Under Graduate Programme

B. Tech.
in
Electrical Engineering

Curriculum of 3rd Year

(as per NEP with effect from batch 2023-24)

सरदार वल्लभभाई राष्ट्रीय प्रोद्योगिकी संस्थान, सूरत

SARDAR VALLBHBHAI NATIONAL INSTITUTE OF TECHNOLOGY, SURAT

विधुत इंजीनियरिंग विभाग

DEPARTMENT OF ELECTRICAL ENGINEERING

SARDAR VALLABHBHAI NATIONAL INSTITUTE OF TECHNOLOGY, SURAT

DEPARTMENT OF ELECTRICAL ENGINEERING

Course Structure and Scheme of Evaluation (Semester wise)
B. Tech. Electrical Engineering (3rd Year Scheme)

Sr. No.	Subjects	Code	Scheme L-T-P	Credits (Min.)	Notional hours of Learning(Approx.)
Fifth Semester (3rd year of UG)					
1.	Control Systems	EE301	3-1-2	5	100
2.	Power Electronic Converters	EE303	3-1-2	5	100
3.	Power System Analysis	EE331	3-1-2	5	100
4.	Global Elective	EE3AA	3-0-0	3	55
5.	Elective	EE3BB	3-0-0	3	55
			Total	**21**	**410**
6.	Minor/Honor/ (M/H#1)	EE3CC	3-X-X	4	70/85
Sixth Semester (3rd year of UG)					
1.	Electrical and Electronic Measurements	EE302	3-1-2	5	100
2.	Micro-processors and Microcontrollers	EE304	3-1-2	5	100
3.	Electrical Machine Design	EE332	3-1-0	4	70
4.	Global Elective	EE3DD	3-0-0	3	55
5.	Elective	EE3EE	3-0-0	3	55
			Total	**20**	**380**
6.	Minor/Honor/ (M/H#1)	EE3FF	3-X-X	4	70/85
7.	MOOC course (Swayam/NPTEL)	EE3XX	3/4-0-0	3/4	70/80
8.	Vocational Training/ Professional Experience (optional) (Mandatory for Exit)	EEV04/ EEP04	0-0-10	5	200 (20x10)

Sr. No.	**Electives**	Code	Scheme L-T-P
B. Tech. III year, V Semester (EE3AA) (Global Elective)			
1.	Optimization Methods	EE351	3-0-0
2.	Random Processes	EE352	3-0-0
3.	Artificial Intelligence Techniques	EE353	3-0-0
B. Tech. III year, V Semester (EE3BB)			
1.	Electrical Traction and Linear Machines	EE354	3-0-0
2.	Power System Operation and Control	EE355	3-0-0
3.	Reliability Evaluation of Electrical Systems	EE356	3-0-0
4.	Cryptography and Cyber Security of Smart Grid	EE357	3-0-0
B. Tech. III year, VI Semester (EE3DD) (Global Elective)			
1.	Robotics	EE361	3-0-0
2.	Sustainable Energy	EE362	3-0-0
3.	Utilization of Electrical Energy	EE363	3-0-0
B. Tech. III year, VI Semester (EE3EE)			
1.	Switchgear and Protection	EE364	3-0-0
2.	Industrial Automation	EE365	3-0-0
3.	Forecasting and Planning Methods	EE366	3-0-0
4.	Instrumentation	EE367	3-0-0
5.	Modern Control Systems	EE368	3-0-0
6.	Wind and Solar Energy Conversion	EE369	3-0-0
7.	State Variable Analysis	EE370	3-0-0

Sr. No.	**for B.Tech. (CE, ME, ChE, IndChe, MaC) students (Minor in Electrical Engineering)**	Code	Scheme L-T-P
1.	Electrical Machine (V semester)	EE381	3-0-2
2.	Power Systems (VI Semester)	EE380	3-0-2

Sr. No.	**for B.Tech. (AI, CSE, ECE, ECVLSI, EnggPhy) students (Minor in Electrical Engineering)**	Code	Scheme L-T-P
1.	Power Systems (V Semester)	EE380	3-0-2
2.	Power Electronics (VI semester)	EE382	3-0-2

Sr. No.	**B.Tech. in Electrical Engineering with Honors** (Vth Semester) (Any one subject)	Code	Scheme L-T-P
1.	Power Electronic Systems and Electrical Drives (V semester)	EE391	3-1-0
2.	Restructuring and Deregulation of Power Systems (V semester)	EE392	3-1-0
3.	Discrete Time Control Systems (V semester)	33393	3-1-0

Sr. No.	**B.Tech. in Electrical Engineering with Honors** (VI Semester) (Any one subject)	Code	Scheme L-T-P
1.	Flexible AC Transmission Controllers	EE394	3-1-0
2.	Optimal Control (VI semester)	EE395	3-1-0

Note: Throughout this scheme structure, the notations L, T, P, C denote lecture, tutorial, practical and credit respectively for the related subject.

B. Tech. III year(Electrical), Semester- V

Control Systems

L	T	P	CREDIT
3	1	2	05

EE301 **Scheme**

1. Course Outcomes (Cos):

At the end of the course students will be able to:

CO1	Classify various types of control systems and to develop mathematical modeling of physical systems
CO2	Analyze the response of various control systems in the time domain
CO3	Analyze the stability of control systems using a variety of methods
CO4	Evaluate the response and stability of control systems using frequency domain techniques
CO5	Design various control schemes for linear systems

2. Syllabus:

- **INTRODUCTION TO CONTROL SYSTEMS:** **(02 Hours)**

  Open loop control and close loop control; Illustrative examples of control systems.

- **MATHEMATICAL MODELS OF PHYSICAL SYSTEMS:** **(10 Hours)**

  Linear and non-linear systems; equations and transfer functions for linear mechanical translational systems and linear electrical network; Force-Voltage and Force-Current analogy; Block diagram representation of control systems; Block diagram reduction; Transfer functions of armature-controlled and field-controlled DC servomotors and 2-phase AC servomotors; Signal flow graph and Mason's gain formula.

- **TIME DOMAIN ANALYSIS OF CONTROL SYSTEMS:** **(08 Hours)**

  Typical test signals; Response of first-order systems; Transient response of a second order system due to step input; Time domain specifications of a second order system; Impulse and ramp response of second order system; Steady-state errors; Static error coefficients; Error series and dynamic error coefficients.

- **CONCEPTS OF STABILITY:** **(08 Hours)**

  Introduction to stability, definition through impulse response function, asymptotic stability and relative stability, Routh-Hurwitz stability criterion. Basic Properties of Root Loci, Construction of Root Loci, Effects of Adding Poles and Zeros.

- **FREQUENCY DOMAIN ANALYSIS OF CONTROL SYSTEMS:** **(09 Hours)**

  Steady state response of a system due to sinusoidal input; Frequency response; Logarithmic plots or Bode diagrams; Log-magnitude versus phase plots; Resonant peak and resonant frequency of a second order system; Polar plots; conformal mapping, principal of argument, Nyquist stability criterion, Stability analysis; Relative stability; Gain margin and phase margin; Closed loop frequency response.

- **DESIGN OF CONTROL SYSTEMS:** **(08 Hours)**

  Introduction to phase lag, phase lead and phase lag-lead networks and their applications. P, PI, PID Controllers.

Total Hours: 45

Tutorials will be conducted separately for 15 hours

3. List of Experiments:

1. To obtain open loop and close loop transfer function for an oven.
2. To control the speed of two-phase AC Servo motor using auto tunable PI controller.
3. To understand the practical Air blower control system and to control the speed Of Blower us Programmable Logic Controller (PLC) and VFD from SCADA.
4. a) To obtain no load speed Vs control voltage curve for the two phase servo motor
   b) To obtain speed –torque curves for the various control voltages of servo motor.
5. To obtain Close Loop Response of an OVEN.
6. To understand the about the transient behavior on practical Air blower control system.
7. To understand the PID controller tuning using MATLAB.
8. To obtain the frequency response of phase lead network
9. a) To obtain step response and to find transient time domain specification for Second order system using MATLAB.
   b) To obtain Bode plot and Root locus using MATLAB.

4. Books Recommended:

1. I. J. Nagrath and M. Gopal, Control system engineering, New Age International Publishers, 3rd Edition, 2001.
2. K. Ogata, Modern control system engineering, Pearson Education Asia, 4th Edition, 2002.
3. B. C. Kuo, Automatic control system, Prentice Hall of India, 7th Edition, 1995.
4. Richard C. Dorf and Robert H Bishop, Modern control system, Pearson Education Asia. 8th Edition, 2004.
5. N. S. Nise, Control System Engineering, John Wiley & sons, 4th Edition, 2004.

B. Tech. III year (Electrical), Semester- V

Power Electronic Converters

L	T	P	CREDIT
3	1	2	05

EE303 Scheme

1. Course Outcomes (COs):

At the end of the course students will be able to:

CO1	Understand the basic principle of operation of semiconductor devices and list applications.
CO2	Analyze and compare the performance of various line commutated converters.
CO3	Analyze and design various DC-DC converters.
CO4	Design single-phase and three-phase inverters for various applications.
CO5	Develop laboratory prototype of power electronic systems.

2. Syllabus:

- **POWER SEMICONDUCTOR DEVICES (9 Hours)**

Review of Power semiconductor devices and their static characteristics: Diode, DIAC, Thyristor, TRIAC, Power BJT, MOSFET, IGBT etc., Thyristor: Characteristics, Two transistor analogy, Gate Characteristics, and Methods of triggering, Gate and Base drive circuits - Preliminary design considerations, Ratings and protection of devices, Temperature control of power devices and heat sink design.

- **LINE COMMUTATED CONVERTERS (15 Hours)**

Principle of phase control, half wave controlled rectifiers, half wave controlled rectifiers with R, R-L, R-L-E load, single phase full wave controlled converters, 2-pulse mid-point converters, 2-pulse half and fully controlled bridge converters with R, R-L, R-L-E load, Three phase converter system with diodes, 3 phase half and fully controlled bridge converters, Effect of source impedance on the performance of the converters, Dual converters. Principle of operation and analysis of AC voltage controllers with R and R-L load.

- **DC-DC CONVERTERS (10 Hours)**

Basic principle of operation, Control strategies – Duty ratio control and frequency control, Types of chopper circuits, Steady state time domain analysis of different types of choppers, Principle of operation and analysis of non-isolated DC-DC converters: Buck, Boost, and Buck-Boost converters.

- **INVERTERS (11 Hours)**

Single phase voltage source inverters, half bridge inverters, full bridge inverters, Steady state analysis, Voltage control in single phase inverters, 3-phase bridge inverters, Pulse width modulated inverters, Reduction of harmonics in inverters.

Total Hours: 45

Tutorials will be conducted separately for 15 hours

3. List of Experiments:

1. Study of IGBT, MOSFET, SCR, TRIAC, DIAC Characteristics.
2. Study of Different SCR Triggering Circuit Trainer – DC, R, R-C, UJT.
3. Study of Single Phase Half Controlled Bridge Converter with R, R-L Load.
4. Study of Single Phase Fully Controlled Bridge Converter with R, R-L Load.
5. Study of Single Phase SCR Full Bridge Inverter Circuit.
6. Study of High Voltage Thyristorised Chopper.
7. Study of Single Phase AC Voltage Controller Using SCR.
8. Study of Single Phase AC Voltage Controller Using Triac.
9. Study of Single Phase Dual Converter Circuit.
10. Study of SCR DC Circuit Breaker Circuit.
11. Study of Three Phase SCR Triggering Circuit Using TCA785 IC.
12. Study of AC Solid State Relay Using IC 555, Opto Coupler & Triac.
13. Simulation of Power EC circuits in PSIM and SIMULINK.

4. Books Recommended:

1. Rashid M. H., "Power Electronics Circuits, Devices, and Applications", Prentice-Hall of India Pvt. Ltd., New Delhi, 4th Edition, 2014.
2. Ned Mohan, Tore M. Undeland and William P. Robbins, "Power Electronics Converters, Applications, and Design", John Willey & Sons, Inc., 3rd Edition, 2003.
3. Bimbhra P. S., "Power electronics", Khanna Publishers, New Delhi, 5th Edition, 2014.
4. Singh M. D., Khanchandani, K. B., "Power electronics", Tata McGraw-Hill Publishing Co. Ltd., New Delhi, 2nd Edition, 2006.
5. Agrawal J. P., "Power electronic systems: Theory and design", Addison Wesley Longman (Singapore) Pte. Ltd. New Delhi, 2nd Edition, 2001.

B. Tech. III year(Electrical), Semester- V

Power System Analysis

L	T	P	CREDIT
3	1	2	05

EE331 Scheme

1. Course Outcomes (Cos):

At the end of the course students will be able to:

CO1	Explain the concept of per unit system and its application in power
CO2	Analyze symmetrical and unsymmetrical fault conditions in electrical power systems.
CO3	Discuss, analyze and compare different methods of power flow analysis in power system and estimate economic load dispatch.
CO4	Classify power system stability, and its importance in power system operation
CO5	Illustrate using software tools (MATLAB, ETAP etc.) to examine system performance with reference to fault, load flow and stability and analyze the results

2. Syllabus:

- **REPRESENTATION OF POWER SYSTEM COMPONENTS (04 Hours)**

  Introduction, single phase solution of balanced three phase networks, the one line diagram and the impedance or reactance diagram, per-unit (pu) system, complex power, synchronous machine, representation of loads.

- **LOAD FLOW STUDIES (08 Hours)**

  Network model formulation, formation of Y bus, power flow problem, different types of buses, approximate power flow, Gauss Seidel method, Newton-Raphson method, Decoupled Power flow studies, Fast Decoupled power flow studies, comparison of power flow methods.

- **ECONOMIC LOAD DISPATCH (05 Hours)**

  Economic dispatch of thermal units and methods of solution, Transmission losses, B matrix loss formula, Composite generation production cost function-solution by gradient search techniques, Nonlinear function optimization

- **SYMMETRICAL FAULT ANALYSIS (08 Hours)**

  Introduction, transient on a transmission line, short circuit of a synchronous machine on no load, short circuit of a loaded synchronous machine, balanced three phase fault, short circuit capacity, fault analysis using bus impedance matrix, selection of protective equipment.

- **UNSYMMETRICAL FAULT ANALYSIS (08 Hours)**

  Symmetrical component analysis of unsymmetrical faults, single line to ground (LG) fault, line to line (LL) fault, double line to ground (LLG) fault, open conductor faults, bus impedance matrix method for analysis of unsymmetrical faults.

- **POWER SYSTEM STABILITY (12 Hours)**

  Importance of stability analysis in power system planning and operation - classification of power system stability - angle and voltage stability – simple treatment of angle stability into small-signal and large-signal (transient) stability Single Machine Infinite Bus (SMIB) system: Development of swing equation - equal area criterion - determination of critical clearing angle and time by using modified Euler method and Runge-Kutta second order method. Algorithm and flow chart.

Total Hours: 45

Tutorials will be conducted separately for 15 hours

3. List of Experiments:

Simulations based on different types of faults, stability and transients using MATLAB and ETAP.

1. To study mathematical modeling of R-L, R-L-C and complex electrical circuit using MATLAB.
2. To study mathematical modeling of 3rd order differential equation.
3. To solve differential equations using Euler's and trapezoidal rule.
4. To observe variable of rotor angle and to find critical clearing time when fault occurs at:
   - (i) Sending end of the line
   - (ii) Mid-point of the line
   - (iii) When the fault at mid-point is cleared by removing the faulty line of SMIB system.
5. To study short circuit analysis of overhead transmission line using MATLAB.
6. To study and obtain sub-transient current for symmetrical fault using ETAP software.
7. To perform load flow analysis using ETAP software.
8. To study and determine fault current for short circuit analysis using ETAP software.

4. Books Recommended:

1. J. J. Grainger and W. D. Stevenson, Power System Analysis, McGraw Hill, New Delhi, 1st Edition, 1994.
2. Hadi Saadat, Power System Analysis, 5th reprint, Tata McGraw Hill publishing Company Ltd, New Delhi, 2004.
3. I. J. Nagrath and D. P. Kothari, Power System Engineering, Tata McGraw Hill publishing Company Ltd., New Delhi, 3rd Edition, 2014.
4. J. Duncan Glover, S. Mulkutla Sarma and Thomas Overby, Power System Analysis and Design, 5th Edition Cengage Learning 2012.
5. Arthur R. Bergen, Vijay Vittal, Power Systems Analysis, Prentice Hall of India, Inc., 2nd Edition, 2000.

B. Tech. III year(Electrical), Semester- V

Optimization Methods

L	T	P	CREDIT
3	0	0	03

EE351 Scheme

1. Course Outcomes (Cos):

At the end of the course students will be able to:

CO1	Explain basic concepts and theoretical principles in optimization.
CO2	Convert the a real-world problem, described in words, into a mathematical formulation and solve them.
CO3	Apply efficient computational procedures to solve optimization problems.
CO4	Compare different optimization methods to solve single variable Optimization problems to find maxima/minima.
CO5	Analyze and apply various optimization methods for getting optimum solution of multi variable optimization problems with different constraints.

2. Syllabus:

- **MATHEMATICAL PRELIMINARIES (04 Hours)**

convex sets, intersection of convex sets, vertices or extreme points of a convex set, convex polyhedron, hyper-planes, closed and open half space, convex functions, Local & Global Maxima and Minima. Saddle point, Unconstrained optimization- First and second order necessary and sufficient conditions.

- **LINEAR PROGRAMMING (12 Hours)**

Standard form, Geometry of LP problems, Definitions and theorems, formulation of LP problems, graphical representation and solution of LP in two-dimensional space. Feasible, Basic Feasible and Optimal solutions, pivotal reduction of a set of linear equations, slack and surplus variables, Simplex method and algorithm, two phase method, degeneracy, Big M method. Duality in linear programming, duality theorems. Integer Linear programming graphical representation, Gomory's cutting plane method for all Integers programming problem.

- **TRANSPORTATION AND ASSIGNMENT PROBLEM (05 Hours)**

Description, finding initial basic feasible solution, test for optimality, new Basic solution. Assignment Problem and its solution.

- **SINGLE VARIABLE OPTIMIZATION ALGORITHMS (05 Hours)**

Optimality Criteria- Uni-modal function-Bracketing Methods-Region-Elimination Methods-Fibonacci & Golden section search –Gradient Based Methods:-Newton-Raphson method, Bisection Method, Secant Method.

- **MULTIVARIABLE OPTIMIZATION ALGORITHMS: (08 Hours)**

Optimality Criteria-Unidirectional Search- Direct Search Methods- Hooke-Jeeves pattern method-Powell's conjugate direction method.

Gradient Based Methods: Steepest Descent Method-Newton's Method-Conjugate Gradient Method-Quasi-Newton method.

- **CONSTRAINED OPTIMIZATION ALGORITHMS: (07 Hours)**

Direct Substitution-Lagrange Multiplier Method-Kuhn-Tucker Conditions- Frank and Wolfe method. Cutting plane method.

- **ADVANCED OPTIMIZATION TECHNIQUES: (04 Hours)**

Introduction to Multi objective Optimization, Genetic Algorithm, Swarm base Optimization techniques and other Nontraditional Optimization Algorithms

Total Hours: 45

3. Books Recommended:

1. S. S. Rao, Engineering Optimization, 3rd Edition, New Age International (P) Ltd, New Delhi, 2004.
2. David G. Luenberger, Linear and Non Linear Programming, 2nd Edition, Addison-Wesley Pub. Co., Massachusetts, 1973.
3. W. L. Winston, Operation Research-Applications & Algorithms, Thomson publications, 2003.
4. W. F. Stoecker, Design of Thermal Systems, 3rd Edition, McGraw Hill, 1989.
5. G. B. Dantzig, Linear Programming and Extensions, Princeton University Press, 1998.

B. Tech. III year(Electrical), Semester- V

Random Processes

L	T	P	CREDIT
3	0	0	03

EE352 Scheme

1. Course Outcomes (Cos):

At the end of the course students will be able to:

CO1	Illustrate with examples the concepts of random variables and probability densities
CO2	Infer the statistical properties of various random variables and their properties
CO3	Develop stochastic models for various real-life problems
CO4	Appreciate the importance of Gaussian random variables and Gaussian density in real-life problems
CO5	Apply concepts of state estimation for linear and nonlinear systems

2. Syllabus:

- **CONCEPTS OF PROBABILITY (06 Hours)**

  Introduction, set theory, probability space, Total and Conditional Probability, Bayes' Theorem, Examples.

- **RANDOM VARIABLES (12 Hours)**

  Concept of random variable, Equivalent Events, Classification of Random variables: Continuous and Discrete, Concepts of probability density function (pdf) and probability mass function (pmf), Cumulative distribution function (cdf), Generation of random variables, Vector random variables, Independent random variables, Co-relatedness and Independence.

- **STATISTICAL PROPERTIES OF SCALAR AND VECTOR RANDOM VARIABLES (14 Hours)**

  Frequently used random variables: Uniform and Gaussian random variables, Concepts of Expectation and moments, second central moment, variance, covariance, autocorrelation matrix, Cross correlation matrix, Correlation coefficient, cross covariance, Marginal probability density, Conditional probability density, Joint probability density, Properties of Gaussian random variables.

- **STOCHASTIC PROCESSES (13 Hours)**

  Difference between stochastic and deterministic system, Concept of random process, stationarity and ergodicity, auto correlation function, cross correlation function and their properties, Gaussian process, Markov process, central limit theorem, white noise-properties. Concepts of modelling: Brownian motion, random walk problem, Linear perturbation models, Models for computer control: Linear and nonlinear discrete dynamic models. Least squares estimate, Kalman and extended Kalman filter.

Total Hours: 45

3. Books Recommended:

1. A. Papoulis & S. U. Pillai, Probability, Random Variables and Stochastic Process, 4th Edition, McGraw Hill, 2002.
2. X. Rong Li, Probability Random Signal and Statistics, CRC Press, 1999.
3. A. H. Jazwinski, Stochastic Processes and Filtering Theory, Dover publication, 2005.
4. V. K., Rohatgi and Md. Ehsanes Saleh, An introduction to probability and statistics, 2nd Edition, Wiley India, 2009
5. P. S. Maybeck, Stochastic Models, Estimation and Control, Vol. 1, Academic Press, 1979.

B. Tech. III year(Electrical), Semester- V

Artificial Intelligence Techniques

L	T	P	CREDIT
3	0	0	03

EE353 Scheme

1. Course Outcomes (Cos):

At the end of the course students will be able to:

CO1	Recognize the need of artificial intelligence
CO2	Classify various artificial neural network based on its topology and processing methods
CO3	Design the ANN for various applications
CO4	Explain the basics of fuzzy logic
CO5	Design the fuzzy logic controller for various applications.

2. Syllabus:

- **INTRODUCTION TO ARTIFICIAL INTELLIGENCE (05 Hours)**

  Foundations of AI, History of AI, Agents and environments, The nature of the Environment, Problem solving Agents, Problem Formulation, Search Strategies

- **KNOWLEDGE AND REASONING FOR AI (06 Hours)**

  Knowledge-based Agents, Representation, Reasoning and Logic, Prepositional logic, First-order logic, Using First-order logic, Inference in First-order logic, forward and Backward Chaining

- **ARTIFICIAL NEURAL NETWORKS (08 Hours)**

  History of Neural Networks, Structure and Functions Of Biological And Artificial Neuron, Neural Network Architectures, Characteristics Of ANN, Basic Learning Laws and Methods. Neural Networks Components and Terminology, Neural Networks Topology, Neural Network Adaption, Comparing Neural Networks and Other information Processing Methods, Preprocessing and Post Processing.

- **ARTIFICIAL NEURAL NETWORKS APPLICATIONS (08 Hours)**

  Single Layer Neural Network and architecture, McCulloch-Pitts Neuron Model, Learning Rules, Perceptron Model, Perceptron Convergence Theorem, Delta learning rule, Outstar Learning, Kohenen Self Organization Networks, Learning Vector Quantization

- **FUZZY SYSTEMS CONCEPTS AND PARADIGMS (06 Hours)**

  Fuzzy sets and Fuzzy Logic, Theory of Fuzzy sets, Approximate Reasoning, Fuzzy Systems Implementations and Fuzzy Rule System Implementation.

- **FUZZY APPLICATIONS (12 Hours)**

  Automated Methods for Fuzzy System: Definitions, Batch Least Squares Algorithm, Recursive Least Squares Algorithm, Gradient Method, Clustering Method, Learning From Examples, Modified Learning From Examples, Decision Making with Fuzzy Information: Fuzzy Synthetic Evaluation, Fuzzy Ordering, Non transitive Ranking, Preference and Consensus, Multi objective Decision Making, Fuzzy Bayesian Decision Method, Decision Making Under Fuzzy States and Fuzzy Actions.

Total Hours: 45

3. Books Recommended:

1. Simon Hakins, Neural Networks, Pearson Education, 3rd Edition 2016.
2. Timothy J. Ross, Fuzzy Logic with Engineering Applications, 3rd Edition, Willey, 2010
3. Yang Xiao, Security and Privacy in Smart Grids, CRC Press Taylor & Francis Group, 2014.
4. Stuart Russell, Peter Norvig: Artificial Intelligence: A Modern Approach, 2nd Edition, Pearson Education, 2007.
5. Eberhart & Shi, Computational Intelligence - Concepts to Implementations, Morgan Kaufmann, 1st Edition, 2007.

B. Tech. III year(Electrical), Semester- V

Electrical Traction and Linear Machines

L	T	P	CREDIT
3	0	0	03

EE354 Scheme

1. Course Outcomes (Cos):

At the end of the course students will be able to:

CO1	Describe the constructional details and classify the linear machines.
CO2	Apply knowledge to find present scenario in traction system
CO3	Obtain speed time curves in traction system
CO4	Compute energy consumption in various traction motor system
CO5	Compare various topologies and control for linear machines

2. Syllabus:

- **TRACTION SYSTEMS** **(07 Hours)**

  Introduction, systems of electric traction systems of track electrification, comparison between DC and AC systems of railway electrification from the point of view of main line and suburban line railway services, Modern traction system.

- **TRAIN MOVEMENT AND ENERGY CONSUMPTION** **(08 Hours)**

  Speed-time curves, mechanics of train movement, energy output from driving axles, factors affecting specific energy consumption of an electric train operating on a given schedule speed.

- **ELECTRIC TRACTION MOTORS AND CONTROL** **(12 Hours)**

  Features, characteristics, types, rating and ventilation, Starting and speed control of DC traction motors, starting methods, transition methods, method of speed control, thyristor control of traction motors, speed control and starting of single phase and three phase induction motors, braking; mechanical considerations and control equipment.

- **LINEAR ELECTRIC MACHINES** **(18 Hours)**

  Classifications and Applications of LEMs, Linear Induction Motors: Topologies, Circuit Theories, Transients, and Control, DC-Excited Linear Synchronous Motors, Superconducting Magnet Linear Synchronous Motors, Flat Linear Permanent Magnet Synchronous Motors: topology and control, Linear DC PM Brushless Motors, Application of linear machines in transportation system.

Total Hours: 45

3. Books Recommended:

1. Ion Boldea, Linear Electric Machines, Drives, and MAGLEVs Handbook, CRC press, 2013.
2. Jacek F. Gieras, Zbigniew J. Piech, Bronislaw Z. Tomczuk, Linear Synchronous Motors, Transportation and Automation Systems, 2nd Edition, CRC press.
3. Gupta, J.B., Utilization of Electrical Energy and Electric Traction, S.K.Kataria and sons, 10th Edition, 1990.
4. Rajput R. K.,Utilization of Electrical Power, Laxmi publications, 1st Edition, 2007.
5. H. Partab, Modern Electric Traction, Dhanpat Rai & Co., 3rd Edition, 2012.

B. Tech. III year(Electrical), Semester- V

L	T	P	CREDIT
3	0	0	03

Power System Operation and Control

EE355 **Scheme**

1. Course Outcomes (Cos):

At the end of the course students will be able to:

CO1	analyze various methods of voltage control.
CO2	analyze various methods of load forecasting.
CO3	model multi-area system for frequency control.
CO4	analyze various methods of contingency analysis.
CO5	apply state estimation methods for power system state estimation.

2. Syllabus:

- **AUTOMATIC GENERATION CONTROL** **(05 Hours)**

Single area load frequency control, speed governing system and characteristics, Multiarea load frequency control; flat frequency, flat tie-line load and tie-line load bias control, Economic Dispatch and AGC, EMS, SCADA.

- **METHODS OF VOLTAGE CONTROL** **(06 Hours)**

Reactive power and its relation to voltage control, location of voltage control equipment, methods of voltage control, excitation control, voltage regulators, tap changing transformers, booster transformers, induction regulators, reactive power injection and voltage control by synchronous condenser.

- **UNIT COMMITMENT** **(06 Hours)**

Constraints in Unit commitment, Spinning reserve, Thermal and hydro constraints, Unit commitment solution methods- Priority list methods, Dynamic programming solution.

- **HYDRO THERMAL SCHEDULING** **(06 Hours)**

Short and long range hydro-thermal scheduling, hydroelectric plant models, scheduling problems, Short range hydro-thermal scheduling: Gradient approach, Pumped storage hydro plant, Dynamic programming solution to the hydrothermal scheduling problems.

- **POWER SYSTEM SECURITY** **(08 Hours)**

Factors affecting power system security, Contingency analysis: Detection of network problems, Correcting the generation approach: Sensitivity methods, compensated factors, correcting the generation dispatch using linear programming.

- **STATE ESTIMATION IN POWER SYSTEMS** **(08 Hours)**

Power system state estimation, least square estimation, state estimation of an AC network, Tracking state estimation of power systems, External system equivalence, Detection and identification of bad measurements, Network observability and Pseudo-measurements, Application of power system state estimation.

- **LOAD FORECASTING TECHNIQUES** **(06 Hours)**

Forecasting methodology, Estimation of periodic components, Estimation: Time series approach, Estimation of stochastic component: Kalman filtering approach, Long term load predictions using econometric models, Reactive load forecast.

Total Hours: 45

3. Books Recommended:

1. J. J. Grainger and W. D. Stevenson, Power System Analysis, McGraw Hill, New Delhi 1st Edition, 2017.
2. A. J. Wood and B.F. Wollenberg, Power Generation Operation and Control, John Wiley & Sons, 2nd Edition.
3. O. I. Elgerd, Electric Energy Systems Theory, McGraw Hill, 2nd Edition, 1982.
4. Arthur R. Bergen, Vijay Vittal, Power system Analysis, Pearson Education (Singapore) Pte, Ltd., 2nd Edition, 2004.
5. I. J. Nagrath & D.P. Kothari, Modern Power System Analysis, Tata McGraw Hill, 4th Edition, 2011.

B. Tech. III year(Electrical), Semester- V

L	T	P	CREDIT
3	0	0	03

Reliability Evaluation of Electrical Systems

EE356 **Scheme**

1. Course Outcomes (Cos):

At the end of the course students will be able to:

CO1	Explain the basic of reliability and its importance for electrical network.
CO2	Implement and model for reliability evaluation of generating systems for LOLE and reliability indices.
CO3	Calculate the duration and frequency of outages and availability from reliability.
CO4	Evaluate the impact of interconnections on reliability.
CO5	Apply the concept of reliability for electrical distribution network for its secure and safe operation with relays, circuit breakers, switches etc.
CO6	Implement the Monte Carlo simulation concept for electrical networks for verification and execution of reliability indices.

2. Syllabus:

- **INTRODUCTION TO RELIABILITY** **(06 Hours)**

Background, quantitative and qualitative assessment, reliability indices and criteria, reliability evaluation techniques, reliability concepts, basic probability concepts, binomial distribution for reliability and probability, engineering applications of binomial distribution, electrical power generation capacity outage probability and reliability, loss of load expectation (LOLE) and calculation of expected energy not supplied (EENS).

- **NETWORK MODELING AND RELIABILITY** **(08 Hours)**

Simple network modeling, series, parallel system, redundant systems, perfect switching and imperfect switching, reliability of complex system, conditional probability approach, cut-set and tie-set approach, event-tree, fault-tree, multi-failure modes, Poisson’s distribution, normal distribution, exponential distribution, Weibull distribution, data analysis, goodness-of-fit tests, reliability evaluation of series/parallel/stand-by systems using probability distribution. Application to electrical network for reliability estimation.

- **DISCRETE AND CONTINUOUS MARKOV PROCESS** **(08 Hours)**

General modeling concept of discrete Markov chain, stochastic transitional probability matrix, limiting states, absorbing states, continuous Markov process, state-space diagrams, limiting and absorbing states of continuous Markov process, time dependent state probabilities, differential equation method, matrix multiplication method, repairable systems reliability, mean time to failure (MTTF), Markov process of electrical systems.

- **FREQUENCY AND DURATION TECHNIQUES** **(11 Hours)**

Concepts of frequency and duration, multi-state problems, mean duration of individual states, frequency balance approach, two stage repair and installation process, electrical power generation model and system risk evaluation, capacity expansion, composite generation and transmission system, state selection, system and load point indices, System risk indices, Individual state load model, Cumulative state load model.

- **MONTE CARLO SIMULATION AND ITS APPLICATIONS** **(12 Hours)**

Concepts of simulation, random variates, conversion of uniform random numbers, application of Monte Carlo Simulation, tossing a coin, throwing a die, repetitive tossing, time dependent reliability, two component non-repairable system, three component non-repairable system, repairable and standby system evaluation, stopping rules, variance reduction techniques, Application to generation capacity reliability evaluation, Reliability/LOLE assessment with chronological /nonchronological load, Application to composite generation and transmission.

Total Hours: 45

3. Books Recommended:

1. Roy Billinton and Ronald N. Allan, Reliability Evaluation of Engineering Systems Concepts and Techniques, 2nd Edition, Springer Science, 1992.
2. Roy Billinton and Ronald N. Allan, Reliability Evaluation of Power Systems, 2nd Edition, Springer Science & Business Media, 1992.
3. T. A. Short, Taylor & Francis group, Distribution Reliability and Power Quality, 1st Edition, 2018.
4. Roy Billinton, Ajit Kumar Verma, Rajesh Karki, Reliable and sustainable Electric Power and Energy Systems Management, Springer, 2014.
5. Chetan Singh., Panida Jirutitijaroen. and Joydeeep Mitra, Electric Power Grid Reliability Evolution: Models and Methods, John Wiley & Sons, 2018.

B. Tech. III year(Electrical), Semester- VI

Cryptography and Cyber Security of Smart Grid

L	T	P	CREDIT
3	0	0	03

EE357 Scheme

1. Course Outcomes (Cos):

At the end of the course students will be able to:

CO1	Explain the concept of encryption and privacy issues and its significance in cyber security
CO2	Explain cryptography and risk analysis using various terms and methods such as attack classification, ciphers, keys etc.
CO3	Evaluate the impact of bad data injection and identification for cyber security using encryption.
CO4	Employ cloud network for information storage for smart grids and its security. The Indian perspective will also be explored.
CO5	Explore the privacy prevention and its methods for smart grids and its management and legal concerns and rules/protocols for cyber security.

2. Syllabus:

- **INTRODUCTION AND OVERVIEW OF THE SECURITY AND PRIVACY ISSUES IN ELECTRICAL NETWORK** **(04 Hours)**

  Security issues in smart grids, Physical network security, Information network security, Privacy issues in smart grids, Reliability in smart grid- preliminaries on reliability quantification, System adequacy quantification, Congestion prevention: An economic dispatch algorithm.

- **CRYPTOGRAPHY FOR CYBER SECURITY** **(12 Hours)**

  Introduction and Overview of Cryptography and security, Historical perspective, Threats, risks, consequences, Physical and Information network security, Preventive and remedial measures, Basics of cryptography: Confusion vs. diffusion, Stream ciphers vs. block ciphers, Symmetric vs asymmetric key cryptography, Merkle Damgard construction, MD family, SHA family, Digital signatures , RSA algorithm, Encryption using non-cryptographic tools, Authentication principles and methods, Passwords, two-factor authentication.

- **BAD DATA DETECTION** **(06 Hours)**

  Preliminaries on falsification detection algorithms, Autocorrelation function (ACF), Time series modeling of load power: Outline of the proposed methodology, Seasonality, Fitting the AR and MA models, Case study: Stabilizing the variance, Fitting the stationary signal, Model fine-tuning and evaluation

- **CLOUD NETWORK DATA SECURITY IN SMART GRID** **(11 Hours)**

  Introduction, Service-level agreements, Live migration of a VM image in cloud computing: Data Migration, Network migration, Architecture and Solutions for: Application Manager, Site Broker, Hybrid cloud broker, Smart Meters and Smart Loads: The Advance Metering Infrastructure (AMI), Internet-Protocol-Based Mesh AMI, Standardization of AMI: ANSI C12.22, IEC 62056, AMI and Distribution Management System Integration (DMI), Software Architecture and Evaluation.

- **PRIVACY PRESERVATION IN SMART GRID** **(08 Hours)**

  End- User Privacy: Introduction and Preliminaries to privacy preservation methods, K- Anonymity cloaking, Location obfuscation, Privacy Preservation using location obfuscation methods, Preliminaries on Mobile nodes trajectory privacy, Location based services, Privacy preservation quantification: Probabilistic model, A Vernoi-based location obfuscation method, Computing the instantaneous privacy level, concealing the movement path.

- **MANAGEMENT ASPECTS IN CYBER SECURITY** **(04 Hours)**

  System Administration policies, Security audit, Penetration testing and ethical hacking, Mandatory Access control, Discretionary Access Control, Monitoring and logging tools, Legal aspects.

Total Hours: 45

3. Books Recommended:

1. William Stallings, Cryptography and network security, Pearson Education.
2. Atul Kahate, Cryptography and Network Security, 2nd Edition Tata McGraw Hill Publication, New Delhi-2006.
3. G. Kianoosh, Boroojeni, M.Hadi Amini and S.S. Iyengar, Smart Grids: Security and Privacy Issues, Springer, 2017.
4. Wade Trapple, Lawrence C. Washington, Introduction to Cryptography with coding Theory, 2nd Edition pearson Education.
5. E.D Knapp, Raj Samani, Applied Cyber Security and the Smart Grid, Elsevier-SYNGRESS.

B. Tech. III year(Electrical), Semester- VI

Electrical and Electronic Measurements

L	T	P	CREDIT
3	1	2	05

EE302 Scheme

1. Course Outcomes (Cos):

At the end of the course students will be able to:

CO1	Identify different standards and explain measurement techniques of resistance, inductance and capacitance.
CO2	Explain magnetic measurement techniques, discuss and analyze utilization of CT and PT.
CO3	Classify different indicating instrument.
CO4	Operate electronic meters and oscilloscope
CO5	Illustrate calibration and traceability of test equipment

2. Syllabus:

- **STANDARDS** **(03 Hours)**

  Standards and their classification. Electrical Standards: EMF, current, resistance and capacitance standards

- **MEASUREMENT of RESISTANCE, INDUCTANCE AND CAPACITANCE** **(08 Hours)**

  Concept of four arm bridge network, Kelvin's double bridge, Anderson bridge, Schering bridge, Wagner earthling device, Localization of cable fault using loop methods

- **MAGNETIC MEASUREMENTS** **(06 Hours)**

  Measurement of flux: ballistic galvanometer, Grassot flux meter, Hall effect devices for measurement of flux, measurement of iron loss by wattmeter method, Hibbert magnetic standard.

- **INSTRUMENT TRANSFORMERS** **(06 Hours)**

  Theory of current and voltage transformer, ratio error and phase angle, burden, turns compensation performance characteristics, testing of CT and PT and applications of CT and PT in measurement of power.

- **INDICATING INSTRUMENTS** **(08 Hours)**

  Classification, operating principles, general construction details of indicating instruments, balancing, control and damping method, theory and construction of PMMC, moving iron and electrostatic instruments, electrodynamics wattmeter.

- **ELECTRONIC METERS AND OSCILLOSCOPE** **(08 Hours)**

  DC amplifier voltmeter, AC voltmeter using rectifiers, true RMS responding voltmeter, Oscilloscope block diagram, CRT and its circuits, vertical deflection systems, delay line, multiple trace, horizontal deflection system, oscilloscope probes, Function generator.

- **CALIBRATION AND MEASUREMENT** **(06 Hours)**

  calibration and traceability of instruments, Calibration of indicating instruments using DC potentiometer, High voltage oil testing equipment, H.V. breakdown tester, Insulation resistance measurement techniques, calibration of energy meter

Total Hours: 45

Tutorials will be conducted separately for 15 hours

3. List of Experiments:

1. To measure unknown resistance using Kelvin's Double Bridge
2. To measure unknown inductance using Anderson Bridge
3. To calibrate voltmeter using Potentiometer.
4. To measure unknown capacitance using Schering Bridge
5. Calibration of single phase energy meter.
6. Testing of Current Transformer using Biffi's method.
7. To find out iron loss and flux density in a given sample of laminated steel core. (Lloyd fisher square)
8. To perform the operation of HV oil testing.
9. To study operation of oscilloscope and function generator.

4. Books Recommended:

1. Golding and Widdis, Electrical measurements and Measuring instruments, Wheeler books, 5th Edition.
2. A. K. Sawhney, Electrical and electronic Measurements and Instrumentation, Dhanpat Rai & Co., 17th Edition.
3. A. D. Helfrick and W. D. Cooper, Modern electronic Instrumentation and Measurement techniques, PHI, 2nd Edition, 2009.
4. D. A. Bell, Electronic Instrumentation and Measurement, Oxford Uni. Press, 3rd Edition, 2013.
5. P. Purkait, B. Biswas, S. Das and C. Koley Electrical and Electronics Measurement and Instrumentation, McGraw Hill Education, 1st Edition, 2013.

B. Tech. III year(Electrical), Semester- VI

Micro-Processors and Micro controllers

L	T	P	CREDIT
3	1	2	05

EE304 Scheme

1. Course Outcomes (Cos):

At the end of the course students will be able to:

CO1	Illustrate with examples basic concepts of digital circuits.
CO2	Explain architecture of 8–bit Microprocessor (8085A), concept of memory and input-output interfacing with timing diagrams.
CO3	Describe architecture of 8 bit microcontroller (8051) with special function registers (SFR), basic on chip peripherals like Timer0, Timer 1, UART, and External Interrupts and program execution timings (MIPS).
CO4	Demonstrate interfacing of external peripheral like ADC, DAC, Key board, LCD and seven segment LED display with 8051 Microcontroller.
CO5	Develop assembly language and embedded 'C' programs with the exposure of Kiel μvision IDE.
CO6	Design and develop using microcontroller, power electronics based electrical systems and provide solution to other real world problems.

2. Syllabus:

- **REVIEW OF DIGITAL LOGIC CONCEPTS** **(04 Hours)**

  Number systems, gates & De-Morgan's equivalents, 3-state logic gates, flip-flops, buffers, decoders,
  Encoders, multiplexers, de-multiplexers.

- **MICROPROCESSOR SYSTEM ARCHITECTURE** **(04 Hours)**

  Introduction, Registers, concept of address and data buses, system control signals, basic bus timing, memory (RAM, ROM), input output devices, Microcomputer systems

- **INTRODUCTION TO 8085A MICROPROCESSOR ARCHITECTURE** **(03 Hours)**

  Introduction to 8085A, pin diagram and pin description, bus timing and instruction timing, de-multiplexing of buses, generation of control signals, concept of interrupts.

- **MEMORY INTERFACING WITH 8085A** **(04 Hours)**

  Different types of memory, memory map, address decoding scheme for different memory, memory timings.

- **INPUT OUTPUT DEVICES INTERFACING WITH 8085A** **(04 Hours)**

  Basic interfacing concepts, peripheral I/O interfacing and memory mapped I/O interfacing

- **8051 MICROCONTROLLER ARCHITECTURE** **(06 Hours)**

  Introduction, 8051 family microcontrollers, hardware architecture, input/output pins, I/O ports and circuits, on chip ram ,general purpose registers ,special function registers, timers-counters, concepts of interrupts.

- **ASSEMBLY LANGUAGE PROGRAMMING OF 8051** **(10 Hours)**

  Concept of IDE (assembler, compiler, linker, de-bugger), addressing modes, data move instructions, arithmetic and logical instructions, jump, loop and call instructions, concepts of subroutines, interrupt service routine.

- **PERIPHERALS OF 8051 – HARDWARE CONCEPTS AND 'C' PROGRAMMING** **(10 Hours)**

  GPIO port architecture, timers, interfacing with push button keys, interfacing with seven segment LED display, interfacing with ADC

Tutorials will be conducted separately for 15 hours **Total Hours: 45**

3. List of Experiments:

(to write and execute assembly language programme for)

1. Arithmetic operations of Signed and Unsigned Numbers
2. Memory Block Movements (Forward, reverse, overlapping)
3. Ascending and descending arrangement of data string.
4. Code conversion. (Hexadecimal, BCD, Binary, ASCII etc.) (Embedded 'C' programming)
5. Toggling of port pin with time delay
6. Sensing of push button keys
7. Two digit second clock based on seven segment display
8. Interrupt driven clock
9. Programming of ADC and DAC

4. Books Recommended:

1. R. S. Gaonker, Microprocessor Architecture, programming and application, Wiley Eastern Limited, 6th Edition, 2013.
2. Kenneth J. Ayala, The 8051 Microcontroller, Penram International 3rd Edition, 1999.
3. M. Mazidi and others, The 8051 Microcontroller and Embedded Systems, Prentice Hall of India, 2nd Edition, 2007.
4. Michael Slater, Microprocessor based Design, Prentice Hall of India, 3rd Edition, 2016.
5. Badri Ram, Fundamentals of microprocessors and microcomputers, Dhanpat Rai & Sons, 4th Edition, 1993.

B. Tech. III year(Electrical), Semester- VI

Electrical Machine Design

L	T	P	CREDIT
3	1	0	04

EE332 Scheme

1. Course Outcomes (Cos):

At the end of the course students will be able to:

CO1	Demonstrate the basic steps involved in design of electrical machines
CO2	Describe the basic equations related to the electric machine design
CO3	Calculate the performance indices of electrical machines
CO4	Estimate the design parameters as per performance requirements
CO5	Analyze the effect of design parameters on the performance of electric machines
CO6	Develop the design of transformers, induction machines, dc machines and synchronous machines

2. Syllabus:

- **GENERAL ASPECTS OF ELECTRICAL MACHINE DESIGN** **(04 Hours)**

  Electrical engineering materials, magnetic circuit design, thermal design

- **TRANSFORMERS** **(10 Hours)**

  Output equation - single phase and three phase power transformers - main dimensions - choice of specific electric and magnetic loadings- design of core, LV winding, HV winding, tank and cooling tubes - prediction of no load current, forces on winding during short circuit, leakage reactance and equivalent circuit based on design data – computer aided design examples.

- **GENERAL CONCEPTS AND CONSTRAINTS IN DESIGN OF ROTATING MACHIN** **(03 Hours)**

  Specific loadings and output equations of AC and DC machines.

- **DC MACHINES** **(08 Hours)**

  Main dimensions - choice of speed and number of poles - design of armature conductors, slots and winding - design of air-gap, field system, commutator, interpoles, compensating winding and brushes – Carter's coefficient - real and apparent flux density – Computer aided design examples.

- **ALTERNATORS** **(10 Hours)**

  Salient pole and turbo alternators - main dimensions - choice of speed and number of poles - design of armature conductors, slots and winding - design of air-gap, field system and damper winding - prediction of open circuit characteristics and regulation of the alternator based on design data –computer aided design examples.

- **INDUCTION MACHINES** **(10 Hours)**

  Main dimensions - design of stator and rotor windings, stator and rotor slots and air-gap of slip ring and squirrel cage motors – calculation of rotor bar and end ring currents in cage rotor - calculation of equivalent circuit parameters and prediction of magnetizing current based on design data – computer aided design examples.

Total Hours: 45

Tutorials will be conducted separately for 15 hours

3. Books Recommended:

1. A. K. Sawhney, Chakrabarti, A Course in Electrical Machine Design, Dhanpat Rai & Co., 2016.
2. Clayton & Hancock, Performance & Design of DC Machines, CBS, 3rd Edition, 2001.
3. M. G. Say, Performance & Design of AC Machines, Pitman, ELBS.3rd Edition, 1983.
4. S.K.Sen, Principles of Electrical Machine Design, Oxford & IBH Pub., 2nd Edition, 2006
5. R. K. Agarwal, Principles of Electrical Machine Design, S. K. Kataria & Co., 2nd Edition, 2012.

B. Tech. III year(Electrical), Semester- VI

Robotics

L	T	P	CREDIT
3	0	0	03

EE361 Scheme

1. Course Outcomes (Cos):

At the end of the course students will be able to:

CO1	Classify and characterize the robots based on the configuration and work volume.
CO2	Analyze the manipulator design, including actuator, drive and sensor issues.
CO3	esign the robots that addresses the human limitations and meets societal requirements.
CO4	apply the forward kinematics, inverse kinematics and Jacobean for serial and parallel robots.
CO5	explain and solve the problems related to robot design and control.

2. Syllabus:

- **INTRODUCTION AND ROBOT KINEMATICS (12 Hours)**

  Basic concepts of Robots and automation, classification, specifications, Application, Notation – Direct Kinematics, Co-ordinate frames, rotations, Homogeneous coordinates, the Arm equation – Kinematic analysis of a typical Robot.

- **DYNAMIC OF ROBOTS (08 Hours)**

  Continuous path motion-interpolated motion – Straight line motion – Tool configuration Jacobian matrix and manipulator Jacobian – Manipulator Dynamics – Kinetic of potential energy – Energized forces – Lagrange's Equation – Euler Dynamic model.

- **ROBOT DRIVES AND CONTROL (09 Hours)**

  Design of drive systems, Hydraulic and Pneumatic drives, Linear and rotary actuators and control valves, Electro hydraulic servo valves, electric drives, Motors, designing of end effectors, Vacuum, magnetic and air operated grippers. The control problem – state equation – Single axis PID control – PD gravity control –Computed torque control – Variable Structure control – Impedance control.

- **ROBOT VISION AND CELL DESIGN APPLICATION (08 Hours)**

  Fundamentals of Robot applications – Robot vision – Image representation – Template – matching – Robot cell design – Safety in Robotics, Robot cell layouts, Multiple Robots and machine interference.

- **ROBOT PROGRAMMING AND APPLICATIONS (08 Hours)**

  Methods of Robot Programming, Characteristics of task level languages lead through programming methods. Types of applications – material handling applications – Machine loading and unloading – spot welding – arc welding – spray painting, workspace analysis and trajectory planning – work envelope of different robots, the pick and place operation.

Total Hours: 45

3. Books Recommended:

1. Robert J. Schilling, Fundamentals of Robotics Analysis and Control, PHI Learning, 2015.
2. S. B. Niku, Introduction to Robotics, Analysis, Systems, Applications, Prentice Hall, 2nd Edition, 2011.
3. Richard D. Klafter, Thomas A Chmielewski, Michael Negin, Robotics Engineering – An Integrated Approach, Eastern Economy Edition, Prentice Hall of India P Ltd., 2006.
4. Saha S. K., Introduction to Robotics, Tata McGraw Hill Education Pvt. Ltd, 2nd Edition, 2017.
5. K. S. Fu, R. C. Gonzalez and C. S. G. Lee, Robotics: Control, Sensing, Vision and Intelligence, McGraw Hill, 2017.

B. Tech. III year(Electrical), Semester- VI

Sustainable Energy

L	T	P	CREDIT
3	0	0	03

EE362 Scheme

1. Course Outcomes (Cos):

At the end of the course students will be able to:

CO1	Explain Sustainability and necessity of Sustainable energy
CO2	Analyse carbon emission and waste disposal problem with various energy sources
CO3	Assess resources and sustainability for different energy sources
CO4	Select appropriate alternatives for power generation considering environment and sustainability.
CO5	Utilize sustainable energy in developing countries

2. Syllabus:

- **SUSTAINABILITY CONCEPTS** **(03 Hours)**

  Overview of Energy Use and Related Issues, Global Change Issues and Responses, Sustainability, Energy, and Clean Technologies, Electric Power System and Requirements for Success, Historical Factor and Prospects for Change in the Electrical Power Grid, Carbon Limitation Policy Option, Sustainable Development Goals for Clean Energy (SDGS).

- **FOSSIL ENERGY** **(03 Hours)**

  Conversion, Power Cycles, Advanced Tech, Types and Characteristics, Fuels, Emissions.

- **NUCLEAR ENERGY** **(04 Hours)**

  Current Technologies Future Technologies and the Fuel Cycle, Nuclear Proliferation and Waste Disposal

- **SOLAR ENERGY** **(06 Hours)**

  Resource Assessment, Concentrating Solar Power, Solar Photovoltaic Systems, Solar Thermal Energy

- **WIND ENERGY** **(06 Hours)**

  Wind Resources, Wind Machinery and Generating Systems, Wind Power Economics, Measure of Sustainability

- **ELECTRICITY GENERATION ALTERNATIVES CONSIDERING ENVIRONMENT AND SUSTAINABILITY** **(12 Hours)**

  Fusion as a Future Energy Source, Carbon Management Options, Geothermal Energy, Biomass Energy, Biomass Conversion to Liquid Fuel, Hydropower, tidal and wave energy, Fuel Cell, Economic Prospects, Environmental and Sustainability Considerations.

- **ELECTRIC POWER, HYDROGEN FUEL** **(03 Hours)**

  Electricity as an Energy Carrier, Hydrogen as an Energy Carrier, Sustainability Issues.

- **APPLICATION** **(08 Hours)**

  Transport in Developing Countries, Lifecycle Analysis of Biomass Conversion, Wind, System Dynamics, Barriers to Entry, Transportation, Electrochemical Energy Conversions, Eco-Buildings, Sustainable Buildings in Developing Countries, Corporate and International Efforts to Abate Global Change/ Sustainability and Global Business, Challenges and Options for Electricity Systems.

Total Hours: 45

3. Books Recommended:

1. Martin A. Abraham, Encyclopedia of Sustainable Technologies, Elsevier Publications, 2024, 2nd Edition.
2. Stephen Peake, Renewable energy power for a sustainable future, Oxford university Press, 2018
3. Tester, J. W., Drake, E. M., Driscoll, M. J.,Golay, M. W., Peters, W. A., Sustainable Energy: Choosing Among Options, MIT Press, 2012, 2nd Edition.
4. Eduardo Rincon-Mejia, Alejandro de las Heras, Sustainable Energy Technologies, CRC Press, 2018
5. Denise Fairchild, Al Weinrub, Energy democracy: Advancing equity in clean energy solutions, Island press, 2017.
6. Mulligan, C. N., Sustainable Engineering: Principles and Implementation, CRC Press, Taylor and Francis Group, 2019.
7. Bakshi, B. R., Sustainable Engineering: Principles and Practice, Cambridge University Press, 2019.
8. David Allen, David Shonnard, Sustainable Engineering: Concepts, Design, and Case Studies, Prentice Hall, 2011.
9. Hazra Somnath, Bhukta Anindya, Sustainable Development Goals an Indian Perspective, Springer, 2018

B. Tech. III year(Electrical), Semester- V

Utilization of Electrical Energy

L	T	P	CREDIT
3	0	0	03

EE363 Scheme

1. Course Outcomes (Cos):

At the end of the course students will be able to:

CO1	Explain basic principles of illumination, electric heating and welding and refrigeration system
CO2	Estimate the lighting requirements for household Lighting and industrial lighting needs and its design
CO3	Calculate the heat developed in different electrical furnaces and ovens
CO4	Evaluate the performance of various electric welding techniques.
CO5	Evaluate the rating of electrical equipment used in refrigeration and air conditioning system.

2. Syllabus:

- **ILLUMINATION** **(13 Hours)**

Nature of light, visibility spectrum curve of relative sensitivity of human eye and wave length of light. Various definitions related to illumination, Laws of illumination, construction and working of Different type of lamps, characteristics, fittings required for various lamps, Calculation of number of light points for interior illumination, calculation of illumination at different points, considerations involved in simple design problems. Illumination schemes: indoor and outdoor, Illumination levels. Main requirements of proper lighting; absence of glare, contrast and shadow. General ideas about different lighting schemes.

- **HEATING** **(12 Hours)**

Advantages of electrical heating. Heating methods: Resistance heating – direct and indirect resistance heating, electric ovens, their temperature range, properties of resistance heating elements, domestic water heaters and other heating appliances and thermostat control circuit. Induction heating; principle of core type and coreless induction furnace. Electric arc heating; direct and indirect arc heating, construction, working and applications of arc furnace. Dielectric heating, applications in various industrial fields. Infra-red heating and its applications. Microwave heating, Power electronics application in heating system.

- **WELDING** **(10 Hours)**

Advantages of electric welding. Principles of resistance welding, types – spot, projection seam and butt welding and welding equipment used. Principle of arc production, electric arc welding, characteristics of arc, carbon arc, metal arc, hydrogen arc welding method of and their applications. Power supply required. Advantages of using coated electrodes, comparison between AC and DC arc welding, welding control circuits, welding of aluminum and copper. Introduction to TIG, MIG Welding, Power electronics application in welding system.

- **REFRIGERATION AND AIR CONDITIONING** **(10 Hours)**

Introduction, Refrigeration systems, domestic refrigerator, Types of air conditioning systems, central air conditioning system, heating of buildings, calculation of rating of electrical equipment, Modern and efficient refrigeration and air conditioning system.

Total Hours: 45

3. Books Recommended:

1. Gupta, J. B., Utilization of Electrical Energy and Electric Traction, S. K. Kataria and sons, 10th Edition, 1990.
2. R. K. Rajput, Utilization of Electrical Power, Laxmi publications, 1st Edition, 2007.
3. C. L. Wadhwa, Generation Distribution and Utilization of Electrical Energy, New Age International publishers, 4th Edition, 2011.
4. E. O. Taylor, Utilization of Electric Energy, Orient Blackswan, 1971.
5. H. Partab, Art and Science of Utilization of Electrical Energy, Dhanpat Rai & Co, 2017.

B. Tech. III year(Electrical), Semester- VI

Switchgear And Protection

L	T	P	CREDIT
3	0	0	03

EE364 Scheme

1. Course Outcomes (Cos):

At the end of the course students will be able to:

CO1	Explain the basic concept of protection of electrical power system
CO2	Demonstrate the function of various Circuit Breakers, fuse and related switches with respect to their construction, theory and applications.
CO3	Explain use of current transformer and potential transformer in protection.
CO4	Identify appropriate relaying schemes to protect Generator, Motor, Transformer and Bus bar based on fault
CO5	Distinguish the various protection methods for the protection of Transmission line

2. Syllabus:

- **FUSES, SWITHCHES AND NEUTRAL GROUNDING (04 Hours)**

  Rewirable fuses, HRC fuses, isolators and earthing switches, selection of fuses. Effectively grounded and ungrounded systems, resonant grounding Methods of neutral grounding.

- **BASIC PRINCIPLES AND RATINGS OF CIRCUIT BREAKERS (04 Hours)**

  Arc phenomenon, arc Interruption theories, arc control devices, recovery and restriking voltages, current chopping, Interruption of capacitive current, resistance switching, circuit breaker operating mechanism and control systems, making current, breaking current symmetrical and unsymmetrical, continuous current rating, MVA capacity.

- **CIRCUIT BREAKERS (10 Hours)**

  Bulk oil circuit breaker, arc controlled devices, MOCB, ACB, ABCB, SF_6 circuit breaker, vacuum circuit breaker and DC circuit breakers, circuit breaker ratings, auto recloser. Testing of circuit Breaker.

- **CURRENT TRANSFORMER AND POTENTIAL TRANSFORMER (03 Hours)**

  Construction, Operation, Vector Diagram of CTs , PTs and CVTs.

- **FUNCTIONS OF PROTECTIVE RELAYING (02 Hours)**

  Fundamental characteristics of relays, standard definition of relay terminologies, relay classifications, operating principles of single and double actuating quantity type electromechanical relays, directional relay, reverse power relay.

- **GENERATOR & MOTOR PROTECTION (06 Hours)**

  Modern methods of protecting generators against faults in stator, rotor and prime movers and other abnormal conditions. Abnormal operating conditions, under voltage, phase and earth fault, overload and unbalanced voltage protections for motors.

- **TRANSFORMER PROTECTION (03 Hours)**

  Protection of transformers, basic differential over current relays, restricted earth fault protection, gas relays, overall generator-transformer differential protection, magnetizing inrush protection.

- **BUSBAR PROTECTION (03 Hours)**

  Protection of outdoor and indoor bus-bar by current differential, voltage differential and directional comparison principles, linear coupler, high impedance schemes.

- **TRANSMISSION LINE PROTECTION** **(05 Hours)**

  Operating characteristics of impedance, reactance relays on R-X diagram, overreach and memory action, ohm and mho types relays and their characteristics, relay response under power swings and effect of fault resistance, setting of distance relays. Carrier Current Protection- Phase comparison and directional comparison principles.

- **BASICS OF NUMERICAL RELAYS** **(05 Hours)**

  Numerical relaying fundamentals, sampling theorem, anti-aliasing filters, least square method for estimation of phasors, Fourier algorithms, Fourier analysis and discrete Fourier transform, estimation of phasors from discrete Fourier transform, Applications for implantation of various numerical relays.

Total Hours: 45

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3. Books Recommended:

1. B. Oza, N. C. Nair, R. P. Mehta, V. H. Makwana, Power System Protection and Switchgear, Tata McGraw Hill Ltd. 1st Edition, 2011.
2. Y. G. Paithankar, S. R. Bhide, Fundamentals of power system protection, Prentice Hall of India, 2nd Edition, 2010.
3. B. Ravindranath, M. Chander, Power system Protection and Switchgear, New Age International Publisher, 2nd Edition, 2018.
4. J. Lewis Blackburn, Protective Relaying: Principles and Applications, Marcel Dekker Incorporation, 3rd Edition, 2006.
5. Badri Ram, D. N. Vishwakarma, Power System Protection and Switchgear, Tata McGraw Hill Publishing Company, New Delhi, 2nd Edition, 2017.

B. Tech. III year(Electrical), Semester- VI

Industrial Automation

L	T	P	CREDIT
3	0	0	03

EE365 **Scheme**

1. Course Outcomes (Cos):

At the end of the course students will be able to:

CO1	Classify various types of Automation
CO2	Explain working principle of various component of Industrial automation
CO3	Discuss various type of controller for Industrial automation
CO4	Develop ladder logic program for PLC for various industrial applications including SCADA
CO5	Discuss case study of Industrial automation

2. Syllabus:

- **INTRODUCTION TO INDUSTRIAL AUTOMATION** **(07 Hours)**

  Need of Industrial Automation, Advantages and disadvantages of automation, automation pyramid.

- **COMPONENTS OF INDUSTRIAL AUTOMATION** **(08 Hours)**

  Overview of sensors to sense position, speed, temperature, pressure, flow, level etc., Transmitter, Architecture of current loop.

- **CONTROLLERS FOR INDUSTRIAL AUTOMATION** **(10 Hours)**

  Introduction, definitions and history of PLC, manufacturing and assembly processes, PLC advantages and disadvantages, overall PLC system, CPU, PLC, input and output modules, program recording devices.

- **PROGRAMMING PLC** **(15 Hours)**

  Ladder diagrams, programming ON/OFF inputs to produce ON/OFF outputs, digital gate logic and contact coil logic, creating ladder diagrams from process control descriptions, timer function, counter function, arithmetic functions, comparison functions.

- **INTRODUCTION TO SCADA** **(04 Hours)**

  Introduction, need, features of SCADA

- **CASE STUDY** **(04 Hours)**

  Industrial automation in various industries, like chemical, textile, oil and Gas, food and beverages etc.

Total Hours: 45

3. Books Recommended:

1. John Webb, Programmable Logic Controllers Principles & Applications, Prentice Hall of India, 1st Edition, 2013.
2. Andrews, Applied Instrumentation in Process Industries, Gulf Professional Publishing; 2nd Edition, 1979.
3. D. Patranabis, Principles of Process Control, Tata Mcgraw Hill, 3rd Edition, 2017.
4. S. K. Singh, Computer Aided Process Control, Prentice Hall of India, 2004.
5. Kevin Collins, PLC Programming for Industrial Automation, Exposure Publishing, 2006.

B. Tech. III year(Electrical), Semester- VI

Forecasting and Planning Methods

L	T	P	CREDIT
3	0	0	03

EE366 Scheme

1. Course Outcomes (Cos):

At the end of the course students will be able to:

CO1	Explain the basics of forecasting and planning for engineering.
CO2	Apply methods of time series decomposition and its smoothing for better forecasting and planning.
CO3	Learn various simple and multiple regression models for forecasting.
CO4	Learn the BOX-Jenkins and ARIMA for forecasting.
CO5	Discuss the basics of planning for engineering applications
CO6	Classify various methods of planning and their applications.

2. Syllabus:

- **FUNDAMENTALS OF FORECASTING (05 Hours)**

The forecasting perspective and Time Series Forecasting, overview of forecasting techniques and tools, time series, and cross-sectional data, and plots, univariate and bivariate statistics, autocorrelation, measuring forecast accuracy, ACF of forecast error, prediction intervals, least square estimates, transformation and adjustments.

- **TIME-SERIES DECOMPOSITION AND EXPONENTIAL SMOOTHING METHODS (08 Hours)**

Principle of decomposition, seasonal adjustment, moving averages, local regression smoothing, classical decomposition, additive and multiplicative decomposition, extensions to X-12 ARIMA, STL decomposition, inner loop, outer loop, choosing the STL parameters, Exponential smoothing methods: Exponential smoothing methods, single exponential smoothing and its adaptive approach, Holt’s linear and Holt-Winter’s method: Pegel’s classification.

- **SIMPLE AND MULTIPLE REGRESSION (08 Hours)**

Least squares estimation, the correlation coefficient, residuals, The F-test for overall significance, confidence intervals for individual coefficients, t-tests for individual coefficients, forecasting using the simple regression model, non-linear relationship, non-linearity in the parameters, using logarithms to form linear models, local regression.

- **BOX-JENKINS METHODOLOGY FOR ARIMA MODELS (06 Hours)**

Examining correlation in time series data, the autocorrelation function, white noise model autocorrelation coefficient, Random walk model, tests for stationarity, ARIMA models of time series, autoregressive, moving average model, Mixtures ARIMA models, identification and estimation of parameters.

- **FORECASTING AND PLANNING (10 Hours)**

The role of forecasting in planning, Comparison and selection of forecasting methods, Introduction to Planning, multidisciplinary nature, role of a planner, definitions and Basics of Planning, Goals and objectives of planning; Components of planning; Benefits of planning; Arguments for and against planning. Planning Process, Levels of Planning in India.

- **PLANNING METHODS (08 Hours)**

Definition of development plan; Types of development plans, Comprehensive planning, requirements for planning; sources of primary and secondary data; questionnaire design, measurement scale and their application, sampling techniques, types of socio-economic surveys; self-surveys, interviews, questionnaires and observer participation, Data requirement for various types of regional plans; Techniques for conducting surveys.

Total Hours: 45

3. Books Recommended:

1. Makridakis, Spyros, Forecasting methods and application, John Wiley, 3rd Edition, 1993.
2. X. Wang & J. R. Mc Donald, Modern Power system planning, McGraw. Hill, 2nd Edition, 2003.
3. A. S. Pabla, Electrical Power system planning, Mac Millan, Delhi, 4th Edition, 1998
4. Sullivan, Power system planning, McGraw. Hill, 1977.
5. E. Lakervi and E. J. Holmes, Electricity distribution network design, IEE, 2nd Edition, 2003.

B. Tech. III year(Electrical), Semester- VI

Instrumentation

L	T	P	CREDIT
3	0	0	03

EE367 **Scheme**

1. Course Outcomes (Cos):

At the end of the course students will be able to:

CO1	Analyze performance characteristics of measurement systems.
CO2	Demonstrate different types of transducers.
CO3	Explain different types of recorders and data transmission techniques.
CO4	Discuss operational amplifier and its applications.
CO5	Classify various digital displays and digital measuring instruments.

2. Syllabus:

- **PERFORMANCE CHARACTERISTICS OF MEASUREMENT SYSTEMS** **(06 Hours)**

  Input-output configuration of instruments and measurement systems, methods of correction for interfering and modifying inputs, static performance characteristics of instruments, noise, signal to noise ratio, errors in measurement

- **TRANSDUCERS** **(10 Hours)**

  Classification of transducers, passive transducers: resistive, inductive and capacitive transducers, active transducers: thermocouple, piezoelectric transducer, taco-generator, pH cell, basic signal conditioning circuits for transducers.

- **DATA TRANSMISSION ,RECORDERS and DATA LOGGERS** **(05 Hours)**

  Introduction to industrial data transmission techniques, Distinction between recorder and data loggers, strip chart recorder, X-Y recorders, data logger

- **OPERATIONAL AMPLIFIER FUNDAMENTALS** **(06 Hours)**

  Operational Amplifier, Basic Op-Amp Configuration, an Op-Amp with Negative Feedback, Voltage Series and Voltage Shunt Configurations, Difference Amplifiers, Specification of An Op-Amp, Offset Voltages and Currents, CMRR, Slew Rate

- **LINEAR APPLICATIONS OF OPERATIONAL AMPLIFIERS** **(06 Hours)**

  Summing, Scaling and Averaging Amplifiers, Voltage to Current Converter with Floating and Grounded Load, Current to Voltage Converter, Integra tor and Differentiator, Instrumentation Amplifier, Isolation amplifier

- **NON-LINEAR APPLICATIONS OF OPERATIONAL AMPLIFIERS** **(06 Hours)**

  Schmitt Trigger, Voltage Comparator, Voltage Limiters And Window Detector, Clippers And Clampers, Peak Detector, Precision Rectifiers, Analog Switches

Total Hours: 45

3. Books Recommended:

1. K. Sawhney, Electrical and electronic Measurements and Instrumentation, Dhanpat Rai & co., 17th Edition.
2. Gayakwad Ramakant, Op-Amps and Linear Integrated Circuits, PHI, 3rd Edition, 1993.
3. A. D. Helfrick and Cooper W. D., Modern electronic Instrumentation and Measurement techniques, Prentice Hall of India, 1997.
4. E. O. Doebelin, Measurement Systems - Application and Design, 4th Edition, McGraw-Hill, New York, 1992.
5. D. A. Bell, Electronic Instrumentation and Measurement, Oxford University press, 3rd Edition, 2013.

B. Tech. III year(Electrical), Semester- VI

Modern Control Systems

L	T	P	CREDIT
3	0	0	03

EE368 Scheme

1. Course Outcomes (Cos):

At the end of the course students will be able to:

CO1	Classify modern control
CO2	Design the compensator using Root locus and Body plots
CO3	Analyze the state space representation of various systems
CO4	Design the state feedback controllers
CO5	Analysis the discrete time Systems

2. Syllabus:

- **INTRODUCTION TO MODERN CONTROL SYSTEMS: (02 Hours)**

  Need for the modern control systems, comparison of classical control systems with modern control systems.

- **COMPENSATOR DESIGN (10 Hours)**

  Compensator Design using Root Locus, Design of root locus, Selective illustration of root locus, Reshaping the root locus, Cascade Lead Compensation, Cascade Lag Compensation, Compensator Design Using Bode Plots: Design of bode plot, Selective illustration of bode plot, Reshaping the Bode Plot, Cascade Lead Compensation, Cascade lag compensator.

- **STATE SPACE ANALYSIS (13 Hours)**

  Introduction to State space, State variable representation including Electrical, Mechanical, Electro-mechanical system, Conversion of state variable Models to Transfer function via direct, cascade, parallel decomposition, solution of state equation, State Transmission Matrix, Concept of Controllability and Observability; Kalman's Theorems on Controllability; and Observability, Alternative Tests (Gilbert's Method) of Controllability and Observability,

- **DESIGN OF STATE FEEDBACK CONTROLLER (08 Hours)**

  Design of State Feedback Controller: Introduction, state Variable Feedback structure, Pole placement Design using State Feedback controller. State feedback with integral control.

- **INTRODUCTION TO DISCRETE TIME SYSTEM (12 Hours)**

  Discrete Time System: sampler, sampling process, Laplace transform of sampled function, z - transform, z - transform of some useful function, stability analysis of Sampled data control system, state-space representation of Discrete time Systems.

Total Hours: 45

3. Books Recommended:

1. I. J. Nagrath & M. Gopal, "Control System Engineering", New Age International Publishers, 3rd Edition, 2001.
2. K. Ogata, "Modern Control System Engineering", Pearson Education Asia, 4th Edition, 2002.
3. B. C. Kuo, "Automatic Control Systems", Prentice Hall of India, 7th Edition, 1995.
4. Nise N. S., "Control System Engineering", John Wiley & sons, 4th Edition, 2004.
5. P. F. Blackman, "Introduction to State Variable Analysis", the McMillan Press, 1st Edition, 1977.

B. Tech. III year(Electrical), Semester- VI

Wind and Solar Energy Conversion

L	T	P	CREDIT
3	0	0	03

EE369 **Scheme**

1. Course Outcomes (Cos):

At the end of the course students will be able to:

CO1	Recognize the limits of the conventional energy sources and examine present scenario of wind and solar energy conversion.
CO2	Explain the working principle of wind energy conversion and identify the suitable turbine and power electronic interfaces.
CO3	Explain the working principle of solar energy conversion, maximum power tracking algorithms and power electronics interface.
CO4	Design the wind and solar energy systems at preliminary level.
CO5	Select the suitable hybrid energy system for a given application.

2. Syllabus:

- **PLACEMENTS OF WIND AND SOLAR ENERGY IN WORLD AND INDIA** **(04 Hours)**

  Conventional energy sources and their limitations, current status of renewable energy sources.

- **WIND ENERGY CONVERSION** **(16 Hours)**

  Introduction, types of wind turbines and their characteristics, wind data and energy estimation, basic components of wind electric conversion system, types of electrical machines suitable for wind energy conversion, maximum power extraction, power electronics interface for wind turbine, different configuration for wind farms.

- **SOLAR PHOTOVOLTAIC POWER CONVERSION** **(16 Hours)**

  Basics of p-n junction, p-n junction exposure to light, photovoltaic cell/module characteristics and effects of light intensity and temperature variations, maximum power point tracking algorithms, power electronics interface for solar Photovoltaics, design of PV applications (domestic loads, battery storage, and irrigation), grid connected PV systems.

- **HYBRID ENERGY SYSTEMS** **(09 Hours)**

  Why hybrid systems?, types of hybrid systems (PV-diesel-battery, wind-PV, fuel cell-PV), limitations of hybrid systems.

Total Hours: 45

3. Books Recommended:

1. J. K. Nayak and S. P. Sukhatme, Solar Energy - Principles of Thermal Collection and Storage, Tata Mcgraw Hill, 4th Edition, 2017.
2. Chetan Singh Solanki, Solar Photovoltaics: Fundamental, Technologies and Applications, 2nd Edition,PHI Learning Pvt. Limited, New Delhi, 2011.
3. Gary L. Johnson, "Wind Energy Systems", Prentice Hall Inc., 1985.
4. Klouse Jägar, et al., Solar Energy: Fundamental, Technology and Systems, Delft University of Technology, Netherlands, 2014.
5. A few IEEE review papers and industrial application notes.

B. Tech. III year(Electrical), Semester- VI

State Variable Analysis

L	T	P	CREDIT
3	1	0	03

EE370 **Scheme**

1. Course Outcomes (Cos):

At the end of the course students will be able to:

CO1	construct state-space models for the systems from the ubiquitous domains (electrical/mechanical).
CO2	correlate differential equations, transfer function model with the state space models and associated convolution
CO3	recast linear, nonlinear, multi input multi output, continuous and discrete systems in state space form.
CO4	design control systems using the state space techniques and analyze the properties of state space models which are essential for developing controllers and observers.
CO5	adopt and design algorithms using state space technique for stabilizing and controlling real world problems.

2. Syllabus:

- **MATHEMATICAL BACKGROUND-MATRICS** **(03 Hours)**

  Definition of Matrices; Matrix Algebra; Matrix Multiplication and Inversion; Rank of a Matrix; Differentiation and Integration of Matrix.

- **STATE SPACE ANALYSIS METHODS AND TECHNIQUES** **(16 Hours)**

  State Variables; State-Space Representation of Electrical and Mechanical and Electromechanical Systems; State Space Representation of Nth Order, Linear Differential Equation; Transformation to Phase Variable Canonical Form; Relationship Between Transfer Functions and State Equations; Characteristic Equation; Eigen Values and Eigen Vectors; Transformation to Diagonal Canonical Form; Jordan Canonical Form.

- **SOLUTION OF THE TIME-INVARIANT SYSTEMS** **(06 Hours)**

  Solution of the Time-Invariant State Equation; State Transition Matrix and its Properties; Transfer Matrix; Transfer Matrix of Closed Loop Systems, Methods of calculations of the matrix exponentials using algebraic and algorithmic methods.

- **CONTROLLABILITY AND OBSERVABILITY** **(08 Hours)**

  Concept of Controllability and Observability; Kalman's Theorems on Controllability; and Observability, Alternative Tests (Gilbert's Method) of Controllability and Observability; Principle of Duality; Relationship among Controllability, Observability and Transfer Function, Decomposition of Transfer Function-Direct, Cascade and Parallel Decomposition; State Diagram

- **LYAPUNOV STABILITY ANALYSIS** **(09 Hours)**

  Stability of Equilibrium State in the Sense of Lyapunov; Graphical Representation of Stability; Asymptotic Stability and Instability; Sign-Definiteness of Scalar Function; Second Method of Lyapunov; Stability Analysis of Linear Systems; Krasovskii's Theorem; Lyapunov Function Based on Variable Gradient Method.

Total Hours: 45

3. Books Recommended:

1. I. J. Nagrath& M. Gopal, "*Control System Engineering*", New Age International Publishers, 3rd Edition, 2001.
2. K. Ogata, "*Modern Control System Engineering*", Pearson Education Asia, 4th Edition, 2002.
3. B. C. Kuo, "*Automatic Control Systems*", Prentice Hall of India, 7th Edition, 1995.
4. Nise N. S., "*Control System Engineering*", John Wiley & sons, 4th Edition, 2004.
5. P. F. Blackman, "*Introduction to State Variable Analysis*", the McMillan Press, 1st Edition, 1977.

B. Tech. III year (CE, ME, ChE, IndChe, MaC) (Minor in Electrical Engineering) , Semester- V

Electrical Machine

L	T	P	CREDIT
3	0	2	04

EE381 **Scheme**

1. Course Outcomes (Cos):

At the end of the course students will be able to:

CO1	Explain the construction and principle of operation of the DC motors, transformers, induction motors, Synchronous generator and Fractional horse power motors.
CO2	Perform tests on the DC motors, transformers, induction motors and Synchronous generator.
CO3	Compute performance parameters of the DC motors, transformers, induction motors and Synchronous generator.
CO4	Analyze the performance of the DC motors, transformers, induction motors and Synchronous generator.
CO5	Select the machines for different real world applications
CO6	Communicate effectively through laboratory report writing, presentation and perform task as an efficient team member

2. Syllabus:

- **DC MOTORS** **(08 Hours)**

  Construction and working principle, EMF equation, Torque equation, Classification of DC motors and their characteristics, Speed control, Braking, Applications.

- **TRANSFORMERS** **(10 Hours)**

  Construction and working principle, Equivalent circuit, Open circuit and Short Circuit tests, Regulation and efficiency, Autotransformers, Different connections of three phase transformers.

- **THREE PHASE INDUCTION MOTOR** **(09 Hours)**

  Construction and working principle, Equivalent Circuit, No load and Blocked rotor tests, Torque equation, Torque–slip characteristics, Speed control, Industrial applications.

- **SYNCHRONOUS GENERATOR** **(09 Hours)**

  Construction, Principle of operation and types, Various types of excitation systems, Equivalent circuit, Determination of voltage regulation by synchronous impedance method.

- **FRACTIONAL HORSE POWER MOTORS** **(09 Hours)**

  Single phase induction motors – Construction and principle of operation, Classification based on starting method, Applications in home appliances.
  Construction and application of Stepper motors, Servomotors and Universal motors.

Total Hours: 45

3. List of Experiments:

1. Determination of efficiency & regulation of single- phase transformer from Open circuit and short circuit test.
2. Load test on single phase transformer
3. Determination of the equivalent circuit parameters from No-Load and Blocked rotor tests of three-phase Induction Motor.
4. Load test on three-phase Induction Motor.
5. Speed control of dc shunt motor
6. Speed torque characteristic of a D. C. Shunt motor.
7. D. C. Series motor, Speed -torque characteristic.
8. Swinburne's test
9. Regulation of an alternator by synchronous impedance method
10. To study the construction and starting method of a single phase induction motor

4. Books Recommendation:

1. D.P.Kothari and I.J.Nagrath, 'Electric Machines', McGraw Hill Education Private Limited, latest Edition.
2. A Fitzgerald, Charles Kingsley, Stephen Umans, 'Electric Machinery', McGraw Hill Education, latest edition.
3. Mukherjee and Chakravorty, Electrical Machines, Dhanpat Rai Pub., New Delhi, latest edition
4. M. G. Say, the performance and design of alternating current machines, CBS Publishers and Distributors, Delhi, latest edition
5. E. Clayton and N. M. Hancock, The Performance and Design of Direct Current Machines,CBS Publishers

B. Tech. III year (CE,ME,ChE, IndChe, MaC) (Minor in Electrical Engineering) , Semester- VI

Power Systems

L	T	P	CREDIT
3	0	2	04

EE380 Scheme

1. Course Outcomes (Cos):

At the end of the course students will be able to:

CO1	Classify and compare the electrical power transmission and distribution.
CO2	Estimate the cost of power generation and the cost of electricity.
CO3	Discuss various protective devices and compare them.
CO4	Analyze the performance of the underground cable.
CO5	Illustrate and the concept of lighting system and various components associated.

2. Syllabus:

- **SUPPLY SYSTEMS** **(04 Hours)**

  AC and DC power supply systems, comparison of ac and dc transmission, advantages of high transmission voltage, various systems of power supply, comparison of conductor materials in overhead system and underground cable system.

- **UNDERGROUND CABLES** **(06 Hours)**

  Underground cables, construction of cables, classification of cables, cables for three phase services, insulation resistance of a single core cable, capacitance of a single core cable, dielectric stresses in a single core cable, most economical conductor size in a cable, grading of cables, capacitance grading and inter-sheath grading, capacitance of three core cable and measurements of capacitances.

- **CHARACTERISTICS AND PERFORMANCE OF POWER TRANSMISSION LINES** **(08 Hours)**

  Conductors, types of conductors in use, bundled conductor, spacing of conductors, symmetrical and unsymmetrical spacing, equivalent spacing, transposition, types of transmission line towers and insulator string Short and medium transmission lines, Line performance, effect of capacitance, charging currents, short and medium lines, calculation by nominal-T, nominal-π and end-condenser method, regulation and efficiency, Concept of ABCD constants, evaluation of ABCD constants for short and medium line.

- **ECONOMIC ASPECTS OF POWER SYSTEM** **(07 Hours)**

  Cost of Generation and Tariff, Power factor and its effect on system economy, Power factor improvement.

- **PROTECTION OF POWER SYSTEM** **(10 Hours)**

  Rewirable fuses, HRC fuses, isolators and earthing switches, selection of fuses. Effectively grounded and ungrounded systems, resonant grounding Methods of neutral grounding, Bulk oil circuit breaker, arc controlled devices, MOCB, ACB, ABCB, SF_6 circuit breaker, vacuum circuit breaker and DC circuit breakers, circuit breaker ratings, auto-recloser, Fundamental characteristics of relays, standard definition of relay terminologies, relay classifications, operating principles of single and double actuating quantity type electromechanical relays, directional relay, differential relay, numerical relay.

- **ILLUMINATION AND LIGHTING SYSTEM** **(10 Hours)**

Nature of light, visibility spectrum curve of relative sensitivity of human eye and wave length of light. Definition: Luminous flux, solid angle, luminous intensity, illumination, luminous efficiency, depreciation factor, coefficient of utilization, space to height ratio, reflection factor, glare, shadow, lux. Laws of illumination. Different type of lamps, construction and working of incandescent and discharge lamps – their characteristics, fittings required for filament lamp, mercury vapour lamp, fluorescent lamp, metal halide lamp, neon lamp. Calculation of number of light points for interior illumination, calculation of illumination at different points, considerations involved in simple design problems. Illumination schemes; indoor and outdoor. Illumination levels. Main requirements of proper lighting; absence of glare, contrast and shadow. General ideas about street lighting, flood lighting, monument lighting and decorative lighting, LED lighting

Tutorials will be conducted separately for 14 hours **Total Hours: 45**

3. List of Experiments:

1. To study mathematical modeling of R-L, R-L-C and complex electrical circuit using MATLAB.
2. To study mathematical modeling of 3rd order differential equation.
3. To solve differential equations using Euler's and trapezoidal rule.
4. To study short circuit analysis of overhead transmission line using MATLAB.
5. To study the operation of definite time over current relay.
6. To study the operation static over voltage relay.
7. To study ferranti effect and determine A, B, C, D parameters of short transmission line.
8. To study characteristics of electro mechanical over current relay.
9. To study characteristics of micro controller based earth fault relay.

4. Books Recommended:

1. J. Nagrath and D. P. Kothari, Modern Power System analysis, Tata McGraw Hill Publishing Company Ltd, New Delhi, 4th Edition, 2011.
2. W. D. Stevenson, Element of Power System Analysis, McGraw Hill, 4th Edition, 1982.
3. Chakrabarti, M. L. Soni, P. V. Gupta, and U. S. Bhatnagar, A Text Book on Power System Engineering, Dhanpat Rai & Co., 2012.
4. L. Wadhwa, Electric Power System, New Age International Ltd, 3rd Edition, 2010.
5. V. K. Mehta, Rohit Mehta, Principles of Power System, S. Chand & Co. 2003

B. Tech. III year (AI,CSE,ECE, ECVLSI, IndPhy) (Minor in Electrical Engineering) , Semester- V

Power Systems	**L**	**T**	**P**	**CREDIT**
	3	**0**	**2**	**04**

EE380 Scheme

1. Course Outcomes (Cos):

At the end of the course students will be able to:

CO1	Classify and compare the electrical power transmission and distribution.
CO2	Estimate the cost of power generation and the cost of electricity.
CO3	Discuss various protective devices and compare them.
CO4	Analyze the performance of the underground cable.
CO5	Illustrate and the concept of lighting system and various components associated.

2. Syllabus:

- **SUPPLY SYSTEMS** **(04 Hours)**

  AC and DC power supply systems, comparison of ac and dc transmission, advantages of high transmission voltage, various systems of power supply, comparison of conductor materials in overhead system and underground cable system.

- **UNDERGROUND CABLES** **(06 Hours)**

  Underground cables, construction of cables, classification of cables, cables for three phase services, insulation resistance of a single core cable, capacitance of a single core cable, dielectric stresses in a single core cable, most economical conductor size in a cable, grading of cables, capacitance grading and inter-sheath grading, capacitance of three core cable and measurements of capacitances.

- **CHARACTERISTICS AND PERFORMANCE OF POWER TRANSMISSION LINES** **(08 Hours)**

  Conductors, types of conductors in use, bundled conductor, spacing of conductors, symmetrical and unsymmetrical spacing, equivalent spacing, transposition, types of transmission line towers and insulator string Short and medium transmission lines, Line performance, effect of capacitance, charging currents, short and medium lines, calculation by nominal-T, nominal-π and end-condenser method, regulation and efficiency, Concept of ABCD constants, evaluation of ABCD constants for short and medium line.

- **ECONOMIC ASPECTS OF POWER SYSTEM** **(07 Hours)**

  Cost of Generation and Tariff, Power factor and its effect on system economy, Power factor improvement.

- **PROTECTION OF POWER SYSTEM** **(10 Hours)**

  Rewirable fuses, HRC fuses, isolators and earthing switches, selection of fuses. Effectively grounded and ungrounded systems, resonant grounding Methods of neutral grounding, Bulk oil circuit breaker, arc controlled devices, MOCB, ACB, ABCB, SF_6 circuit breaker, vacuum circuit breaker and DC circuit breakers, circuit breaker ratings, auto-recloser, Fundamental characteristics of relays, standard definition of relay terminologies, relay classifications, operating principles of single and double actuating quantity type electromechanical relays, directional relay, differential relay, numerical relay.

- **ILLUMINATION AND LIGHTING SYSTEM** **(10 Hours)**

Nature of light, visibility spectrum curve of relative sensitivity of human eye and wave length of light. Definition: Luminous flux, solid angle, luminous intensity, illumination, luminous efficiency, depreciation factor, coefficient of utilization, space to height ratio, reflection factor, glare, shadow, lux. Laws of illumination. Different type of lamps, construction and working of incandescent and discharge lamps – their characteristics, fittings required for filament lamp, mercury vapour lamp, fluorescent lamp, metal halide lamp, neon lamp. Calculation of number of light points for interior illumination, calculation of illumination at different points, considerations involved in simple design problems. Illumination schemes; indoor and outdoor. Illumination levels. Main requirements of proper lighting; absence of glare, contrast and shadow. General ideas about street lighting, flood lighting, monument lighting and decorative lighting, LED lighting

Tutorials will be conducted separately for 14 hours **Total Hours: 45**

3. List of Experiments:

1. To study mathematical modeling of R-L, R-L-C and complex electrical circuit using MATLAB.
2. To study mathematical modeling of 3rd order differential equation.
3. To solve differential equations using Euler's and trapezoidal rule.
4. To study short circuit analysis of overhead transmission line using MATLAB.
5. To study the operation of definite time over current relay.
6. To study the operation static over voltage relay.
7. To study ferranti effect and determine A, B, C, D parameters of short transmission line.
8. To study characteristics of electro mechanical over current relay.
9. To study characteristics of micro controller based earth fault relay.

4. Books Recommended:

1. J. Nagrath and D. P. Kothari, Modern Power System analysis, Tata McGraw Hill Publishing Company Ltd, New Delhi, 4th Edition, 2011.
2. W. D. Stevenson, Element of Power System Analysis, McGraw Hill, 4th Edition, 1982.
3. Chakrabarti, M. L. Soni, P. V. Gupta, and U. S. Bhatnagar, A Text Book on Power System Engineering, Dhanpat Rai & Co., 2012.
4. L. Wadhwa, Electric Power System, New Age International Ltd, 3rd Edition, 2010.
5. V. K. Mehta, Rohit Mehta, Principles of Power System, S. Chand & Co. 2003

B. Tech. III year (AI, CSE, ECE, ECVLSI, IndPhy) (Minor in Electrical Engineering), Semester- VI

Power Electronics

L	T	P	CREDIT
3	0	2	04

EE382 Scheme

1. Course Outcomes (Cos):

At the end of the course students will be able to:

CO1	Understand the basic principle of operation of semiconductor devices and list applications.
CO2	Analyze and compare the performance of various line commutated converters.
CO3	Analyze and design various DC-DC converters.
CO4	Design single-phase and three-phase inverters for various applications.
CO5	Develop laboratory prototype of power electronic systems.

2. Syllabus:

- **POWER SEMICONDUCTOR DEVICES AND APPLICATIONS (15 Hours)**

  Review of Power semiconductor devices and their static characteristics: Diode, DIAC, Thyristor, TRIAC, Power BJT, MOSFET, IGBT etc., Thyristor: Characteristics, Two transistor analogy, Gate Characteristics, and Methods of triggering, Gate and Base drive circuits - Preliminary design considerations, Ratings and protection of devices, Temperature control of power devices and heat sink design.
- **LINE COMMUTATED CONVERTERS (10 Hours)**

  Principle of phase control, half wave controlled rectifiers, half wave controlled rectifiers with R, R-L, R-L-E load, single phase full wave controlled converters, 2-pulse mid-point converters, 2-pulse half and fully controlled bridge converters with R, R-L, R-L-E load, Three phase converter system with diodes, 3 phase half and fully controlled bridge converters, Effect of source impedance on the performance of the converters, Dual converters. Principle of operation and analysis of AC voltage controllers with R and R-L load.
- **DC-DC CONVERTERS (10 Hours)**

  Basic principle of operation, Control strategies – Duty ratio control and frequency control, Types of chopper circuits, Steady state time domain analysis of different types of choppers, Principle of operation and analysis of non-isolated DC-DC converters: Buck, Boost, and Buck-Boost converters.
- **INVERTERS (10 Hours)**

  Single phase voltage source inverters, half bridge inverters, full bridge inverters, Steady state analysis, Voltage control in single phase inverters, 3-phase bridge inverters, Pulse width modulated inverters, Reduction of harmonics in inverters.

Total Hours: 45

3. List of Experiments:

1. Study of IGBT, MOSFET, SCR, TRIAC, DIAC Characteristics.
2. Study of Different SCR Triggering Circuit Trainer – DC, R, R-C, UJT.
3. Study of Single Phase Half Controlled Bridge Converter with R, R-L Load.
4. Study of Single Phase Fully Controlled Bridge Converter with R, R-L Load.
5. Study of Single Phase SCR Full Bridge Inverter Circuit.
6. Study of High Voltage Thyristorised Chopper.
7. Study of Single Phase AC Voltage Controller Using SCR.
8. Study of Single Phase AC Voltage Controller Using Triac.
9. Study of Single Phase Dual Converter Circuit.
10. Study of SCR DC Circuit Breaker Circuit.
11. Study of Three Phase SCR Triggering Circuit Using Tca785 IC.
12. Study of AC Solid State Relay Using IC 555, Opto Coupler & Triac.
13. Simulation of Power EC circuits in PSIM and SIMULINK.

4. Books Recommended:

1. Bimbhra P. S., “Power electronics”, Khanna Publishers, New Delhi, 5th Edition, 2014.
2. Rashid M. H., “Power Electronics Circuits, Devices, and Applications”, Prentice-Hall of India Pvt. Ltd., New Delhi, 4th Edition, 2014.
3. Singh M. D., Khanchandani, K. B., “Power electronics”, Tata McGraw-Hill Publishing Co. Ltd., New Delhi, 2nd Edition, 2006.
4. Ned Mohan, Tore M. Undeland and William P. Robbins, “Power Electronics Converters, Applications, and Design”, John Willey & Sons, Inc., 3rd Edition, 2003.
5. Agrawal J. P., “Power electronic systems: Theory and design”, Addison Wesley Longman (Singapore) Pte. Ltd. New Delhi, 2nd Edition, 2001.

B. Tech. III year (Electrical Engineering with Honors), Semester- V

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Power Electronics Systems and Electrical Drives

EE391 Scheme

1. Course Outcomes (Cos):

At the end of the course students will be able to:

CO1	Explain the basic concept of PESs
CO2	Apply various power electronic converters to DC and AC drives
CO3	Devise different control techniques for DC and AC drives
CO4	Compare the performance of various methods of drive control
CO5	Decide the suitability of PESs for applications in emerging areas.

2. Syllabus:

- **INTRODUCTION TO DRIVES AND DC DRIVES (10 Hours)**

  Introduction to drives, Fundamental torque equation, speed-torque convention and multi quadrant operation, dynamics of motor load combination, nature and classification of load torque, calculation of acceleration time in transient operation, acceleration time for specific nature of motor and load torque, stability of electrical drives, Selection of Motor Power Rating.
  DC Drives: Phase controlled DC-Drives: Operation with continuous and discontinuous modes, Supply Harmonics, Power Factor and Ripple in motor current; Chopper Controlled DC Drives, Sources current harmonics in chopper, Converter Ratings and closed loop control scheme.

- **AC DRIVES (12Hours)**

  Induction Motor Drives: Speed control techniques: Stator voltage control, Variable frequency control, Open loop V/f control, Static rotor resistance control and Slip power recovery control schemes, Slip compensation technique.
  Synchronous Motor Drives: Self-controlled schemes, Variable frequency control of multiple synchronous motor, Permanent magnet AC motor drives, Control of Brushless DC Motor Drives and its applications.

- **ADVANCED POWER ELECTRONICS CONVERTERS (10 Hours)**

  Isolated DC-DC Converters: Fly-back, Forward, Push-Pull converter, Half and Full bridge converter, topologies, control and design; Active Front End Converter and its control for unity power factor operation; Multilevel Inverters; Modulation techniques: SPWM and SVM, Design of Inductor and Transformer.

- **APPLICATIONS OF POWER CONVERTERS (10 Hours)**

  Applications of DC-DC converters for MPPT techniques, Electric Vehicles (EVs) and Power Supply Design; Uninterruptible Power Supply; Application of PESs in Distribution system for Power Conditioning, PESs applications in Distributed Energy System such as Solar, Diesel Engine, Wind based isolated and grid connected system.

Tutorials will be conducted separately for 14 hours **Total Hours: 45**

3. List of Experiments:

1. Study of Speed Control of DC Shunt Motor Using Single Phase Fully Controlled Converter.
2. Controlling of DC Motor with Single Phase Dual Converter.
3. Study of Speed Control of Three Phase AC Induction Motor (V/F Control).
4. Experimental investigation of a 5 HP Induction Motor Drive.
5. Study of DSP Controlled Induction Motor Drive.
6. Study of DSP Controlled BLDC Motor Drive.
7. Simulation of V/F control of 3 phase induction motor using MATLAB.
8. Simulation of speed control of three phase induction motor using stator voltage control (AC Voltage controller) in MATLAB.

4. Books Recommended:

1. Rashid M. H., "Power Electronics Circuits, Devices, and Applications", Prentice-Hall of India Pvt. Ltd., New Delhi, 4th Edition, 2014.
2. Ned Mohan et al, "Power Electronics: Converters, Applications, and Design", John Wiley & Sons. Inc., 3rd Edition, 2003.
3. Bin Wu, High-Power Converters and AC Drives, A John Wiley and Sons, Inc., Publication, 2nd Edition, 2017.
4. B. K. Bose, "Modern Power Electronics & AC Drives", Pearson, 1st Edition, 2002.
5. Dubey G.K, "Fundamentals of Electrical Drives", Narosa Publishing House, 2nd Edition, 2002.
6. R. Krishnan "Electric motor drives Modeling, Analysis and Control" PHI-India, 1st Edition, 2015.

B. Tech. III year (Electrical Engineering with Honors), Semester- VI

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Flexible AC Transmission Controllers

EE394 **Scheme**

1. Course Outcomes (Cos):

At the end of the course students will be able to:

CO1	Explain the basic principle of power transmission and reactive power control.
CO2	Analyze shunt compensation and its requirement.
CO3	Evaluate series compensation and its requirement
CO4	Analyze of shunt-series compensation and its requirement.
CO5	Design of controllers for FACTS devices.

2. Syllabus:

- **LOAD COMPENSATION** **(08 Hours)**

Requirement and objectives of load compensations, Practical considerations, power factor and voltage regulations, balancing of unsymmetrical loads, Active filters: : Principle of operation, Analysis, Configurations, Control system, Applications.

- **REACTIVE POWER COMPENSATION** **(08 Hours)**

Analysis of uncompensated AC line, Passive reactive power compensation, Compensation by a series capacitor connected at the mid-point of the line, Effect on Power Transfer capacity, Compensation by STATCOM and SSSC

- **STATIC SHUNT COMPENSATORS** **(10 Hours)**

Static Var Compensators (TCR, FC-TCR, TSC-TCR): Principle of operation, Analysis, Configurations, Control system, Applications, protection aspect. STATCOM: Principle of operation, Analysis of six pulse and multi-pulse converters, Control systems, Applications.

- **STATIC SERIES COMPENSATORS** **(10 Hours)**

Concept of controlled series compensation, (TCSC, GCSC): Principle of operation, Analysis, Configurations, Control system, Applications. SSSC: Principle of operation, Analysis, Configurations, Control system, Applications.

- **COMBINED COMPENSATORS** **(09 Hours)**

(UPFC,IPFC) Principle of operation, Analysis, Configurations, Control system, Applications.

Tutorials will be conducted separately for 15 hours **Total Hours: 45**

3. Books Recommended:

1. K. R. Padiyar, FACTS Controller in Power Transmission and Distribution, New Age international, 1st Edition, 2007.
2. N.G. Hingorani, Understanding FACTS, IEEE Press, Standard Publishers Distributor, 2001.
3. T. J. E. Miller, Reactive Power Control in Electric Systems, John Wiley, 2010.
4. R. Mathur, N. Mohan and R. K. Varma, Thyristor–based FACTS Controllers for Electrical Transmission System, Wiley Inter-Science, 2011.
5. Acha E., Agelidis V. G., Anaya-Lara O., T.J.E. Miller, Power Electronics Control in Electrical System, Newnes Power Engineering Series, 2002.

B. Tech. III year (Electrical Engineering with Honors), Semester- V

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Restructuring and Deregulation of Power System

EE392 **Scheme**

1. Course Outcomes (Cos):

At the end of the course students will be able to:

CO1	Explain the basics and benefits of restructuring and deregulations
CO2	Evaluate the market scenario and completion in deregulated environment
CO3	Judge the pricing and agreements associated with deregulation policies.
CO4	Explore the contingency and ancillary service management restructured and deregulated system.
CO5	Explore the impact of availability and unavailability in terms of reliability indices

2. Syllabus:

- **DEREGULATION OF THE ELECTRICITY SUPPLY INDUSTRY** **(06 Hours)**

  Deregulation, Reconfiguring Power systems, unbundling of electric utilities, Background to deregulation and the current situation around the world, benefits from a competitive electricity market, after-effects of deregulation.

- **POWER SYSTEM OPERATION IN COMPETITIVE ENVIRONMENT** **(11 Hours)**

  Role of the independent system operator, Operational planning activities of ISO: ISO in Pool markets, ISO in Bilateral markets, Operational planning activities of a GENCO: Genco in Pool and Bilateral markets, market participation issues, competitive bidding.

- **TRANSMISSION OPEN ACCESS AND PRICING ISSUES** **(08 Hours)**

  Power wheeling, Transmission open access, pricing of power transactions, security management in deregulated environment, congestion management in deregulation.

- **ANCILLARY SERVICES MANAGEMENT** **(08 Hours)**

  General description of some ancillary services, ancillary services management in various countries, reactive power management in deregulated electricity markets

- **RELIABILITY AND DEREGULATION** **(12 Hours)**

  Reliability analysis: interruption criterion, stochastic components, component models, calculation methods, Network model: stochastic networks, series and parallel connections, minimum cut sets, reliability costs, Generation, transmission and distribution reliability, Reliability and deregulation: conflict, reliability analysis, effects on the actual reliability, regulation of the market.

Tutorials will be conducted separately for 15 hours **Total Hours: 45**

3. Books Recommended:

1. K. Bhattacharya, MHT Bollen and J.C Doolder, Operation of Restructured Power Systems, Kluwer Academic Publishers, USA, 2001.
2. Lei Lee Lai, Power System Restructuring and Deregulation, John Wiley and Sons, UK. 1st Edition, 2001.
3. Fred I Denny and David E. Dismukes, Power System Operations and Electricity Markets, CRC Press, LLC, 1st Edition, 2002.
4. Mohammad Shaidehpur, Muwaffaq Alomoush, _Restrctured electrical Power Systems, Operation, Trading and Volatility, Marcel Dekker Publications.
5. Xiao Ping Zhang, Restructured electrical Power Systems with equilibrium Models, John Wiley & Sons, 1st Edition, 2010.

B. Tech. III year(Electrical Engineering with Honors), Semester- VI

Flexible AC Transmission Controllers

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EE394 — Scheme

1. Course Outcomes (Cos):

At the end of the course students will be able to:

CO1	Explain the basic principle of power transmission and reactive power control.
CO2	Analyze shunt compensation and its requirement.
CO3	Evaluate series compensation and its requirement
CO4	Analyze of shunt-series compensation and its requirement.
CO5	Design of controllers for FACTS devices.

2. Syllabus:

- **LOAD COMPENSATION** **(08 Hours)**

  Requirement and objectives of load compensations, Practical considerations, power factor and voltage regulations, balancing of unsymmetrical loads, Active filters: : Principle of operation, Analysis, Configurations, Control system, Applications.

- **REACTIVE POWER COMPENSATION** **(08 Hours)**

  Analysis of uncompensated AC line, Passive reactive power compensation, Compensation by a series capacitor connected at the mid-point of the line, Effect on Power Transfer capacity, Compensation by STATCOM and SSSC

- **STATIC SHUNT COMPENSATORS** **(10 Hours)**

  Static Var Compensators (TCR, FC-TCR, TSC-TCR): Principle of operation, Analysis, Configurations, Control system, Applications, protection aspect. STATCOM: Principle of operation, Analysis of six pulse and multi-pulse converters, Control systems, Applications.

- **STATIC SERIES COMPENSATORS** **(10 Hours)**

  Concept of controlled series compensation, (TCSC, GCSC): Principle of operation, Analysis, Configurations, Control system, Applications. SSSC: Principle of operation, Analysis, Configurations, Control system, Applications.

- **COMBINED COMPENSATORS** **(09 Hours)**

  (UPFC,IPFC) Principle of operation, Analysis, Configurations, Control system, Applications.

Tutorials will be conducted separately for 15 hours **Total Hours: 45**

3. Books Recommended:

1. K. R. Padiyar, FACTS Controller in Power Transmission and Distribution, New Age international, 1st Edition, 2007.
2. N.G. Hingorani, Understanding FACTS, IEEE Press, Standard Publishers Distributor, 2001.
3. T. J. E. Miller, Reactive Power Control in Electric Systems, John Wiley, 2010.
4. R. Mathur, N. Mohan and R. K. Varma, Thyristor–based FACTS Controllers for Electrical Transmission System, Wiley Inter-Science, 2011.
5. Acha E., Agelidis V. G., Anaya-Lara O., T.J.E. Miller, Power Electronics Control in Electrical System, Newnes Power Engineering Series, 2002.

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B. Tech. III year (Electrical Engineering with Honors), Semester- V

Discrete-time Control Systems

EE393 Scheme

1. Course Outcomes (Cos):

At the end of the course students will be able to:

CO1	Classify various Discrete-Time control systems
CO2	Analyze the Discrete-Time control systems with Z transformation
CO3	Design Discrete-Time control systems and to assess the stability of DTCS
CO4	Obtain and analyze State-space representations of discrete-time systems
CO5	Design various discrete-time systems control schemes

2. Syllabus:

- **INTRODUCTION TO DISCRETE-TIME CONTROL SYSTEMS** **(04 Hours)**

  Introduction, digital control systems, quantizing and quantization error, data acquisition, conversion, and distribution systems.

- **THE Z TRANSFORMATION** **(08 Hours)**

  The z transform, transforms of elementary functions, important properties and theorems of the z transform, the inverse z transform, z transform method for solving difference equations.

- **Z-PLANE ANALYSIS OF DISCRETE-TIME CONTROL SYSTEMS** **(08 Hours)**

  Impulse sampling and data hold, obtaining the z transform by the convolution integral method, reconstructing original signals from sampled signals, the pulse transfer function, realization of digital controllers and digital filters.

- **DESIGN OF DISCRETE-TIME CONTROL SYSTEMS** **(10 Hours)**

  Introduction, mapping between the S plane and the z plane, stability analysis of closed-loop systems in the z plane, transient and steady-state response analysis, design based on the root-locus method, design based on the frequency-response method, analytical design method.

- **STATE-SPACE ANALYSIS** **(10 Hours)**

  State-space representations of discrete-time systems, solving discrete-time state-space equations, pulse-transfer-function matrix, discretization of continuous-time state-space equations, Lyapunov stability analysis.

- **POLE PLACEMENT AND OBSERVER DESIGN** **(05 Hours)**

  Controllability, observability, useful transformations in state-space analysis and design, via pole placement, state observers, servo systems.

Tutorials will be conducted separately for 15 hours **Total Hours: 45**

3. Books Recommended:

1. K. Ogata, Discrete Time Control System, Pearson Education, Inc., 2nd Edition, 2015.
2. B. C. Kuo, Discrete Data Control System, Prentice-Hall, 2nd Edition, 1992.
3. I. J. Nagrath and M. Gopal, Control System Engineering" New Age International Publishers, 3rd Edition, 2001.
4. M. Gopal, Digital control System, McGraw-Hill Education, 4th Edition, 2017.
5. B. C. Kuo, Automatic Control System, Prentice Hall of India, 7th Edition, 1995.

B. Tech. III year (Electrical Engineering with Honors), Semester- VI

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Optimal Control

EE395 **Scheme**

1. Course Outcomes (Cos):

At the end of the course students will be able to:

CO1	Formulate optimal control problem
CO2	Solve optimal control problems using calculus of variation approach
CO3	Apply Linear Quadratic Regulator for the state space control
CO4	Formulate robust control problem
CO5	Solve H_2 and H_∞ control problems

2. Syllabus:

- **INTRODUCTION TO OPTIMAL CONTROL** **(10 Hours)**

  Introduction, Optimization, Optimal control, Plant model, Performance index, Constraints, Formulating an optimal control problem with examples.

- **CALCULUS OF VARIATIONS** **(10 Hours)**

  Concept of functional, Optimum of a functional, The basic variational problem Fixed end point problem, Free end point problem, Extrema of functionals with constraints, Variation approach to optimal control systems, Hamiltonian approach.

- **LINEAR QUADRATIC OPTIMAL CONTROL SYSTEMS** **(25 Hours)**

  Finite time linear quadratic regulator problem formulation, Analytical solution of Matrix Differential Riccati Equation (Similarity transformation approach), Infinite horizon regulator problem, Analytical solution of the Algebraic Riccati equation, Frequency domain interpretation of LQR, LQR with a specified degree of stability, Time optimal control systems, Problem formulation, Solution of the time optimal control system.

Total Hours: 45

3. Books Recommended:

1. Donald E. Kirk, Optimal Control: an introduction, Dover Publications, 2006.
2. DesineniSubbaram Naidu, Optimal Control Systems, CRC Press, 2003.
3. Geir E. Dullerud, Fernando Paganini, A Course in Robust Control Theory, Springer, 2010.
4. K. Zhou, J.C. Doyle and K. Glover, Robust & Optimal Control, Prentice Hall Inc. NY 1998.

B. Tech. III year (Electrical), Semester- VI

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Vocational Training/Professional Experience (Optional)(Mandatory for Exit)

EEV04/EEP04 **Scheme**

1. Course Outcomes (Cos):

At the end of the course students will be able to:

CO1	Explain Finite Element Method (FEM)
CO2	Develop model using FEM
CO3	Compute electrostatic and electromagnetic field in various model using FEM
CO4	Control electrostatic and electromagnetic field in various model of FEM
CO5	Design and analysis inductor, transformer, rotating electrical machines using FEM

2. Syllabus:

- **INTRODUCTION** **(05 Hours)**

  Review of Electromagnetic Field Theory. Review of High Voltage Engineering. Review of Electrical Machine Design

- **ELECTROSTATIC FIELD COMPUTATION** **(06 Hours)**

  Estimation and Control of Electric Stress

- **NUMERICAL METHODS FOR ELECTRIC FIELD COMPUTATION** **(06 Hours)**

  Finite Element Method, Charge Simulation Method, Boundary Element Method

- **ELECTROMAGNETIC FIELD COMPUTATION** **(06 Hours)**

  Inductor, Transformer and Rotating Electrical Machine

Total Hours: 45

3. LIST OF EXPERIMENTS:

Sl. No.	Name of the FEM based Experiments	Hours
1.	Introduction to Commercial FEM software	10
2.	Modelling and Electrostatic field computation in various electrode systems	10
3.	Modelling and Electrostatic field computation in single phase and three phase Cable, Capacitor, Overhead Transmission Line	20
4.	Modelling and Electromagnetic field computation in air core inductor	10
5.	Modelling and Electromagnetic field computation in Inductor, Transformer, Rotating Electrical Machines	20
6.	Design of Inductor	10
7.	Estimation and Control of electrostatic and electromagnetic stresses in Inductor	10
8.	Design of Transformer	10
9.	Estimation and Control of electrostatic and electromagnetic stresses in Transformer	10
10.	Design of Rotating Electrical Machines	20
11.	Estimation and Control of electrostatic and electromagnetic stresses in Rotating Electrical Machines	20
12.	Continuous Evaluation	30
	Total (Notional Hours)	**200**

B. Tech. III year(Electrical), Semester- VI

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Vocational Training/Professional Experience (Optional)(Mandatory for Exit)

(Hands-on training: FPGA based Control of Power Electronic Converters)

EEV04/EEP04 **Scheme**

1. Course Outcomes (Cos):

At the end of the course students will be able to:

CO1	Write programs using Verilog HDL code.
CO2	Simulate the programs using integrated development environment (IDE).
CO3	Interface the FPGA with external hardware using ADC/DAC.
CO4	Generate gate pulses to control various power electronic converters.
CO5	Develop a laboratory prototype of FPGA based controller for PE converters.

2. Syllabus:

- **INTRODUCTION** **(04 Hours)**

  Review of digital logic circuits, Different kinds of programmable logic devices: Field Programmable Gate Array (FPGA), Programmable Logic Device (PLD), FPGA manufacturers (Xilinx, Altera, Actel, Lattice Semiconductor, Atmel). FPGA applications. Adjoining devices. Instruments and software.

- **THE STRUCTURE OF FPGA** **(05 Hours)**

  FPGA general description. Different kinds of FPGA packages. FPGA architecture. Internal hard modules of FPGA (CLB, Block RAM, DCM), their meanings and usage. Different kinds of I/O modules, their usage and configuration

- **FPGA DESIGN FLOW** **(06 Hours)**

  Architecture design. Project design using Verilog Hardware Description Language (HDL). Defining testing methodology and test bench design. RTL simulation, synthesizing, implementation, gate level simulation of design. Reusing of internal hard modules during design and implementation.

- **FPGA CONFIGURATION AND TESTING METHODOLOGY** **(08 Hours)**

  Different types of FPGA configuration files. Generation of configuration file and its loading into FPGA. Functional and gate level testing. SDF file description and usage.

Total Hours: 45

3. LIST OF EXPERIMENTS:

Sl. No.	Name of the Experiment	Hours
1.	Introduction to integrated development environment (IDE) for system Verilog	6
2.	Getting acquainted with Verilog programming (i) Full adder, (ii) Up-down counter (iii) LED blink (iv) LCD display	10
3.	Interfacing using GPIO pins	6
4.	Generation of Arbitrary waveforms using Look up table (LUT)	10
5.	ADC/DAC interfacing	10
6.	Open-loop control of DC-DC converters (i) Buck (ii) Boost (iii) Buck-boost	10
7.	Square wave operation of Single-phase inverter (i) Half- Bridge with R and R-L load (ii) Full- Bridge with R and R-L load	8
8.	Single phase AC voltage controller with R and R-L load	8
9.	Operation of three phase inverter in 120° and 180° conduction modes	8
10.	Generation of gating pulses using Sine PWM technique	8
11.	Transformation from 3-phase to 2-phase	8
12.	Transformation from 2-phase to arbitrarily rotating reference frame	8
13.	Mini Project	50
14.	Continuous Evaluation	30
	Total (Notional Hours)	200

3. BOOKS RECOMMENDATION:

1. “Verilog HDL”, A guide to Digital Design and Synthesis Samir Palnitkar SunSoft Press 1996.
2. P. Chu Pong, “FPGA Prototyping by Verilog Examples”, Xilinx Spartan, 3rd version, 2008
3. DE1-SoC Getting started Guide for ALTERA Cyclone V GX, “https://www.terasic.com.tw/cgibin/page/archive.pl?Language=English&CategoryNo=165&No=836&PartNo=4#contents”
4. NPTEL video Lectures on “Hardware modelling using Verilog by Prof. Indaranil Sengupta, IIT Kharagpur”.

B. Tech. III year (Electrical), Semester- VI

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Vocational Training/Professional Experien (Optional) (Mandatory for Exit)

EEV04/EEP04 - Embedded System and Power Electronics System Development **Scheme**

1. Course Outcomes (Cos):

At the end of the course students will be able to:

CO1	Develop understanding of embedded system designing
CO2	Develop understanding of power electronics system designing
CO3	Designing gate drivers and PCBs
CO4	Modelling power converter and its control.
CO5	Develop power converter for practical application

2. Syllabus:

- **POWER SEMICONDUCTOR DEVICES** **(05 Hours)**

  Review of modern-day power semiconductor switched, their characteristic and control.

- **GATE DRIVING AND POWER COMPONENT DESIGING** **(05 Hours)**

  Isolated and non-isolated gate driving circuit designing

- **EMBEDDED SYSTEM PROGRAMMING** **(05 Hours)**

  Basics of embedded system, architecture, and peripheral programming

- **POWER ELECTRONICS APPLICATIONS** **(05 Hours)**

  Applications in renewable power generation, electrical vehicle, motor drive, power supplies

Total Hours: 20

3. LIST OF EXPERIMENTS:

Sl. No.	Name of the Experiments	Hours
1.	Revising the basis components	10
2.	Power Semiconductor Switches and it's Control	20
3.	Simulation in MATLAB/Simulink	20
4.	C Language for Embedded System Programmers	10
5.	Embedded C Programing of 8-bit Microcontroller	30
6.	Embedded C Programing of 32-bit Microcontroller	30
7.	Programming STM32Fxx Microcontroller using MATLAB/Simulink	30
8.	PCB Designing	10
9.	Internet of Things (IoT) and Other Applications	05
10.	Project Development	35
	Total (Notional Hours)	**200**

4. BOOKS RECOMMENDATION:

1. Ünsalan, Cem, Hüseyin Deniz Gürhan, and Mehmet Erkin Yücel. Embedded System Design with ARM Cortex-M Microcontrollers. Springer International Publishing, 2022.
2. Zappa, Franco. Microcontrollers. Hardware and Firmware for 8-bit and 32-bit Devices. Società Editrice Esculapio, 2020.
3. Umanand, L. Power electronics: essentials and applications. Wiley India Pvt. Limited, 2009.