B.Tech. in ELECTRICAL & ELECTRONICS ENGINEERING
(2022 Scheme)

Year	THIRD SEMESTER						FOURTH SEMESTER					
	Sub. Code	**Subject Name**	**L**	**T**	**P**	**C**	**Sub. Code**	**Subject Name**	**L**	**T**	**P**	**C**
II	MAT 2122	Engineering Mathematics - III	2	1	0	3	MAT 2227	Engineering Mathematics - IV	2	1	0	3
	ELE 2121	Electrical Circuit Analysis	3	1	0	4	ELE 2221	Analog System Design	2	1	0	3
	ELE 2122	Digital System Design	2	1	0	3	ELE 2222	Power Electronics	2	1	0	3
	ELE 2123	Electrical Machinery - I	3	1	0	4	ELE 2223	Linear Control Theory	2	1	0	3
	ELE 2124	Electromagnetic Field Theory	2	1	0	3	ELE 2224	Generation, Transmission & Distribution	3	1	0	4
	ELE 2125	Microcontrollers	2	1	0	3	ELE 2225	Electrical Machinery - II	2	1	0	3
	ELE 2141	Digital System Design Lab	0	0	3	1	ELE 2241	Analog System Design Lab	0	0	3	1
	ELE 2142	Microcontroller Lab	0	0	3	1	ELE 2242	Electrical Machinery Lab	0	0	3	1
			14	**6**	**6**	**22**			**13**	**6**	**6**	**21**
	Total Contact Hours (L + T + P)		**26**				**Total Contact Hours (L + T + P)**		**25**			
III	**FIFTH SEMESTER**						**SIXTH SEMESTER**					
	HUM 3022	Essentials of Management	3	0	0	3	HUM 3021	Engg Economics and Financial Management	3	0	0	3
	ELE 3121	Power System Analysis	3	1	0	4	ELE 3221	Measurements & Instrumentation	3	1	0	4
	ELE 3122	Digital Signal Processing	2	1	0	3	ELE ****	Flexible Core - II (A2/B2/C2)	3	0	0	3
	ELE 3123	Switchgear & Protection	3	0	0	3	ELE ****	PE – 1 / Minor Specialization	3	0	0	3
	ELE ****	Flexible Core - I (A1/B1/C1)	3	0	0	3	ELE ****	PE – 2 / Minor Specialization	3	0	0	3
	IPE 4302	OE-1 Creativity, Problem Solving and Innovation	3	0	0	3	*** ****	Open Elective-2	3	0	0	3
	ELE 3141	Power Electronics Lab	0	0	3	1	ELE 3241	Measurements & Instrumentation Lab	0	0	3	1
	ELE 3142	Systems Simulation Lab	0	0	3	1	ELE 3242	Power System Lab	0	0	3	1
			17	**2**	**6**	**21**			**18**	**1**	**6**	**21**
	Total Contact Hours (L + T + P) + OE		**22+3=25**				**Total Contact Hours (L + T + P) + OE**		**22+3=25**			
IV	**SEVENTH SEMESTER**						**EIGHTH SEMESTER**					
	ELE ****	PE – 3 / Minor Specialization	3	0	0	3	ELE 4291	Industrial Training (MLC)				1
	ELE ****	PE – 4 / Minor Specialization	3	0	0	3	ELE 4292	Project Work				12
	ELE ****	PE – 5	3	0	0	3	ELE 4293	Project Work (B Tech – Honours) **				20
	ELE ****	PE – 6	3	0	0	3	ELE ****	B Tech – Honours Theory – 1** (V semester)				4
	ELE ****	PE - 7	3	0	0	3	ELE ****	B Tech – Honours Theory – 2** (VI semester)				4
	*** ****	Open Elective–3	3	0	0	3	ELE ****	B Tech – Honours Theory – 3** (VII semester)				4
	ELE 4191	Mini Project (Minor specialization) *				8						
			18	**0**	**0**	**18/26**						**13/33**
	Total Contact Hours (L + T + P) +OE		**15 + 3 = 18**									

*Applicable to students who opted for minor specialization

**Applicable to eligible students who opted for and successfully completed the B Tech – honours requirements

Flexible Core / Minor Specializations	Other Program Electives	Open Electives
Flexible Core - I ELE 3124: Modern Power Converters ELE 3125: Distributed Generation Systems ELE 3126: Communications Systems ELE 3127: Foundations of EV & Hybrid Vehicles **Flexible Core - II** ELE 3222: Solid state Drives ELE 3223: Smart Grid Technologies ELE 3224: Control system Design ELE 3225: Automotive Mechanics for Electric Vehicles **Minor Specializations** **I. Computational Intelligence (BME, ECE, EEE, ICE)** ELE 4409: Artificial Intelligence ECE 4409: Machine Learning ELE 4410: Soft Computing Techniques ECE 4410: Computer Vision **II. Embedded Systems (ECE, EEE, ICE)** ECE 4411: Embedded System Design ELE 4411: FPGA Based System Design ECE 4412: Internet of Things ELE 4412: Real Time Systems **III. Signal Processing (ECE, EEE, ICE)** ECE 4413: Advanced Digital Signal Processing ELE 4413: Linear Algebra for Signal Processing ECE 4414: Digital Speech Processing ELE 4414: Digital Image Processing **IV. Illumination Technology (ECE, EEE, ICE)** ELE 4401: Lighting Science: Devices and Systems ELE 4402: Integrated Lighting Design ELE 4403: Lighting Controls: Technology & Applications ELE 4404: Solid State Lighting **V. E-Mobility (BME, ECE, EEE, ICE)** ELE 4415: EV Battery Technology and Power Train Development ELE 4416: EV Charging Infrastructure, Vehicle Testing & Homologation ELE 4417: EV Vehicle Design & Analysis ELE 4418: EV Data Analytics & Cyber Security	**Other Program Electives** ELE 4441: Building Automation Systems ELE 4442: Computer Architecture & Organization ELE 4443: Data Structures & Algorithms ELE 4444: Demand Side Management ELE 4445: Energy Analytics ELE 4446: Energy Auditing ELE 4447: Energy Storage Devices ELE 4448: HVDC & FACTS ELE 4449: Introduction to Data Science ELE 4450: Microgrids ELE 4451: Power System Operation & Control ELE 4452: Power System Restructuring & Market Operations ELE 4453: Renewable Energy	**Open Electives** ELE 4311: MATLAB for Engineers ELE 4312: Essentials of Energy Auditing ELE 4313: Solar Photovoltaics ELE 4314: Introduction to Renewable Energy ELE 4315: Introduction to Lighting Design ELE 4316: Utilization of Electrical Energy

SEMESTER: 03

MAT 2122: ENGINEERING MATHEMATICS – III [2 1 0 3]

Course Learning Outcomes: At the end of the course, the students will be able to:

CO1	Find the independent solutions of system of linear equations.
CO2	Apply concept of orthonormal basis and orthonormal projections in practical situations.
CO3	Apply the suitable matrix decomposition methods for dimension reduction process
CO4	Formalize the semantics of programming languages and the specification of programs.
CO5	Acquire the knowledge of Fourier series expansions and apply them in engineering domain

Linear Algebra: Systems of Linear Equations, Matrices, Solving Systems of Linear Equations, Vector Spaces, Linear Independence, Basis and Rank, Linear Mappings, Affine Spaces. Analytic Geometry: Norms, Inner Products, Lengths and Distances, Angles and Orthogonality, Orthonormal Basis, Orthogonal Complement, Inner Product of Functions, Orthogonal Projections, Rotations. Matrix Decompositions: Determinant and Trace, Eigenvalues and Eigenvectors, Cholesky Decomposition, Eigen decomposition and Diagonalization, Singular Value Decomposition, Matrix Approximation. Fourier Series and Transforms: Periodic function, Fourier Series expansion. even and odd functions, functions with arbitrary periods, Half range expansionsFourier transform, basic properties, Parseval's identity and applications.

References:

1. Marc Peter Deisenroth, A. Aldo Faisal, Cheng Soon Ong, *Mathematics for Machine Learning*, Cambridge University Press, 2020.
2. Grewal B.S. - *Higher Engineering Mathematics*, Khanna Publishers, 43rd edition, 2015
3. Stephen H. Friedberg Lawrence E Spence, *Arnold J Insel, Elementary Linear Algebra: A Matrix Approach Introduction to Linear Algebra*, Second Edition, 2019.
4. David Lay, Steven Lay, Judi McDonald, *Linear Algebra and Its Applications*, Pearson, 2019.
5. Gilbert Strang, *Introduction to Linear Algebra*, Fifth Edition (2016), Wellesley-Cambridge Press.
6. Mordechai Ben-Ari, *Mathematical Logic for Computer Science,* Third Edition, Springer.
7. Narayanan, Ramaniah and Manicavachagom Pillay, *Advanced Engineering Mathematics, Vol 2 and 3, Vishwanthan Publishers Pvt Ltd. 1998*
8. Erwin Kreyszig, Advanced Engineering Mathematics, 5th edn., Wiley Eastern, 1985

ELE 2121: ELECTRICAL CIRCUIT ANALYSIS [3 1 0 4]

Course Learning Outcomes: At the end of the course, the students will be able to:

CO1	Apply the knowledge of Kirchhoff's laws to determine the steady state response of DC and AC circuits using network theorems
CO2	Classify systems based on their properties and perform CT convolution to find the steady state response of LTI system
CO3	Perform transient analysis of electrical circuits by applying time domain and Laplace transform techniques.
CO4	Analyse the spectral characteristics of continuous-time periodic and aperiodic signals using Fourier analysis.
CO5	Analyze the given network to compute its two port parameters.
CO6	Analyze the Electrical circuits and LTI systems response by selecting an appropriate simulation tool

Controlled sources, Network Theorems. Signals: Continuous time signals, classification, Elementary CT signals, Operations on signals. Systems and properties, LTI systems, convolution integral, Characterisation. Time domain analysis: Initial and final conditions, Transients analysis of RL, RC and RLC circuits. Laplace domain analysis: Laplace transforms of signals, Transformed circuits, analysis. Frequency domain analysis: Continuous Time Fourier Series, representation, Continuous time Fourier transform, properties, transfer function, frequency response. Two port networks: Z, Y, T and h parameters, Series, parallel and cascade connections. Self-study: simulation-based studies of the selected topics.

References:

1. Hayt W. H., J. E. Kemmerly & S. M. Durbin, *Engineering Circuit Analysis,* 9e, TMH, 2020
2. Van Valkenberg, *Network Analysis*, 3e, PHI, 2009
3. Nilsson J. W. & S. A. Reidel, *Electric Circuits*, 11e, Pearson, 2019.
4. Haykin S., *Signals and Systems*, 2e Wiley, 2007
5. NPTEL Course: https://nptel.ac.in/courses/117/101/117101055/

ELE 2122: DIGITAL SYSTEM DESIGN [2 1 0 3]

Course Learning Outcomes: At the end of the course, the students will be able to:

CO1	Apply the minimization methods for the systematic reduction of Boolean algebraic expressions
CO2	Design combinational circuits using specified SSI & MSI devices, and Verilog HDL given a set of specifications.
CO3	Design sequential circuits using Flip Flops for a given set of specifications using standard IC and programmable IC .
CO4	Design Sequential Finite State Machines (FSM) using logic components using standard IC and programmable IC.
CO5	Appreciate digital systems at different levels of abstraction and the applications of digital systems

Combinational logic circuits: Overview of Algebraic simplification of Boolean expressions and realization using logic gates, minimization using Karnaugh map, Combinational circuit design using MSI chips: Multiplexers; demultiplexers; encoders; decoders; parity generators; parity checkers, Arithmetic circuits, Sequential logic circuits: flipflops and ripple counter, Shift registers, Analysis and design of synchronous sequential finite state machines, Digital System Implementation Options: Introduction to ASIC, Introduction to HDL, Gate level modeling, Data flow modeling, Behavioral modeling of combinational and sequential circuits, Self- Study- Simulation of combinational and sequential digital circuits, Silicon Processing

References:

1. Givone, Digital Principles & Design, TMH 2011.
2. Charles H Roth, Lizy Kurian John,Byeong Kil Lee, Digital Systems Design using Verilog, First edition, Global Engineering Publishers, 2015
3. Ronald J. Tocci, Digital Systems - Principles & Applications, Pearson, 2005.
4. Brown & Vranesic, Fundamentals of Digital Logic with Verilog HDL design, TMH,2012
5. NPTEL Courses: https://nptel.ac.in/courses/108/106/108106177/

ELE 2123: ELECTRICAL MACHINERY - I [3 1 0 4]

Course Learning Outcomes: At the end of the course, the students will be able to:

CO1	Evaluate the performance of single-phase transformers in terms of losses, efficiency, and voltage regulation based on steady-state equivalent circuit.
CO2	Analyze different types of three-phase transformer connections for power transmission and distribution systems.
CO3	Design winding arrangements for three-phase AC machines based on the given specifications.
CO4	Assess the performance of induction motors in terms of torque, slip, power, and efficiency based on steady-state equivalent circuit.
CO5	Select DC machines based on performance characteristics for various applications.

Single-phase transformers: Construction, working principle, equivalent circuit, performance analysis, parallel operation. Autotransformers. Three-phase transformers: Types, construction, connections, inrush current, and harmonics. Three-phase induction motors: Types, construction, working principle, winding diagram, equivalent circuit, performance analysis, testing, starting, braking, speed control, induction generators. Single-phase induction motors: Double field revolving theory, types, characteristics. DC Generators: Construction, working principle, armature winding, armature reaction, commutation. DC Motors: Types, characteristics, starting, braking, speed control, testing. Self-study: Extended exercises on analyses of electrical machines covered.

References:

1. I. J. Nagrath, D. P. Kothari, *Electric Machines (5e)*, TMH, 2017.
2. A. Langsdorf, *Theory of Alternating Current Machine (2e)*, TMH, 2009.
3. M. G. Say, *Alternating Current Machines (5e)*, CBS, 2002.
4. https://nptel.ac.in/courses/108/106/108106071/
5. https://nptel.ac.in/courses/108/106/108106072/

ELE 2124: ELECTROMAGNETIC FIELD THEORY [2 1 0 3]

Course Learning Outcomes: At the end of the course, the students will be able to:

CO1	Apply mathematical techniques to describe the spatial variations of a vector using orthogonal co-ordinate systems to understand the concepts of electromagnetism

CO2 Evaluate the various parameters of static electric and magnetic fields in different media using laws of electromagnetism analytically as well as through numerical simulations
CO3 Discuss the concepts of electromagnetic dynamics related to Maxwell's equations
CO4 Apply Maxwell's equations to obtain the solutions of the electromagnetic waves propagating in different media
CO5 Discuss plane wave reflection at the boundary between different media to understand the concept of shielding effectiveness

Vector analysis: Vector algebra, Rectangular, Cylindrical and Spherical Coordinate systems, Electrostatics: Field intensity, Flux density, Boundary conditions, Capacitance, Laplace's and Poisson's equations, Magnetostatics: Field intensity, Flux density, Boundary conditions, Magnetic forces, Inductance, Time varying fields: Maxwell's equations, Uniform Plane wave: Wave equation and its solution, Wave propagation in different media, Poynting's theorem, Wave polarization – Perpendicular and Parallel polarization, Shielding theory – Plane wave and near Field shielding theory, Applications, Self-study: extended study in selected topics

References:

1. William Hayt, *Engineering Electromagnetics*, TMH, 8th edition, 2011
2. Mathew Sadiku, *Elements of Electromagnetics*, Oxford University Press, 2014
3. Jan W. Gooch John K. Daher, *Electromagnetic Shielding and Corrosion Protection for Aerospace Vehicles*, Springer, 2007
4. NPTEL Courses: Electromagnetic Fields: http://nptel.ac.in/courses/108106073/
5. Markus Zahn, *Electromagnetic Field Theory*. (Massachusetts Institute of Technology: MIT OpenCourseWare). https://ocw.mit.edu/resources/res-6-002-electromagnetic-field-theory-a-problem-solving-approach-spring-2008/textbook-contents/

ELE 2125: MICROCONTROLLERS [2 1 0 3]

Course Learning Outcomes: At the end of the course, the students will be able to:

CO1 Discuss the architecture of 8051 microcontroller to understand the instructions for assembly programming
CO2 Analyse the working of 8051 timers, interrupts, to program them for given applications
CO3 Design 8051 based system development using assembly/ embedded C programming for practical applications.
CO4 Describe the architecture of ARM7TDMI to program ARM7 based microcontroller
CO5 Develop an ARM7 based system for practical applications by understanding the responsibilities to professional engineering practice.

Introduction to microprocessors and microcontrollers, general purpose and embedded systems, CISC and RISC architectures, AT89C51 (8051) microcontroller: Architecture, pin diagram, addressing modes, instruction set, programming, stack, subroutines, GPIO, timers, serial port, interrupts. Interfacing keyboard, LCD, ADC and DAC to 8051. Embedded software development in 'C'. Programming 8051 in 'C'. ARM processors: ARM7TDMI; Processor modes, visible registers, ARM instruction set, programming, stack, subroutine, exceptions and pipelined architecture. ARM7 based NXPLPC21XX microcontroller: architecture, programming, interfacing. Self-study on Extended Embedded C programming, case studies on realisation of microcontroller based system design for practical applications.

References:

1. Muhammad Ali Mazidi and Gillispie Mazidi, *The 8051 Microcontroller and embedded systems, using assembly and 'C'*, Pearson education, 2013.
2. Kenneth. J. Ayala, *The 8051 Microcontroller and embedded systems, using assembly and 'C'*, Cengage Learning, 2009.
3. Steve Furber, *ARM System - on – Chip Architecture*, Pearson, Second Edition, 2015
4. William Hohl, Hinds Christopher, *ARM Assembly Language*, CRC Press, 2016
5. NPTEL Course: https://nptel.ac.in/courses/106/105/106105193/

ELE 2141: DIGITAL SYSTEM DESIGN LAB [0 0 3 1]

Course Learning Outcomes: At the end of the course, the students will be able to:

CO1 Test the designed digital circuits using standard ICs
CO2 Demonstrate the functional verification of a digital circuit using HDL
CO3 Create FPGA based digital circuit for a given application
CO4 Function as a team member in lab project to adopt inclusive approach in engineering practice

Design and Test Digital circuits using standard ICs: Design, Implement and test combinational circuits, asynchronous sequential circuit and synchronous sequential circuit

Digital System Design using Programmable ASICs: Familiarization to HDL, modeling styles and design flow environment, Digital circuit design using Verilog HDL and implementation on FPGA, Design and develop FPGA based digital circuit for a given application

References:

1. Givone, Digital Principles & Design, TMH 2011.
2. Charles H Roth, Lizy Kurian John,Byeong Kil Lee, Digital Systems Design using Verilog, First edition, Global Engineering Publishers, 2015
3. Ronald J. Tocci, Digital Systems - Principles & Applications, Pearson, 2005.
4. Brown & Vranesic, Fundamentals of Digital Logic with Verilog HDL design, TMH,2012

ELE 2142: MICROCONTROLLER LAB [0 0 3 1]

Course Outcomes: At the end of the program the students will be able to

CO1 Execute 8051 Microcontroller programs using KeilµVision-4 software
CO2 Develop programs to familiarize interrupts of 8051 microcontroller
CO3 Interface and program ADC, DAC, LCD and Hex keypad to 8051 microcontrollers
CO4 Analyze the LPC2148 based programs
CO5 Evaluate selected simulation/hardware exercises in the microcontroller through a Minor group project to provide a solution for the benefit of society

Module I: Experiments using 8051 Microcontroller simulator.
Module II: Interfacing exercises using 8051 microcontroller
Module III: Experiments using ARM7 processor based microcontroller.
Mini-Project: Microcontroller based system design.

References:

1. Muhammad Ali Mazidi and Gillispie Mazidi, *The 8051 Microcontroller and embedded systems, using assembly and 'C'*, Pearson education, 2013.
2. Kenneth. J. Ayala, *The 8051 Microcontroller and embedded systems, using assembly and 'C'*, Cengage Learning, 2009.
3. ESAMCB 51 Microcontroller manual.
4. ARM 7 Based NXP LPC 2148 Manual.
5. https://nptel.ac.in/courses/106/105/106105193/

SEMESTER: 04

MAT 2227: ENGINEERING MATHEMATICS – IV [2 1 0 3]

Course Learning Outcomes: At the end of the course, the students will be able to:

CO1 Understand the probability aspects and apply in engineering models
CO2 Know the concept of random variables and their applications
CO3 Quantify the uncertainty in the data using aspects of probability
CO4 Apply the concept of vector gradient and gradient descent in physical phenomenon
CO5 Apply and analyse the optimistic solutions for the machine learning problems.

Probability and Distributions: Construction of a Probability Space, Discrete and Continuous Probabilities, Sum Rule, Product Rule, and Bayes' Theorem, Summary Statistics and Independence, Distributions: Binomial, Poisson, uniform, normal, Chi-square and exponential distributions. Multivariate Random variables and Stochastic Process: Two and higher dimensional random variables, covariance, correlation coefficient. Moment generating function, functions of one dimensional and two dimensional random variables. Static probabilities: review and prerequisites generating functions, difference equations. Dynamic probability: definition and description with examples. Markov chains, transition probabilities. Vector Calculus: Differentiation of Univariate Functions, Partial Differentiation and Gradients, Gradients of Vector-Valued Functions, Gradients of Matrices, Useful Identities for Computing Gradients, Backpropagation and Automatic Differentiation, Higher-Order Derivatives, Linearization and Multivariate Taylor Series. Optimization: Basic solution, Convex sets and function, Simplex Method, Optimization Using Gradient Descent, Constrained Optimization and Lagrange Multipliers.

References:

1. Marc Peter Deisenroth, A. Aldo Faisal, Cheng Soon Ong, *Mathematics for Machine Learning*, Cambridge University Press, 2020.
2. P L Meyer, Introductory Probability and Statistical Applications, Addison Wiley.
3. Medhi. J. Stochastic Processes, Wiley Eastern.
4. Murray R. Spiegel, Vector Analysis Theory and Problems, Schaum's Outline Series, 2019.
5. Hamdy A. Taha, "Operations Research: An Introduction", 8th Edn., Pearson Education (2008).
6. Sheldon M. Ross, Introduction to Probability Models Eleventh Edition Elsevier.
7. E. S. Page, L. B. Wilson, An Introduction to Computational Combinatorics, Cambridge University Press.
8. Bhat U R, Elements of Applied Stochastic Processes, John Wiley.

ELE 2221: ANALOG SYSTEM DESIGN [2 1 0 3]

Course Learning Outcomes: At the end of the course, the students will be able to:

CO1	Execute 8051 Microcontroller programs using KeilμVision-4 software
CO2	Develop programs to familiarize interrupts of 8051 microcontroller
CO3	Interface and program ADC, DAC, LCD and Hex keypad to 8051 microcontrollers
CO4	Analyze the LPC2148 based programs
CO5	Evaluate selected simulation/hardware exercises in the microcontroller through a Minor group project to provide a solution for the benefit of society

Review of MOSFET charecteristics, structure, biasing,current mirrors,Basic amplifier cconfigurations, CS, CG, CD configurations. Small signal model frequency response, high frequency MOS model. Cascaded amplifier and large signal amplifier. Basic differntial amplifier, common mode and differntial mode signals , OPAMP configuration, OPAMP in linear mode, voltage follower property and inversion property, OPAMP with positive and nagative feedback, Linear and Nonlinear applications of OPAMP, waveform generations, 555 timer based applications. **Self-study:** Design and SPICE simulation studies on MOSFET based amplifiers and op-amp based circuits

References:

1. Behzad Razavi., Fundamentals of Microelectronics, 2E, Wiley Publishers, 2013
2. Sergio Franco, Design with Operational Amplifiers analog Integrated Circuits, 4E, McGraw-Hill series, 2014.
3. Adel S. Sedra, Kenneth C. Smith, Arun N. Chandorkar, *Microelectronic Circuits: Theory and Application* (8e), Oxford, 2020.
4. NPTEL Courses: https://nptel.ac.in/courses/108/108/108108114/
5. NPTEL Courses: https://nptel.ac.in/courses/117/105/117105147/

ELE 2222: POWER ELECTRONICS [2 1 0 3]

Course Learning Outcomes: At the end of the course, the students will be able to:

CO1	Analyse uncontrolled rectifiers and line commutated converters with resistive and inductive loads
CO2	Design non - isolated topologies of DC-DC converters for different load conditions
CO3	Analyse various switching schemes for inverters.
CO4	Choose an appropriate power semiconductor device for a given application
CO5	Illustrate the role of power electronics in various emerging areas

Power Diode, SCR Family, MOSFET, IGBT: Structure, Operation, Static Characteristics, Dynamic Characteristics and Ratings. Protection of Power Electronic Devices. Comparison of Power Electronic Devices. Select devices (Part Numbers) for application. Design of High side and Low side Gate drive circuit. Analysis of Single-Phase Uncontrolled Rectifiers with filter circuit. Analysis of Single Phase Fully Controlled Full Wave Rectifiers with R, RL, RLE Load and RL Load with Freewheeling Diode. Analysis of Three Phase Fully Controlled Full Wave Rectifiers with R load. Analysis and design of Buck and Boost converter. Analysis of Single-Phase Half Bridge and Full Bridge Inverter with R and RL Load (Square Wave, Bipolar and Unipolar SPWM Technique); Analysis of Three Phase Inverters (180^0 and SPWM Technique); Space Vector Pulse Width Modulation; Multi Level Inverters; Current Source Inverter. Application of Power Electronics in Power System, Renewable Energy Systems, Motor Control, SMPS and UPS, and LED Drivers. Creating Design files for customer specifications. Self-study: Verification of the driver circuit design through simulations, Analysis and simulation of Three Phase Fully Controlled Full Wave Rectifiers with RL Load, Analysis and design of Buck-Boost converter through simulations, Analysis and simulation of Three Phase Inverters (120^0 mode).

References:

1. Hart D. W., *Introduction to Power Electronics*, PH, 2010.
2. Ned Mohan et. al., *Power Electronics, Converters, Applications & Design* (2e), Wiley,2001.
3. Rashid M.H., *Power Electronics, Circuits, Devices and Applications*, PHI, 2010.

4. Robert W. Erikson, Dragan Maksimovic, *Fundamentals of Power Electronics*(2e), Springer,2005
5. NPTEL Courses: https://nptel.ac.in/courses/108/102/108102145/

ELE 2223: LINEAR CONTROL THEORY [2 1 0 3]

Course Learning Outcomes: At the end of the course, the students will be able to:

CO1	Derive transfer function and state space models of physical systems by applying the knowledge of mathematics and engineering principles.
CO2	Analyse the performance of linear time-invariant systems using principles of mathematics and modern tools.
CO3	Analyse the stability of linear systems using appropriate graphical techniques and modern tools.
CO4	Design controllers to achieve time domain and frequency domain specifications for control system applications.
CO5	Implement appropriate controllers for engineering and societal applications using modern tools.

Control systems terminologies, Mathematical modelling of Electrical circuits, Mechanical systems (translational & rotary) and Electro-Mechanical systems including geared LTI systems using transfer function approach, reduction of sub-systems, signal flow graphs, , State Space modelling approach, Time domain response of 1st order and 2nd order systems, RH criteria, Root Locus technique, Bode plots, Nyquist Plots, Design concepts of lead, lag compensators and their realization, Design concepts of P, PI, PID controllers for LTI systems and their realization. Self Study: Simulation Practice &Controller realization

References:

1. Norman S. Nise, *Control Systems Engineering*, John Wiley & Sons, Inc, 2010
2. Ogata K, *Modern Control Engineering*, Englewood Cliffs, NJ: Prentice Hall, 2010
3. Gopal M., *Control Systems: Principles and Design*, McGraw Hill, 2008
4. K.R. Varmah, *Linear Control Theory* , Tata McGraw Hill Education, 2010
5. Prof. S.D. Agashe IIT Bombay, Control systems: http://nptel.ac.in/courses/108101037/

ELE 2224: GENERATION, TRANSMISSION & DISTRIBUTION [3-1-0-4]

Course Learning Outcomes: At the end of the course, the student must be able to

CO1	Discuss the working of conventional and non-conventional power plants with an emphasis on environment & sustainability
CO2	Estimate the transmission line parameters for various conductor configurations
CO3	Analyze the electrical & mechanical performance of overhead transmission lines by modelling the line
CO4	Apply methods to improve voltage distribution across a string insulator & in underground cables
CO5	Comprehend various distribution schemes & reliability indices
CO6	Demonstrate energy management at generation & consumer levels

General layout of a power system, conventional and unconventional power generation, computation of line parameters for 1-phase and 3-phase, line compensation, need for reactive power compensation, sag and tension calculations, overhead insulators and grading of insulators, underground cables, corona, distribution schemes, reliability indices and introduction to LVDC & architecture of 48 V DC distribution. Self-study on the selected topics.

References:

1. J. Duncan Glover, Mulukutla S Sarma and Thomas J Overbye, *Power System Analysis and Design*, 5th ed, Cengage Learning, 2012.
2. S.N. Singh, *Electric Power Generation, Transmission & Distribution*, PHI, 6th printing, 2011.
3. Nag P K, *Power plant engineering*, Tata Mc Graw Hill, 2005.
4. Wadhwa, *Electrical Power System*, 3rd edition, New Age Intl, 2013.
5. NPTEL course https://nptel.ac.in/courses/108/102/108102047/

ELE 2225: ELECTRICAL MACHINERY - II [2 1 0 3]

Course Learning Outcomes: At the end of the course, the students will be able to:

CO1	Estimate the induced EMF and voltage regulation of non-salient pole synchronous generators based on the circuit model
CO2	Analyze the performance of the synchronous generators and motors under variable excitation and load conditions.
CO3	Assess the performance of salient pole synchronous machines based on the two-reaction theory

CO4 Demonstrate the understanding of constructional features and control circuits of special electrical machines
CO5 Compare the performance characteristics of special machines based on applications to demonstrate the need for sustainable development

Alternators: Constructional features, working principle, harmonics. Modeling of the non-salient pole and salient pole alternators, phasor diagrams, voltage regulation, synchronization, characteristics, alternator connected to the infinite bus, load sharing. Synchronous motors: Synchronizing power and torque, performance characteristics, power factor correction. Special electrical machines- Synchronous reluctance motors, Stepper motors, Switched reluctance Motors, Permanent magnet brushless DC Motors, Permanent magnet synchronous motors: Construction, working principle, control, and performance analysis. Self-study: Extended exercises on analyses of electrical machines covered.

References:

1. I. J. Nagrath, D. P. Kothari, *Electric Machines (5e)*, TMH, 2017.
2. A. Langsdorf, *Theory of Alternating Current Machine (2e)*, TMH, 2009.
3. K Venkataratnam, Special Electrical Machines, Universities Press (India), 2021.
4. https://nptel.ac.in/courses/108/106/108106072/
5. https://nptel.ac.in/courses/108/102/108102156/

ELE 2241: ANALOG SYSTEM DESIGN LAB [0 0 3 1]

Course Learning Outcomes: At the end of the program the students will be able to:

CO1 Design and implement wave shaping circuit, regulated power supply, and amplifier circuit using discrete components.
CO2 Design and verify biasing circuits and frequency response of MOSFET Amplifier
CO3 Design, implement and verify Op-amp circuits for various linear applications.
CO4 Design implement and verify Op-amp circuits for various nonlinear applications and pulse generation using 555 timer IC
CO5 Design implement and verify the Op-amp based RC phase shift oscillator
CO6 Determine appropriate methodologies for solving analog circuits using a Spice simulator (LT-Spice) and analog circuit analysis

Design and Test analog circuit using MOSFETs: Regulated power supply and MOSFET amplifier circuit. Analog system design using standard ICs: Design and test Op-amp based amplifiers, voltage to current converter, integrator, differentiator, biquad active filter, effect of negative feedback, Schmitt trigger, Waveform generators, 555 timer based astable and Monostable filter. Design, develop/simulate and analysis the analog circuit for a given applications.

References:

1. Behzad Razavi., "*Fundamentals of microelectronics*", 2E, Wiley Publishers
2. Sergio Franco, "*Design with Operational Amplifiers and Analog Integrated Circuits*", 3E. McGraw-Hill series
3. Jim Karki, "Application Report Understanding Operational Amplifier Specifications" SLOA011B-January 2018-Revised July 2021. Texas Instruments
4. Thomas R. Brown, Jr "Hand Book of Operational Amplifier Applications" Application report SBIOA092B-October 2001-reviced September 2016. Texas Instruments
5. Colin May, *"Passive Circuit Analysis with LTspice1 An Interactive Approach"*, Springer Nature Switzerland AG 2020

ELE 2242: ELECTRICAL MACHINERY LAB [0 0 3 1]

Course Learning Outcomes: At the end of the course, the students will be able to:

CO1 Evaluate the performance of transformer and induction machines.
CO2 Analyse the steady-state operating characteristics of induction machines & DC machines.
CO3 Distinguish between the characteristics of synchronous generators and motors.
CO4 Design and develop the winding diagrams of AC and DC machines.
CO5 Interpret the dynamic characteristics of electrical machines through simulation studies.
CO6 Discuss the importance of safe operating engineering practice to mitigate the safety risks in working area

Single-phase transformers: OC and SC test. Three-phase induction machine: No load & blocked rotor tests; Load test on three-phase induction motor and generator; DC machines: Speed control; Swinburne's test; Retardation test. Synchronous machines: Voltage regulation of alternator; V and inverted V curves of the alternator and synchronous motor. Dynamic modeling and simulation analysis of the starting transients, and braking of three-phase induction motors. Design and development of the winding diagrams of AC and DC machines.

References:

1. I. J. Nagrath, D. P. Kothari, Electric Machines (5e), TMH, 2017.
2. A. Langsdorf, Theory of Alternating Current Machine (2e), TMH, 2009.
3. A. E. Clayton & N. N. Hancock, The Performance and Design of Direct Current Machines, CBS, 2004.
4. A. K. Sawhney, Electrical Machine Design, Dhanpat Rai Publications, 2016.
5. https://nptel.ac.in/courses/108/106/108106071/
6. https://nptel.ac.in/courses/108/106/108106072/

SEMESTER: 05

HUM 3022: ESSENTIALS OF MANAGEMENT [2 1 0 3]

Definition of management and systems approach, Nature & scope. The Functions of managers, Principles of Management. Planning: Types of plans, steps in planning, Process of MBO, how to set objectives, strategies, policies and planning premises, Strategic planning process and tools. Nature and purpose of organizing, Span of management, factors determining the span, Basic departmentation, Line and staff concepts, Functional authority, Art of delegation, Decentralization of authority. HR theories of planning, Recruitment, Development and training. Theories of motivation, Special motivational techniques. Leadership – leadership behavior & styles, Managerial grid. Basic Control Process, Critical Control Points & Standards, Budgets, Non-budgetary control devices. Profit and Loss control, Control through ROI, Direct, Preventive control. PROFESSIONAL ETHICS - Senses of Engineering Ethics, Variety of moral issues, Types of inquiry, Moral dilemmas, Moral Autonomy, Kohlberg's theory, Gilligan's theory, Consensus and Controversy, Models of professional roles, Theories about right action, Self-interest, Customs and Religion, Uses of Ethical Theories. GLOBAL ISSUES - Managerial practices in Japan and USA & application of Theory Z. The nature and purpose of international business & multinational corporations, unified global theory of management, Entrepreneurship and writing business plans. Multinational Corporations, Environmental Ethics, Computer Ethics, Weapons Development, Engineers as Managers, Consulting Engineers, Engineers as Expert Witnesses and Advisers, Moral Leadership, Code of Conduct, Corporate Social Responsibility.

References:

1. Harold Koontz & Heinz Weihrich (2020), "Essentials of Management", McGraw Hill, New Delhi.
2. Peter Drucker (2004), "The practice of management", Harper and Row, New York.
3. Vasant Desai (2007), "Dynamics of entrepreneurial development & management", Himalaya Publishing House.
4. Poornima M Charantimath (2006), "Entrepreneurship Development", Pearson Education.
5. Mike W. Martin & Ronald Schinzinger (2003), "Ethics in engineering", Tata McGraw Hill, New Delhi.
6. Govindarajan M, Natarajan S, & Senthil Kumar V S (2004), "Engineering Ethics", Prentice Hall of India, New Delhi.
7. R. S. Nagarazan. (2004), "A text book on professional ethics and human values", New age international publishers, New Delhi.

ELE 3121: POWER SYSTEM ANALYSIS [3 1 0 4]

Course Learning Outcomes: At the end of the course, the students will be able to

CO1	Apply the various representations of power system components to analyse per unit calculations
CO2	Examine the Short circuit calculation on different power system apparatus to develop solution for Symmetrical three phase faults
CO3	Interpret unsymmetrical faults by comprehending the knowledge of symmetrical components to investige complex power system problem.
CO4	Evaluate the different aspects of power system stability and security risks using modern tool.
CO5	Investigate the complex load flow problem by applying appropriate technique for steady state conditions.

Single line diagram, per unit concept, selection and change of base quantities, three winding transformer in power system, symmetrical short circuit calculation, current limiting reactor, selection of circuit breakers, symmetrical components, sequence networks, unsymmetrical fault analysis in loaded and unloaded system involving transformers, admittance model of power system, load flow solution by numerical method, stability studies, equal area criterion. Write MATLAB program for Load flow solution techniques and swing equation and equal area criterion.

References:

1. Stevenson William D, Elements of Power System Analysis (4e), TMH, 2014
2. Nagrath I.J. & D.P.Kothari, Modern Power System Analysis (2e), TMH, 2013

3. Hadi Saadat, Power System Analysis, TMH, 2004
4. Elgerd Olle I., Electric Energy System Theory, TMH, 2011
5. Stagg & Elabid, Computer methods in Power System Analysis, MGH, 1986

ELE 3122: DIGITAL SIGNAL PROCESSING [2 1 0 3]

Course Learning Outcomes: At the end of the course, the students will be able to:

CO1	Analyse discrete time (DT) signals and systems mathematically using time and frequency domain techniques
CO2	Compute DFT using FFT algorithms for signal processsing.
CO3	Realize DT-LTI systems using various structures
CO4	Design frequency selective digital filters using pole-zero approach for the given application
CO5	Design linear phase FIR and IIR filters for the given specifications
CO6	Understand the applications of DSP

Time domain analysis of discrete-time signals & systems: linear-time invariant systems, impulse response, convolution, causality and stability, representation of LTI systems, frequency domain analysis of discrete-time signals and systems: discrete-time Fourier series, discrete-time Fourier transform, properties and applications, Z-transform representation of discrete time signals and systems, properties and applications. Sampling in time and frequency domain. Discrete Fourier transform (DFT) and properties, linear convolution using DFT. Computation of DFT using Fast Fourier transform (FFT), decimation-in-time and decimation-in-frequency FFT algorithms. Digital filter structures, digital FIR and IIR filter. FIR filter design: FIR design by Window method. IIR filter design: classical filter design using Butterworth approximations, impulse invariant and bilinear transformation methods. Applications of DSP. Self-study: simulation-based studies of the selected topics.

References:

1. Haykin Simon and Barry Van Veen, Signals and systems, (2e), John Wiley & Sons, 2007.
2. John G. Proakis, Dimitris G Manolakis, Digital Signal Processing: Principles, Algorithms, and Applications, (4e), Pearson, 2007
3. Oppenheim A. V. and R. W. Schafer, Discrete time signal processing, (3e), Pearson, 2014
4. Ingle, Vinay K., and John G. Proakis, *Digital signal processing using MATLAB*, 3e Cengage Learning, 2012.
5. NPTEL course: https://nptel.ac.in/courses/108/101/108101174/

ELE 3123: SWITCH GEAR &PROTECTION [3 0 0 3]

Course Learning Outcomes: At the end of the course, the students will be able to:

CO1	Anaylse the various arc extinction methods used in circuit breakers
CO2	Analyse the principles of operation and construction of various types of Circuit breakers, Fuses and Isolators.
CO3	Analyse the different types of electromechanical relays for power system protection
CO4	Analyze abnormal operating conditions of various power system components to design the suitable protection schemes.
C05	Apply modern control techniques to overcome the limitations of Electromagnetic relays.
CO6	Discuss the role of Quality Management system and continuous improvement for power system protection

Fuses. Neutral grounding: Circuit breakers: Arc phenomenon, arc interruption theories, Special duties. CB types: Oil circuit breakers, Air circuit breakers, SF6 CB, Vacuum CB, CO2 CB, MCB, MCCB and HVDC circuit breakers. CB rating, testing, operating mechanism, Autoreclosure, metal clad switchgear, GIS. Isolators and earthing switches. Protective Relaying: Functions, characteristics, standard definition of relay terminologies, classifications & operating principles. Protection schemes for bus zone, transformer, alternator, transmission Line and Induction Motor. Static Relays, Numerical relaying: Building blocks, signal conditioning, DFT, phasor estimation, numerical relaying algorithms. Introduction to SCADA, IEDs and IEC 61850 protocol. Self-study on selected topics.

References:

1. Rao S.S., Switchgear Protection and Power systems, Khanna Publishers, 2015.
2. Badriram and Vishwakarma, Power System Protection & Switchgear, MGH, 2014.
3. Ravindranath & Chander, Power System Protection and Switchgear, New Age International, 2018.
4. Mason, The Art and Science of Protective Relaying, Wiley, 1972.
5. Ravindra P. Singh, Digital Power System Protection, PHI, 2007.

ELE 3141: POWER ELECTRONICS LAB [0 0 3 1]

Course Learning Outcomes: At the end of the course, the students will be able to:

- CO1 Analyse power electronic circuits through hardware and digital simulation using tools from MathWorks, PSIM and LTSpice
- CO2 Design gate driver circuits for power semiconductor devices.
- CO3 Design filter circuits for rectifiers and DC-DC converters to limit ripple at specified level.
- CO4 Implement the controller for Voltage Source Inverter using SPWM technique.
- CO5 Illustrate speed control of DC and AC motor drives using various power converters.
- CO6 Implement selected simulation/hardware exercises in the Power Electronics domain through Minor group project work by understanding intellectual property rights.

Design of gate driver circuit, Study of Uncontrolled Rectifier Circuits with filter circuit, Effect of non-linear load on Single phase and Three phase supply, Controlled Rectifier with R and RL loads, Power quality analysis of AC voltage controller, Design and Realization of DC-DC Buck Converter, Design of controller for Inverter circuits, Power Electronic circuit simulation using SPICE and MATLAB, Speed Control of Motors using Power Electronics.

References:

1. Hart D. W., *Power Electronics*, Tata Mcgraw-Hill, 2011
2. Ned Mohan et. al., *Power Electronics, Converters, Applications & Design (*2e), Wiley.2010
3. Bose B.K., *Modern Power Electronics and AC Drives*, Pearson, 2010
4. Rashid M. H. *SPICE for Power Electronics and Electrical Power*, PH, 1993

ELE 3142: SYSTEMS SIMULATION LAB [0 0 3 1]

Course Learning Outcomes: At the end of the course, the students will be able to:

- CO1 Construct the mathematical models of the physical systems using simulation tool for analysing the performance
- CO2 Design controllers and compensators for improving the performance of control systems
- CO3 Apply z-transform, DTFT, and DFT techniques for analysing discrete-time signals and systems using a simulation tool
- CO4 Design FIR filters and Butterworth IIR filters for processing the discrete time signals
- CO5 Develop control/ digital signal processing systems for multi-discipliänry applications by working in a team

Mathematical modeling of physical systems with MATLAB scripts and SIMULINK, DC motor characteristics using Simulink, stability analysis using Bode plot, root locus, and Nyquist plot, design of controllers, analysis of discrete-time signals using discrete-time Fourier transform, discrete Fourier transform, and Z-transform, digital filter structures, digital IIR and FIR filter design, application of filtering techniques, applications of control system and DSP.

References:

1. Norman Nise, *Control System Engineering*, (8e), Wiley, 2019.
2. Ogata, K, *Solving Control Engineering Problems with MATLAB*, (1e), Prentice-Hall, 1994
3. John G. Proakis, Dimitris G Manolakis, *Digital Signal Processing: Principles, Algorithms, and Applications*, (4e), Pearson, 2007
4. Ingle, Vinay K., and John G. Proakis, *Digital signal processing using MATLAB*, (3e) Cengage Learning, 2012.
5. S. K. Mitra, Digital Signal Processing Laboratory Using MATLAB, (2e), 2001

SEMESTER: 06

HUM 3021: ENGINEERING ECONOMICS AND FINANCIAL MANAGEMENT [2 1 0 3]

Time value of money, Interest factors for discrete compounding, Nominal & effective interest rates, Present and future worth of Single, Uniform, and Gradient cash flow. Related problems and case studies. Bases for comparison of alternatives, Present worth amount, Capitalized equivalent amount, Annual equivalent amount, Future worth amount, Capital recovery with return, Rate of return method, Incremental approach for economic analysis of alternatives, Replacement analysis. Break even analysis for single product and multi product firms, Break even analysis for evaluation of investment alternatives. Physical & functional depreciation, Straight line depreciation, declining and double declining balance method of depreciation, Sum-of-the-Years Digits, Sinking Fund and Service Output Methods, Case Study. Balance sheet and profit & loss statement. Meaning & Contents. Ratio analysis, financial ratios such as liquidity ratios, Leverage ratios, Turn over ratios, and profitability ratios, Drawbacks. Safety and Risk, Assessment of Risk and safety, Case study, Risk Benefit Analysis and Reducing Risk.

References:

1. Chan S. Park, "Contemporary Engineering Economics", 4th Edition, Pearson Prentice Hall, 007.
2. Thuesen G. J, "Engineering Economics", Prentice Hall of India, New Delhi, 2005.
3. Blank Leland T. and Tarquin Anthony J., "Engineering Economy", McGraw Hill, Delhi, 2002.
4. Prasanna Chandra, "Fundamentals of Financial Management", Tata McGraw Hill, Delhi, 2006.
5. Mike W. Martin and Roland Schinzinger, "Ethics in Engineering", Tata McGraw Hill, New Delhi, 2003.
6. Govindarajan M, Natarajan S, Senthil Kumar V. S, "Engineering Ethics", Prentice Hall of India, New Delhi, 2004

ELE 3221: MEASUREMENTS & INSTRUMENTATION [3 1 0 4]

Course Learning Outcomes: At the end of the course, the students will be able to:

CO1	Discuss the basic characteristics of instrumentation systems by understanding the working of traditional electrical sensors
CO2	Select appropriate transducers for various electrical/electronic measurements by understanding their working principles.
CO3	Evaluate the performance of developed signal conditioning modules for various measured electrical signals
CO4	Discuss the working of popular industrial signal transmission protocols and modern data display devices
CO5	Develop ladder-logic programs for PLCs as part of modern industrial instrumentation
CO6	Design an instrumentation system to meet the needs of society, health, and safety

Electrical instrumentation, characteristics, electromagnetic interference, Moving Coil and Moving Iron Instruments, Bridge circuits for R, L and C measurements, Modern Transducers for R, L and C measurements, Signal conditioning - Signal Isolation, Charge amplifiers, Instrumentation amplifiers, Active filters, Sallen Key Topology, State Variable Filters, Successive Approximation, Flash A/D Converter, R 2R and Binary weighted D/A converter, communication using MODBUS and CANBUS, Industrial instrumentation through programmable logic controllers, Case study - ECG, Digital Frequency Meter, Digital Energy Meter. Self-study: extended study in selected topics, case studies and programming exercises.

References:

1. A. K Sawhney and Puneet Sawhney, *A course in electrical & electronic measurement and instrumentation"*, 19e, Dhanpat Rai & Sons, 2016.
2. Sergio Franco, *Design with Operational Amplifiers and Analog Integrated Circuits*, 4e, McGraw Hill, 2014.
3. W. Bolton, *Programmable Logic Controllers*, 4e, ELSEVIER, 2006.
4. NPTEL Courses: https://nptel.ac.in/courses/108/105/108105153/
5. Manufacturers Data sheets, Industry reference guides and modern literatures.

ELE 3241: MEASUREMENTS & INSTRUMENTATION LAB [0 0 3 1]

Course Learning Outcomes: At the end of the course, the students will be able to:

CO1	Build Virtual instrument simulations by exploring National Instruments LabVIEW software
CO2	Analyze a three-OPAMP Instrumentation amplifier and analog filter for given specifications.
CO3	Develop digital instruments using LabVIEW and applications of NI Data Acquisition platform.
CO4	Implement suitable ladder logic programs for simulation exercises using PLC operating software
CO5	Investigate a complex problem by developing a capstone mini project using laboratory skills making use of technical literature.

Module 1: Familiarization and programming exercises of LabVIEW
Module 2: Signal conditioning circuits for Realization of Instrumentation Amplifier and Analog Filter.
Module 3: Digital Instrumentation System using LabVIEW and data acquisition.
Module 4: Ladder logic programming exercises for Programmable Logic controllers.
Mini project: Measurements and Instrumentation related hardware/ simulation based projects
References:

1. Jovitha Jerome, *Virtual Instrumentation Using LabVIEW,* PHI learning private limited, 2010.
2. K.R.K. Rao ,C.P. Ravikumar, *Analog system lab pro kit manual*', MikroElektronika Ltd, 2012.
3. Jeffrey Travis, Jim Kring, *LabVIEW for Everyone: Graphical Programming Made Easy and Fun*, 3e, Prentice Hall Professional, 2009.

4. W. Bolton, *Programmable Logic Controllers*, 4e, ELSEVIER, 2006.
5. NPTEL Courses: https://nptel.ac.in/courses/108/105/108105063/

ELE 3242: POWER SYSTEMS LAB [0 0 3 1]

Course Outcomes: At the end of the course, the student must be able to

CO1	Perform load flow, transient stability, short circuit studies and relay co-ordination using simulation software.
CO2	Analyze the performance of transmission lines under various loading & fault conditions using transmission line simulator
CO3	Validate various time/PSM characteristics of a microcontroller based over current relay
CO4	Determine the Power quality indicators for any threephase load using Schneider Electric Power meter/Energy meter
CO5	Determine the fill factor & efficiency of a solar cell using solar simulator
CO6	Work in a team and communicate effectively on mitigating power system security risks

Software Module: Transmission line performance, relay co-ordination, load flow analysis, transient stability and short circuit studies using simulation tools

Hardware Module: Numerical overcurrent relay, solar simulator, digital energy meter, transmission line simulator.

References:

1. Stagg G W & El-Abiad A H, *Computer Methods in Power System Analysis*, Medtech, 2019.
2. Hadi Saadat, *Power System Analysis*, MGH, 2004.
3. Nagrath I.J. & D.P.Kothari, *Modern Power System Analysis,* (4e), TMH, 2011.
4. Badriram and Vishwakarma, *Power System Protection & Switchgear*, TMH, 2013.
5. MiPower and PSCAD user manuals.

SEMESTER: 08

ELE 4291: INDUSTRIAL TRAINING

Course Outcomes: At the end of the course, the student must be able to

CO1	Understand the behavioural guidelines in an organization/industry and practice professionalism and ethics.
CO2	Write a technical report on major observations/ experience during training at industry adhering to scientific conventions
CO3	Communicate the major technical observations effectively during the industrial training, using audio-visual aids
CO4	Understand quality management and quality assurance practices of electrical machines as per standards

Each student has to undergo industrial training for a minimum period of 4 weeks. This may be taken in a phased manner during the vacation starting from the end of third semester. Student has to submit to the department a training report in the prescribed format and also make a presentation of the same. The report should include the certificates issued by the industry.

ELE 4293: PROJECT WORK/PRACTICE SCHOOL

Course Outcomes: At the end of the course, the student must be able to

CO1	Assess the work available in the literature related to the project to identify the limitations, risks and analyse associated safety, commercial, economic, environmental and societal impact.
CO2	Practice planning and time management in solving a problem, identifying the resources, estimating the project cost and risks, and complying with the regulations to demonstrate the professional skills to work effectively in a team.
CO3	Develop the ability to adopt a methodological approach to solve the task/design/problem in electrical/multi-disciplinary/management stream by applying the relevant mathematics, statistics, natural science and engineering principles, concepts, and technologies.
CO4	Enhance and adopt the computing/coding/statistical analysis, development of physical prototypes/hardware, experimentation, and testing skills to achieve the set objectives.
CO5	Document the work done with a technical report, adhering to scientific conventions and ethical guidelines.
CO6	Communicate effectively the process and outcome of the project using audio-visual aids

The project work may be carried out in the institution/industry/ research laboratory or any other competent institutions. The duration of the project work shall be a minimum of 16 weeks which may be extended up to 24 weeks. A mid-semester evaluation of the project work shall be done after about 8 weeks. An interim project report on the progress of the work shall be submitted to the department during the mid-semester evaluation. The final evaluation and viva-voice will be conducted after submission of the final project report in the prescribed form. Student has to make a presentation on the work carried out, before the department committee as part of project evaluation.

FLEXIBLE CORE COURSES:

ELE 3124: MODERN POWER CONVERTERS [3 0 0 3]

Course Learning Outcomes: At the end of the course, the students will be able to:

CO1	Discuss the fundamentals of switched-mode power converters
CO2	Design dc-dc converter topologies for various power conversion applications
CO3	Analyse soft-switched dc-dc converter topologies.
CO4	Design the control system for DC/DC converter topologies by mathematically modeling the converter dynamics.
CO5	Design magnetics for DC/DC converter in switched mode power supply application.

Switched Mode Power converters: generalized comparison between switched mode and linear regulators, operation and steady state performance of buck, boost, buck-boost, cuk : continuous conduction mode, discontinuous conduction mode; Performance analysis of converters using DC Transformer model; DC-DC converters with isolation-Fly back converter, Forward converter, push pull converter, half bridge and full bridge DC-DC converters; Resonant Converters- series and parallel loaded converters in continuous and discontinuous mode of operation, zero current switch resonant converter (ZCS), zero voltage switch resonant converter (ZVS); Control techniques; Converter modelling- equivalent circuit modelling of converters using state space averaging technique; Closed loop converter design – PID design issues. **Design of Magnetic Components,** Review of magnetic circuits, Design of Inductors, Design of two winding high frequency transformers. Self-Study: SEPIC converter Simulation Using Idealized Components. Current Fed Converters. Simulation of Converter with soft switching. Simulation of DC-DC converter with closed loop control. Losses in magnetic elements, design of multilinking transformers.

References:

1. Robert W. Erickson, Dragan Maksimovic; Fundamentals of Power Electronics, (2 ed), Springer, 2005
2. Hart D. W., Introduction to Power Electronics, PH, 2010.
3. Ned Mohan et. al., Power Electronics, Converters, Applications & Design (2e), Wiley.2001
4. Issa Batarseh, Power Electronic Circuits (1e), Wiley, 2014
5. P. Krein, Elements of Power electronics, OUP, 1998
6. L Umanand, S R Bhat, Design of magnetic components for switched mode power converters (1e), New Age International, 1992.
7. NPTEL Courses: https://nptel.ac.in/courses/108/102/108102145/
8. Coursera group of courses on power electronics specialization by University of Colorado, Boulder: https://www.coursera.org/specializations/power-electronics.

ELE 3125: DISTRIBUTED GENERATION SYSTEMS [3 0 0 3]

Course Learning Outcomes: At the end of the course, the students will be able to:

CO1	Understanding different distributed energy-generating technology and demonstrating their working principle.
CO2	Design Solar photovoltaic cells & Wind energy systems to provide the required power generation as per needs and specifications.
CO3	Analyze the impact of grid integration and control aspects of DGs.
CO4	Analyze a microgrid taking into consideration the planning and operational issues of the DGs to be connected to the system
CO5	Identify & Analyse the different energy storage systems with distributed generating systems

Introduction to Distributed Generation Systems- Principle and Structure of DGS- Features of DGS, Distributed Generation Technologies-Overview, Integrating Distributed Energy Resources with the Grid, Planned/non-planned DG, Micro Grid and it's features. DG Technologies DG Technologies: Wind Energy Conversion System, Photovoltaic Systems-PV grid tied systems and different configurations. Micro turbine Generation, diesel power plant, Small Hydro Generation Systems, Fuel Cells.Energy Storage Technologies-Different Energy storage technologies-Overview, Design

Issues and control of Distributed Generation Systems-General model of DGS, Technical Regulation of DG integration, DG Optimization and Energy Management..microgrid-modes of operation & isuues.

References:

1. G.B. Gharehpetian and S. Mohammad Mousavi Agah "*Distributed Generation Systems. Design, Operation and Grid Integration*," Butterworth-Heinemann, 2017.
2. H. Lee Willis & Walter G Scott, Distributed Power Generation planning & Evaluation", Taylor & Francis Group,2000.
3. Math Bollen & Fainan Hassan," Integration of distributed generation in the power systems'",AJohn wiley & sons , INC, Publications, 2011
4. Bo Zhao, Caisheng Wang, Xuesong Zhang "*Grid integrated and standalone photovoltaic distributed generation systems analysis, design and control*," Wiley, 2017.
5. Nikos Hatziargyriou, microgrid: Architecture and Control. Wiley-IEEE Press. 2014

ELE 3126: COMMUNICATION SYSTEMS [3 0 0 3]

Course Learning Outcomes: At the end of the course, the students will be able to:

CO1	Discuss the concepts of analog, pulse, digital band-pass and spread spectrum modulation techniques used for electronic communication.
CO2	Apply time domain and frequency domain analysis to evaluate the performance parameters of analog modulation schemes.
CO3	Compute the bandwidth and data rates in pulse, basic digital band-pass modulation, and spread spectrum techniques.
CO4	Illustrate the importance of data security and error control coding in communication system.
CO5	Discuss the challenges of the current wireless communication systems and networks.

Elements of communication systems; Analog Communication techniques: Amplitude modulation schemes and frequency modulation; Pulse modulation schemes; Shift keying techniques – frequency, phase and amplitude; Channel encoding and decoding technologies; Conceptual idea of encryption and decryption; Communication protocols and networking; Internet of Things; Wireless sensor actuator network; Applications: Spread spectrum and mobile communications Self-study: Simulation based studies of the selected topics.

References:

1. Simon Haykin, *Communication Systems*, John Wiley & Sons, 4e, 2009.
2. NPTEL Courses: https://nptel.ac.in/courses/106/105/106105166/
3. Stallings William, *Cryptography and network security: principles and practices*, Pearson Education, 2006.
4. Geng Hwaiyu, *Internet of Things and Data Analytics* Handbook, John Wiley & Sons, 2017.
5. Verdone Roberto et al., *Wireless sensor and actuator networks: technologies, analysis and design,* Academic Press, 2010.

ELE 3127: FOUNDATIONS OF EV & HYBRID VEHICLES [3 0 0 3]

Principles for Electric Vehicles: EV Industry, EV Technology and Automotive Revolution, Electrical Engineering for EV, Battery Technology

Control system for Electric Vehicles: Motor and Controller Systems, EV Numerical Calculations, EV Charging Infrastructure, Practical session - Well-to-wheel analysis of EV architecture

Essentials for Electric Vehicles: Electrical Requirement, Power Distribution Specifications, Electronic Control System, Practical session - EV connection and system analysis

Types of components in Electric Vehicles: EV Standards and Classifications, Selection for Electrical and Electronic Components, Practical session - EV hardware components

Principles for Hybrid Vehicles: Introduction to Hybrid Vehicles, Battery Chemistry, Efficiency, Definition and Parameters for Hybrid Systems, Electric Motors, Generators and Power Electronics for Hybrid Systems, Control Systems, Hybrid Electric Vehicle Operation, Practical session - Numerical study on powertrain sizing of HEV

References:

1. James Larminie and John Lowry, "Electric Vehicle Technology Explained", Wiley, 2nd ed, 2012, ISBN: 978-1-119-94273-3.
2. Iqbal Husain, "Electric and Hybrid Vehicles: Design Fundamentals", Routledge, 3rd Ed, 2021, ISBN: 9780367693930
3. Muhammad Ehsani, Mehrdad Ehsani, and Ali Emadi, "Electric Vehicle Systems Architecture and Standardization Needs", Reports of the PPP European Green Vehicles Initiatives, Springer, 2015.
4. Ali Emadi, "Advanced Electric Drive Vehicles", CRC Press, 1st Ed, 2014, ISBN: 9781138072855.

5. Rodrigo Garcia-Valle and João A. Peças Lopes, "Electric Vehicle Integration into Modern Power Networks", Springer, 2013, ISBN: 978-1461401339.
6. Chris Mi and M. Abul Masrur, "Hybrid electric Vehicles, Principles and Applications with Practical perspectives", WILEY, 2nd Ed, 2017, ISBN: 978-1-118-97054-6.
7. "Introduction to Electric Vehicles" - offered by IIT Delhi on NPTEL Link: https://archive.nptel.ac.in/courses/108/106/108106170/

ELE 3222: SOLID STATE DRIVES [3 0 0 3]

Course Learning Outcomes: At the end of the course, the students will be able to:

CO1	Discuss the components and dynamics of electric drives to meet the requirements of a mechanical load.
CO2	Analyse the control schemes for DC drives using various line commutated converters.
CO3	Analyse the performance of Chopper fed DC drives for multi-quadrant operation
CO4	Analyse scalar and vector control schemes for induction motor drives
CO5	Evaluate the control schemes of various special electrical machines for different applications

Fundamentals of Electric Drives: components, dynamics, multi-quadrant operation, equivalent moment of inertia and torque, nature and classification of load torque, steady state stability, classes of motor duty. DC drives: Single phase and three phase controlled rectifier fed dc drives, speed torque characteristics, waveforms, expressions for voltage, current, speed, torque and power. PWM rectifiers fed DC drives. Chopper fed DC drives, quadrant of operation. Demonstration of open loop and closed loop control of drives with/without Regenerative braking. AC drives: Induction motor drives – stator voltage control, slip power recovery scheme, V/f control, principle of vector control: FOC and DTC. Comparison of scalar and vector control schemes. Overview of scalar and vector control schemes of PMSM, BLDC. Applications: Solar and battery powered drives, Traction drives. Self-study: Selection of Motor Power rating/ classes of motor duty, Effect of armature current ripples on motor performance, Analysis and simulation of Static rotor resistance control, Overview of Scalar and vector control schemes of SRM.

References:

1. Dubey G.K., *Power Semiconductor Controlled Drives*, PH, 1989.
2. Dubey G.K., *Fundamentals of Electric Drives*, Narosa, 2010.
3. Murphy J.M.D.& F.G.Turnbull, *Power Electronic Control of AC motors*, Pergamon 1989.
4. Bose B.K., *Modern Power Electronics and AC Drives*, Pearson, 2010
5. NPTEL Courses: https://nptel.ac.in/courses/108/104/108104140/

ELE 3223: SMART GRID TECHNOLOGIES [3 0 0 3]

Course Learning Outcomes: At the end of the course, the students will be able to:

CO1	Understand various aspects of the smart grid, including, Technologies, Components, Architecture, challenges and Applications.
CO2	Understand the Smart Grid communications and Advanced measurement instruments in Smart Grid
CO3	Analyze the integration of distributed energy sources and energy storage in Smart Grid
CO4	Analyze the various computational tools/methods employed in Smart Grid design.
CO5	Identify control-room technologies for system-wide remote monitoring, protection, and risk management of smart grid cyber security

Smart Grid and it's necessity, Advantages of building integrated and distributed power systems- concept of smart grid, Architecture of smart grid system, Standards for smart grid system, Smart grid communications technology, Switching techniques and communication channels, Wide area monitoring systems, Phasor measurement units (PMU), smart metering, Communication infrastructure and protocols for smart metering, Supervisory Control and data Acquisition (SCADA), Demand Response - Large-scale renewable energy integration, Energy storage at distribution level Smart micro grids, Electric Vehicles and Vehicle-to-Grid Systems, Computational Tools, Optimization techniques to smart grid, Hybridizing Optimization Techniques and Applications to the Smart Grid, Computational Challenges, Interoperability- Benefits and Challenges of Interoperability, Model for Interoperability in the Smart Grid Environment, Approach to Smart Grid Interoperability Standards, Smart Grid Cyber Security-Cyber Security Risks, Cyber Security Concerns Associated with AMI.

References:

1. James Momoh, "Smart Grid – fundamentals of design and analysis", John Wiley and Sons, 2012.
2. Takuro Sato, Daniel M. Kammen, Bin Duan, Martin Macuha, Zhenyu Zhou, Jun Wu, Jun Wu, and Solomon Abebe Asfaw "Smart grid standards : specifications, requirements, and technologies", Wiley 2015.

3. Janaka B. Ekanayake, Nick Jenkins, Kithsiri Liyanage, Jianzhong Wu, and Akihiko Yokoyama, "Smart Grid: Technology and Applications" Wiley, New Delhi, 2015.
4. Lars T. Berger, Krzysztof Iniewski, "Smart Grid Applications, Communications and Security" Wiley, New Delhi, 2015.
5. Salman K. Salman, "Introduction to the Smart Grid: Concepts, technologies and evolution" Institution of Engineering and Technology (IET), 2017.

ELE 3224: CONTROL SYSTEM DESIGN [3 0 0 3]

Course Learning Outcomes: At the end of the program the students will be able to:

CO1	Design of industrial digital controllers for linear time invariant continous time systems as per specifications
CO2	Analyze stability of nonlinear systems using describing function and Lypanouv method
CO3	Design state feedback controllers, estimators and optimal controllers for applications
CO4	Demonstrate the design of advanced controllers using software
CO5	Appraise the concepts of robust control, adaptive control and model reference control

Control system performance objectives, Design of cascade & feedback compensation, Scalar and multivariable control systems, Industrial PID controllers, state space systems and PID control, PID tuning, Pole placement techniques for design of controllers and observers, Kalman filter, Robust control, techniques; Non-linear control system design: Linearization, compensation and design of non-linear systems, design of non-linear control system using phase plane analysis, Lyapunov stability; optimal control theory and applications; Adaptive Control ; Self tuning control; Model reference adaptive control; practical aspects: Control system design examples; Self study : MATLAB & SIMULINK for Control system Design.

References:

1. Katsuhiko Ogata, *Modern Control Engineering* (5e), PHI, 2010.
2. Stanley M. Shinners, *Advanced modern control system theory and design*, John Wiley & Sons, 1998.
3. V. I. George, C.P. Kurian, Digital Control Systems (1e), Cengage learning, 2012.
4. Norman S. Nise, *Control Systems Engineering (5e)*, John Wiley & Sons Inc, 2010.
5. K.R. Varmah, *Modern Control Theory*, CBS Publishers & Distributors Pvt. Ltd.,2020

ELE 3225: AUTOMOTIVE MECHANICS FOR ELECTRIC VEHICLES [3 0 0 3]

Automotive Engineering & Vehicle Dynamics: Vehicle Dynamics Fundamentals, Tire Mechanics and Dynamics, Suspension Systems, Braking Systems, Aerodynamics, Powertrain Systems, Vehicle Stability Control, Vehicle Safety, Vehicle Dynamics Simulation, Electric and Hybrid Vehicle Dynamics, Practical session - EV Dynamics & calculations.
Sketching for Automotive EV Design [Software-based]: Introduction to Automotive Sketching Software, Overview of Vehicle Design Process and Automotive Sketching, Basic Sketching Techniques and Tools in the Software, Sketching Car Exteriors, Interiors and Details, Creating Different Views and Angles of the Vehicle, Rendering and Presenting the Final Sketches, Understanding Proportions, Perspectives and Shapes in Automotive Sketching, Creating Sketches for Different Vehicle Types (Sedans, SUVs, and Trucks), Tips and Tricks for Automotive Sketching in the Software.
Advanced EV Modelling Using SolidWorks Tool [Software-based]: Introduction to EV Technology and Its Benefits, Basic Vehicle Design Principles, Design and Modelling of Chassis and Frame, Suspension Systems, Design and Modelling of Braking and Steering Systems, Design and Modelling of Electrical Components for EVs, Battery Pack Design and Modelling for 2, 3 and 4 Wheelers, Motor and Drivetrain Design and Modelling for 2, 3 and 4 Wheelers, Design and Modelling of Wheels and Tires for 2, 3 and 4 Wheelers, Testing and Simulation of Vehicle Performance Using Solid Works, Design for Manufacturability and Assembly Considerations, Sustainability and Environmental Impact Considerations in EV Design, Practical session - EV hardware components walkthrough.
Multibody Dynamics with MSC Adams [Software-based]: Introduction to MSC Adams Software and Its Capabilities, Setting Up the Modelling Environment in MSC Adams, Multi-body Dynamics Principles and Application to Vehicle Systems Modelling, Vehicle Suspension Systems Modelling, Vehicle Steering Systems Modelling, Vehicle Braking Systems Modelling, Practical session - EV Component design & modeling.
EV Analysis with MSC Adams (Software-based): Tire Force and Characteristics Modelling, Vehicle Dynamics Analysis Including Simulating Ride and Handling, Vehicle Stability and Rollover Events, Optimisation Techniques for Vehicle Designs Using MSC Adams, Integration of MSC Adams Models with Other Software Tools for System-level Simulations and Analysis, Practical session - EV body design analysis.

References:

1. James Larminie and John Lowry, "Electric Vehicle Technology Explained", Wiley, 2nd ed, 2012, ISBN: 978-1-119-94273-3.

2. Du, H., Cao, D., & Zhang, H. (n.d.). "Modelling, Dynamics, and Control of Electrified Vehicles", Woodhead Publishing, 2017, ISBN-13: 9780128127865
3. Zaman N., "Automotive Electronics Design Fundamentals", Springer, 2015, ISBN-13: 9783319359793
4. Gianfranco Pistoia, "Electric & Hybrid Vehicles", Elsevier, 1st ed, 2010, ISBN: 9780444638250.
5. Chau, K. T., "Electric Vehicle Machines and Drives: Design, Analysis and Application", John Wiley and Sons, Inc., 2015, ISBN-13: 9781118752524.
6. Ehsani, Mehrdad, "Modern Electric, Hybrid Electric, and Fuel Cell Vehicles", CRC, 2019, ISBN-13: 9780367137465.
7. Hughes, Austin, "Electric Motors and Drives", Newnes (an Imprint of Butterworth-Heinemann Ltd), 2019, ISBN-13: 9780081026151
8. Chris Ni and M. Abul Masrur, "Hybrid electric Vehicles, Principles and Applications", WILEY, 2nd Ed, 2017, ISBN: 978-1-118-97054-6
9. "Introduction to Electric Vehicles" - offered by IIT Delhi on NPTEL Link: https://archive.nptel.ac.in/courses/108/106/108106170/

MINOR ELECTIVES:

ELE 4409: ARTIFICIAL INTELLIGENCE [3 0 0 3]

Course Learning Outcomes: At the end of the course, the students will be able to:

- CO1 Explore the concept of Artificial Intelligence and its effect on prevalent technologies
- CO2 Evaluate the role of artificial agents in various environments
- CO3 Apply different search techniques on various applications.
- CO4 Analyze various real-world Knowledge representation techniques.
- CO5 Design solution for a real-world problems by understanding the dynamic behavior of the system

Foundations of Artificial Intelligence, Intelligent Agents and Environments, The concept of Rationality, The Nature of Environments, Problem Solving agents, Searching for Solutions, Uninformed search strategies, Informed (Heuristic) search strategies, Heuristic functions, local search algorithms, and optimization problems, Adversarial Search and Constraint satisfaction Problems, Knowledge and Reasoning, Knowledge-based agents, The wumpus world, propositional logic, first-order logic, syntax and semantics, Knowledge representation, Ontological Engineering, Uncertain knowledge and Reasoning, Acting under uncertainty, Basic probability notation, semantics of Bayesian network.

Self-study: Case studies/simulation of various search techniques

References:

1. Stuart Russell & Peter Norvig, *Artificial Intelligence A Modern Approach*, 3e, Pearson, 2012.
2. Elaine Rich, Kevin Knight & Shivashankar B. Nair, *Artificial Intelligence*, 3e, Tata McGraw Hill, 2012
3. David L. Poole & Alan K. Mackworth, *Artificial Intelligence: Foundations of Computational Agents,* 2e, CUP, 2017
4. NPTEL Courses: http://nptel.ac.in/courses/106105077/

ECE 4409: MACHINE LEARNING [3 0 0 3]

Course Learning Outcomes: At the end of the course, the student will be able to:

- CO1 Understand basics of machine learning algorithms.
- CO2 Analyze dimensionality reduction techniques for feature selection.
- CO3 Explain artificial neural network (ANN) and its initialization, training & validations.
- CO4 Describe the various parametric, nonparametric, and graphical methods of classifiers.
- CO5 Describe evaluation measures for classifier performances.

Introduction to Machine Learning, Feature reduction techniques, Linear Discrimination, Artificial Neural Networks (ANN), Parameter estimation methods], Evaluation measures: Graphical methods, clustering methods, Reinforcement learning (RL)

References:

1. Alpaydin E, *Introduction to Machine Learning*, (*2e*), MIT Press. 2010.
2. Duda R.O, Hart P.E. and Stork D.G., *Pattern Classification*, (*2e*), Wiley, 2001
3. Bishop C. M., *Pattern Recognition and Machine Learning*, Springer, 2007.
4. Andrew Barto and Richard Sutton, Reinforcement learning an Introduction, MIT press, 1998.

5. Jensen R. and Shen Q. *Computational Intelligence and Feature Selection*: Rough and Fuzzy Approaches, Vol. 8, IEEE Press Series on Computational Intelligence, John Wiley and Sons, 2008.

ELE 4410: SOFT COMPUTING TECHNIQUES [3 0 0 3]

Course Learning Outcomes: At the end of the course, the students will be able to:

CO1 Understand the fundamental concepts of Artificial Neural Networks
CO2 Identify various neural network architectures, algorithms, applications, and their limitations
CO3 Apply the basics of Fuzzy logic theory in engineering applications
CO4 Analyze Genetic Algorithms and their applications
CO5 Apply soft computing techniques to solve the real-time problems

Introduction to soft computing techniques, Artificial Neural networks, basic models, Models of ANN, Hebb network, training algorithms, perceptron networks, perceptron training algorithms, back-propagation networks, radial basis functions, Fundamental concept of Fuzzy logic, fuzzification and defuzzification methods, methods of membership value assignments, fuzzy arithmetic, fuzzy reasoning, fuzzy inference systems, fuzzy decision making, Genetic algorithms, classification of GA, Adaptive neuro-fuzzy inference systems, Fuzzy Artificial Neural Networks, Applications of Soft computing techniques to solve real-time problems
Self-study topic: Simulation of ANN, Fuzzy logic applications using MATLAB/Python programming

References:

1. Jacek M. Zurada., *Introduction to Artificial Neural Systems*, JPH, 2016
2. Timothy J. Ross, *Fuzzy logic with engineering applications*, McGraw Hill publications, 2012
3. Sivanandam & Deepa, *Principles of Soft computing*, Wiley India, 2009
4. Rajasekaran & Vijayalakshmi Pai, *Neural networks, Fuzzy logic and Genetic algorithms,* PHI,2003
5. NPTEL Courses: https://nptel.ac.in/courses/106/105/106105173/

ECE 4410: COMPUTER VISION [3 0 0 3]

Course Learning Outcomes: At the end of the course, the students will be able to:

CO1 Describe image formation using a pinhole camera and explain preprocessing techniques.
CO2 Analyze different local image features such as SIFT, HOG, and texture.
CO3 Contrast different image segmentation methods based on clustering, model fitting and probabilistic modelling
CO4 Explain the geometry of two views and discuss the least square estimation method for camera calibration with radial distortion.
CO5 Evaluate various techniques for building classifiers with examples of their use in vision applications

Pinhole cameras, Image formation, Sources, Image, features representation, Segmentation, Segmentation, and fitting using probabilistic methods: Expectation-maximization algorithm. The geometry of two views and Camera calibration, Pattern Classification

Reference:

1. David A. Forsyth and Jean Ponce, Computer Vision: A Modern Approach, Pearson Education, 2003
2. Richard Szeliski, Computer Vision: Algorithms and Applications, Springer, 2010
3. Richard Hartley and Andrew Zisserman, Multiple View Geometry in Computer Vision, 2nd Edition, Cambridge University Press, 2004
4. Linda Shapiro and George Stockman, Computer Vision, Pearson Education, 2001

ECE 4411: EMBEDDED SYSTEM DESIGN [3 0 0 3]

Course learning outcomes: At the end of the course, the student will be able to:

CO1 Describe embedded system design tools and methodologies
CO2 Discuss the standard software and hardware Building Blocks of EmbeddedSystem
CO3 Develop programming skills for embedded systems
CO4 Design computational models for Embedded systems
CO5 Describe life cycle of embedded system design and testing.

Embedded systems overview, Embedded Software: Interrupts, interrupt latency, shared data problems. que scheduling, Real-time operatingsystem architecture, Introduction to the real-time operating system; Embedded hardware: standard peripherals; Communicationprotocols; Designing embedded system using FSM models. Hardware and software co-design; Embedded C programming; Embedded development life cycle (EDLC

References:

1. Frank Vahid & Tony Givargis, "Embedded system design", Wiley Publication, 2002.
2. An Embedded software primer, David E Simon, Addison Wesley.
3. Shibu K. V, "Introduction to embedded systems", Mc Graw Hill Publication, 2013.
4. Raj Kamal, "Embedded Systems", 2^{nd} edition, Tata McGraw Hill

ELE 4411: FPGA BASED SYSTEM DESIGN [3 0 0 3]

Course Learning Outcomes: At the end of the course, the students will be able to:

CO1 Design Digital circuits using PLDs
CO2 Develop a model for testing the combinational and sequential circuits.
CO3 Analyze the FPGA based systems for optimizing size, speed, and power consumption
CO4 Create digital systems on FPGAs
CO5 Work in a team to develop FPGA based system

Overview of Digital Systems – Implementation options, FPGA –Architecture, Programming technologies, Altera & Actel logic cells, I/O Blocks, Programmable interconnects, Logic implementation, Design verification- Test bench codes, Hardware testing, FPGA Architectural options; granularity of function and wiring resources, reconfigurable architectures- Fine grained, Coarse grained, Medium grained, Embedded multipliers, adders, MACs, processor cores, Configuring an FPGA; Vendor specific issues, Logic block architecture, timing models-static and dynamic timing analysis, Input and Output cell characteristics, Power dissipation, Partitioning and placement, Routing resources, Embedded system design using FPGAs, DSP using FPGAs, Multi FPGA systems, Reconfigurable systems, Application case studies. Self-study: Developing and synthesizing RTL based circuit for the given application.

References:

1. M.J.S. Smith, *Application Specific Integrated Circuits*, (1e), Pearson, 2002
2. Peter Ashenden, *Digital Design (Verilog): An Embedded Systems Approach Using Verilog*, (1e), Elsevier, 2007
3. Clive Maxfield, *The Design Warriors Guide to FPGAs*, (1e), Elsevier, 2004
4. Hauck, S. and DeHon, *A Reconfigurable computing: the theory and practice of FPGA-based computation*, (1e), Elsevier, 2010.
5. NPTEL Course: https://nptel.ac.in/courses/117/108/117108040/

ECE 4412: INTERNET OF THINGS [3 0 0 3]

Course learning outcomes: At the end of the course, the student will be able to:

CO1 Describe IoT trend settings, realization, and demonstration.
CO2 Discuss the key wireless technologies evolved to support the requirements of IoT systems.
CO3 Describe reference architecture and IoT protocols.
CO4 Elaborate trends and transitions in cloud landscape to cope with advancements in IoT.
CO5 Describe various analytical approaches, frameworks, algorithms, platforms, engines, and methods for squeezing out value-adding IoT data.

Demystifying the IoT Paradigm, IoT Protocols, and Technologies, Concept of Device-to-Device/Machine-to-Machine Integration, Device-to-Cloud Integration, Realization of IoT Ecosystem Using Wireless Technologies; Infrastructure and Service Discovery Protocols for the IoT Ecosystem; Next-Generation Clouds for IoT Applications and Analytics; Cloud Computing; Emerging Field of IoT Data Analytics; Software Defined Networking (SDN)

References:

1. Raj P. and Raman A. C., *The Internet of Things: Enabling Technologies, Platforms and Use Cases*, CRC Press, 2017
2. Bagha A. and Medisetti V, *Internet of Things: A Hands on Approach*, University Press
3. Holler J., Tsiatsis V., Mulligan C., Karnouskos S., Avesand S., and Boyle D., *From Machine to Machine to the Internet of Things: Introduction to a New Age of Intelligence*, Academic Press, 2014
4. Vahid F, Givargis T., *Embedded Systems Design: A Unified Hardware/Software Introduction*, Wiley Publications, 2000
5. Axelson J, *Parallel Port Complete*, Penram Publications.

ELE 4412: REAL TIME SYSTEMS [3 0 0 3]

Course Learning Outcomes: At the end of the course, the students will be able to:

- CO1 Describe the characteristics of real-time systems and address timing constraints for time critical applications.
- CO2 Design and develop feasible clock driven and event driven real-time task schedulers for uniprocessor systems.
- CO3 Optimize real-time task schedulers to schedule aperiodic and sporadic tasks.
- CO4 Develop task schedulers to handle task dependencies and shared resources. Design task schedulers for multi-processor systems and distributed Systems.
- CO5 Understand the functions of real-time operating systems and analyze the real-time communication requirements and associated protocols and standards.

Introduction to real time systems, terminology, characteristics, real time system design issues. Types of real time systems, timing constraints, task dependencies, precedence constraints, precedence graph. Real time task scheduling: Clock driven schedulers; frame size constraints, Event driven schedulers; static and dynamic priority based schedulers. Schedulability/feasibility tests. Scheduling aperiodic and sporadic jobs. Handling task dependencies and resource constraints; priority inversion, dead-lock. Task scheduling on multiprocessor and distributed systems. Real time operating systems: kernels, queues, semaphores, benchmarking. Real time POSIX. Real time communication: Clock synchronisation, IEEE 802.5, IEEE802.4 standards. *Self-study*: Task scheduling, schedulability tests and real time communication

References:

1. Jane W.S. Liu, Real time systems, Pearson Education, 2013.
2. Qing Li and Caroline Yao, Real time concepts for Embedded Systems, Taylor & Francis Group, 2017.
3. C.M. Krishna, Kang.G. Shin, Real time systems, Tata McGraw-Hill Edition, 2012.
4. (Real Time Systems) http://nptel.ac.in/courses/106105036/
5. (Real Time Systems) http://nptel.ac.in/courses/106105086/

ECE 4413: ADVANCED DIGITAL SIGNAL PROCESSING [3 0 0 3]

Course Learning Outcomes: At the end of the course, the student will be able to:

- CO 1 Discuss decimation and interpolation operations and describe interpolated FIR and poly phase filter implementations.
- CO 2 Analyse DFT filter bank and QMF bank.
- CO 3 Describe concepts of multi resolution analysis and analyse filter bank for STFT and wavelet transform.
- CO 4 Develop LMS and RLS algorithms and discuss their important applications.
- CO 5 Analyse cepstrum of signals and describe homomorphic system for convolution and its applications.

Multi-rate signal processing, Multi-resolution analysis, Short-time Fourier transform and discrete-time wavelet transform, filter-bank for STFT and wavelet transform, Adaptive filtering, and Homomorphic signal processing.

References:

1. Vaidyanathan P. P, *Multirate Systems and Filter Banks*, Prentice Hall, India, 1993.
2. Gadre V M, Abhyankar A S, *Multiresolution and Multirate Signal Processing: Introduction, Principles and Applications*, McGraw Hill, 2017.
3. Orfanidis S. J, *Optimum Signal Processing*, McGraw Hill , NJ, 2007.
4. Oppenheim A.V and Schafer R.W., *Digital Signal Processing*, PHI Learning, 2008.

ELE 4413: LINEAR ALGEBRA FOR SIGNAL PROCESSING [3 0 0 3]

Course Learning Outcomes: At the end of the course, the students will be able to:

- CO1 Formulate, apply, solve and interpret systems of linear equations in several variables
- CO2 Apply concepts of vector spaces to solve linear algebraic problems
- CO3 Decompose linear transformations according to their spectra
- CO4 Apply orthogonality and least squares technique to line, curve, and shape fitting
- CO5 Understand eigen value and singular value decomposition and applications to signal and image processing

Vectors, matrices, norms, Lp-norms, Holder, Cauchy - Schwarz, and triangular inequalities, inner product spaces and their applications. System of linear equations and its solution sets, Gaussian elimination and back-substitution, echelon forms, matrix operations, LU - factorization, inverse matrices, Gauss-Jordan technique, transpose, elimination, and permutation matrices. Row space, column space, and null space of a matrix, bases and dimension, rank and nullity of a matrix, matrices as linear transformations, pseudo-inverse and applications, change of basis, affine transformations. Orthogonal subspaces, projections, Gram-Schmidt process, generalized Fourier series, QR factorization, least squares and their applications. Symmetric, Orthogonal, Hermitian, Unitary, Jacobian, and Hessian matrices, singular value decomposition and related applications. Characteristic equation, diagonalization, Jordan canonical form, special matrices, positive definite matrices and applications to signal processing. Singular value decomposition: theory and applications to signal and image processing. Self-study: implementation of topics discussed in MATLAB. Find and implement the applications in signal processing.

References:

1. Gilbert Strang, "Linear Algebra and its Applications", 3rd edition, Thomson Learning Asia, 2003.
2. David C. Lay, "Linear Algebra and its Applications", 3rd edition, Pearson Education (Asia) Pvt. Ltd, 2005.
3. Vittal Rao, "Advanced Matrix Theory and Linear Algebra for Engineers", NPTEL: https://nptel.ac.in/courses/111/108/111108066/#
4. Gilbert Strang, "Linear Algebra", MITOCW: https://ocw.mit.edu/courses/mathematics/18-06-linear-algebra-spring-2010/

ECE 4414: DIGITAL SPEECH PROCESSING [3 0 0 3]

Course Learning Outcomes: At the end of the course, the student will be able to:

CO1	Understand the human speech production system, different speech sounds and describe digital models.
CO2	Analyze various time domain and spectral features of speech.
CO3	Compute pitch period and formants of voiced speech signal using LPC parameters.
CO4	Describe the speech signal processing applications in speech coding and speech synthesis.
CO5	Describe the speech processing application in speech enhancement and speech recognition.

Fundamentals of speech; Time domain analysis of speech; Short-time Fourier analysis of speech: Homomorphic processing of speech; linear predictive coding of speech; Speech Processing Applications; Speech Synthesis:

References:

1. Rabiner L.R and Schaffer R.W, "Digital Processing of Speech Signals", Prentice Hall, NJ, 2007.
2. Thomas F. Quatieri, "Discrete.time Speech Signal Processing—Principles and Practice", Pearson Education, Inc., 2004.
3. Douglas O' Shaughnessy, "Speech Communications. Human and Machine Reading", Addison Wesley, 1987.
4. Dr. Shaila D. Apte, "Speech and Audio Processing", Wiley India, 2012.
5. Lawrence Rabiner, Biing-Hwang Juang, B. Yegnanarayana, "Fundamentals of Speech Recognition", Pearson, 2011 (Fifth Impression).

ELE 4414: DIGITAL IMAGE PROCESSING [3 0 0 3]

Course Learning Outcomes: At the end of the course, the students will be able to:

CO1	Characterize and analyze the 2D continuous and discrete space signals and systems in spatial and frequency domain
CO2	Learn 2D DFT, DCT, KLT, Walsh, Hadamard transforms, Haar wavelet transforms
CO3	Perform image enhancement/transformation/filtering in spatial and frequency domain
CO4	Elucidate the mathematical modeling of image restoration and compression
CO5	Understand morphological operators for image processing
CO6	Perform detection and segmentation of objects

Characterization of continuous and discrete/digital image, 2D sampling and quantization, 2D continuous and discrete space signals. 2D systems and their properties. 2D convolution sum. 2D continuous and discrete space Fourier transforms and properties. 2D discrete Fourier transform (DFT), discrete cosine transform (DCT), Karhunen-Loève transform (KLT), Haar wavelet transform, Walsh and Hadamard transform. Basic gray-level transformation, histogram processing, image enhancement in the spatial domain, bilateral filters, nonlocal means filters, rotation, interpolation. Image enhancement in the frequency domain. Image degradation/restoration process, noise models. Image Compression, image compression models, image compression standards. Image pyramid. Morphological image processing. Correlation or template matching, normalized cross correlation. Basic segmentation techniques, segmentation by fitting lines, curves, shapes. Active contours. Applications to biomedical image processing. Self-study: Implementation of image processing topics discussed in MATLAB/ImageJ/Python.

References:

1. Lim J. S., Two-dimensional signal and image processing, Prentice Hall, 1990.
2. Jain A. K., Fundamentals of digital image processing, Prentice Hall, 1989.

3. Gonzalez R. C. and Woods R. E., Digital image processing, Pearson, Fourth Edition, 2018.
4. William K. Pratt, Digital image processing, Wiley, Fourth Edition, 2007.
5. W. Burger and M. J. Burge, Digital image processing – An algorithmic introduction using Java, First edition, 2007.
6. B. K. Biswas, "Digital Image Processing", NPTEL: https://nptel.ac.in/courses/117/105/117105079/
7. Aggelos K. Katsaggelos, "Fundamentals of Digital Image and Video Processing", Coursera: https://www.coursera.org/learn/digital

ELE 4401: LIGHTING SCIENCE: DEVICES AND SYSTEMS [3 0 0 3]

Course Learning Outcomes: At the end of the course, the students will be able to:

CO1	Understand the fundamentals of lighting science and propagation of light
CO2	Analyze the importance of photometric quantities & units, and their relation for the effective design.
CO3	Understand the basics of black body radiator and related laws
CO4	Evaluate conventional and solid-state lamps and their accessories for field applications.
CO5	Measure and Analyze the photometric characteristics of a luminaire.

Electromagnetic spectrum, anatomy of eye, spectral eye sensitivity, Photometric, radiometric and quantum quantities, Relation between photometric quantities, Incandescence, Luminescence, Thermal radiators, Plank's Law, Wein's law, Stephan-Boltzmann's law, Construction & working principle of artificial light sources, Performance characteristics of conventional and solid-state lamps, Optical control of light, Screening devices, Light distribution diagrams of luminaires, Photometry measurements, Evaluation of total luminous flux. Self-study: Simulation and Case study of the selected topics

References:

1. Spiros Kitsinelis, *Light Sources: Technologies & Applications*, CRC press, 2010
2. Robert Karlicek, *Handbook of Advanced Lighting Technology*, Springer Publications, 2017
3. M.A. Cayless & A.M. Marsdon, *Lamps & Lighting*, 4e, Oxford & IBH publishing company, 1996.
4. Cotton H., *Principles of Illumination*, Chapman & Hall Ltd., London, 1960.
5. NPTEL Course: https://nptel.ac.in/courses/108/105/108105061/

ELE 4402: INTEGRATED LIGHTING DESIGN [3 0 0 3]

Course Learning Outcomes: At the end of the course, the students will be able to:

CO1	Appraise calculation terminologies and techniques for interior and exterior lighting design.
CO2	Design of energy efficient lighting systems satisfying quality and quantity standards for interior lighting applications and with the use of modern tools
CO3	Design of energy efficient lighting systems satisfying quality and quantity standards for road lighting applications and with the use of modern tools.
CO4	Design of energy efficient lighting systems satisfying quality and quantity standards in flood lighting of monuments and sports lighting and with the use of modern tools.
CO5	Apply the Integration of daylight with artificial light for energy saving and comfort.

Interior lighting design Objectives, importance of Illuminance, uniformity and glare, factor affecting performance of lighting system, impact of Surface Reflectance's & Room proportions on Lighting, Maintenance Aspects, Types of interior lighting, Methods of Design Calculations, CU calculation Methods, Glare evaluation methods, Flood lighting design objectives, Flood lighting design method, Road Lighting Objectives, Geometrical factors affecting performance of road lighting, Basic Lightings schemes, Road lighting design method, Tunnel Lighting design considerations, Tunnel lighting design method, Sports Lighting design objectives, Sports lighting design method, Daylighting strategies, Shading devices, Glazing Area, and day light factor. Self-study: Simulation assisted case studies on both interior and exterior lighting applications, and Recent trends in daylight and artificial light integration strategies.

References:

1. Robert Karlicek, Handbook of Advanced Lighting Technology, Springer Publications, 2017.
2. N K Kishore, "Illumination Engineering", NPTEL, [Online]. Available: https://nptel.ac.in/courses/108/105/108105061/, 2009.
3. Prafulla C. Sorcar, "Energy Saving Lighting Systems", VNR Company, 1982.
4. Robbins Cluade L, "Day Lighting", VNR Company,1986.
5. Mark S. Rea, "The IESNA Lighting Handbook: Reference & Application", Illuminating Engineering Society of North America, 10 Ed, 2011.

ELE 4403: LIGHTING CONTROL, TECHNOLOGY & APPLICATIONS [3 0 0 3]

Course Learning Outcomes: At the end of the course, the students will be able to:

CO1	Understand the basic functionality and characteristics of lighting control system components
CO2	Selection of appropriate sensor technology to optimize the performance of a given application
CO3	Apply lighting control technology and algorithm for a given scenario
CO4	Understand commissioning and energy codes for lighting control system
CO5	Identify appropriate communication protocols and networking methods for lighting control system application

Basic components of lighting control system, Sensor strategies: Occupancy sensor, Daylight harvesting, Photo sensors, Camera based lighting control: High dynamic range Imaging, Control technologies and algorithm, Artificial Intelligence in lighting comfort and daylighting, Daylight prediction methods, Human centric lighting, Zoning, LEED credits relevant to lighting, Lighting controls and Energy Conservation code, Payback period calculation, Networking and Communication strategies for lighting control : DMX 512, DALI, KNX, BacNet protocols and Li Fi technology, Power over Ethernet, ZigBee, Wireless sensor network, Internet of things – lighting control aspect

Self-study: Simulation on sensor and control strategies, communication and networking for lighting control, Case Study- KNX, BacNet protocols and Li Fi technology

References:

1. Robert S Simpson, *Lighting control technology and applications*, McGraw-Hill Higher Education, Focal Press, 2003
2. *LEED reference guide for building design and construction*, U.S Green Building Council, 2013
3. *Energy Conservation Building Code 2017*, Bureau of Energy Efficiency, Govt. of India
4. Farahani, Shahin. *ZigBee wireless networks and transceivers,* Newnes, 2011
5. NPTEL Courses, https://nptel.ac.in/courses/108/105/108105060/

ELE 4404: SOLID STATE LIGHTING [3 0 0 3]

Course Learning Outcomes: At the end of the course, the students will be able to:

CO1	Understand the electrical and optical characteristics of light emitting diodes, comprehend the principles of light generation.
CO2	Understand the various radiometric, photometric and calorimetric parameters of LED light sources
CO3	Analyze the techniques of white light generation using simulation tools.
CO4	Calculate the design parameters of drivers for LEDs.
CO5	Analyze the reliability of LED products and assess the advancements of LED lighting in various applications.

Introduction of LEDs, Electrical and optical characteristics of LEDs, Temperature dependence of LEDs, Light receptors of human eye, radiometric, colorimetric and photometric units, CIE chromaticity, Binning, Mac dam ellipse, Study of spectral characteristics of LEDs, white light generation using monochromatic LEDs, CRI and CQS, Color matching functions, Color Mixing Algorithm and Verification, DC and AC LED driving circuits, dimming, LED lifetime, Thermal analysis model for LEDs, Lumen maintenance and lifetime testing of solid-state lighting products, Reliability of LED products, Overview on lighting advancements- Colour tunable lighting, Human centric smart lighting, Horticulture.
Self Study: Simulation and case studies of selected topics.

References:

1. E. Fred Schubert, "*Light Emitting Diodes*", Cambridge University Press, 3E, 2018
2. Vinod Kumar Khanna, "*Fundamentals of Solid state Lighting*" CRC press,2014
3. Clemens J M Lasance and Andras Poppe, "*Thermal management for LED applications*", Springer Publications, 2014
4. M Nisa Khan,"*Understanding LED Illumination*",CRC Press, 2014
5. Daniel W Hart," *Power Electronics*", McGraw- Hill, 2011

ELE 4415: EV BATTERY TECHNOLOGY AND POWERTRAIN DEVELOPMENT [3 0 0 3]

Battery Fundamentals: Basics of Batteries, Battery Parameters, Lithium-Ion Characteristics, Thermal Runaway Battery Management System (BMS), Functionality, Practical session - Battery Selection and Connection Process with Vehicle Sensors.

Battery Management Systems: SOC/SOH Estimation, Cell Balancing, Protection, Thermal Management, CAN Communication, Practical session - BMS development.
Battery Pack Design & Modelling: Overview of Battery & BMS System, Electrical Design, Mechanical Design: Calculations and Mechanical Design using ANSYS, Heat Transfer, Thermal Design of Battery Pack, Battery Pack Assembly and Test, Thermal Analysis on Battery Pack, MATLAB/Simulink-based Battery Pack Modelling, Practical session - Battery life cycle testing.
Powertrain and Charging Systems of Electric Vehicles: Introduction to EV Powertrain, Overview, Architecture and Components of EV Powertrain, Thermal Management of EV Powertrain, EV Charging Systems and Types of Chargers.
Modelling, Simulation, and Analysis of EV Powertrain Components: Modelling and Simulation of EV Powertrain Components in MATLAB, Modelling and Analysis of EV Powertrain Components in SolidWorks, Analysis of EV Powertrain Components in ANSYS, Case Study on Powertrain of Existing Models.

References:

1. James Larminie and John Lowry, "Electric Vehicle Technology Explained", Wiley, 2nd ed, 2012, ISBN: 978-1-119-94273-3.
2. JIANGONG, D. H. Z., "Advances in lithium-ion batteries for electric vehicles: Degradation Mechanism, health estimation, and lifetime prediction", Elsevier – Health Science, 2024, ISBN-13: 9780443155437.
3. R. Xiong, "Battery Management Algorithm for Electric Vehicles", Springer, 2020, ISBN-13: 9789811502507.
4. Rui Xiong and Weixiang Shen, "Advanced battery management technologies for electric vehicles", John Wiley & Sons Inc, 2019, ISBN-13: 9781119481645.
5. Hannes Hick, Klaus Ku¨pper, and Helfried Sorger, "Systems engineering for automotive powertrain development", Springer, 2021, ISBN-13: 9783319996288.
6. Christopher D. Rahn, "Battery Systems Engineering", Wiley, 1st Ed, 2013, ISBN:9781119979500.
7. Noshin Omar, "Electric Vehicle Batteries: Moving from Research towards Innovation", Reports of the PPP European Green Vehicles Initiatives, Springer, 2015.
8. Gonzalo Abad and Joaquim Lois, "Power Electronics and Electric Drives for Traction Applications", Wiley, 2016, ISBN: 978-1-118-95442-3.
9. John G. Hayes and G. Abas Goodarzi, Electric Powertrain: Energy Systems, Power Electronics and Drives for Hybrid, Electric and Fuel Cell Vehicles", Wiley, 2017, ISBN: 978-1-119-06364-3.

ELE 4416: EV CHARGING INFRASTRUCTURE, VEHICLE TESTING & HOMOLOGATION [3 0 0 3]

EV Business Management and Vehicle Testing: Introduction to EV (2W, 3W & 4W) Market & Opportunities, Electric Vehicle Design Procedure and ICE Model, Introduction to EV Management, EV Homologation and Testing, FAME India and Manufacturing Guidelines, EV Certification Process, EV Charging, Electric Vehicle and Retrofitting, Motor Technology and EV Motor Market Analysis, EV Categories and Proposed Changes, EV Retrofitting Business, Battery Technology in EV, EV Battery Market Analysis, Practical session - Conducting a market analysis of the EV Charging.
Fundamentals of Product Development Planning: Introduction to Product Development Plan, Segment Selection, Product Design Plan, Product Validation Plan, Vehicle Dynamics Selection, Product Design Validation, Product Specification - Competitor Analysis, Selection of Off-the-Shelf Parts.
Effective Development Methods for Product Innovation: Development Methods, Product Development Plan, Unit Economics, Design Feasibility, Design for Manufacturing, DFMEA & PFMEA, Business Plan, Product Launch, POC / MVP / Working Prototype, Practical session - Using the market analysis results to develop a business plan for an EV Charging.
Understanding EV Charging Technologies and Infrastructure: Overview of EV Charging Technologies, EV Charging Standards and Protocols, Types of EV Chargers and Charging Stations, EV Charging Infrastructure Design, Site Selection and Planning, Practical session - Case Studies of Successful EV Charging Infrastructure Projects.
Designing and Managing EV Charging Infrastructure: Electrical and Mechanical Design Considerations, Safety and Regulatory Compliance, EV Charging Infrastructure Installation and Maintenance, Charging Network Management, EV Charging Network Design and Deployment, Payment Systems and Revenue Management, Data Management and Analytics on Charging Station,

References:

1. M. S. Alam, R. K. Pillai, and N. Murugesan, "Developing Charging Infrastructure and Technologies for Electric Vehicles", IGI Global, 2021, ISBN-13: 9781799868590, ISBN-10: 1799868591.
2. Vahid Vahidinasab and Behnam Mohammadi-Ivatloo, "Electric Vehicle Integration via Smart Charging", Springer, 2022, ISBN-13: 9783031059087, ISBN-10: 3031059085.
3. Sivaraman Palanisamy, Sharmeela Chenniappan, and Sanjeevikumar Padmanaban, "Fast-Charging Infrastructure for Electric and Hybrid Electric Vehicles", John Wiley & Sons, 2023, ISBN-13: 9781119987741, ISBN-10: 1119987741.

4. Sulabh Sachan, Sanjeevikumar Padmanaban, and S. Deb, "Smart Charging Solutions for Hybrid and Electric Vehicles", John Wiley & Sons, 2022, ISBN-13: 9781119768951, ISBN-10: 1119768950.
5. R. Wang, P. Wang, and G. Xiao, "Intelligent Microgrid Management and EV Control Under Uncertainties in Smart Grid", Springer, 2017, ISBN-13: 9789811350870, ISBN-10: 9811350876.

ELE 4417: EV VEHICLE DESIGN & ANALYSIS [3 0 0 3]

Introduction to Analog Electronics: Introduction to Basic Electronics, Diode Fundamentals, Rectifiers and Filters, Power Electronics for EVs: Voltage Regulators, Inverters and Converters, Special Purpose Diodes, Transistors and Types of Transistors, Operational Amplifier (Op-Amp).
Fundamentals of Digital Electronics: Digital Electronics, EV Control Systems, EV Communication Networks, Microcontrollers and Microprocessors, Introduction to Proteus Software, Circuit Development Using Proteus.
Essentials for Designing and Simulation Using MATLAB: Overview and Environment, Basic Syntax, Variables and Commands, Commands, M-files, and Types, Operators, Decision Making and Loops, Vectors, Matrix, and Arrays, Colon Notation and Numbers, Strings and Functions, Numbers, Plotting and Graphics, Algebra, Calculus, Differential, and Integration, Polynomials and Transforms, Programming EV Systems in MATLAB, Simulink and Fitting, Developing SIMULINK Models for Vehicle Units, Advisor and QSS Toolbox, QSS-based Vehicle Control, Practical session - Analyse and troubleshoot electronic circuits using simulation tools and lab equipment.
EV Architecture Modelling Using MATLAB [Software-based]: Motor Development and Induction Motor Characteristics, Simulink Model to Calculate Vehicle Configuration, Multi-level Inverter Design and Simulation, Solar PV-based Charger Development, DC-DC Converter, Modelling of Li-ion Battery Pack, Design of EV Using QSS Toolbox, Battery Thermal Modelling, BMS Modelling, Electric 4W Powertrain Modelling, Practical session - Data analysis and visualization using MATLAB for vehicle system.
Design of EV System Using MATLAB [Software-based]: Power Required to Overcome Resistance Forces Acting on the Vehicle, Power Converters in Electric Vehicles, Inverters in Electric Vehicles, Motor and Motor Controllers, Modelling of EV Battery and BMS, Practical session - Modelling and simulation of EV powertrain components, such as motors, controllers, and inverters, using MATLAB/Simulink.

References:

1. James Larminie and John Lowry, "Electric Vehicle Technology Explained", Wiley, 2nd ed, 2012, ISBN: 978-1-119-94273-3.
2. Iqbal Husain, "Electric and Hybrid Vehicles: Design Fundamentals", Routledge, 3rd Ed, 2021, ISBN: 9780367693930.
3. Ali Emadi, "Advanced Electric Drive Vehicles", CRC Press, 1st Ed, 2014, ISBN: 9781138072855.
4. Sandeep Dhameja, "Electric Vehicle Battery Systems", Butterworth-Heinemann, 2st Ed, 2002, ISBN: 978-0750699167.
5. Singh, Sanjeev, et al., "Electric Vehicle Components and Charging Technologies" IET, 2024, ISBN-13: 9781839536717.
6. Das, Shuvra, "Modeling for Hybrid and Electric Vehicles Using Simscape", Springer, 2022, ISBN-13: 9783031003806.

ELE 4418: EV DATA ANALYTICS & CYBER SECURITY [3 0 0 3]

Cyber Security for Automotive Vehicle Systems: Automotive Industry, Automotive Megatrends, Automotive Development Process, Automotive Electrical and Electronics, Automotive Software Technology, The Connected Car, Automotive Cybersecurity.
Advanced Mobility Services: Mobile Apps for Connected Car, Car Hailing and Ride Sharing, Connected Parking and Automated Valet Parking, ADAS and Autonomous Driving.
Data Analytics for EV and Automotive Systems: Introduction to Data Analytics and Its Application in the Automotive Industry, Understanding of the Data Analytics Pipeline, Overview of Data Analytics, Its Tools, and Techniques, EV Data Collection and Analysis, Sensors and Data Collection in EVs, Data Acquisition and Pre-processing, Statistical Analysis of EV Data, Practical session - Conducting a vulnerability assessment on an in-vehicle network, and developing a report on the findings with recommendations for mitigations.
Automotive System Data Collection and Analysis: Automotive Systems (such as Engines, Transmissions, Brakes, etc.), Data Acquisition and Pre-processing, Statistical Analysis of Automotive System Data, Regression, Classification and Clustering, Principal Component Analysis (PCA) and Linear Discriminant Analysis (LDA), Predictive Maintenance Techniques in Automotive Systems, Fault Detection and Diagnosis, Remaining Useful Life (RUL) Prediction, Practical session - Developing predictive maintenance models for automotive systems.
Introduction to Big Data Platforms: Introduction to Big Data Platforms and Tools (such as Hadoop, Spark, and Kafka), How to Use Big Data Platforms to Process and Analyze Automotive Data, Practical session - Case studies showcasing the application of data analytics in the automotive industry.

References:
1. Mashrur Chowdhury, Amy Apon and Kakan Dey, "Data Analytics for Intelligent Transportation Systems", Elsevier, 1st Ed, 2017, ISBN: 978-0128097151.
2. Tyson Macaulay, Bryan L. Singer, and John R. Vacca, "Cybersecurity for Industrial Control Systems: SCADA, DCS, PLC, HMI, and SIS", CRC Press, 1st Ed, 2011, ISBN: 978-1439801963.
3. James Larminie and John Lowry, "Electric Vehicle Technology Explained", Wiley, 2nd ed, 2012, ISBN: 978-1-119-94273-3.
4. David Ward and Paul Wooderson, "Automotive Cybersecurity: An Introduction to ISO/SAE 21434", SAE International, 1st Ed, 2021, ISBN: 978-1468600803.
5. Dartmann Guido, Anke Schmeink and Houbing Song, "Big Data Analytics for Cyber-Physical Systems: Machine Learning for the Internet of Things", Elsevier, 1st Ed, 2019, ISBN: 978-0128166376.
6. Craig Smith, "The Car Hacker's Handbook: A Guide for Penetration Tester", No Starch Press US, 1st Ed, 2016, ISBN: 978-1593277031.
7. Root, Alex, "Python for Data Analytics", Independently published, 2019, ISBN-13: 9781691418831.
8. Runkler, Thomas A., "Data Analytics", Springer, 2020, ISBN 9783658297794.
9. Janeja, Vandana P., "Data Analytics for Cybersecurity", Cambridge University Press, 2022, ISBN-13: 9781108415279.

PROGRAM ELECTIVES:

ELE 4441: BUILDING AUTOMATION SYSTEMS [3 0 0 3]

Concept of intelligent, green, and smart building. Overview of Digital Controllers, Network and Communication protocols, Introduction to Building Management Systems, General BMS architecture, Communication Systems and standards for BMS. Application of internet for Automation and Management. Introduction to HVAC and Optimal control methods for HVAC Systems. Lighting Control Systems and protocols. Security and Safety Control Systems such as Access Control and Fire Alarm Systems. System Integration and Convergence. Energy Management, Green Building (LEED) concept and examples. Introduction to LonWorks. Energy saving with variable speed drives.

References:
1. V. K. Jain, "Automation Systems in Smart and Green Buildings", published by Khanna Publishers (2009), ISBN-13: 978-8174092373
2. Reinhold A. Carlson, Robert A. Di Giandomenico, "Understanding Building Automation Systems: Direct Digital Control, Energy Management, Life Safety, Security/access Control, Lighting, Building Management Programs"
3. Ronnie J. Auvil, "HVAC Control Systems", Second Edition Hardcover January 1, 2007
4. Thomas L. Norman, "Integrated Security Systems Design: Concepts, Specifications, and Implementation (v. 1)", CPP PSP CSC (2007)

ELE 4442: COMPUTER ARCHITECTURE & ORGANIZATION [3 0 0 3]

Course Learning Outcomes: At the end of the course, the students will be able to:

CO1	Describe general and specific computer architectures and to analyze instruction formats
CO2	Design of processing unit and control path of a processor-based system
CO3	Discuss memory hierarchy and cache mapping techniques.
CO4	Explain basic input and output techniques
CO5	Appraise the concept of pipelining

Introduction to Computer Architecture: Components, Instruction Set Architecture, Instruction Types and Addressing modes, CPU structures: General Register CPU; Accumulator based machine, Stack based machine, Memory Organization: Memory hierarchy, Cache memory, Virtual memory, Datapath design: General Register design, shifters, adders, ALU design, representation of numbers, Multiplication of signed and unsigned integers, Division of unsigned integers – restoring and non-restoring methods, Control path design: Hardwired and Micro-programmed, Micro-instruction formats, control unit organization, control unit optimization, Types of architecture: RISC, CISC, Architecture trends and implications for the future -dual core, multicore, superscalar architecture, Input/ Output interfacing, Pipelining and parallel processing.

Self Study: Simulation of datapath unit, controller unit and microcomputer

References:
1. William Stallings, *Computer Organization and Architecture*, 10e, Pearson, 2016
2. David Harris and Sarah Harris, *Digital Design and Computer Architecture*, Elsevier, 2008
3. David Patterson and John Hennessy, *Computer Organization and Design*, Elsevier, 2007.
4. M. Raffiquzzman, *Fundamentals of Digital logic and microcomputer design*, 5e, Wiley, 2005

5. NPTEL Courses: https://nptel.ac.in/courses/106/106/106106092/

ELE 4443: DATA STRUCTURES & ALGORITHMS [3 0 0 3]

Course Learning Outcomes: At the end of the course, the students will be able to:

CO1	Understand fundamental Data Structures including linked lists, trees, binary search trees, stacks, queues, priority queues, and hash tables.
CO2	Create data structures and use them in implementations of abstract data types.
CO3	Understand and estimate the algorithmic complexity of simple, non-recursive programs.
CO4	Devise novel solutions to small-scale programming challenges involving data structures and recursion.
CO5	Select appropriate data structures and algorithms for problem-solving and justify the choice.

Data Structures, abstract data types, basic data structures and their representations: arrays, queues, circular queues, stacks, linked lists, singly and doubly linked lists, trees, binary trees, tree traversals, binary search trees, graphs, basic operation on data structures using pseudocode. Analysis of Algorithms, time complexity, space complexity, asymptotic notations, master theorem, iterative and recursive algorithms, Searching and Sorting, Algorithm design techniques, Greedy method, Divide and Conquer, Shortest Path Algorithms, Prim's algorithm, Kruskal's algorithm, Knapsack problem, Dynamic programming and Backtracking, Hashing

Self-study: programming practice of certain real-time applications on the topics such as searching, sorting etc.

References:

1. Cormen, Leiserson and Rivest, *Introduction to Algorithms*, 3e, MGH 2009
2. Aho, Hopcroft and Ulmann, *Design and Analysis of Algorithms*, 1e, Pearson 2002
3. Mark Allen Weiss, *Data Structures and Algorithm Analysis in C*, 2e, Pearson 2010
4. Horowitz and Sahni, *Fundamentals of computer algorithms*, 2e, Universities Press. 2008
5. NPTEL Courses: https://nptel.ac.in/courses/106/102/106102064/

ELE 4444: DEMAND SIDE MANAGEMENT [3 0 0 3]

Course Learning Outcomes: At the end of the course, the students will be able to:

CO1	Understand energy management principles. Assess energy performance of a facility through energy audits. Compare different energy projects.
CO2	Understand the importance of different parts of a tariff. Devise electricity tariff. Illustrate the economics of power factor improvement.
CO3	Assess energy efficiency of electrical appliances. Show the impact of variable speed drives on energy consumption. Apply building energy codes to conserve energy in buildings.
CO4	Apply load management techniques. Explain the working of advanced metering infrastructure.
CO5	Choose best practices and technologies in electrical systems.

Energy conservation Act, Standard and labelling, Energy audit, Energy action planning, financial analysis, Project management, Energy conservation and efficiency, Energy monitoring and targeting. New and renewable energy sources. Distributed Generation, General tariff form, Dynamic pricing, Time-of-Day (TOD) pricing, Realtime pricing, Private and public supply. Economic load sharing. Power factor of common appliances causes and effects of low power factor, economics of power factor improvement, Lighting, Refrigerators, Air-conditioners, Distribution transformers, Electric motors. Variable Speed Drive (VFD) Applications, Fans, and pumps. Cogeneration, Trigeneration, Daylighting. ECBC code. Demand Side Management approaches – Load shifting, Load categorization, Consumer Categorization, Electric Vehicles Smart meters, Advance metering infrastructure (AMI), Smart thermostat. DSM challenges. Best practices and technologies in Electrical System. Measurement and verification of energy performance of organizations. Perform Achieve Trade (PAT). Internet of Things (IoT). Industry 4.0. Self-study: Case studies on energy audit of electrical and thermal facilities. Energy management using renewable energy sources.

References:

1. Guidebooks for National Certification Examination, 2020, [E-book] Available: http://aipnpc.org/Guidebooks.aspx.
2. Guidebook: Refresher Course for Certified Energy managers and Auditors, 2020, [E-book] Available: http://refreshercourse.in/Module/RC_Material.pdf
3. R. K. Rajput, Utilization of Electrical Power, 2006
4. Ashish Mathur, Demand Side Management, LAP Lambert Academic Publishing, 2012
5. NPTEL - Technologies for Clean and Renewable Energy Production, https://nptel.ac.in/courses/103/107/103107157/

ELE 4445: ENERGY ANALYTICS [3 0 0 3]

Course Learning Outcomes: At the end of the course, the students will be able to:

- CO1 Understand the notion of energy data analytics under various domains of the energy ecosystem.
- CO2 Apply Python programming, its data analytics libraries for analyzing and exploring energy-related data using statistical tools.
- CO3 Identify various types of supervised and unsupervised data analytics techniques as applicable to specific energy analytics use cases.
- CO4 Apply various types of supervised and unsupervised machine learning & deep learning models as applicable to specific energy analytics use cases.
- CO5 Hypothesize the issues, impacts, tools, and mechanisms pertaining to energy analytics on new and emerging technologies.

Energy ecosystem, Energy sources, Key steps in energy analytics, Application of energy analytics in electricity sector areas, Decarbonization, decentralization, and digitalization of electricity sector, Energy datasets, Energy dashboards (electricity, power markets, renewables, coal, oil, gas), Python programming basics, Python libraries – NumPy, Pandas, Matplotlib, Seaborn, Scikit-learn, Data visualization, Exploratory Data Analysis basics & statistical tools, Forecasting and prediction, Clustering, Monitoring & Control, Regression, Time-series analysis, Neural Networks, Support Vector Machines, Tree-based approaches, Clustering approaches, Hybrid approaches, Evaluation matrices, EVs - mobility, battery, charging type & charging station, metering, user behavior, etc. analytics, EV telematics, Analytics on Energy-efficient buildings, Roof-top solar, Residential batteries, Smart appliances, Smart metering. Self-study: Forecasting and prediction related exercises on energy datasets using machine and deep learning.

References:

1. EMC Education Services, "Data Science & Big Data Analytics: Discovering, Analyzing, Visualizing and Presenting Data", John Wiley & Sons, Inc., 2015.
2. G. J. Myatt, W. P. Johnson, "Making Sense of Data I: A Practical Guide to Exploratory Data Analysis and Data Mining", Second Edition, John Wiley & Sons Publication, 2014.
3. Frederik vom Scheidt, et al., "Data analytics in the electricity sector – A quantitative and qualitative literature review," Energy and AI, Elsevier, vol. 1, Aug 2020.
4. Websites of NITI Aayog, CEA, RLDCs, IEX, Nordpool, PJM, etc.
5. NPTEL Course: https://nptel.ac.in/noc/courses/noc22/SEM1/noc22-cs32/ (Python for Data Science).

ELE 4446: ENERGY AUDITING [3 0 0 3]

Course Learning Outcomes: At the end of the course, the students will be able to:

- CO1 Understand general aspects of energy management and energy audit. Choose energy projects based on financial analysis. Plan energy audits.
- CO2 Understand energy efficiency in electrical utilities. Demonstrate the importance of appropriate motor loading and speed control in fans and pumps. Suggest suitable energy conservation methods in buildings.
- CO3 Understand energy efficiency in thermal utilities. Calculate efficiencies of boilers and furnaces using direct method. Suggest appropriate technologies for improving efficiency of thermal utilities.
- CO4 Assess performance of equipment and utility systems. Measure key performance indicators of electrical and thermal utilities.
- CO5 Suggest best practices in building energy management and conservation.

Energy Scenario, Energy conservation Act 2001, Basics of energy and its forms, Energy management and audit, Energy action planning, financial management, Project management, Energy monitoring and targeting, Electrical systems, Electric motors, Fans and Pumps, Lighting systems, HVAC, and refrigeration systems. Energy conservation in buildings and Energy Conservation Building Code (ECBC) Fuels and combustion, Boilers, Cogeneration, Heat exchangers, perform achieve trade (PAT), Energy Efficiency Performance Indicators for Industries, Plant energy efficiency data analytics, EPI, AAHEPI, Power factor improvement, Demand side management. Self-study: Case studies on energy audit of electrical and thermal facilities. Energy management using renewable energy sources.

References:

1. Guidebooks for National Certification Examination, 2020, [E-book] Available: http://aipnpc.org/Guidebooks.aspx.
2. Guidebook: Refresher Course for Certified Energy managers and Auditors, 2020, [E-book] Available: http://refreshercourse.in/Module/RC_Material.pdf
3. Wayne C. Turner, Energy Management Handbook, Fifth Edition, Fairmont Press, 2004

4. NPTEL - Energy conservation and waste heat recovery - https://nptel.ac.in/courses/112/105/112105221/

ELE 4447: ENERGY STORAGE DEVICES [3 0 0 3]

Course Learning Outcomes: At the end of the course, the students will be able to:

CO1	Understanding the importance and working Principle of different Energy Storage Technologies.
CO2	Modeling and Control of Secondary Rechargeable cells & Fuel Cells
CO3	Design of Energy storage devices for a given application
CO4	Design of Hybrid Energy storage system and it's Power Management.
CO5	Design of Energy Storage Devices for Electric Vehicle.

Importance of energy storage and introduction to different forms of energy storage. Trends in power system development and energy storage as a structural unit of a power system, Energy and power balance in a storage unit, mathematical model of energy storage, applications of energy storage- utilities, transport, industry, house hold. Energy storage techniques: Electrochemical energy storage- Secondary batteries, electrical circuit modeling of a cell, estimation of state of charge, state of health, Energy and power estimation of battery pack, and battery charge controller design. Fuel cells: History – working principle - thermodynamics of fuel cell process –Types of fuel cells – Modeling of fuel cell-Fuel Cell System Design. Case Study on Electrical Vehicle- Architecture of Hybrid EV, Plug-in hybrid EV, Electric Vehicles, and System design Consideration, rating and sizing of energy storage devices for EV. Thermal energy storage: General considerations-storage media- Containment- Power extraction, Flywheel storage, Superconducting magnetic energy storage: Basic principles, Superconducting coils, Cryogenic systems, Power extraction, Environmental and safety problems, Pumped hydro storage: Basic Principle-The power extraction system-The central store for pumped hydro. Compressed air energy storage, Power system considerations for energy storage: Integration of energy storage systems-Effect of energy storage on transient regimes in the power system.

References:

1. Robert Huggins, "Energy Storage: Fundamentals, Materials and Applications", Springer, 2015.
2. Gregory L Plett-"Battery Management Systems," Volume- 1, Battery Modeling, Artech House Publishers, 2015.
3. R. Bove and S. Ubertini "Modeling Solid Oxide Fuel Cells," Springer, 2008.
4. John G. Hayes and G. Abas Goodarzi, "Electric Powertrain-Energy Systems, Power Electronics and Drives for Hybrid, Electric and Fuel Cell Vehicles" John Wiley&Sons Ltd. 2018.
5. F. Naseri, E. Farjah and T. Ghanbari, "An Efficient Regenerative Braking System Based on battery/Supercapacitor for Electric, Hybrid, and Plug-In Hybrid Electric Vehicles With BLDC Motor," in IEEE Transactions on Vehicular Technology, vol. 66, no. 5, pp. 3724-3738, May 2017

ELE 4448: HVDC & FACTS [3 0 0 3]

Course Learning Outcomes: At the end of the course, the student must be able to

CO1	Understand the problems of uncompensated HVAC line and provide conventional solution
CO2	Discuss the various types of HVDC & FACTS
CO3	Describe the converter configuration for HVDC & FACTS
CO4	Implement control strategies for HVDC & FACTS controllers
CO5	Analyze the performance of power system with various FACTS controllers & select appropriate FACTS controller

HVDC transmission system, merits & demerits, applications and schemes of HVDC, equivalent circuit diagram of two-terminal HVDC link, control characteristics, grid firing units, converter faults. Performance of uncompensated, shunt & series capacitor compensated line, Introduction to FACTS controllers-configuration and working principle of SVC, STATCOM, TCSC, SSSC, and UPFC, steady-state characteristics, performance of line with FACTS controllers, power quality issues, working principle of DVR, DSTATCOM, UPQC. Self-study on the selected topics.

References:

1. K R Padiyar, *FACTS Controllers in power transmission and distribution systems*, New Age International publishers, New Delhi, 2007.
2. Narendra G Hingorani & L. Gyugyi, *Understanding FACTS: Concepts and Technology of flexible AC transmission systems*, IEEE Press, 2000.
3. K R Padiyaar, *HVDC power transmission systems, Technology and System Interactions*, New Age International publishers, New Delhi, 1999.
4. Vijay K. Sood,'HVDC and FACTS Controller', Kluwer Academic Publisher, 2004.
5. *Bhim Singh*, Ambrish Chandra, Kamal Al-Haddad, *Power Quality*: *Problems and Mitigation Techniques*, Wiley, 2014.

ELE 4449: INTRODUCTION TO DATA SCIENCE [3 0 0 3]

Course Learning Outcomes: At the end of the course, the students will be able to:

CO1	Discuss various Python libraries and data visualization techniques.
CO2	Analyse and apply exploratory data analysis and statistical tools.
CO3	Apply various types of supervised techniques on datasets.
CO4	Create decision trees, random forests, and clusters for various datasets.
CO5	Apply various neural networks models to datasets.
CO6	Apply natural language processing to texts

Introduction to Data Science; Python libraries and visualization techniques; Statistical tools; Exploratory data analysis; Model building and analysis- Linear and Logistic Regressions, Decision Trees, Random Forests and Clustering methods, Neural Networks; Introduction to Natural Language Processing. Self-study: Simulation based studies of the selected topics.

References:

1. Joel Grus, *Data Science From Scratch: First Principles With Python*, 2e, O'Reilly, 2015
2. J. VanderPlas, *Python Data Science Handbook*, O'Reilly, 2016
3. Steven Bird, Ewan Klein & Edward Loper, Natural Language Processing with Python, 1e, O'Reilly, 2009
4. https://nptel.ac.in/courses/106/106/106106179/
5. https://nptel.ac.in/courses/106/106/106106184/

ELE 4450: MICROGIRDS [3 0 0 3]

Course Learning Outcomes: At the end of the course, the students will be able to:

CO1	Understand the energy crisis and appreciate the modern day solutions
CO2	Understand the concept of Microgrid and study the different types of Microgrid and operating modes of Microgrid
CO3	Design and analyse a sample campus Microgrid
CO4	Analyse the stability in Microgrids
CO5	Understand the role of Microgrid controller and its functions

Microgrid Concept and Structure, Operation Modes, Control Mechanism of the Connected Distributed Generators in a Microgrid, Control Structure in Grid-connected Mode, Control Structure in Islanded Mode, Participation in the Frequency Regulation, Power Dispatching, Power Management, Mathematical Modelling, Closed-Loop State-Space Model, Microgrid Control Hierarchy, Global Control, Droop Control, Virtual Impedance Control, Hierarchical Power Management and Control, Operation Layers and Control Functions, DC Microgrid Control, Virtual Inertia-based Stability and Regulation Support, Intelligent Control Technologies, Emergency Control and Load Shedding in Microgrids, Protection Schemes. Self-study: Simulation based studies of the selected topics.

References:

1. Hatziargyriou N, "Microgrids: Architectures & Control", John Wiley & Sons, 2014.
2. Bevrani H, Francois B, Ise T, "Microgrid Dynamics and Control", John Wiley & Sons, 2017.
3. Blaabjerg F," Control of Power Electronic Converters and Systems", Academic Press, 2018.
4. Bahrami S,"Smart Microgrids: From Design to Laboratory-Scale Implementation", Springer, 2019
5. Farhangi H, "Smart Microgrids: Lessons from campus Microgrid design and implementation", CRC Press, 2017.
6. NPTEL: https://onlinecourses.nptel.ac.in/noc20_ee84/preview.

ELE 4451: POWER SYSTEM OPERATION AND CONTROL [3 0 0 3]

Course Learning Outcomes: At the end of the course, the students will be able to:

CO1	Understand Modern Power system structure and its constraints
CO2	Design control and compensation schemes for real and reactive power
CO3	Apply and understand different methods for optimal scheduling of Thermal Generators with Renewable Energy Sources
CO4	Develop an understanding of Optimal Load Flow and Unit Commitment
CO5	Apply and understand Power system Security analysis and state estimation

Review of Modern Power System & its characteristics: Overview of course of Power System Operation & control and methodology of teaching-learning, Modern Power system and its characteristics, Operating states, Equipment and Stability Constraints, Transmission line constraints. Optimal Economic Scheduling: Optimal scheduling of Thermal unit with Hybrid Sources. Optimal Load Flow and Unit Commitment: Optimal Power Flow Problem with and without Inequality Constraints on different variables. Unit Commitment Cost function Formulation and Constraints, Solution method- Priority List Method, Dynamic Programming Method and Optimal Unit Commitment with Security Constraints. Power System Security and State estimation: Introduction to Power system security, Factors affecting Security, Different Contingency Analysis. Introduction to State Estimation, Different methods of State Estimation, Detection and Identification of Bad Data, The Role of State Estimation in Power System Operations. Self-study: Simulation based studies of the selected topics.

References:

1. Wood and Wollenberg, "Power Generation Operation & Control", Wiley, 2011.
2. Jizhong Zhu, "Optimization Of Power System Operation" Wiley-IEEE Press, 2009.
3. K. Uma Rao, "Power System Operation and Control" Willey, 2013.
4. NPTEL Course: https://nptel.ac.in/courses/108/101/108101040
5. NPTEL Course: https://nptel.ac.in/courses/108/104/108104052

ELE 4452: POWER SYSTEM RESTRUCTURING AND MARKET OPERATONS [3 0 0 3]

Course Learning Outcomes: At the end of the course, the students will be able to:

CO1	Understand Power System Restructuring and Market Overview
CO2	Apply and understand different Operations in Power Market
CO3	Develop and understanding of Market Power Risk Analysis
CO4	Design Ancillary Service Auction Market
CO5	Apply and understand Transmission Congestion Management, Open Access and Pricing

Power system restructuring: Introduction, Motivation for restructuring of Power system, Indian Power Sector-Past and Present Status, Market structure and Operation. Operations in Power Market: Power Pools, Transmission Network and Electricity Markets, Arbitrage in Electricity market, Available Transfer Capability (ATC), Methods of ATC determinations. Market Power Risk Analysis: Game Theory, Power Transactions Game, Problems, Market Competition with Incomplete Information, Market Competition for Multiple Electricity Products. Introduction of Asset Valuation, Ancillary Service Auction Market: Ancillary Services for restructuring, Forward Ancillary Service Auction-Sequential and Simultaneous approaches, Transmission Pricing: Introduction, Transmission Pricing Methods, A comprehensive transmission Pricing Scheme. Self-study: Examples and studies of the selected topics.

References:

1. Loi Lei Lai, "Power System Restructuring and Deregulation", John Wiley & Sons Ltd, England, 2001.
2. M. Shahidehpour, H. Yamin, and L. Zuyi, "Market Operations in Electric Power Systems". New York: Wiley, 2002.
3. Yong-Hua Song and Xi-Fan Wang (Eds.), "Operation of Market-oriented Power Systems", Spinger-Verlag London Limited, 2003.
4. D. S. Kirschen and G. Strbac, "Fundamentals of power system economics", John Wiley & Sons, 2004.
5. NPTEL Course: https://nptel.ac.in/courses/108/101/108101005

ELE 4453: RENEWABLE ENERGY [3 0 0 3]

Course Learning Outcomes: At the end of the course, the students will be able to:

CO1	Understand various energy sources, techniques and tolls used in the field of Renewable Energy and the grid integration of renewable energy
CO2	Design and simulate the Photovoltaic system to generate power as per needs and specifications and analyze it's performance.
CO3	Design the wind energy conversion systems to generate power as per the specifications and analyze it's performance.
CO4	Design of bio-mass plant to generate power as per the specifications and analyze the performance.
CO5	Analyze the Geothermal Energy, Energy from the oceans and tidal energy conversion systems and it's application

Energy sources and their availability - Solar Energy - solar radiation and measurements, solar energy storage, - Solar Photo-Voltaic systems design - Wind Energy - estimation, Maximum power and power coefficient, wind energy conversion systems - design considerations and applications - Energy from Bio-Mass - Sources of bio-mass, Biomass conversion technologies - Thermo-chemical conversion and Biochemical conversions, Anaerobic digestion and Fermentation, Bio-gas generation Pyrolysis and Liquefaction, Classification of Gasifiers, Energy plantation -Energy from the Oceans - Ocean Thermal Energy Conversion, Open and Closed Cycle plants, Site selection considerations, Origin of tides, Tidal energy conversion systems, Wave energy conversion systems –Integration of Renewable energy in to grid, Hybrid Energy Systems.

References:

1. Khan B. H., Non-conventional Energy Resources, TMH, 2006.
2. Twidell J. W. & Weir A. D., Renewable Energy Resources, ELBS, 1986.
3. Mukherjee D. & Chakrabarti S., Fundamentals of Renewable Energy Systems, New Age Intl., 2004.
4. C.S. Solanki, Solar Photovoltaics Fundamentals, Technologies and Applications, PHI Learning Pvt. Ltd. , 2016
5. D.P. Kothari, K.C.Singal and R. Ranjan, Renewable Energy Sources and Emerging Technology, PHI Learning Pvt. Ltd. , 2014

OPEN ELECTIVES:

ELE 4311: MATLAB FOR ENGINEERS [3 0 0 3]

Course Learning Outcomes: At the end of the course, the students will be able to:

- CO1 Use MATLAB development environment for creating and solving engineering problems
- CO2 Build, simulate and analyze non-linear dynamic systems using Simulink
- CO3 Develop interactive user interface applications using App Designer
- CO4 Configure and interface external hardware using MATLAB

Introduction to MATLAB live script environment, matrices & arrays, calling functions, 2D & 3D plots, conditional statements, loop control statements, user-defined functions; evaluating an expression, solving equations, differentiation, integration, sum, limit; simple and multiple linear regression analysis, evaluating the goodness of fit using MATLAB; ordinary differential equations in Simulink, conditional blocks, subsystems, MATLAB function block, introduction to Simscape; introduction to App Designer, programming various objects like axes, botton, edit field, slider, label; interfacing Arduino, raspberry pi and smartphone sensors with MATLAB.

Self-study: Simulation studies on Symbolic Math, Statistical Methods and GUI development

References:

1. https://www.mathworks.com/
2. Stephen J. Chapman, *Essentials of MATLAB Programming*,6e, Cengage Learning 2019,
3. Rudra Pratap, *Getting Started with MATLAB,* 7e, Oxford University Press, 2019
4. Self-paced online courses - https://matlabacademy.mathworks.com/

ELE 4312: ESSENTIALS OF ENERGY AUDITING [3 0 0 3]

Course Learning Outcomes: At the end of the course, the students will be able to:

- CO1 Understand general aspects of energy management and energy audit. Choose energy projects based on financial analysis. Plan energy audits.
- CO2 Understand energy efficiency in electrical utilities. Demonstrate the importance of appropriate motor loading and speed control in fans and pumps. Suggest suitable energy conservation methods in buildings.
- CO3 Understand energy efficiency in thermal utilities. Calculate efficiencies of boilers and furnaces using direct method. Suggest appropriate technologies for improving efficiency of thermal utilities.
- CO4 Assess performance of equipment and utility systems. Measure key performance indicators of electrical and thermal utilities.
- CO5 Suggest best practices in building energy management and conservation.

Types of energy, Primary energy reserves, Commercial energy production, Energy needs of a growing economy, Electricity pricing, Tariffs, Energy security, Energy conservation. Energy conservation Act 2001, Electricity Act 2003, Energy policy, Objectives of Energy management and Auditing, Types of Energy audit, Benchmarking, Energy performance, Matching energy usage to requirement, maximizing system efficiencies, Fuel and energy substitution, Instruments and metering for energy audit, Bureau of Energy Efficiency regulations, Energy balance and material balance, Sankey diagram, Assessing energy profile and establishing baseline, Financial analysis techniques, Energy performance contracting and role of ESCOs, Project planning techniques, Energy monitoring and targeting, Energy management information systems, Energy and environment, Renewable energy sources, Demand side management.

References:

1. Guidebooks for National Certification Examination, 2020, [E-book] Available: http://aipnpc.org/Guidebooks.aspx.
2. Guidebook: Refresher Course for Certified Energy managers and Auditors, 2020, [E-book] Available: http://refreshercourse.in/Module/RC_Material.pdf
3. Wayne C. Turner, Energy Management Handbook, Fifth Edition, Fairmont Press, 2004
4. NPTEL - Energy conservation and waste heat recovery - https://nptel.ac.in/courses/112/105/112105221/

ELE 4313: SOLAR PHOTOVOLTAICS [3 0 0 3]

Course Learning Outcomes: At the end of the program the students will be able to:

CO1	Understand the sun and the Earth, Measurement and Estimation of solar irradiation
CO2	Analyse the performance of P-N junction under different conditions, introduction to solar cells
CO3	Design of solar photovoltaic modules to generate specific power, analyse the performance
CO4	Analyse the performance of different types of battery used in SPV power system
CO5	Design and MPPT control of different converters used in SPV power system

Solar Radiation: Spectrum, Terminologies, Measurement, Estimation; Sun-Earth Movement & Angles, Sun Tracking, PN Junction Diode & Characteristics, Solar Cell, Photovoltage, Light Generated Current, I-V equation & Characteristics: Short Circuit Current, Open Circuit Voltage, Maximum Power Point, Fill Factor, Efficiency, Losses, Equivalent Circuit, Effect of Series & Shunt Resistance, Solar Radiation, Temperature on Efficiency, Solar PV Modules: Series & Parallel connection, Hotspots, Bypass & Blocking Diodes, Power Output, Ratings, I-V & Power Curve, Effect of Solar Irradiation & Temperature, Balance of System (BOS): Batteries: Classification, Capacity, Voltage, Depth of Discharge, Life Cycle, Factors affecting Battery Performance; Charge Controllers, DC to DC Converters, DC to AC converters, Maximum Power Point Tracking (MPPT). Self study: Solar Radiation data collection for India , Losses in solar cells, Applications of SPV system, Mechanical Energy storage systems

References

1. Chetan Solanki, *Solar Photovoltaics: Fundamentals, Technologies and Application*, PHI New Delhi, 2009.
2. G.N. Tiwari, *Solar Energy: Fundamentals, Design, Modeling and Applications*, Narosa Publications New Delhi, 2013.
3. Suneel Deambi, *Photovoltaic System Design*, CRC Press USA, 2016.
4. Frank Kreith and D. Yogi Goswami, *Energy Management and Conservation Handbook* (2e), CRC Press USA, Fairmont Press, USA, 2017.
5. John Balfour, Michael Shaw and Nicole B. Nash, *Advanced Photovoltaic Installations*, Jones & Barlett Learning USA, 2013.
6. Nptel courses: https://nptel.ac.in/courses/115/107/115107116/

ELE 4314: INTRODUCTION TO RENEWABLE ENERGY [3 0 0 3]

Course Learning Outcomes: At the end of the course, the students will be able to:

CO1	To Understand the Need, importance and scope of non - conventional and alternate energy resources
CO2	To analyze & Understand and analysis role of solar energy and its components required to generate power for rural households
CO3	To understand major concepts of wind energy, components required to generate power
CO4	To analyze & understand Hybrid Energy system and utilization of Biogas plants.
CO5	Analyze the Geothermal energy, Energy from the oceans and tidal energy conversion systems-Application

Energy sources and their availability, current power scenario in India.
- Solar Energy - solar radiation and measurements, solar energy storage, - Solar Photo-Voltaic systems and modules. Wind Energy- estimation, Maximum power and power coefficient, wind energy conversion systems - design considerations and applications. Energy from the Oceans - Ocean Thermal Energy Conversion, Open and Closed Cycle plants, Site selection considerations, Origin of tides, Tidal energy conversion systems, Wave energy conversion systems - Hybrid Energy Systems, Life Cycle Costing. Self-Study Component standalone PV system Topology. Calculate the air parameters at different conditions, wind power and average wind power, impact of installation height Life Cycle Costing. Energy from Bio-Mass - Sources of bio-mass, Bio-mass conversion technologies - Thermo-chemical

conversion and Bio-chemical conversions, Anaerobic digestion and Fermentation: Estimate of Energy and Power in Single and Double Cycle Tidal System

References:

1. Mukherjee. D & S. Chakrabarti, Fundamentals of Renewable Energy Systems, New Age Intl., 2005
2. Khan B. H, Non conventional Energy Resources, TMH, 2006
3. Twidell J. W & Weir A. D, Renewable Energy Resources, ELBS, 1986
4. Rai G. D., Non Conventional Energy Sources, Khanna Publishers, 1997
5. Rao S & B. B Parulekar, Energy Technology, Khanna Publishers, 1997
6. Bansal N K, Kleemann M & Meliss M., Renewable Energy Sources and Conversion Technology,TMH, 1990
7. Bansal N K, Kleemann M & Meliss M., Renewable Energy Sources and Conversion Technology,TMH, 1990
8. Mohamed A. EL_Sharkawi. Wind Energy An Introduction,CRC Press Taylor & Francis Group, 2016.
9. Chetan Singh Solanki. Solar Photovoltaics Fundamentals, Technologies and Applications,PHI learning Privite Limited,2011.

ELE 4315: INTRODUCTION TO LIGHTING DESIGN [3 0 0 3]

Course Learning Outcomes: At the end of the course, the students will be able to:

CO1	Understand the fundamentals of lighting science
CO2	Analyze the importance of photometric quantities & units, and their relation for the effective design.
CO3	Evaluate conventional and solid-state lamps and their accessories for field applications
CO4	Design of energy efficient lighting systems satisfying quality and quantity standards in interior lighting applications and with the use of modern tools.
CO5	Appreciate the importance of daylight and select appropriate daylighting strategies for efficient design.

Electromagnetic spectrum, Anatomy of eye, Spectral eye sensitivity, Photometric quantities & Units, Relation between photometric quantities, Construction & working principle of artificial light sources, Performance characteristics of conventional and solid-state lamps, Optical control of light, Photometry measurements, Evaluation of total luminous flux, Generation of IES file, Light distribution diagrams of luminaires, Types of Interior lighting, Factors affecting the performance of lighting system, Lumen method of lighting design, Glare evaluation methods, Design of lighting system using simulation tool for various lighting applications, Importance of daylighting, daylighting strategies. Self-study: Comparison of photometric and radiometric quantities, Principle of operation & Performance characteristics of low-pressure gaseous discharge lamp, and Simulation assisted lighting design case studies.

References:

1. Spiros Kitsinelis, Light Sources: Technologies & Applications, CRC press, 2010
2. Robert Karlicek, Handbook of Advanced Lighting Technology, Springer Publications, 2017
3. N K Kishore, “Illumination Engineering”, NPTEL, [Online].
   Available: https://nptel.ac.in/courses/108/105/108105061/, 2009.
4. National Lighting Code, Bureau of Indian Standards, SP 72, 2010.
5. Robbins Cluade L, “Day Lighting”, VNR Company,1986.

ELE 4316: UTILIZATION OF ELECTRICAL ENERGY [3 0 0 3]

Course Learning Outcomes: At the end of the course, the students will be able to:

CO1	Identify a right drive for a particular application
CO2	Summarize different types of electrical traction systems.
CO3	Describe and calculate tractive power and specific energy consumption
CO4	Distinguish between various types of heating methods and Welding methods
CO5	Design Illumination systems for various applications

Electric traction: Railway electrification – definition and analysis of traction effort – speed – time curve – traction motors - battery driven vehicles - energy efficiency drives – advanced speed control measures- tractive effort calculations - electric braking - control wire - A.C. traction - recent trend in electric traction. Illumination: Production of light - lighting calculations - high frequency, low pressure discharge tubes. Electric furnaces and welding: Resistance, inductance and Arc Furnaces - Construction and fields of application - control equipment, high frequency dielectric heating, resistance - welding equipment - characteristics of carbon and metallic arc welding - butt welding - spot welding. Electro-chemical processes: Electrolysis – Electroplating – Electro deposition – Extraction of metals Current, Efficiency - Batteries – types – Charging Methods. Overview of Electric Vehicles in India, Vehicle Dynamics, Vehicle Subsystems: EV Power-train Storage for EVs, Fundamentals of EV. Self-study on selected topics.

References:

1. S. C. Tripathy, *Electric Energy Utilisation and Conservation*, Tata McGraw Hill , 1991
2. W. F. Stocker and J.W. Jones, *Refrigeration & Air Conditioning Refrigeration & Air Conditioning*, McGraw Hill , 1985
3. N.V. Suryanarayana, *Utilisation of Electric Power*, Wiley Eastern Ltd. , 1993
4. J. B. Gupta –Utilization of electric power and electric traction- S K Katharia & Sons, 1994
5. NPTEL Course: https://onlinecourses.nptel.ac.in/noc22_ee53/preview