy coder, system integration and Future generation hardware codecs.

### 7.43.5 Learning Resources:

#### 7.43.5.1 Text Books:

1. Richardson, Iain E, "The H.264 advanced video compression standard", John Wiley & Sons.
2. Parhi, Keshab K., and Takao Nishitami, "Digital signal processing for multimedia systems", CRC Press.
3. Parhi, Keshab K, "VLSI digital signal processing systems: design and implementation", John Wiley & Sons, 2007.

#### 7.43.5.2 Reference Books:

1. Lee, Jae-Beom, and Hari Kalva. The VC-1 and H. 264 video compression standards for broadband video services. Vol. 32, Springer
2. Tian, Xiaohua, M. Le Thinh, and Yong Lian, Entropy Coders of the H. 264/AVC Standard, Springer.
3. Lin, Youn-Long Steve, et al. VLSI Design for Video Coding, Springer.
4. Ramachandran, and Seetharaman, "Digital VLSI systems design", Springer

## 7.44 Reliability Engineering

| Course Code | Courses Name | Course Type | L - T - P | Credits | Total Hours |
|---|---|---|---|---|---|
| EE562 | Reliability Engineering | Theory | 3 - 0 - 0 | 3 | 42 |

### 7.44.1 Objectives:

The objectives of studying this course are to,

1. Introduce the fundamental concepts of reliability engineering in electrical systems.
2. Understand reliability metrics, failure rates, and life expectancy of electrical components.
3. Analyze reliability modeling techniques, including series, parallel, and complex systems.
4. Explore maintenance strategies and fault tolerance methods for electrical equipment.
5. Study reliability enhancement techniques for power systems, machines, and electronics.
6. Apply reliability engineering principles to optimize electrical system performance and safety.

### 7.44.2 Course Outcome:

At the completion of this course, the student shall acquire knowledge and ability to,

1. CO1 : Recognize the basic reliability principles of engineering systems (probabilistic analysis, simulation
2. CO2: Evaluate system reliability using decomposition, transformation, and inversion techniques for time-dependent failure models.
3. CO3: Apply design methodologies for reliability improvement, including failure analysis and fault tree analysis.
4. CO4: Utilize reliability estimation techniques and empirical methods for real-world electrical engineering applications.

### 7.44.3 CO - PO Mapping:

| **Relationship of Course Outcomes to Program Outcomes** | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **CO ↓** | **PO** | | | | | | | | | | | |
| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
| CO1 | H | H | M | M | M | M | L | L | L | L | L | M |
| CO2 | H | H | H | H | H | M | L | L | L | L | L | H |
| CO3 | H | H | H | H | H | M | L | L | L | L | L | H |
| CO4 | H | H | H | M | H | M | L | L | L | L | M | H |
| **H = High correlation; M = Medium correlation; L = Low correlation** | | | | | | | | | | | | |

### 7.44.4 Syllabus:

**Module 1:** Causes and types of failures, reliability expressions for constant, increasing and decreasing hazard rates. Data Analysis, Probability plots for various distributions (exponential, Weibull, Normal and Gamma), series, parallel, series-parallel, standby and k-out-of-m modeling.

**Module 2:** System reliability: evaluation techniques, including methods of bounds, decomposition and transformation techniques, single and multiple variable inversion techniques for minimizing system reliability expression, time-dependent failure models, state-dependent systems.

**Module 3:** Design for reliability: Reliability specification and system measurements, reliability allocation, design methods, failure analysis, system safety and fault tree analysis.

**Module 4:** Maintainability and Availability: analysis of downtime, repair-time distribution, stochastic point processes, system repair time, preventive maintenance, systems availability, design trade-off analysis.

**Module 5:** Analysis of failure date: data collections and empirical methods, reliability testing, reliability estimation and applications in electrical engineering.

### 7.44.5 Learning Resources:

#### 7.44.5.1 Text Books:

1. Charles E. Ebeling, “An introduction to Reliability and Maintainability Engineering”:, MGH.
2. E. Balagurusamy, “Reliability Engineering”, TMH, 1984

#### 7.44.5.2 Reference Books:

1. Roy Bilinton and Ronald N. Allan, “Reliability Evaluation of Power System”, 2nd edition, Plenum press, NY
2. L S Srinath, “Reliability Engineering”, East-West Press

# Part III

# Course Content : Open Elective Courses

**(Offered by EEE Department for the students of other Departments)**

# Module 8

# Open Elective Courses:

## 8.1 Electrical System Design for Buildings

| Course Code | Courses Name | Course Type | L - T - P | Credits | Total Hours |
|---|---|---|---|---|---|
| EE900 | Electrical System Design for Buildings | Theory | 3 - 0 - 0 | 3 | 42 |

### 8.1.1 Objectives:

The objectives of studying this course are to,

1. Provide an in-depth understanding of electricity market structures and operations.
2. Examine key challenges faced by electricity markets globally and their solutions.
3. Analyze different types of market operational and control issues.
4. Explore various electricity market models used worldwide.
5. Develop mathematical models to address market challenges and improve efficiency.
6. Understand emerging trends and innovations shaping modern electricity markets.

### 8.1.2 Course Outcome:

At the completion of this course, the student shall acquire knowledge and ability to,

1. CO1 : Grasp the basic principles of Electrical System Design for Buildings and effectively apply them to solve engineering problems.
2. CO2 : analyse the significance of Electrical System Design for Buildings and its wide-range of applications.
3. CO3 : comprehend the fundamental concepts of Distribution Systems, Wiring, Electrical system design, Smart Buildings, automation, testing and their practical applications.
4. CO4 : evaluate the techniques involved in Electrical System Design for Buildings.

### 8.1.3 CO - PO Mapping:

| **Relationship of Course Outcomes to Program Outcomes** | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **CO ↓** | **PO** | | | | | | | | | | | |
| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
| CO1 | H | H | H | M | M | M | H | H | H | M | M | H |
| CO2 | H | H | H | M | M | M | H | H | H | M | M | H |
| CO3 | H | H | H | M | M | M | H | H | H | M | M | H |
| CO4 | H | H | H | M | M | M | H | H | H | M | M | H |
| **H = High correlation; M = Medium correlation; L = Low correlation** | | | | | | | | | | | | |

### 8.1.4 Syllabus:

**Module 1:** **Introduction:** Basics of electrical systems in buildings, electrical designs in construction projects, Standards and codes, Electrical Load Estimation and Demand Calculations, load forecasting, Load factors, Power factor considerations, Tariff, Smart metering and load management..

**Module 2:** **Distribution Systems and Wiring:** Distribution boards, panels and switchgear, Transformer selection and placement, Earthing and bonding techniques, Types of wiring, Cable selection, Voltage drop calculations, Smart wiring technologies, Types of lighting, Lux calculations, Illumination schemes, Energy Efficiency Schemes, National Electrical Code.

**Module 3:** **Electrical system design and Smart Buildings:** Electrical system design, estimation and costing for various buildings– domestic, commercial complex, hospitals, schools, cinema theatres, small industries. Design of electrical installations of high-rise buildings: electrical aspects of lifts, escalator services, stand by generators. Solar PV integration and renewable energy, Fire and shock hazard prevention, Green buildings, Net-zero and energy-positive buildings, Certifications & Policies.

**Module 4:** **Automation and Testing:** Building Management Systems (BMS), Heating Ventilation and Air Conditioning (HVAC), Energy-efficient designs, IoT and relevant technology integration, Insulation resistance, earth resistance, continuity tests, Power quality, Safety of electrical installations.

### 8.1.5 Learning Resources:

#### 8.1.5.1 Text Books:

1. K.B.Raina, S.K.Bhattacharya, Electrical Design, Estimating and Costing, New Age International(p) Ltd.Publishers,NewDelh
2. Surjit Singh. Electrical Estimating and Costing, Dhanpat Rai & Co., Delhi, 2005.
3. ISI, National Electrical Code, Bureau of Indian Standard Publications.
4. G. Ramamurthy, Hand book of Electrical Power Distribution, Universities Press (India) Private Ltd., NewDelhi, 2004.

#### 8.1.5.2 Reference Books:

1. N Alagappan, S Ekambaram, Electrical estimating and Costing, McGraw-Hill,1999.
2. Narang K.L., A Text Book of Electrical Engineering Drawing, Tech India Publications, 1963
3. Er. V. K. Jain, Er. Amitabh Bajaj, Design of Electrical Installations, University Science Press.
4. Code of practice for Electrical wiring installations, (System voltage not exceeding 650 volts), Indian Standard Institution, IS: 732-1983.
5. Guide for Electrical layout in residential buildings, Indian Standard Institution, IS: 4648-1968.
6. Relevant Research papers

## 8.2 General Aspects of Electrical Safety

| Course Code | Courses Name | Course Type | L - T - P | Credits | Total Hours |
|---|---|---|---|---|---|
| EE901 | General Aspects of Electrical Safety | Theory | 3 - 0 - 0 | 3 | 42 |

### 8.2.1 Objectives:

The objectives of studying this course are to,

1. Provide comprehensive knowledge of electrical hazards and associated risks.
2. Explore various grounding techniques to ensure electrical safety.
3. Understand essential safety procedures for handling electrical systems.
4. Learn different electrical maintenance techniques for system reliability.
5. Develop awareness of emergency response and first aid for electrical accidents.
6. Emphasize the importance of safety compliance and standards in electrical engineering.

### 8.2.2 Course Outcome:

At the completion of this course, the student shall acquire knowledge and ability to,

1. CO1 : Grasp the basic principles of Electrical Safety and effectively apply them to solve engineering problems.
2. CO2 : Analyse the significance of Electrical Safety and its wide-range of applications.
3. CO3 : Comprehend the fundamental concepts of electrical hazards, grounding, bonding, safety methods, handling emergencies and their practical applications.
4. CO4 : Evaluate the techniques involved in Electrical Safety.

### 8.2.3 CO - PO Mapping:

| **Relationship of Course Outcomes to Program Outcomes** | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **CO ↓** | **PO** | | | | | | | | | | | |
| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
| CO1 | H | H | H | M | M | M | H | H | H | L | M | H |
| CO2 | H | H | H | M | M | M | H | H | H | L | M | H |
| CO3 | H | H | H | M | M | M | H | H | H | L | M | H |
| CO4 | H | H | H | M | M | M | H | H | H | L | M | H |
| **H = High correlation; M = Medium correlation; L = Low correlation** | | | | | | | | | | | | |

### 8.2.4 Syllabus:

**Module 1:** **Introduction:** Importance of electrical safety, Primary and secondary hazards- arc, blast, shocks-causes and effects-safety equipment, flash and thermal protection, head and eye protection, rubber insulating equipment, hot sticks, insulated tools, barriers and signs, safety tags, locking devices, voltage measuring instruments, proximity and contact testers, electrician's safety kit. electrical one line diagram.

**Module 2:** **Requirements for grounding and bonding:** Definitions. System grounding, purpose of grounding, grounding methods, grounding of low voltage and high voltage systems. Bonding of electrically conducting materials and other equipments, connection of grounding and bonding equipment.

**Module 3:** **Safety methods:** Pre job briefings, hot-work decision tree, safe switching of power system, lockout-tag out, flash hazard calculation and approach distances. Arc protection requirements, safety equipment, procedures for low, medium and high voltage systems. one-minute safety audit, Electrical safety programme structure, company safety, safety policy programme implementation, employee electrical safety teams, safety audit, accident prevention-first aid, rescue techniques, accident investigation, Indian Electricity Acts related to Electrical Safety.

**Module 4:** **Electrical maintenance and Emergency response:** Reliability centered maintenance (RCM), eight step maintenance programme, maintenance requirement for specific equipment and location, regulatory bodies, national electrical safety code, standards for electrical safety at workplace, occupational safety and health administration standards, first aid for burns and shocks, Cardiopulmonary Resuscitation (CPR) for electric shock victims, Case studies and accident prevention.

### 8.2.5 Learning Resources:

#### 8.2.5.1 Text Books:

1. John Cadick, Mary Capelli-Schellpfeffer, Dennis Neitzel, Al Winfield, 'Electrical Safety Handbook', McGraw-Hill Education, 4th Edition, 2012.

2. Maxwell Adams. J, 'Electrical Safety- a guide to the causes and prevention of electric hazards', The Institution of Electric Engineers, IET 1994.

1. Ray A. Jones, Jane G. Jones, 'Electrical Safety in the Workplace', Jones & Bartlett Learning, 2000.

2. Relevant Research papers

## 8.3 Introduction to Non-Conventional Energy

| Course Code | Courses Name | Course Type | L - T - P | Credits | Total Hours |
|---|---|---|---|---|---|
| EE902 | Introduction to Non-Conventional Energy | Theory | 3 - 0 - 0 | 3 | 42 |

### 8.3.1 Objectives:

The objectives of studying this course are to,

1. Recognize the importance of alternate energy in the evolving energy landscape.
2. Explore various alternate energy sources and their associated technologies.
3. Understand the principles and working mechanisms of renewable energy systems.
4. Analyze the environmental and economic impacts of renewable energy adoption.
5. Evaluate the challenges and opportunities in integrating alternate energy sources into existing grids.
6. Foster awareness of sustainable energy solutions for future energy demands.

### 8.3.2 Course Outcome:

At the completion of this course, the student shall acquire knowledge and ability to,

1. CO1 : Study the basic portions of electrical engineering which are required to understand power production from renewable energy sources
2. CO2: Enable the student to design and evaluate a renewable power generator at system level
3. CO3: Enable the student to evaluate the feasibility of a particular renewable energy source based on resource availability and techno-economic considerations
4. CO4: Enable the student to identify the potential benefits and challenges associated with replacing a conventional energy source with an alternate source

### 8.3.3 CO - PO Mapping:

| **Relationship of Course Outcomes to Program Outcomes** | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **CO ↓** | **PO** | | | | | | | | | | | |
| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
| CO1 | M | L | L | L | L | L | L | L | L | L | L | L |
| CO2 | M | L | H | L | L | L | H | L | L | L | L | H |
| CO3 | M | L | M | L | M | L | H | L | L | L | H | H |
| CO4 | M | L | L | L | M | H | H | L | L | L | L | L |
| **H = High correlation; M = Medium correlation; L = Low correlation** | | | | | | | | | | | | |

### 8.3.4 Syllabus:

**Module 1:** **Introduction:** Overview of global and national energy scenarios, Necessity for sustainable and alternative energy solutions, Examination of various renewable energy technologies and options.

**Module 2:** **Solar Energy:** Principles of solar radiation and measurement techniques,Solar thermal energy conversion methods, Fundamentals of photovoltaic (PV) cells, materials, and technologies, Design of PV power generation systems.

**Module 3:** **Wind Energy:** Wind resource assessment and characteristics, Fundamentals of wind turbine aerodynamics, Wind turbine configurations and technologies, Wind energy systems.

**Module 4:** **Other Renewable Energy Sources:** Hydropower: Classification of hydroelectric power plants, small and large-scale hydro systems, and pumped hydro storage, Biomass energy: Technologies and applications, Geothermal and ocean energy: Potential, technologies, and utilization.

**Module 5:** **Energy Storage and Integration:** Role of energy storage in renewable energy systems, Battery technologies and their applications in power systems.

**Module 6:** **Environmental and Economic Considerations:** Life cycle assessment of renewable energy technologies, Economic feasibility analysis and policy frameworks, Environmental impacts and mitigation strategies.

### 8.3.5 Learning Resources:

#### 8.3.5.1 Text Books:

1. S P Sukhatme, J K Nayak, "Solar Energy: Principles of thermal collection and Storage," 3rd edition, McGraw Hill Education 2008

2. Chetan Singh Solanki, Solar Photovoltaics: fundamentals, Technologies and Applications, Prentice Hall of India, 2011.

3. S N Bhadra, D Kastha and S Banerjee, 'Wind Electric Systems', Oxford Publications, 2nd Edition, 2007

#### 8.3.5.2 Reference Books:

1. Twidell, J. and Weir, T., Renewable Energy Resources, Taylor & Francis, 3rd Edition, 2015.

2. Principles of Solar Engineering, D.Y. Goswami, F.Kreith and J.F. Kreider, Taylor and Francis, Philadelphia, 2000.

3. Boyle, G., Renewable Energy: Power for a Sustainable Future, Oxford University Press, 3rd Edition, 2012

## 8.4 Electric Vehicle Technology

| Course Code | Courses Name | Course Type | L - T - P | Credits | Total Hours |
|---|---|---|---|---|---|
| EE903 | Electric Vehicle Technology | Theory | 3 - 0 - 0 | 3 | 42 |

### 8.4.1 Objectives:

The objectives of studying this course are to,

1. Understand the basic architecture, key components, and classifications of Electric Vehicles (EVs), including BEVs, FCEVs, HEVs, and PHEVs.
2. Compare EV technology with ICE vehicles, highlighting differences in performance and efficiency.
3. Learn vehicle mechanics, transmission systems, and design parameters, focusing on propulsion power, traction force, and vehicle dynamics.
4. Explore the types, requirements, and operational characteristics of EV motors, including starting, braking, speed, and torque control.
5. Understand the role of power converters, study power electronic switches, and analyze converters for EVs.
6. Learn the fundamentals of electric drives, their modeling, and control to ensure optimal EV motor performance.

### 8.4.2 Course Outcome:

At the completion of this course, the student shall acquire knowledge and ability to,

1. CO1 : Understand the architecture, components, and classification of electric vehicles, and compare EV technologies with internal combustion engine vehicles.
2. CO2: Analyze vehicle mechanics and dynamics including transmission, propulsion power, and drive cycle for different EV operating modes.
3. CO3: Evaluate the types, requirements, and characteristics of EV motors, including speed and torque control.
4. CO4: Demonstrate understanding of power electronic devices and design basic converters for EV applications.
5. CO5: Apply principles of electric drives, including modeling and control, in the context of EV performance.

### 8.4.3 CO - PO Mapping:

| **Relationship of Course Outcomes to Program Outcomes** | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **CO ↓** | **PO** | | | | | | | | | | | |
| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
| CO1 | H | M | L | L | M | M | H | M | L | L | L | H |
| CO2 | H | H | M | M | M | L | M | L | L | L | L | M |
| CO3 | H | M | H | M | M | L | M | L | L | L | M | H |
| CO4 | H | M | H | H | H | L | M | L | L | M | M | H |
| CO5 | H | H | H | M | H | L | M | L | L | M | M | H |
| **H = High correlation; M = Medium correlation; L = Low correlation** | | | | | | | | | | | | |

### 8.4.4 Syllabus:

**Module 1:** **EV Architecture:** History, Basics of Electric Vehicles, Components of Electric Vehicle, EV classification: Battery Electric Vehicles (BEVs), Fuel-Cell Electric Vehicles (FCEVs) , Hybrid Electric Vehicles (HEVs), Plug-in Hybrid Electric Vehicles (PHEVs),Comparison with Internal Combustion Engine technology - Types of EVs and HEVs configuration, Battery charging technologies, Battery management system.

**Module 2:** **Vehicle mechanics:** Vehicle fundamentals, Transmission system, Vehicle design parameters-Vehicle dynamics- Propulsion power, Traction force, drive cycle, Traction force equation and vehicle dynamics in different modes of operation of EV.

**Module 3:** **Motors for EV:** Requirements of EV motors, Comparison with Industrial motors, Classification and characteristics study of EV Motors. Construction and working principle, Operating characteristics, starting, braking, speed and torque control of a EV motor of interest.

**Module 4:** **Power Converters and Drive for EV:** Need for power converters in EV, Introduction to power electronic switches, study of VI characteristics of PE switches, Realisation of a basic DC/DC and DC/AC converter, study of converter required for the EV motor studied in detailed, Concept of Electric drive, Requirements of electric drive in EV, Modelling and control of electric drive in EV considering the motor keeping in mind.

### 8.4.5 Learning Resources:

#### 8.4.5.1 Text Books:

1. James Larminie , “Electric Vehicle Technology Explained”, John Wiley & Sons, 2003.
2. Behrooz Mashadi and David Crolla , “Vehicle Powertrain Systems “,Wiley, 2012
3. Mehrdad Ehsani, Yimin Gao, Stefano Longo, Kambiz Ebrahimi , “Modern Electric, Hybrid Electric, and Fuel Cell Vehicles” Third edition CRC Press, 2018

#### 8.4.5.2 Reference Books:

1. Iqbal Husain, “Electric and Hybrid Vehicles, Design Fundamentals,” CRC Press,2003.
2. K Wang Hee Na, AC Motor Control & Electrical Vehicle Application, CR Press, Taylor & Francis Group, 2019
3. Ali Elamadi, “Handbook of Automotive Power Electronics and Drives”, CRC publishers, 2012.

**The End**