EC (1282) - 29.04.2026

Appendix-92
Resolution No. 4-1-7

Department of Electrical Engineering
Faculty of Technology
University of Delhi
Detailed Course Structure and Curriculum of B.Tech. (EE) Fourth Year

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Course Structure of B. Tech. (EE) Fourth Year

Semester VII						
S. No.	**Course Domain**	**Course Title**	**Credits***			**Total Credits**
			L	**T**	**P**	
1	DSC-19	Electrical Drives	3	0	1	4
2	DSE-05	Select a course from the specified list of DSE-05				4
3	DSE-06/ GE-07	Select a course from the specified list of DSE-06/ GE-07				4
4	DSE-07/ GE-08	Select a course from the specified list of DSE-07/ GE-08				4
5	Dissertation on Major OR Dissertation on Minor OR Academic project/ Entrepreneurship					6
					Total Credits	**22**

Semester VIII						
S. No.	**Course Domain**	**Course Title**	**Credits***			**Total Credits**
			L	**T**	**P**	
1	DSC-20	Power Quality and FACTS	3	0	1	4
2	DSE-08	Select a course from the specified list of DSE-08				4
3	DSE-09/ GE-09	Select a course from the specified list of DSE-09/ GE-09				4
4	DSE-10/ GE-10	Select a course from the specified list of DSE-10/ GE-10				4
5	Dissertation on Major OR Dissertation on Minor OR Academic project/ Entrepreneurship					6
					Total Credits	**22**

**Credits*
L (01 Credit) is equivalent to 01 contact hour per week.
T (01 Credit) is equivalent to 01 contact hour per week.
P (01 Credit) is equivalent to 02 contact hours per week.

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Pool of DSEs offered by the Department of Electrical Engineering in Fourth Year

S. No.	Semester	DSE	DSE
1.	VII	DSE-05	Advanced Power System Analysis
2.			Cyber Security for Smart Grid
3.		DSE-06	High Voltage Engineering
4.			Power System Optimization
5.		DSE-07	Advanced Power Converters
6.			Modern Distribution System Design
7.	VIII	DSE-08	HVDC Transmission
8.			Net Zero Building Design
9.		DSE-09	Generalized Machine Theory
10.			Power System Security
11.		DSE-10	Analytical Instrumentation
12.			Biomedical Instrumentation

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Specializations and Minor offered by the Department of Electrical Engineering

S. No.	Sem	GE	Minor in EE (Open only for CSE/ECE)	Specializations for EE / Minors for ECE/CSE		
				Robotics & Automation	**Sustainable Energy Engineering**	**Electric and Hybrid Vehicle**
1	VII	DSE-06/ GE-07	Element of Electrical Power System	Nonlinear Control System	Machine Learning Applications in Sustainable Energy Development	Electro-Chemistry of Fuel Cells
2	VII	DSE-07/ GE-08	Control System Applications in Electrical Engineering	Digital Robotic Control	Control of Renewable Energy Integrated Systems	Modeling and Simulation of EHV
3	VIII	DSE-09/ GE-09	Power Plant Engineering	Real Time Embedded System	Smart Energy Storage System	Embedded Based Smart System Design
4			Machine Learning Applications in Electrical Engineering	Process Control	Wind and Small Hydro Power Generation	Computer Aided Design of Electric Machines
5	VIII	DSE-10/ GE-10	Clean Energy Technologies	Optimal and Robust Control	Smart Grid Technologies	EV Charging Infrastructure
6			Introduction to Smart Grid	Robotics in Biomedical Engineering	Energy Management Systems and SCADA	Electrical Vehicle System Design

Detailed Syllabus of Discipline Specific Core (DSC) Courses of B. Tech. (EE) – SEMESTER VII

Electrical Drives (DSC-19)

(Credit Distribution and Pre-Requisites of the Course)

Course title	Credits	Credit distribution of the course			Prerequisite of the course (if any)
		Lecture	Tutorial	Practical	
Electrical Drives	4	3	0	1	Power Electronics, Electrical Network Analysis, Electric Machine I

Course Objectives:

1. Describe the components of the Electric Drives System and their choice criterion.
2. Analyze the steady state and transient stability of Electric Drives
3. Understand the various control techniques for electric drive systems.
4. Select the particular motor according to the duty it is used in drives
5. Comprehend the basic concepts of DC & AC drives and know their characteristics.

Course Outcomes:

At the end of this course, students will demonstrate the ability to:

1. After studying the basic concepts of electric drives.
2. Understanding of power circuit configuration of the phase-controlled rectifiers and choppers for the speed control of DC motor drives.
3. Design static Scherbius and Kramer drives to implement slip power recovery schemes
4. Design and implementation of synchronous motor drives with fixed frequency and variable frequency sources

UNIT-I ***(13 hours)***

Fundamentals Of Electric Drives

Electrical drives and introduction: Electric drives, advantages of electrical drives, parts of electrical drives, and choice of electrical drives. Types of loads, load with translational motion, load with rotational motion, load torque that varies with time, Selection of Motor Power Rating.

Dynamics Of Electrical Drives

Fundamental torque equation, speed-torque convention, and multi-quadrant operation, dynamics of motor load combination, nature and classification of load torque, measurement of moment of inertia, calculation of acceleration time in transient operation, acceleration time for specific nature of motor and load torque, load equalization, stability of electrical drives

UNIT-II ***(12 hours)***

Rectifier control of DC drives- separately excited DC motor drives using controlled rectifiers single-phase fully controlled rectifier fed drives (discontinuous and continuous mode of operation), critical speed - single-phase semi converter fed drives (continuous mode of operation) - three-phase semi converter and fully controlled converter fed drives (continuous mode of operation) - dual converter control of DC motor - circulating current mode.

Chopper control of DC drives - two-quadrant and four-quadrant chopper drives - motoring and regenerative braking - chopper-fed DC series motor drive - closed-loop speed control for separately excited DC motor.

UNIT-III ***(08 hours)***

Three phase induction motor drives: Stator voltage control - Stator frequency control – v/f control - below and above base speed – Voltage Source Inverter (VSI) fed v/f control using sine-triangle PWM - static rotor resistance speed control employing chopper – static slip power recovery speed control scheme for speed control below synchronous speed.

UNIT-IV ***(12 hours)***

Concept of space vector – Clarke and Park transformation – field orientation principle – Introduction to direct vector control of induction motor drives – decoupling of flux and torque components - space vector diagram and block diagram**.**

Three Phase Synchronous Motors

Review of Three phase Synchronous Motor and its performance, self-controlled schemes, Variable frequency control of multiple synchronous motor, Permanent magnet AC motor drives, Brushless DC Motor Drives

Essential Readings:

1. G. K. Dubey*, Fundamentals of Electrical Drives*, Narosa Publishing House (2nd Edition, 2008 or later).
2. R. Krishnan, *Electric Motor Drives: Modeling, Analysis, and Control*, Pearson Education.
3. Werner Leonhard, *Control of Electrical Drives*, Springer (3rd Edition, 2001).
4. Vedam Subrahmanyam, *Electrical Drives: Concepts and Applications*, McGraw Hill / TMH.
5. B. K. Bose, *Modern Power Electronics and AC Drives*, Pearson Publication.

Suggested Readings:

1. P. C. Sen, *Principles of Electric Machines and Power Electronics*, John Wiley & Sons, 3rd Edition.
2. M. H. Rashid, *Power Electronics: Circuits, Devices, and Applications*, Prentice Hall / Pearson.
3. N. Mohan, T. M. Undeland, and W. P. Robbins, *Power Electronics: Converters, Applications, and Design*, John Wiley & Sons, 3rd Edition.
4. Bin Wu and Mehdi Narimani, *High-Power Converters and AC Drives*, Wiley-IEEE Press, 2nd Edition, 2017.
5. P. Vas, *Sensorless Vector and Direct Torque Control*, Oxford University Press.

Practical Component: ***(30 Hours)***

List of Experiments:

1. Study of speed control of Thysistor controlled DC Drive.
2. Study of speed control of Chopper-fed DC Drive
3. Experimental studies on different types of braking of separately excited DC motor. (a) Dynamic braking (b) Plugging
4. Study of PWM Inverter fed 3 phase Induction Motor control.
5. Study of VSI / CSI fed Induction motor Drive.
6. Study of V/f control of 3phase Induction motor drive.
7. Study of permanent magnet synchronous motor drive fed by PWM Inverter.
8. Study of Regenerative / Dynamic braking operation for DC Motor.
9. Study of Regenerative / Dynamic braking operation of AC motor.
10. Study of PC/PLC based AC/DC motor control operation.

(Note: Course instructor may add/delete/update new experiments in addition to the above suggested practical exercise.)

Detailed Syllabus of Discipline Specific Elective (DSE) courses for B.Tech. (EE) – SEMESTER VII

Advanced Power System Analysis (DSE-05)

(Credit Distribution and Pre-Requisites of the Course)

Course title	**Credits**	**Credit distribution of the course**			**Prerequisite of the course (if any)**
		Lecture	**Tutorial**	**Practical**	
Advanced Power System Analysis	4	3	0	1	Power System Analysis

Course Objectives:

1. To analyze a Power System Network using graph theory.
2. To interpret the formation of Network matrices.
3. To construct the necessity of load flow studies and various methods of Analysis.
4. To understand the contingency.
5. To formulate the power system matrix for an unbalanced system.

Course Outcomes:

At the end of this course, students will demonstrate the ability to:

1. Formulate Y_{BUS} and Z_{BUS} matrices for power network analysis, including modifications and coupled branches.
2. Apply load flow methods (Gauss-Seidel, N-R, decoupled, DC) to solve transmission and load flow for distribution systems.
3. Perform contingency analysis for single/multiple outages using piecewise and reduction techniques.
4. Analyze three-phase unbalanced systems and faults in the phase domain.

UNIT-I ***(15 hours)***

Introduction:

Admittance Model and Network Calculations, Branch and Node Admittances, Mutually Coupled Branches in Y_{BUS}, An Equivalent Admittance Network, Modification of Y_{BUS}, Network Incidence Matrix and Y_{BUS}, Sparsity and Near Optimal Ordering. Impedance Model and Network Calculations, the Bus Admittance and Impedance Matrices, Thevenin’s Theorem and Z_{BUS}, Algorithms for building Z_{BUS}, Modification of existing Z_{BUS}, Calculation of Z_{BUS} elements from Y_{BUS}, Power Invariant Transformations, Mutually Coupled Branches in Z_{BUS}.

UNIT-II ***(12 hours)***

Computer-based load flow analysis: Gauss-Seidel method, N-R Method, Decoupled method, fast decoupled method, comparison between power flow solutions. DC load flow. Load flow for distribution systems.

UNIT-III ***(10 hours)***

Contingency Analysis, Adding and Removing Multiple Lines, Piecewise Solution of Interconnected Systems, Analysis of Single Contingencies, Analysis of Multiple Contingencies, System Reduction for Contingency and Fault Studies.

UNIT-IV ***(08 hours)***

Formulation of the Y_{BUS} matrix of a three-phase unbalanced system, Fault Analysis: Fault analysis in the phase domain.

Essential Readings:

1. John J. Grainger and W. D. Stevenson, "Power System Analysis", McGraw-Hill Education.
2. I. J. Nagrath and D. P. Kothari, "Modern Power System Analysis", McGraw Hill Publishing Company Ltd, 2nd Edition.
3. J. Duncan Glover and M.S. Sarma, "Power System Analysis and Design", Nelson Engineering.
4. Abhijit Chakrabarti and Sunitha Halder, "Power Systems Analysis, operation and control", PHI Learning Pvt. Ltd.

Suggested Readings:

1. Olle. L. Elgerd, "Electrical Energy Systems Theory", McGraw Hill Education.
2. Prabha Kundur, "Power Systems Stability and Control", McGraw-Hill Publishing Company Ltd.
3. K. Uma Rao, "Power System Operation and Control", Wiley India Pvt. Ltd.
4. P.S.R. Murthy, "Operation and Control in Power Systems", BS Publications.
5. Robert H. Miller and Jamesh H. Malinowski, "Power System Operation", McGraw-Hill Professional Pub.

Practical Component: ***(30 Hours)***

List of Experiments:

1. Build Y_{BUS} from branch/node data and verify sparsity using the incidence matrix.
2. Construct Z_{BUS} by building algorithms and computing elements from YBUS.
3. Implement Gauss-Seidel load flow and compare convergence with Newton-Raphson, decoupled, and fast decoupled methods for large system power flow.
4. Develop a DC load flow model for quick active power assessment.
5. Analyze single contingencies by line removal and performance metrics.
6. Evaluate multiple contingencies with piecewise interconnected solutions.
7. Formulate a three-phase YBUS and perform phase-domain fault analysis.
8. Formulate a load flow for unbalanced systems.

(Note: Course instructor may add/delete/update new experiments in addition to the above suggested practical exercise.)

Cyber Security for Smart Grid (DSE-05)

(Credit Distribution and Pre-Requisites of the Course)

Course title	Credits	Credit distribution of the course			Prerequisite of the course (if any)
		Lecture	Tutorial	Practical	
Cyber Security for Smart Grid	4	3	0	1	Introduction to Electrical and Electronics Engineering

Course Objectives:

1. Introduce students to the architecture, operation, and evolution of the smart electric grid as a cyber-physical system.
2. Provide fundamental knowledge of sensing, communication, and control technologies used in smart grids.
3. Familiarize students with basic cybersecurity concepts, threats, and vulnerabilities in smart grid environments.
4. Enable students to understand common cyber-attacks and basic protection mechanisms used in power system applications.

Course Outcomes:

At the end of this course, students will demonstrate the ability to:

1. Explain the operational structure and key components of a smart grid.
2. Describe sensing, communication, and networking principles used in smart grid systems.
3. Identify major smart grid communication and control protocols used in power systems.
4. Analyze basic cybersecurity threats and vulnerabilities affecting smart grid infrastructure.
5. Understand fundamental security mechanisms and real-world cyber-attack case studies in smart grids.

UNIT-I ***(13 hours)***

Smart Grid Fundamentals: Overview of the conventional electric power grid and its operation, causes of failures and disturbances in power grid operation, learning from historical blackout events and grid failures, evolution toward the smart grid.

Cyber-Physical Systems: Smart grid architecture and its classification as a cyber-physical system, key components of a smart grid: sensors, control systems, and information and communication technologies, introduction to cybersecurity challenges in smart grids, organizational structures for ensuring system reliability, role of standards and interoperability.

UNIT-II ***(12 hours)***

Sensing: Sensing and measurement in smart grids, introduction to Phasor Measurement Units (PMUs): need, basic working principle, applications, and time synchronization, smart meters and their role in advanced metering infrastructure.

Communication and Networking: Communication infrastructure in smart grids, communication performance parameters: propagation delay, transmission delay, queuing delay, jitter, data loss, and corruption, layered communication models: OSI and TCP/IP, overview of physical, data link, network, transport, and application layers with relevance to smart grid communication.

UNIT-III ***(10 hours)***

Smart Grid Communication Protocols: Introduction to power system application-layer protocols, SCADA systems and their importance in monitoring and control, overview of SCADA communication protocols: DNP3 and IEC 61850, Inter-Control Center Communication Protocol (ICCP), synchro phasor communication standard IEEE C37.118, communication requirements for smart metering and distributed energy resources.

Control Infrastructure: Conventional and modern control centers, introduction to fault-tolerant computing, basic concepts of cloud computing in smart grid control centers.

UNIT-IV ***(10 hours)***

Cybersecurity Fundamentals, Attacks, and Protection in Smart Grid: Basic cybersecurity concepts: threats, vulnerabilities, and risks in power systems, CIA triad: confidentiality, integrity, and availability, privacy concerns and consumer data protection in smart grids, introduction to cryptography concepts: encryption, authentication, symmetric and asymmetric encryption, digital signatures, and certificates, overview of cybersecurity standards such as IEC 62351 and NERC CIP, common network attacks on smart grids: Denial-of-Service, spoofing, and malware, basic protection mechanisms: firewalls, intrusion detection systems, and secure communication protocols, case studies of major cyber-attacks on power grids including Stuxnet and the Ukraine power grid attack.

Essential Readings:

1. A.K. Srivastava, V. Venkataramanan, C. Hauser, Cyber Infrastructure for the Smart Electric Grid, Willey-IEEE Press.
2. A. Sreejith, K.S. Swarup, Cyber-Security for Smart Grid Control: Vulnerability Assessment, Attack Detection, and Mitigation, Transactions on Computer Systems and Networks, Springer.
3. S. Sridhar, A. Hahn, and M. Govindarasu, Cyber-Physical System Security for the Smart Grid, Elsevier.

Suggested Readings:

1. Eric D. Knapp and Joel T. Langill, Industrial Network Security, Syngress.
2. William Stallings, Cryptography and Network Security: Principles and Practice, Pearson Education.

Practical Component: ***(30 Hours)***

List of Experiments:

1. To study the architecture and components of a smart grid using simulation tools.
2. To model a basic power distribution system and observe its operation under normal conditions.
3. To study the working and applications of Phasor Measurement Units (PMUs).
4. To analyze communication delay, jitter, and packet loss in a simple smart grid communication network.
5. To study OSI and TCP/IP protocol layers using network simulation tools.
6. To simulate basic SCADA communication using DNP3 or IEC 61850 concepts.
7. To analyze the impact of Denial-of-Service (DoS) attacks on smart grid communication networks.
8. To demonstrate spoofing attacks and their effects on network communication.
9. To study basic encryption and authentication techniques for securing smart grid data.
10. To implement a simple firewall or intrusion detection mechanism for smart grid communication.
11. To analyze real-world smart grid cyber-attack case studies and propose basic mitigation measures.

(Note: Course instructor may add/delete/update new experiments in addition to the above suggested practical exercise.)

High Voltage Engineering (DSE-06)

(Credit Distribution and Pre-Requisites of the Course)

Course title	Credits	Credit distribution of the course			Prerequisite of the course (if any)
		Lecture	Tutorial	Practical	
High Voltage Engineering	4	3	0	1	Mathematics-I, Electromagnetic Field Theory

Course Objectives:

1. To know about generation voltages and currents to test the electrical equipment.
2. To understand the general aspects of electrical testing methods.
3. To understand the need for testing and procedures of the electrical devices.
4. To understand the need for high voltages, high currents, and transients.

Course Outcomes:

At the end of this course, students will demonstrate the ability to:

1. Understand the general aspects of electrical testing methods.
2. Analyze various generation and measurement techniques for high Voltages and Currents.
3. Identify the overvoltages in power systems and outline the principles of insulation coordination for various parts of the power system.
4. Analyze various generation and measurement techniques for high Voltages and Currents.

UNIT-I ***(10 hours)***

Introduction to High Voltage Engineering: Electric field stresses. Gas/Vacuum as an insulator, Liquid dielectrics. Solids and composites, Estimation and control of Electric stress, Numerical methods for electric field computation. Surge voltages, their distribution and control, Applications of insulation materials in transformers, rotating machines, circuit breakers, cables, power capacitors, and bushings.

UNIT-II ***(11 hours)***

Generation of High Voltages: Generation of high direct voltages, half and full wave rectifier circuits, voltage multiplier circuits, Van de Graff generators, electrostatic generators, examples - generation of alternating voltages, testing transformers, cascaded transformers, resonant transformers, examples - impulse voltages, Standard lightning and switching surge and associated parameters and their corrections, impulse voltage generator circuits, Marx circuit, operation, design and construction of impulse generators, examples - impulse current generator - control systems.

UNIT-III ***(12 hours)***

Measurement and Testing: Measurement of high voltages: Sphere gaps, factors affecting sphere gap measurements, correction factors. Measurement of high AC voltage: Capacitance voltage dividers, Chubb-Fortescue method, CVT, electrostatic voltmeters. Measurement of high DC voltage: Resistive voltage dividers, Generating voltmeter. Measurement of impulse voltage: Capacitance divider, Impedance matching. Measurement of transient currents: Resistive shunt, Magnetic coupling, Hall Effect current transducers, Integrating and differentiating type Rogowski coils. Digital techniques in HV measurements, DSO.

UNIT-IV ***(12 hours)***

Insulation Materials and Breakdown: Introduction to solid, liquid and gaseous insulators used in power equipment. Classifications of insulation based on temperature withstand limits, dielectric losses, ageing of insulation materials (paper–press board) and remaining life analysis. Applications of nanofilled materials for outdoor and indoor insulation. Introduction to solid, liquid and gaseous dielectrics. Breakdown in gas and gas mixtures-breakdown in uniform and non-uniform fields-Paschen's law-Townsends criterion-streamer mechanism-corona discharge-breakdown in electro negative gases. Breakdown in liquid dielectrics-suspended particle mechanism. Breakdown in solid dielectrics - intrinsic, streamer and thermal breakdown.

Essential Readings:

1. Kuffel and Zaengl, High Voltage Engineering Fundamentals, 2nd ed., Newness, 2002.
2. M. S. Naidu, V. Kamaraju, High Voltage Engineering, 3rd ed., McGraw-Hill,1995.
3. M. Khalifa, High Voltage Engineering: Theory and Practice, Dekker, 1990.

Suggested Readings:

1. H. M. Ryan, High Voltage Engineering and Testing, IEE 2001.
2. Wadhwa C L, High Voltage Engineering, New Age International, New Delhi,1994.

Practical Component: ***(30 hours)***

List of Experiments:

1. AC, DC and impulse breakdown test of solid insulation.
2. Oil breakdown test using oil test kit.
3. Capacitance and tanδ measurement of insulator.
4. Dielectric characteristics of solid insulating material using impedance analyzer.
5. Measurement of insulation resistance of cable.
6. Mapping of electric field lines between two charges using MATLAB
7. Simulation of dc/impulse voltage generation circuits using PSPICE/PSCAD.
8. Preparation of epoxy nanocomposite plotting the electrical field distribution in an insulating material using COMSOL (with and without void).
9. Field distribution between plates of a parallel plate capacitor using ANSYS and COMSOL using Finite Element Method.

(Note: Course instructor may add/delete/update new experiments in addition to the above suggested practical exercise.)

Power System Optimization (DSE-06)

(Credit Distribution and Pre-Requisites of the Course)

Course title	**Credits**	**Credit distribution of the course**			**Prerequisite of the course (if any)**
		Lecture	**Tutorial**	**Practical**	
Power System Optimization	4	3	0	1	Power System Analysis

Course Objectives:

1. Understand feed-forward neural networks, feedback neural networks, and learning techniques.
2. Understand Non-linear problems.
3. Understand the concept of metaheuristic algorithm.
4. Develop genetic algorithm for applications in electrical engineering.

Course Outcomes:

At the end of this course, students will demonstrate the ability to:

1. Explain linear and non-linear optimization methods, including basic LP and NLP techniques.
2. Describe feed-forward and feedback neural networks and related AI concepts.
3. Formulate and solve multistage decision problems using dynamic programming.
4. Design and apply genetic algorithms for constrained and unconstrained optimization problems.
5. Use classical methods and genetic algorithms to solve and interpret key power system problems such as load flow, ELD, unit commitment, reactive power optimization, and OPF.

UNIT-I ***(10 hours)***

Introduction:

Introduction to Artificial Neural Networks, Artificial Intelligence and Neural networks, Introduction to optimization and classical optimization techniques. Linear Programming: Standard form, geometry of LPP, Simplex Method pf solving LPP, revised simplex method, duality, decomposition principle, and transportation problem.

UNIT-II ***(08 hours)***

Non-Linear Problem (NLP):

One dimensional method, Elimination methods, Interpolation methods, Unconstrained optimization techniques-Direct search and Descent methods, constrained optimization techniques, direct and indirect methods.

UNIT-III ***(12 hours)***

Dynamic Programming:

Multistage decision processes, concept of sub-optimization and principle of optimality.

Genetic Algorithm:

Introduction to genetic Algorithm, working principle, coding of variables, fitness function. GA operators; Similarities and differences between Gas and traditional methods; Unconstrained and constrained optimization using Genetic Algorithm, real coded gas, Advanced Gas, global optimization using GA.

UNIT-IV ***(15 hours)***

Applications to Power System-I:

Load flow studies, Economic Load Dispatch in thermal and Hydro-thermal system using GA and classical optimization techniques.

Applications to Power System-II:
Unit commitment problem, reactive power optimization. Optimal power flow, LPP and NLP techniques to optimal flow problems.

Essential Readings:

1. S. S.Rao, “Optimization - Theory and Applications”, Wiley-Eastern Limited.
2. David G. Luenberger, “Introduction of Linear and Non-Linear Programming”, Addison Wesley Publishing Company.
3. E. Polak, “Computational methods in Optimization”, Academic Press Inc.
4. L.P. Singh, “Advanced Power System Analysis and Dynamics”, New Age International Private Limited.

Suggested Readings:

1. Donald A. Pierre, “Optimization Theory with Applications”, Dover Publications.
2. Kalyanmoy Deb, “Optimization for Engineering Design: Algorithms and Examples”, PHI Publication.
3. D. E. Goldberg, “Genetic Algorithm in Search Optimization and Machine Learning”, Addision-Wesley Publication.

Practical Component: ***(30 Hours)***

List of Experiments:

1. To formulate and solve linear programming problems using the simplex method and compare manual and software-based solutions for selected electrical engineering cases.
2. To implement and analyze one-dimensional and unconstrained non-linear optimization methods (e.g., line search / direct search) for standard test functions relevant to engineering problems.
3. To model a multistage decision problem and apply dynamic programming to demonstrate the principle of optimality for a simple resource allocation or scheduling task.
4. To design and implement a basic genetic algorithm, including coding of variables, fitness function, and genetic operators, for solving an unconstrained optimization problem.
5. To apply genetic algorithms and classical optimization techniques for Economic Load Dispatch of a thermal power system and compare their performance in terms of cost and convergence.
6. To formulate and solve the unit commitment or optimal power flow problem using suitable optimization techniques (LPP/NLP or GA) and analyze the impact of constraints on system operation.
7. To model and train a simple feed-forward neural network for an engineering function approximation or classification task, and study the effect of learning parameters on performance.
8. To apply optimization techniques and genetic algorithms to reactive power optimization or voltage profile improvement in a small test power system and evaluate the resulting system performance.

(Note: Course instructor may add/delete/update new experiments in addition to the above suggested practical exercise.)

Advanced Power Converters (DSE-07)

(Credit Distribution and Pre-Requisites of the Course)

Course title	Credits	Credit distribution of the course			Prerequisite of the course (if any)
		Lecture	Tutorial	Practical	
Advanced Power Converters	4	3	0	1	Power Electronics, Electrical Network Analysis, Electric Machine

Course Objectives:

This course covers

1. Advanced converter topologies.
2. Resonant and dual-active bridge converters.
3. Impedance source converters.
4. Power electronics applications in high-performance systems.

Course Outcomes:

At the end of this course, students will demonstrate the ability to:

1. To understand isolated and non-isolated converter topologies, resonant converters, and advanced DAB configurations.
2. To analyze converter modeling, impedance source converters, and control strategies for high-performance applications.
3. To design advanced power converters, including resonant and multilevel impedance source converters.
4. To evaluate converter efficiency, power flow control, and system performance under various operating conditions.

UNIT-I ***(13 hours)***

Introduction: Basics isolated and non-Isolated converter topologies, advantages and disadvantages, state- space and small signal modeling of the basic converter topology, Introduction to advanced converter topologies such as multilevel converter, resonant converter, dual active bridge, matrix converter, overview of power electronics converters application.

Higher Order Converters and Mult quadrant Operation - Boost Circuit, Two- Stage, Three-Stage, Higher Stage Boost Circuit, Introduction to double and triple Boost Circuit; Circuit Description, Discontinuous Region, Switched Component Converters, Switched Capacitors DC/DC Converters, Switched Inductor Four-Quadrant DC/DC Converter, Continuous Mode, Discontinuous Mode.

UNIT-II ***(12 hours)***

Resonant Converter: Introduction, need of Resonant Power Converter; Resonant Converter Applications; Overview of Resonant, Quasi-Resonant and Zero-Transition Converter Topologies; Design Considerations Rectifiers: Basics and types of Rectifiers; Current Rectifiers; Voltage Rectifiers; Series / Parallel Resonant Inverters: Introduction, Series Resonant Inverters, Parallel Resonant Inverters, Series-parallel Resonant Inverters; Resonant DC-DC Converters: Series Resonant Converters, Parallel Resonant Converters, Series-Parallel Resonant converters, LLC Converters, Bidirectional CLLC Converters.

UNIT-III ***(08 hours)***

Dual Active Bridge Converters: Basic principles and configurations of Dual Active Bridge (DAB) converters; Comparison with other converter topologies; Converter Modeling and Analysis: Small-signal modeling of DAB converters, Analysis of steady-state and transient behavior, Power flow analysis and efficiency optimization techniques; Control Strategies for DAB Converters: Voltage and current control techniques, Phase-shift modulation and its implementation**.**

UNIT-IV ***(12 hours)***

Introduction to Special Machine Drives & Synchronous motors Drive: Construction, operation from fixed frequency supply –starting, speed-torque characteristics, pulling in, braking of motor various special motors such as Synchronous Motor, BLDC, Switch Reluctance Motor, PMSM. Variable speed Drives. Self-controlled synchronous motor drive employing load commutated inverter. brushless dc motor controllers–rotor position measurement, commutation logic, speed controller.

Essential Readings:

1. Bin Wu and Mehdi Narimani, *High-Power Converters and AC Drives*, Wiley-IEEE Press, 2nd Edition, 2017.
2. Ned Mohan, Tore M. Undeland, and William P. Robbins, *Power Electronics: Converters, Applications, and Design*, John Wiley & Sons, 3rd Edition, 2003.
3. M. H. Rashid (Ed.), *Power Electronics Handbook*, Butterworth-Heinemann / Elsevier, 5th Edition, 2017.
4. D. Grahame Holmes and Thomas A. Lipo, *Pulse Width Modulation for Power Converters: Principles and Practice*, IEEE Press / Wiley, 2003.

Suggested Readings:

1. Robert W. Erickson and Dragan Maksimović, *Fundamentals of Power Electronics*, Springer, 2nd Edition, 2001.
2. Jose Rodriguez and Patricio Cortes, *Predictive Control of Power Converters and Electrical Drives*, Wiley-IEEE Press, 2012.
3. B. K. Bose, *Modern Power Electronics and AC Drives*, Pearson Education, 2002.
4. L. Umanand, *Power Electronics: Essentials and Applications*, John Wiley India, 2009.

Practical Component: ***(30 Hours)***

List of Experiments:

1. Simulation and analysis of basic isolated (flyback, forward) and non-isolated (buck, boost, buck-boost) converter topologies: Compare advantages/disadvantages, efficiency, and ripple using MATLAB/Simulink.
2. State-space modeling and small-signal analysis of a basic boost converter; verify step response and stability.
3. Simulation of higher-order boost converters (two-stage, three-stage, or quadratic boost): Study voltage gain, continuous/discontinuous modes, and comparison with conventional boost.
4. Simulation of switched-capacitor or switched-inductor DC-DC converters; analyze four-quadrant operation (e.g., switched-inductor four-quadrant converter in continuous and discontinuous modes).
5. Overview simulation: Multilevel converter (e.g., cascaded H-bridge or diode-clamped) and basic resonant converter topology; compare with conventional converters for applications like renewables.
6. Simulation of series-parallel resonant inverter and resonant DC-DC converters (series, parallel, and series-parallel types).
7. Design and simulation of LLC resonant converter: Study gain characteristics, soft-switching, and efficiency optimization.
8. Simulation of bidirectional CLLC resonant converter: Analyze power flow in both directions and compare with LLC.
9. Simulation of single-phase Dual Active Bridge (DAB) converter: Implement phase-shift modulation, analyze power flow, steady-state behavior, and efficiency.
10. Small-signal modeling and control of DAB converter: Simulate voltage/current control strategies and transient response.
11. Simulation of self-controlled synchronous motor drive using load-commutated inverter or brushless DC motor (BLDC) controller: Study rotor position sensing, commutation, and speed control.

(Note: Course instructor may add/delete/update new experiments in addition to the above suggested practical exercise.)

Modern Distribution System Design (DSE-07)

(Credit Distribution and Pre-Requisites of the Course)

Course title	Credits	Credit distribution of the course			Prerequisite of the course (if any)
		Lecture	Tutorial	Practical	
Modern Distribution System Design	4	3	0	1	Power Transmission and Distribution

Course Objectives:

1. Understand the components of electric power distribution systems.
2. Modelling of different distribution system components.
3. Understand the analysis methods, specially developed for the distribution system.
4. Understand the distribution system protection devices.
5. Understand the components of distribution automation systems.

Course Outcomes:

At the end of this course, students will demonstrate the ability to:

1. Understand the structure and components of modern electric power distribution systems.
2. Develop basic skills for modeling key distribution system elements such as lines, transformers, regulators, capacitors, and DG units.
3. Grasp and apply analysis methods specifically developed for radial and weakly meshed distribution networks, including load-flow techniques.
4. Understand the principles, operation, and coordination of distribution protection devices.
5. Gain foundational knowledge of distribution automation systems and their role in improving reliability and system performance.

UNIT-I ***(05 hours)***

Structure of a distribution system, Distribution feeder configurations and substation layouts, Nature of loads.

UNIT-II ***(15 hours)***

Approximate methods of analysis, Computation of transformer and feeder loading, “K” Factors, voltage drop and power loss calculations, Distribution of loads, and various geometric configurations.

UNIT-III ***(10 hours)***

Modelling of distribution system components, Overhead lines, feeders and cables, Single and three phase distribution transformers, Voltage regulators, Load models, Capacitor banks, Distributed generation.

UNIT-IV ***(15 hours)***

Distribution system analysis, Load flow analysis:
Backward/forward sweep, Load flow analysis: Direct approach, Load flow analysis: Direct approach for weakly meshed systems.

Distribution system protection

Distribution system protection devices, Problems in distribution systems, and the need for automation.

Essential Readings:

1. Turan Gonen, “Electric Power Distribution System Engineering”, CRC Press.
2. A. S. Pabla, “Electric Power Distribution”, McGraw-Hill Publication.

3. James A Momoh, “Electric Power Distribution, Automation, Protection and Control”, CRC Press.

Suggested Readings:

1. Abdelhay A. Sallam and Om P. Malik, “Electric Distribution Systems”, Wiley Publication.
2. William H. Kersting, “Distribution System Modeling and Analysis”, CRC Press.
3. Subrahmanyam S. Venkata, Anil Pahwa, “Electric Power and Energy Distribution Systems Models, Methods, and Applications”, John Wiley & Sons.

Practical Component: ***(30 Hours)***

List of Experiments:

1. Study of Radial and Ring Feeder Configurations; measure voltage profiles and load currents under balanced/unbalanced residential loads to observe feeder performance.
2. Model single-bus and double-bus substation arrangements; analyze fault isolation and load transfer between feeders with varying load natures.
3. Calculate the voltage drop and power loss in a feeder.
4. Load a single-phase distribution transformer with stepped loads; calculate efficiency, "K" factors, and geometric load distribution while measuring voltage regulation.
5. Measure R, L, and C parameters of overhead lines and underground cables using an LCR meter; simulate capacitance effects and compare voltage profiles with Carson's equations.
6. Implement on-load tap-changing regulators and switched capacitors on a feeder; observe power factor improvement and voltage stability under varying loads.
7. Simulate radial distribution load flow; iterate backward current summation and forward voltage updates for a 33/11 kV feeder with DG integration.
8. Program matrix-based direct method for feeders; compare convergence with backward/forward sweep and analyze voltage profiles in unbalanced systems.

(Note: Course instructor may add/delete/update new experiments in addition to the above suggested practical exercise.)

Detailed Syllabus of Discipline Specific Core (DSC) courses for B.Tech. (EE) – SEMESTER VIII

Power Quality and FACTS (DSC-20)

(Credit Distribution and Pre-Requisites of the Course)

Course title	Credits	Credit distribution of the course			Prerequisite of the course (if any)
		Lecture	Tutorial	Practical	
Power Quality and FACTS	4	3	0	1	Power Systems, Power Electronics, Electrical Machines, Control Systems

Course Objectives:

1. To understand the characteristics of AC transmission and the effect of shunt and series reactive compensation.
2. To understand the working principles of FACTS devices and their operating characteristics.
3. To understand the basic concepts of power quality.
4. To understand the working principles of devices to improve power quality.
5. To solve numerical problems on the topics studied

Course Outcomes:

At the end of this course, students will demonstrate the ability to:

1. Analyse the uncompensated AC transmission line.
2. Explain the working principles of FACTS devices and their operating characteristics.
3. Apply FACTS devices for power flow control and stability.
4. Identify different issues of power quality in the distribution system.
5. Apply different compensation and control techniques for DSTATCOM6. explain the working principle of the dynamic voltage restorer and UPQC.

UNIT-I ***(12 hours)***

Transmission Lines and Series/Shunt Reactive Power Compensation: Basics of AC Transmission. Analysis of uncompensated AC transmission lines. Passive Reactive Power Compensation. Shunt and series compensation at the mid-point of an AC line. Comparison of Series and Shunt Compensation.
Thyristor-based Flexible AC Transmission Controllers (FACTS): Description and Characteristics of Thyristor-based FACTS devices: Static VAR Compensator (SVC), Thyristor Controlled Series Capacitor (TCSC), Thyristor Controlled Braking Resistor and Single Pole Single Throw (SPST) Switch. Configurations/Modes of Operation, Harmonics and control of SVC and TCSC. Fault Current Limiter.

UNIT-II ***(12 hours)***

Voltage Source Converter based (FACTS) controllers: Voltage Source Converters (VSC): Six Pulse VSC, Multi-pulse and Multi-level Converters, Pulse-Width Modulation for VSCs. Selective Harmonic Elimination, Sinusoidal PWM and Space Vector Modulation. STATCOM: Principle of Operation, Reactive Power Control: Type I and Type II controllers, Static Synchronous Series Compensator (SSSC) and Unified Power Flow Controller (UPFC): Principle of Operation and Control. Working principle of Interphase Power FlowController. Other Devices: GTO Controlled Series Compensator. Fault Current Limiter.

UNIT-III ***(11 hours)***

Application of FACTS: Application of FACTS devices for power-flow control and stability improvement. Simulation example of power swing damping in a single-machine infinite bus system using a TCSC. Simulation example of voltage regulation of transmission mid-point voltage using a STATCOM.

Power Quality Problems in Distribution Systems: Power Quality problems in distribution systems: Transient and Steady state variations in voltage and frequency. Unbalance, Sags, Swells, Interruptions, Wave-form Distortions: harmonics, noise, notching, dc-offsets, fluctuations. Flicker and its measurement. Tolerance of Equipment: CBEMA curve.

UNIT-IV ***(10 hours)***

DSTATCOM: Reactive Power Compensation, Harmonics and Unbalance mitigation in Distribution Systems using DSTATCOM and Shunt Active Filters. Synchronous Reference Frame Extraction of Reference Currents. Current Control Techniques for DSTATCOM.

Dynamic Voltage Restorer and Unified Power Quality Conditioner: Voltage Sag/Swell mitigation: Dynamic Voltage Restorer – Working Principle and Control Strategies. Series Active Filtering. Unified Power Quality Conditioner (UPQC): Working Principle. Capabilities and Control Strategies.

Essential Readings:

1. Narain G. Hingorani and Laszlo Gyugyi, *Understanding FACTS: Concepts and Technology of Flexible AC Transmission Systems*, IEEE Press / Wiley-IEEE Press, 1999.
2. K. R. Padiyar, *FACTS Controllers in Power Transmission and Distribution*, New Age International Publishers, 1st Edition, 2007.
3. Bhim Singh, Ambrish Chandra, and Kamal Al-Haddad, *Power Quality: Problems and Mitigation Techniques*, John Wiley & Sons Ltd., 2015.
4. Roger C. Dugan, Mark F. McGranaghan, Surya Santoso, and H. Wayne Beaty, *Electrical Power Systems Quality*, McGraw-Hill Education, 3rd Edition, 2012.

Suggested Readings:

1. R. Mohan Mathur and Rajiv K. Varma, Thyristor-Based FACTS Controllers for Electrical Transmission Systems, IEEE Press / John Wiley & Sons, 2002.
2. Math H. J. Bollen, Understanding Power Quality Problems: Voltage Sags and Interruptions, IEEE Press, 2000.
3. Arindam Ghosh and Gerard Ledwich, Power Quality Enhancement Using Custom Power Devices, Springer, 2012.
4. J. Arrillaga, N. R. Watson, and S. Chen, Power System Quality Assessment, John Wiley & Sons, 2000.

Practical Components: ***(30 hours)***

List of Experiments:

1. The Effect of Nonlinear Loads on Power Quality.
2. Study of the Voltage Sag and Voltage Swell with Passive Load and Starting of Induction Motor.
3. To demonstrate the Voltage & Current Distortions with the LED load.
4. To Reduce the Current Harmonics with Filters.
5. To Study the Capacitor Switching Transients.
6. Study the Current Harmonics in BLDC Motor.
7. Study the Effect of Voltage Flicker.
8. Analysis and Simulation of harmonics for various residential loads.
9. Study the neutral current of unbalanced nonlinear load of a 3-Ph System.
10. Reducing the Voltage Sag and Swell Problem in Distribution System Using DVR with PI Controller.

(Note: Course instructor may add/delete/update new experiments in addition to the above suggested practical exercise.)

Detailed Syllabus of Discipline Specific Elective (DSE) courses for B.Tech. (EE) – SEMESTER VIII

HVDC Transmission (DSE-08)

(Credit Distribution and Pre-Requisites of the Course)

Course title	Credits	Credit distribution of the course			Prerequisite of the course (if any)
		Lecture	Tutorial	Practical	
HVDC Transmission	4	3	0	1	Power Transmission and Distribution, Power Electronics

Course Objectives:

1. Appraise the need of HVDC technology for bulk power transmission and choose appropriate type of HVDC link and converter.
2. To understand the harmonics and faults occur in the system and their prevention.
3. To evaluate the operation and efficacy of different controllers and analyze the different faults in HVDC systems.
4. To evaluate the issues related to harmonics, reactive power control and protection of HVDC systems.

Course Outcomes:

At the end of this course, students will demonstrate the ability to:

1. Identify HVDC power terminal equipment, classify type of HVDC connectivity and planning of HVDC system.
2. Interpret different types of converter control techniques.
3. Understand the choice of pulse conversion, control characteristic, firing angle control.
4. Calculate voltage and current harmonics, and design of filters and understand the reactive power necessity of conventional control.

UNIT-I ***(11 hours)***

Introduction and Analysis of HVDC Converter: Comparison of HVAC and HVDC transmission system, Applications of DC transmission, Description of DC transmission system, Configurations, Modern trends in DC transmission.

Choice of converter configuration, Simplified analysis of Graetz circuit, Converter bridge characteristics, Characteristics of a twelve-pulse converter, Detailed analysis of converters with and without overlap.

UNIT-II ***(12 hours)***

HVDC Converter and Reactive Power control: General, Principles of DC link control, Converter control characteristics, System control hierarchy, Firing angle control, Current and extinction angle control, Starting and stopping of DC link, Power control, Higher level controllers.

Reactive power requirements in steady state, Sources of reactive power, Static VAR systems, Reactive power control during transients, Harmonics and filters, Generation of harmonics, Design of AC filters and DC filters.

UNIT-III ***(12 hours)***

Smoothing reactor, DC line and Fault Protection: Introduction, Smoothing reactors, DC line, Transient over voltages in DC line, Protection of DC line, DC breakers, Monopolar operation, Effects of proximity of AC and DC transmission lines.

Converter faults, Protection against over-currents, Over voltages in a converter station, Surge arresters, Protection against over-voltages.

UNIT-IV ***(10 hours)***

Component Models for the Power Flow analysis of AC/DC Systems: General, Converter model, Converter control, Modelling of DC network, Modelling of AC networks. Modelling of DC links, Solution of DC load flow, Discussion, Per unit system for DC quantities.

Essential Readings:

1. Kimbark, E.W., 'Dircct Current Transmission-vol.1', Wiley Inter science, New York, 1971.
2. Padiyar, K.R.,'HVDC transmission systems', New Age Publishers, 2017.
3. Kamakshaiah, S and Kamaraju, V, 'HVDC Transmission', IT Edition, Tata McGraw Hill Education (India), New Delhi 2017.

Suggested Readings:

1. Arrilaga, J., 'High Voltage Direct Current Transmission', 2nd Edition, Institution of Engineering and Technology, London, 1998.
2. Vijay K. Sood, 'HVDC and FACTS Controllers', Kluwer Academic Publishers, New York, 2013.

Practical Components: ***(30 hours)***

List of Experiments:

1. Study of various HVDC transmission system components and its applications.
2. Study of AC/DC side voltage and current waveforms of six pulse converter system under variable RL Load using simulation.
3. Study of AC/DC side voltage and current waveforms of twelve pulse converter system under variable R-L Load using simulation.
4. Study of reactive power control in HVDC transmission system.
5. Study of various types of Multi terminal HVDC transmission system.
6. Some simulation practices based on HVDC power and voltage stability.
7. Study of DC link control in VSC based HVDC transmission system.
8. Study of various passive filters used in LCC based HVDC transmission system.
9. Operation of VSC for power factor correction at AC side of HVDC system using sinusoidal pulse width modulation.

(Note: Course instructor may add/delete/update new experiments in addition to the above suggested practical exercise.)

Net Zero Building Design (DSE-08)

(Credit Distribution and Pre-Requisites of the Course)

Course title	Credits	Credit distribution of the course			Prerequisite of the course (if any)
		Lecture	Tutorial	Practical	
Net Zero Building Design	4	3	0	1	Introduction to Electrical and Electronics Engineering

Course Objectives:

1. Introduce global building energy scenarios, nZEB principles, and green rating systems.
2. Analyze energy usage, modeling, load calculations, and comfort factors in buildings.
3. Explore renewable integrations like BiPV, storage, and grid-interactive systems.
4. Examine smart buildings, BAS, and energy auditing practices.
5. Foster skills in sustainable design for net-zero and positive-energy buildings.

Course Outcomes:

At the end of this course, students will demonstrate the ability to:

1. Define nZEB, EPI, site/source energy, and apply green ratings.
2. Model building envelopes using RC networks and calculate HVAC loads.
3. Evaluate renewables and storage for building energy balance.
4. Assess comfort metrics and passive/active strategies.
5. Implement BAS concepts and conduct basic energy audits.

UNIT-I ***(12 hours)***

Building Energy Consumption: Global Energy and Environmental Scenario, Building Energy Consumption, What is nZEB? Why Zero? Energy Units & Conversions, Definitions, Site and Source Energy, Energy Basis vs. GHG Basis, Building Energy Systems, Energy Performance Indices. Concept of Green Buildings and Ratings.

UNIT-II ***(18 hours)***

Energy Usage in Buildings: Energy use intensity, End uses, Energy transfer processes in building space, Building energy modelling and simulation: Building envelope model-Thermal network model, Resistance-Capacitance (RC) network, transfer function method, single zone model of building space, Heating/cooling load calculation HVAC and Lighting systems, Principles for Net Zero Building Enclosures, Passive and Active Systems.

Occupancy Comfort Analysis and Evaluation: Interactions between forms of comfort and building energy use, Including Thermal comfort, Visual comfort and daylighting, indoor air quality, acoustic comfort, and occupant comfort calculations.

UNIT-III ***(15 hours)***

Renewable Energy for Buildings: Review of renewable energy technologies, BiPV, BiPV/T, BaPV, Solar thermal systems with storage, Solar air-conditioning, combined heat and power, Energy storage: Batteries-Lithium, Lead-acid, Thermal energy storage-Phase change materials, hydrogen. Geothermal. Smart buildings: Grid-interactive buildings, Energy Management, Electric vehicles, Vehicle-Building-Grid integration, smart homes, and positive energy buildings.

UNIT-IV ***(10 hours)***

Introduction to Smart Buildings, Building Automation Systems, Case Studies in Smart Building Implementation, and Introduction to Energy Auditing.

Essential Readings:

1. M.S. Sodha and N.K. Bansal, “Solar Passive: Building Science and Design”, Pergamon Press.
2. M. H. Chilogioji and E. N. Oura, “Energy Conservation in Commercial and Residential Buildings,” Marcel Dekker Inc., New York.
3. F. S. Dubin and C. G. Long, “Energy Conservation Standards for Building Design,” Construction and Operation McGraw Hill.

Suggested Readings:

1. M. Majumdar, “Energy efficient Buildings in India,” Tata Energy Research Institute, Ministry of Non Conventional Energy Sources, 2002.
2. J. Khazaii, “Energy-Efficient HVAC Design: An Essential Guide for Sustainable Building,” Springer 2014.

Practical Component: ***(30 Hours)***

List of Experiments:

1. Verify site vs source energy conversions using sample data.
2. Simulate RC thermal network for single-zone building model.
3. Calculate EUI and EPI from building consumption records.
4. Analyze thermal comfort via PMV/PPD for indoor conditions.
5. Measure daylighting levels and visual comfort metrics.
6. Test BiPV output under varying irradiance conditions.
7. Evaluate PCM storage for thermal load shifting.
8. Demonstrate BAS control on mock HVAC/lighting setup.

(Note: Course instructor may add/delete/update new experiments in addition to the above suggested practical exercise.)

Generalized Machine Theory (DSE-09)

(Credit Distribution and Pre-Requisites of the Course)

Course title	Credits	Credit distribution of the course			Prerequisite of the course (if any)
		Lecture	Tutorial	Practical	
Generalized Machine Theory	4	3	1	0	Electrical Machines I, Electrical Machines II

Course Objectives:

1. Express the revolving field and reference frame theory.
2. Develop mathematical models of three-phase AC machines and parameters in different reference frames.
3. Simulate the transient performance of three-phase AC machines in different reference frames.

Course Outcomes:

At the end of this course, students will demonstrate the ability to:

1. Develop the basic two pole model representation of electrical machines using the basic concepts of generalized theory.
2. Apply linear transformation for the steady state and transient analysis of different types of rotating electrical machines.
3. Understand the linear transformation equations of rotating electrical machines incorporating the concept of power invariance.

UNIT-I ***(15 hours)***

Introduction and Reference Frame Transformations:

Unified approach to the analysis of electrical machine performance - per unit system - Basic two pole model of rotating machines- Primitive machine -Conventions -transformer and rotational voltages in the armature voltage and torque equations, resistance, inductance and torque matrix.

Passive linear transformation in machines-invariance of power transformation from a displaced brush axis-transformation from three phase to two phase and from rotating axes to stationary axes-Physical concept of Park's transformation

UNIT-II ***(10 hours)***

DC Machines:

Application of generalized theory to separately excited DC generator: steady state and transient analysis, Separately excited DC motor- steady state and transient analysis, Transfer function of separately excited DC generator and motor- DC shunt and series motors: Steady state analysis and characteristics.

UNIT-III ***(12 hours)***

Synchronous Machines:

synchronous machine reactance and time constants-Primitive machine model of synchronous machine with damper windings on both axes. Balanced steady state analysis-power angle curves.

Induction Machines:

Primitive machine representation. Transformation- Steady state operation-Equivalent circuit. Torque slip characteristics.

UNIT-IV ***(08 hours)***

Single phase induction motor:

Revolving Field Theory equivalent circuit- Voltage and Torque equations-Cross field theory-Comparison between single phase and poly phase induction motor.

Essential Readings:

1. Charles Concordia, Synchronous Machines- Theory and Performance, John Wiley and Sons Incorporate, New York.1988.
2. Say M. G., Introduction to Unified Theory of Electrical Machines, Pitman Publishing, 1978.
3. Alexander SLangsdorf, Theory of Alternating Current Machinery, Tata McGraw Hill, 2nd revised edition, 2001.

Suggested Readings:

1. Mukhopadhyay A. K., Matrix Analysis of Electrical Machines, New Age, 1996.
2. Vas P., Electrical Machines and Drives: A Space-Vector Theory Approach (Monographs in Electrical and Electronic Engineering), Oxford University Press, 1993.

Tutorial Component: ***(15 Hours)***

(Note: The course instructor will design tasks to complete the tutorial component of the course.)

Power System Security (DSE-09)

(Credit Distribution and Pre-Requisites of the Course)

Course title	Credits	Credit distribution of the course			Prerequisite of the course (if any)
		Lecture	Tutorial	Practical	
Power System Security	4	3	1	0	Power Transmission and Distribution, Power System Analysis

Course Objectives:

1. Understand the concept of power system security and control.
2. Understand the economic operation of the power system.
3. Load frequency control.
4. Understand the voltage and reactive power control.
5. Understand the concept of State Estimation.

Course Outcomes:

At the end of this course, students will demonstrate the ability to:

1. Explain the structure, control centre functions, SCADA, operating states, and security of a modern power system.
2. Model and analyze single-area and two-area load frequency control schemes, including PI/AGC, for steady-state and dynamic performance.
3. Describe and model automatic voltage regulators and excitation systems, and evaluate methods of voltage and reactive power control using transformers and reactive compensation.
4. Discuss and compare methods of voltage and reactive power management, such as shunt, series, and phase-angle compensation in transmission networks.

UNIT-I ***(08 hours)***

Introduction:

Structure of power systems, Power system control center and real time computer control, SCADA system, Level decomposition in power system, Power system security, Various operational stages of power system, Power system voltage stability.

UNIT-II ***(15 hours)***

Load Frequency Control:

Concept of load frequency control, Load frequency control of single area system: Turbine speed governing system and modelling, block diagram representation of single area system, steady state analysis, dynamic response, control area concept, P-I control, load frequency control and economic dispatch control. Load frequency control of two area system: Tie line power modelling, block diagram representation of two area system, static and dynamic response.

UNIT-III ***(15 hours)***

Automatic Voltage Control:

Schematic diagram and block diagram representation, different types of Excitation systems & their controllers.

Voltage and Reactive Power control: Concept of voltage control, methods of voltage control-control by tap changing transformer. Shunt Compensation, series compensation, phase angle compensation.

UNIT-IV ***(07 hours)***

State Estimation:
Detection and identification, Linear and non-linear models.

Essential Readings:

1. P.S.R. Murty, “Operation and control in Power Systems”, BS Publications.
2. Allen J. Wood, Bruce F. Wollenberg and Gerald B. Sheblé, “Power Generation, Operation and Control”, John Wiley & Sons.
3. O.I. Elgerd, “Electric Energy System Theory”, Tata McGraw-Hill Publishing Company Limited.

Suggested Readings:

1. I. J. Nagrath and D. P. Kothari, “Modern Power System Analysis”, McGraw Hill Publishing Company Ltd.
2. Prabha Kundur, “Power Systems Stability and Control”, McGraw-Hill Publishing Company Ltd.
3. T. K. Nagsarkar and M.S. Sukhiza, “Power System Analysis”, Oxford University Press.

Tutorial Component: ***(15 Hours)***

(Note: The course instructor will design tasks to complete the tutorial component of the course.)

Analytical Instrumentation (DSE-10)

(Credit Distribution and Pre-Requisites of the Course)

Course title	Credits	Credit distribution of the course			Prerequisite of the course (if any)
		Lecture	Tutorial	Practical	
Analytical Instrumentation	4	3	0	1	Introduction to Electrical and Electronics Engineering

Course Objectives:

1. To introduce the students to the basics of analytical instrumentation techniques and their applications.
2. To learn quantitative and qualitative analysis techniques of samples of industrial gases and products.
3. To teach the students how to analyze data obtained from analytical instrumentation and interpret the results.
4. To familiarize the students with the principles of analytical instruments like spectrometers, chromatographs, and biosensors.

Course Outcomes:

At the end of this course, students will demonstrate the ability to:

1. Understand knowledge on fundamental principles and concepts of analytical instruments.
2. Describe the various processes for analyzing the samples of industrial products.
3. Apply the knowledge of sampling and analyzing of the industrial products.
4. Evaluate and judge the accuracy of the process for analyzing samples.

UNIT-I ***(13 hours)***

Analytical Spectroscopy Instruments: Elements and types of Analytical Instruments, Ultraviolet and Visible Absorption Spectroscopy, Different types of Spectrophotometers, Sources of Errors and Calibration, Infrared Spectrophotometers – Basic Components and Types, Sample Handling Techniques. Instruments for absorption photometry, single beam and double beam spectrophotometer.

UNIT-II ***(10 hours)***

Flame Emission and Atomic Absorption Spectroscopy: Introduction, Instrumentation for flame spectrometric methods, Flame emission spectrometry, atomic absorption spectrometry, atomic fluorescence spectrometry, Interferences associated with Flames & furnaces, applications, comparison of FES and AAS.

UNIT-III ***(12 hours)***

Chromatography: Gas Chromatograph – Basic Parts of a Gas Chromatograph, Methods of Measurement of Peak Areas, Liquid Chromatograph – Types, High Pressure Liquid Chromatograph**.**
pH meters and Ion Analyzers: Principle of pH Measurement, Electrodes for pH Measurement, pH Meters, Ion Analyzers, Blood pH Measurement.

UNIT-IV ***(10 hours)***

Radiochemical Instruments: Fundamentals of Radiochemical Methods, Radiation Detectors, Liquid Scintillation Counters, Gamma Spectroscopy. X-Ray Spectrometers: Instrumentation for X-Ray Spectrometry, X-Ray Diffractometers, X-Ray Absorption Meters, Electron Probe Micro analyzer.

Essential Readings:

1. Braun, R. D., Introduction to Instrumental Analysis, McGraw Hill, 2008.
2. Khandpur, R. S., Handbook of Biomedical Instrumentation, Tata McGraw Hill, 2000.
3. Currell, G., Analytical Instruments: Performance Characteristics and Quality, Wiley 2008.

Suggested Readings:

1. Willard, H. H., Merritt, L. L., Dean, J. A., Settle, F. A., “Instrumental Methods of Analysis”, CBS Publishing & Distribution, 1990.
2. Patranabis, D. Principles of Industrial & Instrumentation, Tata McGraw Hill, 1998.

Practical Component: ***(30 hours)***

List of Experiments:

1. Test and calibrate the spectrophotometer.
2. Measure the percentage transmission, absorption, and concentration of the given sample using a spectrophotometer.
3. Study of each part of the gas chromatograph.
4. Analyze the given gas mixture using a gas chromatograph.
5. Measure refractive index using a refractometer.
6. Analyze the given sample using a refractometer.
7. Measure the pH of the given solution using the double electrode method.
8. Analyze the given sample using a colorimeter.

(Note: Course instructor may add/delete/update new experiments in addition to the above suggested practical exercise.)

Biomedical Instrumentation (DSE-10)

(Credit Distribution and Pre-Requisites of the Course)

Course title	Credits	Credit distribution of the course			Prerequisite of the course (if any)
		Lecture	Tutorial	Practical	
Biomedical Instrumentation	4	3	0	1	Introduction to Electrical and Electronics Engineering

Course Objectives:

1. To explore the human body parameter measurements setups.
2. To introduce fundamentals of human physiology and their qualitative measurement.
3. To recognize the therapeutic methods of treatment and the associated instrumentation.
4. To acquire knowledge about the origin of bio-potential, bio-signals and their measurement.

Course Outcomes:

At the end of this course, students will demonstrate the ability to:

1. Understand the problem, identify and formulate solutions in the field of Bio-Medical Engineering for current and future issues.
2. Analyze the cardiac, brain and muscular physiological systems with the related diagnostic measurement methods.
3. Describe the principle and working of cardiac pacemakers, defibrillators, BP measurement, blood flow meters, CO measurement, respiration measurements and their implementation.
4. Analyze various measurement techniques for human physiological parameters.

UNIT-I ***(10 hours)***

Fundamentals of Biomedical Instrumentation: Sources of biomedical signals, Basic Medical Instrumentation system, Performance requirements of medical instrumentation systems. PC based medical instruments, General constraints in design of biomedical instrumentation systems.

Bioelectric Signals and Electrodes: Origin of Bioelectric signals, Types of bioelectric signals-ECG, EEG, EMG, Recording electrodes like Electrode – Tissue interface, polarization, skin contact-impedance, Silver-silver chloride electrodes, Electrodes for ECG, EEG, EMG, Microelectrodes.

UNIT-II ***(13 hours)***

Patient Monitoring System: Bedside patient monitoring systems, Central monitors, Measurement of heart rate – Average heart rate meter, Instantaneous heart rate meter, Measurement of pulse rate, Definition of oximeter & Pulse oximeter.

Blood Pressure Measurement: Introduction, Indirect methods of blood pressure measurement: Korotkoff‟s method, Rheographic method, differential auscultatory technique, Oscillometric technique.

Measurement of Respiration Rate: Impedance pneumography, CO2 method of respiration rate measurement, Apnoea detectors.

UNIT-III ***(10 hours)***

Blood Flow Measurement: Electromagnetic blood flow meter- Principle and Square wave electromagnetic flowmeter. Doppler shift blood flow velocity meter, Blood flow measurement by Doppler imaging.

Cardiac Output Measurement: Measurement of continuous cardiac output derived from the aortic pressure waveform, ultrasound method.

Cardiac Pacemakers and Defibrillators: Need for cardiac pacemaker, External pacemaker, Implantable pacemaker, Types of Implantable pacemakers, Programmable pacemakers, Power sources for Implantable pacemaker. Need for a Defibrillator, DC defibrillator, Pacer-Cardioverter-Defibrillator.

UNIT-IV ***(12 hours)***

Electrocardiograph: Physiology of the heart, Electrical activity of the heart and Electrocardiogram (ECG), Normal & Abnormal cardiac Rhythms, Block diagram-description of an Electrocardiograph, ECG leads, Effects of artifacts on ECG Recordings, Multi- channel ECG machine.

Electroencephalograph: Block diagram description of an Electroencephalograph, 10-20 electrode systems, computerized analysis of EEG. Electromyograph, Biofeedback instrumentation.

Therapeutic Instruments: Cardiac-assist devices, Pump oxygenators, Total artificial heart, Hemodialysis, Lithotripsy, Ventilators, Infant incubators, Drug infusion pumps, Ambulatory and Implantable Infusion systems, Anesthesia Machines, Electrosurgical unit.

Essential Readings:

1. R. S. Khandpur, ‘Handbook of Bio-Medical instrumentation’, Tata McGraw Hill Publishing Co Ltd., 2003.
2. Leslie Cromwell, Fred J. Weibell, Erich A. Pfeiffer, ‘Bio-Medical Instrumentation and Measurements’, second edition, Pearson Education, 2002.
3. D. Patranabis, ‘Principles of Industrial & Instrumentation’, Tata McGraw Hill, 1998.

Suggested Readings:

1. J. Webster, ‘Medical Instrumentation’, John Wiley & Sons,1995.
2. L. A. Geddes and L. E. Baker, ‘Principles of Applied Bio-Medical Instrumentation’, John Wiley & Sons, 1975.

Practical Component: ***(30 hours)***

List of Experiments:

1. Perform the measurements based on transducers and plot the characteristics.
2. Compare performance of a variety of electrodes.
3. Measurement of Blood Pressure.
4. Measurement of Blood Glucose level.
5. Analyze Instrumentation amplifier for biomedical signals.
6. Learn pulse oximeter/ Diathermy.
7. Simulate the real time ECG monitoring and ECG wave analysis.
8. Simulate the real time EEG monitoring and EEG wave analysis.

(Note: Course instructor may add/delete/update new experiments in addition to the above suggested practical exercise.)

Department of Electrical Engineering
Faculty of Technology
University of Delhi

List of Discipline Specific Elective (DSE)/ Generic Elective (GE) courses offered for Minors / Specializations by the Department of Electrical Engineering in Fourth Year

1. **Minor in EE (Offered to ECE and CSE)**
   a. DSE-06/ GE-07: Element of Electrical Power System
   b. DSE-07/ GE-08: Control System Applications in Electrical Engineering
   c. DSE-09/ GE-09: Power Plant Engineering
   d. DSE-09/ GE-09: Machine Learning Applications in Electrical Engineering
   e. DSE-10/ GE-10: Clean Energy Technologies
   f. DSE-10/ GE-10: Introduction to Smart Grid

2. **Minor/Specialization in Robotics and Automation (Offered to EE, ECE, and CSE)**
   a. DSE-06/ GE-07: Nonlinear Control System
   b. DSE-07/ GE-08: Digital Robotic Control
   c. DSE-09/ GE-09: Real Time Embedded System
   d. DSE-09/ GE-09: Process Control
   e. DSE-10/ GE-10: Optimal and Robust Control
   f. DSE-10/ GE-10: Robotics in Biomedical Engineering

3. **Minor/Specialization in Sustainable Energy Engineering (Offered to EE, ECE, and CSE)**
   a. DSE-06/ GE-07: Machine Learning Applications in Sustainable Energy Development
   b. DSE-07/ GE-08: Control of Renewable Energy Integrated Systems
   c. DSE-09/ GE-09: Smart Energy Storage System
   d. DSE-09/ GE-09: Wind and Small Hydro Power Generation
   e. DSE-10/ GE-10: Smart Grid Technologies
   f. DSE-10/ GE-10: Energy Management Systems and SCADA

4. **Minor/Specialization in Electric and Hybrid Vehicle (Offered to EE, ECE, and CSE)**
   a. DSE-06/ GE-07: Electro-Chemistry of Fuel Cells
   b. DSE-07/ GE-08: Modeling and Simulation of EHV
   c. DSE-09/ GE-09: Embedded Based Smart System Design
   d. DSE-09/ GE-09: Computer Aided Design of Electric Machines
   e. DSE-10/ GE-10: EV Charging Infrastructure
   f. DSE-10/ GE-10: Electrical Vehicle System Design

Detailed Syllabus of Generic Elective (GE) courses offered for Minors / Specializations by Department of Electrical Engineering in SEMESTER VII

Element of Electrical Power System (DSE-06/ GE-07)

(Credit Distribution and Pre-Requisites of the Course)

Course title	Credits	Credit distribution of the course			Prerequisite of the course (if any)
		Lecture	Tutorial	Practical	
Elements of Electrical Power System	4	3	1	0	Introduction to Electrical and Electronics Engineering, Mathematics-I

Course Objectives:

1. To introduce the fundamental structure and components of electrical power systems.
2. To explain the principles of power generation from various sources and basic economic concepts.
3. To analyze transmission line parameters and performance characteristics.
4. To familiarize students with distribution systems and basic power system operation techniques.

Course Outcomes:

At the end of this course, students will demonstrate the ability to:

1. Describe the structure of power systems and apply the per-unit system for simple analysis.
2. Explain the working principles of different power generation methods and understand economic operation concepts.
3. Calculate basic transmission line parameters and evaluate line performance using equivalent circuit models.
4. Describe distribution systems and apply introductory concepts of load flow, protection, and faults.

UNIT-I ***(10 hours)***

Introduction to Electrical Power Systems: Structure of power systems including generation, transmission, distribution, and utilization; Load characteristics: types of loads, load curves, load duration curves, diversity factor, load factor; Per-unit system: definition, advantages, base values, per-unit representation of system components.

UNIT-II ***(08 hours)***

Power Generation: Conventional sources: thermal, hydroelectric, and nuclear power plants (working principles, efficiency, and site selection); Non-conventional sources: solar, wind, and biomass (basics of energy conversion and grid integration).

UNIT-III ***(15 hours)***

Power Transmission: Overhead transmission lines: types of conductors, bundle conductors, resistance calculation, skin effect; Inductance and capacitance: calculation for single and three-phase lines, GMD and GMR concepts; Equivalent circuit model: nominal pi and T representations for short, medium, and long lines; Performance analysis: voltage regulation, efficiency, surge impedance loading; Corona: critical disruptive voltage, power loss; HVDC transmission: monopolar and bipolar links, advantages over AC, basic converter operation (rectifier and inverter modes).

UNIT-IV ***(12 hours)***

Power Distribution and Basic Operation: Distribution systems: radial, ring main, and interconnected types; Substation equipment: transformers, circuit breakers, insulators; Voltage drop calculations, power factor improvement using capacitors; Load flow studies: bus classification (PQ, PV, slack), basic concepts and importance; Introduction to symmetrical faults: types and basic concepts; System protection: principles of overcurrent relays, differential relays, distance relays.

Essential Readings:

1. John J. Grainger and William D. Stevenson, Power System Analysis, McGraw Hill Education, 4th Edition, 2017.
2. I. J. Nagrath and D.P. Kothari, Modern Power System Analysis, Tata McGraw Hill, 5th Edition, 2011.
3. Hadi Saadat, Power System Analysis, PSA Publishing, 3rd Edition, 2011.

Suggested Readings:

1. Ashfaq Husain, Electrical Power Systems, CBS, 5th edition, 2018.
2. C. L. Wadhwa, Electrical Power Systems, New Age International Publishers, 8th Edition, 2017.

Tutorial Component: ***(15 hours)***

List of Tutorial Tasks:

1. Problems related to comparison of conventional vs. smart grid features and benefits.
2. Problems related to calculation of drivers and challenges in smart grid adoption.
3. Problems related to identification of smart grid functions from real-world scenarios.
4. Problems related to conceptual modelling of smart grid domains and components.
5. Problems related to per-unit representation and sizing of AMI and PMU in sample systems.
6. Problems related to integration of DER and energy storage in smart grid architecture.
7. Problems related to selection of communication technologies for different smart grid layers.
8. Problems related to interpretation of IEC 61850 standards in substation automation.
9. Problems related to basic cyber-security risk assessment in smart grid communication.
10. Problems related to renewable integration and microgrid operation modes.
11. Problems related to demand response and V2G calculations in smart grid applications.
12. Problems related to economic and policy analysis of smart grid initiatives.

(Note: The course instructor may add/delete/update new tutorial tasks in addition to the above suggested tutorial tasks.)

Control System Applications in Electrical Engineering (DSE-07/ GE-08)

(Credit Distribution and Pre-Requisites of the Course)

Course title	Credits	Credit distribution of the course			Prerequisite of the course (if any)
		Lecture	Tutorial	Practical	
Control System Applications in Electrical Engineering	4	3	0	1	Introduction to Electrical and Electronics Engineering, Mathematics-I

Course Objectives:

1. To introduce the basic principles of feedback control systems and their modeling.
2. To explain time-domain analysis and stability concepts for control systems.
3. To familiarize students with frequency-domain techniques and controller design.
4. To emphasize practical applications of control systems in electrical engineering domains such as power systems and electric drives.

Course Outcomes:

At the end of this course, students will demonstrate the ability to:

1. Model simple electrical systems and analyze their dynamic response using transfer functions.
2. Evaluate stability and performance of feedback control systems in the time domain.
3. Apply frequency response methods for system analysis and basic controller tuning.
4. Understand and describe control applications in electrical power systems and motor drives.

UNIT-I ***(12 hours)***

Introduction to Control Systems: Open-loop and closed-loop control systems, feedback concepts; Mathematical modeling of electrical systems: transfer functions of Electrical circuits; Block diagram representation and reduction, signal flow graphs; Standard test signals, time response specifications.

UNIT-II ***(10 hours)***

Time-Domain Analysis: First and second-order systems, steady-state error, error constants; Stability analysis: Routh-Hurwitz criterion; Root locus technique: basic rules, plotting, and applications to control design.

UNIT-III ***(11 hours)***

Frequency-Domain Analysis: Bode plots, gain margin, phase margin, Nyquist stability criterion; PID controllers: structure, effects of proportional, integral, and derivative actions, basic tuning methods (Zeigler-Nichols).

UNIT-IV ***(12 hours)***

Applications in Electrical Engineering: Speed control of DC motors using armature and field control; Voltage and frequency control in power systems (AVR basics); Load frequency control in power systems; Introduction to control in induction motor drives (V/f control); PLC basics for industrial electrical control.

Essential Readings:

1. Norman S. Nise, Control Systems Engineering, Wiley, 8th Edition, 2020.
2. Katsuhiko Ogata, Modern Control Engineering, Prentice Hall, 5th Edition, 2010.
3. Benjamin C. Kuo, Automatic Control Systems, Prentice Hall, 10th Edition, 2010.

Suggested Readings:

1. I. J. Nagrath and M. Gopal, Control Systems Engineering, New Age International Publishers, 6th Edition, 2018.
2. Gopal K. Dubey, Fundamentals of Electrical Drives, Narosa Publishing House, 2nd Edition, 2001.

Practical Component: ***(30 Hours)***

List of Experiments:

1. To derive the transfer function of a DC motor; plot step response using MATLAB/Simulink.
2. To build simple RLC on breadboard (resistors/capacitors/inductors); measure response with oscilloscope, then simulate in Simulink for comparison.
3. To simulate first/second-order systems in MATLAB; compute error constants for ramp input.
4. To test stability of sample EE systems (e.g., feedback loop); plot poles using MATLAB/Simulink.
5. Frequency response for a PID-controlled system; analyze gain/phase margins.
6. To sketch locus in MATLAB for motor speed control; verify gain effects on a basic op-amp hardware setup.
7. To Implement Zeigler-Nichols on Arduino kit with DC motor (e.g., L298N driver); tune for setpoint tracking.
8. To program simple motor start/stop sequence using open source PLC Simulator (e.g., LogixPro).

(Note: Course instructor may add/delete/update new experiments in addition to the above suggested practical exercise.)

Nonlinear Control System (DSE-06/ GE-07)

(Credit Distribution and Pre-Requisites of the Course)

Course title	Credits	Credit distribution of the course			Prerequisite of the course (if any)
		Lecture	Tutorial	Practical	
Nonlinear Control System	4	3	0	1	Introduction to Electrical and Electronics Engineering, Mathematics-I

Course Objectives:

1. To understand the fundamentals of non-linear systems.
2. To understand the modeling concepts of non-linear systems.
3. To understand the stability of non-linear systems.
4. To acquire the knowledge of various non-linear control techniques.

Course Outcomes:

At the end of this course, students will demonstrate the ability to:

1. Model the non-linear systems considering practical applications.
2. Design and analyze the non-linear control systems.
3. Analyze the stability of non-linear systems.
4. Apply practically the various concepts on the non-linear systems under different conditions.

UNIT-I ***(15 hours)***

Introduction: Introduction to non-linear system, General Properties of linear and non-linear systems, perturbation theory, and perturbation dynamics, controllability and observability of non-linear systems, Lipschitz continuity, existence and uniqueness of solution of non-linear systems, common differences with linear system, types of nonlinearities, inherent nonlinearity (Saturation, dead zone, Hysteresis, Back-lash), intentional non-linearity, non-linear phenomenon (Frequency-amplitude dependence, multi-valued response and jump resonance, sub-harmonic oscillation, limit cycle, Frequency entrainment, Asynchronous quenching).

UNIT-II ***(10 hours)***

Modeling of Non-Linear Systems: Modeling of simple mechanical systems, degree-of freedom, configuration spaces and state-space representation, equilibrium points/operating points, Jacobian linearization.

Mathematical Notions: Notion of vector field, trajectories, vector field plot, phase plane portrait, positively invariant sets and classification of equilibrium points.

UNIT-III ***(12 hours)***

Qualitative Analysis of Second Order Systems: Second-order systems, periodic solution, Bendixson's theorem and Poincare-Bendixson criteria, phase plane analysis: Introduction to phase-plane analysis, method of Isoclines for constructing Trajectories, singular points, phase-plane analysis of nonlinear control systems.

Notions of Stability of Non-Linear Systems: Lyapunov theorem, small gain theorem, describing function method, asymptotic stability, exponential stability.

UNIT-IV ***(08 hours)***

Lyapunov's Stability Notions: Lyapunov's direct and indirect stability, La-Salles's invariance principle and its examples.
Non-Linear Control Techniques: Feedback linearization, backstepping, variable structure control, nonlinear observers.

Essential Readings:

1. Nonlinear Systems, H Khalil, Macmillan, 3rd edition, 2002.
2. Nonlinear systems: analysis, stability, and control, Springer Science & Business Media, Shankar Sastry, 2013 .
3. Non-linear differential equations, Elsevier by Sansone, Giovanni, and Roberto Conti., 2014 .

Suggested Readings:

1. Nonlinear Control Systems: Analysis and Design, H J Marquez, Hoboken: Wiley-Interscience, 2003.
2. Applied Nonlinear control by J J Slotine and W P Li, Prentice Hall, 1991.
3. Analysis and Design of Nonlinear Control Systems by A Astolfi, L Marconi, 2008.

Practical Component: ***(30 Hours)***

List of Experiments:

1. To study saturation and dead zone non-linearity using describing function technique of a relay control system
2. To draw phase trajectory of a given non-linear system.
3. To study and analysis of Pendulum/inverted pendulum system.
4. To study and analysis of Mass-Spring system.
5. To study and analyze Limit cycles and Phase portraits for nonlinear systems.
6. To study the existence of periodic orbits in different nonlinear systems.
7. To study and perform bifurcation Analysis of nonlinear system.
8. Simulations on the describing function method for other common nonlinearities.
9. To design a controller for a nonlinear system (SMC, Adaptive, Backstepping, NN Based, Feedback linearization).
10. Case Study-1
11. Case Study-2

(Note: Course instructor may add/delete/update new experiments in addition to the above suggested practical exercise.)

Digital Robotic Control (DSE-07/ GE-08)

(Credit Distribution and Pre-Requisites of the Course)

Course title	Credits	Credit distribution of the course			Prerequisite of the course (if any)
		Lecture	Tutorial	Practical	
Digital Robotic Control	4	3	0	1	Introduction to Electrical and Electronics Engineering, Mathematics-I

Course Objectives:

1. To understand the basic terminologies and concepts associated with Robotics and end effectors.
2. To analyze and understand the transformation of the end effectors' position and be familiar with the kinematics and dynamics of robots.
3. To understand the robot work cell layout and the recent trends in the application of artificial intelligence and expert systems in robotics.
4. To acquire knowledge on emerging developments in robots.

Course Outcomes:

At the end of this course, students will demonstrate the ability to:

1. Recognize the basics of robots and apply the concepts associated with end effectors.
2. Acquire the knowledge about robotic control system, feedback devices and sensors.
3. Evaluate transformation of end effectors position and being familiar with the kinematics and dynamics of robots.
4. Analyze the robot work cell layout and application of artificial intelligence in robotics.

UNIT-I ***(15 hours)***

Introduction to Robotics and End Effectors: Introduction to Robotic, History - Developments in Robotics, Robot anatomy, Definition and law of robotics, Terminology of Robotics, Accuracy and repeatability, dexterity, compliance, RCC device of Robotics-Simple problems, Specifications of Robot-Speed of Robot- Robot joints and links, Robot Drive systems-Hydraulic, Pneumatic and Electric system. End Effectors - Mechanical grippers-Slider crank mechanism, cam type, Screw type, Rotary actuators, Magnetic grippers, Vacuum grippers, Gripper force analysis, Gripper selection and design considerations.

UNIT-II ***(12 hours)***

Robot Controls and Sensors: Control system for robot joint- Controllers, Control system analysis – Transient Response, Steady state, Trajectory planning of end effectors. Feedback devices-Encoder, Resolver, LVDT-Motion Interpolations, Adaptive control Sensors in robot, Characteristics of sensing devices, Selections and need of sensors, Touch sensors-Tactile sensor, Proximity and range sensors, Force sensor-Light sensors, Pressure sensors, Robotic vision sensor.

UNIT-III ***(10 hours)***

Robot Transformations, Kinematics and Dynamics Robot kinematics-Types-2D, 3D Transformation, inverse kinematics, Scaling, Rotation, Translation, Homogeneous Transformations, multiple transformations. Kinematic equations using Homogeneous Transformations - Joints, frame assignment to links, Orientation, direct kinematics Solving Kinematic equations – Velocities and Static forces in manipulators:- Jacobians, singularities, static forces, Jacobian in force domain, Dynamics:- Introduction to Dynamics.

UNIT-IV *(08 hours)*

Robot Cell Design and Artificial Intelligence Applications Robot work cell design - control-Sequence control operator interface, safety monitoring devices in Robot Mobile robot working principle, actuation using MATLAB, NXT Software Introduction to Artificial Intelligence, Need and application of AI techniques, Artificial neural networks in manufacturing automation, Fuzzy decision and control, robots and application of robots using AI and fuzzy.

Essential Readings:

1. Robotics Engineering an Integrated Approach, Phi Learning., Richard D. Klafter, Thomas. A, Chri Elewski, Michael Negin, 2009.
2. Engineering Foundation of Robotics, Prentice Hall Inc., Francis N. Nagy, Andras Siegler, 1987.
3. Digital control system analysis and design. Prentice Hall Press Phillips, Charles L., and H. Troy Nagle. 2007.

Suggested Readings:

1. Robotics Technology and flexible automation,Tata McGraw-Hill Education, Deb. S.R, 2009.
2. Technology Programming and Applications, McGraw Hill, Mikell P Groover & Nicholas G Odrey, Mitchel Weiss, Roger N Nagel, Ashish Dutta, Industrial Robotics, 2012.

Practical Component: ***(30 Hours)***

List of Experiments:

1. Introduction to programming using Arduino ide, Programming inputs and outputs.
2. Interfacing Arduino with LED to Blink and fade.
3. Interfacing Arduino with Buzzer.
4. Interfacing digital read - proximity sensor and serial monitor with Arduino.
5. Interfacing digital input - ultrasonic sensor with Arduino for measuring distance.
6. Bidirectional speed control of DC motor through L293D or ULN2003 interface.
7. Interfacing analog output -Servo Motor with Arduino.
8. Angular positioning of servo motor by using the ultrasonic sensor with Arduino.
9. Controlling servo motor by using the Potentiometer with Arduino.
10. Interfacing Bluetooth Module and IR Sensor with Arduino.

(Note: Course instructor may add/delete/update new experiments in addition to the above suggested practical exercise.)

Machine Learning Applications in Sustainable Energy Development (DSE-06/ GE-07)

(Credit Distribution and Pre-Requisites of the Course)

Course title	Credits	Credit distribution of the course			Prerequisite of the course (if any)
		Lecture	Tutorial	Practical	
Machine Learning Applications in Sustainable Energy Development	4	3	0	1	Fundamentals of Computer Programming

Course Objectives:

1. To introduce fundamental concepts of artificial intelligence and machine learning relevant to energy systems.
2. To develop computational proficiency in Python for data analysis and ML implementation.
3. To provide a strong understanding of supervised and unsupervised learning techniques.
4. To enable students to formulate and solve optimization problems encountered in renewable energy systems.
5. To apply machine learning methods to real-world problems in alternative energy generation, forecasting, and system diagnostics.

Course Outcomes:

At the end of this course, students will demonstrate the ability to:

1. Explain core concepts of machine learning and implement basic ML workflows using Python.
2. Apply supervised learning techniques for regression and classification problems in energy datasets.
3. Analyze unlabeled energy data using clustering and probabilistic learning methods.
4. Formulate and solve optimization problems relevant to renewable energy systems.
5. Design ML-based solutions for forecasting, energy estimation, demand analysis, and fault detection in alternative energy applications.

UNIT-I ***(15 hours)***

Foundations of Machine Learning and Python Programming: Introduction to artificial intelligence and machine learning; types of machine learning; ML workflow; data representation and preprocessing. Basics of Python programming for ML: variables, data types, control structures, functions, libraries for numerical computing and data handling.

UNIT-II ***(10 hours)***

Supervised Learning Techniques: Regression methods: linear regression, gradient descent optimization, weighted least squares, and logistic regression. Classification methods: k-Nearest Neighbors (kNN), discriminant function analysis, Bayesian decision theory, and decision tree learning.

UNIT-III ***(10 hours)***

Unsupervised Learning and Optimization Techniques: Clustering techniques: k-means clustering, hierarchical clustering, Optimization fundamentals: problem formulation, decision variables, objective functions, constraints, maxima and minima; solving optimization problems relevant to engineering applications.

UNIT-IV ***(10 hours)***

Machine Learning Applications in Alternate Energy Systems: Weather and solar/wind data forecasting; estimation of energy generation from renewable energy sources; building energy demand prediction; system fault detection, diagnostics, and performance monitoring using ML techniques.

Essential Readings:

1. K. P. Murphy, *Machine Learning: A Probabilistic Perspective*, MIT Press, 1st Edition, 2012.
2. B. K. Bose, *Artificial Intelligence Techniques in Smart Grid and Renewable Energy Systems*, Springer, 1st Edition, 2018.
3. E. Alpaydin, *Introduction to Machine Learning*, MIT Press, 3rd Edition, 2014.

Suggested Readings:

1. R. Whig, D. Sharma, S. Aneja, A. Elngar, and J. Silva, *Artificial Intelligence and Machine Learning for Sustainable Development: Innovations, Challenges, and Applications*. Boca Raton, FL, USA: CRC Press, 2024.
2. A. C. Müller and S. Guido, *Introduction to Machine Learning with Python*, O'Reilly Media, 1st Edition, 2016.

Practical Component: ***(30 Hours)***

List of Experiments:

1. To study Python programming basics for data analysis using NumPy, Pandas, and Matplotlib.
2. To study data preprocessing and feature extraction techniques for renewable energy datasets using Python.
3. To study the implementation of linear regression for solar and wind power generation prediction using MATLAB/Python.
4. To study gradient descent–based optimization for training regression models using MATLAB/Python.
5. To study logistic regression for the classification of operating conditions in energy systems using MATLAB/Python.
6. To study k-Nearest Neighbor (kNN)–based classification for fault identification in energy data using MATLAB/Python.
7. To study decision tree–based classification for system condition monitoring using Python.
8. To study formulation and solution of optimization problems for improving energy system performance using MATLAB/Python.
9. To study weather data–based forecasting of renewable energy generation using machine learning models using Python.
10. To study machine learning–based fault detection and diagnostics in renewable energy systems using Python.

(Note: The Course instructor may add/delete/update new experiments in addition to the above suggested practical exercise.)

Control of Renewable Energy Integrated Systems (DSE-07/ GE-08)

(Credit Distribution and Pre-Requisites of the Course)

Course title	Credits	Credit distribution of the course			Prerequisite of the course (if any)
		Lecture	Tutorial	Practical	
Control of Renewable Energy Integrated Systems	4	3	0	1	Energy and Its Resources

Course Objectives:

1. To provide a fundamental understanding of photovoltaic and wind energy conversion systems.
2. To develop knowledge of modelling techniques for PV and wind energy systems.
3. To introduce control strategies for standalone, grid-connected, and hybrid renewable energy systems.
4. To enable students to simulate and analyze renewable energy systems and their control mechanisms.
5. To expose students to recent research trends and intelligent control applications in renewable energy systems.

Course Outcomes:

At the end of this course, students will demonstrate the ability to:

1. Explain the principles, classification, benefits, and challenges of renewable energy integrated systems.
2. Model photovoltaic cells, PV arrays, and wind energy systems using mathematical and simulation tools.
3. Develop and simulate control strategies for standalone and grid-connected renewable energy systems.
4. Evaluate system performance using case studies and interpret recent research developments in intelligent control of renewable energy systems.

UNIT-I ***(06 hours)***

Introduction to Renewable Energy Systems: Overview of renewable energy sources: photovoltaic and wind energy systems. Classification of renewable energy integrated systems. Benefits and challenges of renewable energy systems. Solar energy potential and assessment.

UNIT-II ***(10 hours)***

Photovoltaic and Wind Energy Systems: Modelling of photovoltaic cells and PV arrays. Maximum Power Point Tracking (MPPT): concept and need, MPPT algorithms and methods. Wind energy fundamentals: wind speed and power relationship (Betz's Law), wind speed distribution, Weibull probability function. Types of wind turbines. Wind turbine power curve and performance metrics.

UNIT-III ***(14 hours)***

Modelling and Control of Renewable Energy Systems: Mathematical modelling of PV systems and wind turbine systems. MPPT techniques: Perturb & Observe (P&O), Incremental Conductance (I&C). Control of renewable energy systems: grid-connected and standalone systems. Introduction to conventional control mechanisms used in renewable energy systems.

UNIT-IV ***(15 hours)***

Control Applications and Case Studies: Design and control of grid-connected, standalone, and grid-interactive renewable energy systems. Case studies related to PV, wind, and hybrid systems. Recent research and developments in intelligent control techniques for renewable energy systems and their applications.

Essential Readings:

1. J. A. Duffie and W. A. Beckman, *Solar Engineering of Thermal Processes*, 4th ed. Hoboken, NJ, USA: Wiley, 2013.
2. J. F. Manwell, J. G. McGowan, and A. L. Rogers, *Wind Energy Explained: Theory, Design and Application*, 2nd ed. Chichester, U.K.: Wiley, 2009.
3. M. Rahman and Y. Khalid, Eds., *Artificial Intelligence in Renewable Energetic Systems: Smart Technologies for Sustainable Development*. Boca Raton, FL, USA: CRC Press, 2022.

Suggested Readings:

1. S. Chakraborty, M. G. Simões, and W. E. Kramer, Eds., *Power Electronics for Renewable and Distributed Energy Systems*. New York, NY, USA: Springer, 2013.
2. J. Momoh, *Smart Grid: Fundamentals of Design and Analysis*. Hoboken, NJ, USA: Wiley-*IEEE Press*, 2012.
3. Journal Research papers from publishers like IEEE/Elseviers/Springers etc.

Practical Component: ***(30 Hours)***

List of Experiments:

1. Modelling and simulation of a photovoltaic cell and PV array characteristics.
2. Implementation and performance analysis of P&O MPPT algorithm for a PV system.
3. Implementation and comparison of the Incremental Conductance MPPT technique for PV systems.
4. Modelling of wind turbine and analysis of wind speed–power characteristics.
5. Simulation of wind turbine power curve and performance metrics.
6. Modelling and control of a standalone photovoltaic system with DC–DC converter.
7. Modelling and simulation of a grid-connected PV system with inverter control.
8. Modelling and simulation of a standalone wind energy conversion system.
9. Performance analysis of a hybrid PV–wind renewable energy system.
10. Case study–based simulation of a grid-interactive renewable energy system with basic control strategies.
11. SIL/HIL implementation of PV system model using a digital real-time simulator.
12. SIL/HIL modelling of wind energy conversion system and analysis of dynamic response under wind variations.
13. SIL/HIL-based control and performance evaluation of a hybrid PV–wind system under grid-connected and standalone modes.

(Note: Course instructor may add/delete/update new experiments in addition to the above suggested practical exercise.)

Electro-Chemistry of Fuel Cells (DSE-06/ GE-07)

(Credit Distribution and Pre-Requisites of the Course)

Course title	Credits	Credit distribution of the course			Prerequisite of the course (if any)
		Lecture	Tutorial	Practical	
Electro-Chemistry of Fuel Cells	4	3	0	1	Introduction to Electrical and Electronics Engineering, Physics

Course Objectives:

1. Understanding of electrochemical principles and introducing fuel cells in the EV context
2. Dive into reaction mechanisms, kinetics, and performance-limiting factors in fuel cells.
3. Cover key components and transport processes critical for EV fuel cell stacks
4. Apply concepts to real-world EV integration, performance analysis, and future outlook

Course Outcomes:

At the end of this course, students will demonstrate the ability to:

1. Explain the working principles, thermodynamics, and electrochemical processes of various fuel cell types.
2. Analyze and compare the performance, advantages, and limitations of different fuel cells such as PEMFC, SOFC, AFC, and others.
3. Evaluate the impact of key fuel cell components and fueling technologies, including hydrogen storage and reforming methods, on system performance.
4. Apply knowledge of fuel cell technologies to practical applications like power generation, transportation systems, and hybrid electric drivetrains while assessing their economic and environmental implications.

UNIT-I ***(12 hours)***

Fundamentals of Electrochemistry and Fuel Cells:

Introduction to electrochemistry: Galvanic vs. electrolytic cells, electrode potentials, Nernst equation, standard hydrogen electrode, reference electrodes. Thermodynamics of electrochemical reactions: Gibbs free energy, cell potential (E°), reversible work, efficiency (theoretical vs. practical), heat of reaction, entropy changes. Fuel cells overview: Definition, difference from batteries (continuous fuel supply), advantages over IC engines (higher efficiency ~50–60%, zero tailpipe emissions), role in EVs (FCEVs as range-extended or pure hydrogen vehicles). Classification of fuel cells: Focus on low-temperature types relevant to EVs (PEMFC, AFC); brief on others (SOFC, MCFC, PAFC, DMFC). Basic fuels for fuel cells: Hydrogen (primary for EVs), challenges with impurities (CO, S poisoning), alternative fuels (methanol, hydrocarbons). Why fuel cells in EVs: Comparison with battery EVs (BEVs) — refueling time, range, energy density.

UNIT-II ***(12 hours)***

Electrochemistry of Fuel Cells – Kinetics and Losses

Electrode kinetics: Butler-Volmer equation, exchange current density, Tafel equation, activation overpotential (η_act). Types of voltage losses/polarizations: Activation, ohmic, concentration (mass transport) losses; polarization curve (V-I characteristics). Fuel cell efficiency: Voltage efficiency, fuel utilization, overall efficiency calculation. Half-cell reactions in PEM fuel cells: Electrocatalysts: Platinum (Pt) and Pt-based alloys, issues with Pt loading/cost, carbon supports, degradation mechanisms (Pt dissolution, agglomeration). ORR kinetics challenges: Slow 4-electron transfer, peroxide formation, poisoning effects.

UNIT-III ***(11 hours)***

Components, Transport Phenomena, and PEM Fuel Cell Design

Proton exchange membrane (PEM): Nafion structure, proton conductivity, water management (humidification needs), thickness effects. Membrane electrode assembly (MEA): Catalyst layers, gas diffusion layers (GDL), microporous layers. Bipolar plates: Materials (graphite, metallic), flow field designs (parallel, serpentine), contact resistance. Mass transport and charge transport: Gas diffusion, proton migration, electron conduction, water transport (electro-osmotic drag, back-diffusion). Heat and water management: Thermal balance, cooling systems, flooding/dehydration issues in PEMFCs. Fuel cell stack for EVs: Series/parallel configuration, power output scaling, system auxiliaries (air compressor, hydrogen recirculation, humidifiers).

UNIT-IV ***(10 hours)***

Performance, Modeling, Applications, and Challenges in EVs

Fuel cell performance testing: Polarization curves, power density, efficiency maps, durability testing.

Modeling of fuel cells: Simple 0D models (equivalent circuit), basic equations for voltage losses, introduction to CFD/1D models for transport. Fuel cell electric vehicles (FCEVs): System integration (fuel cell + battery hybrid), powertrain architecture, hydrogen storage (compressed, liquid), refueling infrastructure. Case studies: Toyota Mirai, Hyundai Nexo — stack specs, efficiency, range. Challenges and advancements: Cost reduction (low-Pt catalysts), durability (>5000–10000 hours for automotive), cold-start issues, hydrogen production/storage/safety. Future in EVs: Role in heavy-duty/long-haul vehicles, comparison with BEVs, policy support (FAME schemes, green hydrogen in India).

Essential Readings:

1. EG&G Technical Services, Inc., *Fuel Cell Handbook*, 7th Edition, U.S. Department of Energy, Office of Fossil Energy, 2004.
2. Mehrdad Ehsani, Yiming Gao, Stefano Longo, and Kambiz Ebrahimi, *Modern Electric, Hybrid Electric, and Fuel Cell Vehicles*, 3rd Edition, CRC Press, 2018.
3. B. Viswanathan and M. Aulice Scibioh, *Fuel Cells: Principles and Applications*, Universities Press.
4. Gregor Hoogers, *Fuel Cell Technology Handbook*, CRC Press / SAE International, 2003.

Suggested Readings:

1. B. H. Khan, Non-Conventional Energy Resources, 2nd Edition, Tata McGraw-Hill, 2013.
2. B. Hart and G. J. Womack, Fuel Cells: Theory and Applications, Chapman and Hall.
3. Fuel Cells for Automotive Applications, Professional Engineering Publishing, UK, 2004.

Practical Component: ***(30 Hours)***

List of Experiments:

1. To demonstrate the electrolysis of water using a reversible PEM fuel cell and verify the stoichiometry of hydrogen and oxygen production.
2. To assemble a single PEM fuel cell and measure its open-circuit voltage under standard operating conditions.
3. To obtain the polarization (V-I) curve and power density curve of a PEM fuel cell and identify different regions of voltage losses.
4. To study the effect of operating temperature on the performance characteristics of a PEM fuel cell.

5. To investigate the influence of gas humidification (relative humidity) on the voltage and performance of a PEM fuel cell.
6. To determine the fuel utilization and overall efficiency of a PEM fuel cell under constant load conditions.
7. To construct a Tafel plot from low-current data and analyze the activation overpotential for the oxygen reduction reaction (ORR).
8. To demonstrate cathode flooding and its impact on mass transport limitations in a PEM fuel cell at high current densities.
9. To evaluate the effect of reactant gas stoichiometry (flow rates) on the polarization behavior and concentration polarization of a PEM fuel cell.
10. To demonstrate the basic operation of a fuel cell + battery hybrid system simulating an EV-like dynamic load profile and observe power sharing.

(Note: Course instructor may add/delete/update new experiments in addition to the above suggested practical exercise.)

Modeling and Simulation of EHV (DSE-07/ GE-08)

(Credit Distribution and Pre-Requisites of the Course)

Course title	Credits	Credit distribution of the course			Prerequisite of the course (if any)
		Lecture	Tutorial	Practical	
Modeling and Simulation of EHV	4	3	0	1	Introduction to Electrical and Electronics Engineering

Course Objectives:

1. To understand the evolution, architecture, and interdisciplinary nature of EVs and HEVs.
2. To develop mathematical and physical models of EV/HEV subsystems.
3. To apply simulation tools, Simulink/Simscape, for system-level analysis.
4. To study control strategies for electric drives and hybrid vehicle architectures.

Course Outcomes:

At the end of this course, students will demonstrate the ability to:

1. Explain EV and HEV architectures and their operating principles.
2. Develop mathematical models for vehicle dynamics and energy storage systems.
3. Model and simulate electric motors and power electronic converters.
4. Analyze AC motor control techniques for traction applications.
5. Simulate and evaluate complete EV/HEV systems using software tools.

UNIT-I ***(09 hours)***

Introduction, Architectures, and Modeling: Introduction to EVs and HEVs, brief history of electric and hybrid vehicles, comparison of EVs and HEVs, interdisciplinary nature of hybrid electric vehicles. series hybrid architecture, parallel hybrid architecture, split power (series–parallel) architecture, system modeling fundamentals, mathematical modeling techniques, overview of software tools for EV/HEV modeling.

UNIT-II ***(12 hours)***

Simscape and Vehicle Dynamics: Physical network approach to modeling: variable types, direction of variables, passive and active elements, physical conserving ports, physical signal ports, getting started with Simscape, longitudinal vehicle load modeling, tractive force calculation and road load modeling.

Energy Storage Modeling: Battery modeling fundamentals, charge and discharge dynamics, State of Charge estimation, thermal modeling of batteries, ultracapacitor modeling.

UNIT-III ***(14 hours)***

DC Motor Modeling and Control: Permanent magnet DC motor modeling, speed and torque control of DC motors, DC motors as traction motors, separately excited DC motor modelling, four-quadrant operation.

Power Electronics and Hardware Control: Role of power electronics in EVs, AC–DC conversion, DC–DC converters: buck and boost, DC motor control using power electronic converters, DC–AC conversion: three-phase inverter, PWM control of inverters.

UNIT-IV ***(10 hours)***

AC Motor Modeling for Traction: Introduction to AC motors for EVs, d–q modeling and vector control, PMSM modeling and control, AC motor drive simulation for traction applications.

Hybrid Vehicle System Modeling: Modeling of series hybrid electric vehicle, modeling of parallel hybrid electric vehicle, split power HEV modeling, overall vehicle supervisory control, performance analysis under different drive cycles.

Essential Readings:

1. Iqbal Husain, Electric and Hybrid Vehicles: Design Fundamentals, CRC Press.
2. James Larminie & John Lowry, Electric Vehicle Technology Explained, Wiley.
3. Mehrdad Ehsani et al., Modern Electric, Hybrid Electric, and Fuel Cell Vehicles, CRC Press.

Suggested Readings:

1. Shuvra Das, Modeling for Hybrid and Electric Vehicles Using Simscape, Elsevier.
2. MATLAB & Simulink Documentation – MathWorks.

Practical Component: ***(30 Hours)***

List of Experiments:

1. Modeling of vehicle longitudinal dynamics in Simulink.
2. Simulation of vehicle road load and tractive effort.
3. Battery modeling with SOC and thermal effects.
4. Ultracapacitor modeling and comparison with battery.
5. PMDC motor modeling and speed control.
6. Four-quadrant DC motor control using DC–DC converter.
7. Modeling of buck and boost converters for EV applications.
8. PMSM modeling with vector (d–q) control.
9. Simulation of a series hybrid electric vehicle.
10. Simulation of a parallel or split-power HEV under a standard drive cycle.

(Note: Course instructor may add/delete/update new experiments in addition to the above suggested practical exercise.)

Detailed Syllabus of Generic Elective (GE) courses offered for Minors / Specializations by Department of Electrical Engineering in SEMESTER VIII

Power Plant Engineering (DSE-09/ GE-09)

(Credit Distribution and Pre-Requisites of the Course)

Course title	Credits	Credit distribution of the course			Prerequisite of the course (if any)
		Lecture	Tutorial	Practical	
Power Plant Engineering	4	3	1	0	Introduction to Electrical and Electronics Engineering, Mathematics-I, Physics

Course Objectives:

1. To introduce sources of energy and the layout of various power plants.
2. To explain the working and performance of steam power plants.
3. To describe the operation of hydroelectric, diesel, and gas turbine power plants.
4. To provide basics of nuclear power plants and power plant economics.

Course Outcomes:

At the end of this course, students will demonstrate the ability to:
1. Identify sources of energy and describe general layouts of power plants.
2. Analyze steam cycles and compute performance parameters of thermal plants.
3. Explain components and operation of hydroelectric, diesel, and gas turbine plants.
4. Understand nuclear reactor types and basic economic aspects of power generation.

UNIT-I ***(12 hours)***
Introduction: Sources of energy, types of power plants, review of thermodynamic cycles in power plants; Fuels and combustion: Coal handling, pulverizers, ash handling, draught systems; Steam Power Plant: General layout, Rankine cycle, reheat and regenerative cycles, efficiency improvement.

UNIT-II ***(10 hours)***
Steam Generators and Turbines: Boilers: fire tube and water tube, high pressure boilers; Steam nozzles and turbines: impulse and reaction types, velocity diagrams, compounding; Condensers and cooling towers.

UNIT-III ***(13 hours)***
Hydroelectric and Diesel/Gas Turbine Plants: Hydroelectric plants: classification, components (penstock, surge tank), turbines (Pelton, Francis, Kaplan); Diesel engine power plants: layout, supercharging; Gas turbine plants: open and closed cycles, components, intercooling, reheating, regeneration.

UNIT-IV ***(10 hours)***
Nuclear Power Plants and Economics: Nuclear fission, reactor types (PWR, BWR), components, safety features; Power plant economics: load curves, load factor, capacity factor, cost analysis, tariffs.

Essential Readings:

1. P.K. Nag, Power Plant Engineering, Tata McGraw Hill, 4th Edition, 2014.
2. R.K. Rajput, Power Plant Engineering, Laxmi Publications, 5th Edition, 2016.

3. Arora and Domkundwar, A Course in Power Plant Engineering, Dhanpat Rai & Co., Latest Edition.

Suggested Readings:

1. G.R. Nagpal and S.C. Sharma, Power Plant Engineering, Khanna Publishers, Latest Edition.
2. Frederick T. Morse, Power Plant Engineering, East-West Press, Latest Edition.

Tutorial Component: ***(15 hours)***

List of Tutorial Tasks:

1. Problems related to classification of power plants based on energy sources and site selection criteria.
2. Problems related to efficiency calculations for Rankine, reheat, and regenerative steam cycles.
3. Problems related to coal handling systems, pulverization, and draught system design considerations.
4. Problems related to classification and performance analysis of different types of boilers (fire-tube vs. water-tube).
5. Problems related to velocity diagrams, compounding methods, and efficiency of impulse vs. reaction turbines.
6. Problems related to condenser performance, vacuum efficiency, and cooling tower heat balance calculations.
7. Problems related to classification of hydroelectric plants and selection of suitable turbines (Pelton, Francis, Kaplan).
8. Problems related to layout design and supercharging effects in diesel engine power plants.
9. Problems related to open/closed cycle analysis of gas turbine plants with intercooling, reheating, and regeneration.
10. Problems related to nuclear reactor types, fuel-moderator-coolant combinations, and safety feature comparisons.
11. Problems related to load curves, load factor, capacity factor, and plant use factor calculations.
12. Problems related to economic analysis including depreciation methods, tariff calculation, and cost comparison of different power plants.

(Note: The course instructor may add/delete/update new tutorial tasks in addition to the above suggested tutorial tasks.)

Machine Learning Applications in Electrical Engineering (DSE-09/ GE-09)

(Credit Distribution and Pre-Requisites of the Course)

Course title	Credits	Credit distribution of the course			Prerequisite of the course (if any)
		Lecture	Tutorial	Practical	
Machine Learning Applications in Electrical Engineering	4	3	0	1	Introduction to Electrical and Electronics Engineering, Mathematics-I, Fundamentals of Computer Programming

Course Objectives:

1. To introduce the fundamentals of machine learning and its relevance to engineering problems.
2. To explain supervised and unsupervised learning techniques with a focus on regression and classification.
3. To cover optimization methods and model evaluation for machine learning models.
4. To emphasize applications of machine learning in electrical engineering domains such as power systems and energy management.

Course Outcomes:

At the end of this course, students will demonstrate the ability to:

1. Understand basic concepts of data science and machine learning, including supervised and unsupervised methods.
2. Apply regression and classification algorithms to solve simple engineering problems.
3. Implement optimization and evaluation techniques using Python tools.
4. Analyze machine learning applications in electrical engineering, such as load forecasting and fault detection.

UNIT-I ***(11 hours)***

Introduction to Machine Learning: Differences between supervised, unsupervised, and reinforcement learning; Probability and statistics basics (sample/population properties, covariance, correlation); Motivation for ML in electrical engineering (e.g., predictive maintenance in power grids).

UNIT-II ***(11 hours)***

Supervised Learning - Regression and Classification: Linear regression, model fitting, coefficient of determination, confidence intervals; Overfitting/underfitting, bias-variance tradeoff, regularization (ridge, LASSO); Logistic and softmax regression; Applications in EE (e.g., load forecasting using regression).

UNIT-III ***(12 hours)***

Unsupervised Learning and Advanced Techniques: Clustering algorithms (k-means, density-based); Dimensionality reduction (SVD, PCA, nonlinear methods like UMAP, t-SNE); Decision trees, ensemble methods (bagging, boosting, random forests); Support vector machines for classification/regression; Hyperparameter tuning (grid search, cross-validation).

UNIT-IV ***(11 hours)***

Neural Networks and EE Applications: Introduction to neural networks (feed-forward, convolutional, recurrent); Loss functions, gradient descent variants (SGD, Adam); Applications in electrical engineering: Fault detection in transmission lines, renewable energy prediction (solar/wind), smart grid optimization, energy consumption forecasting.

Essential Readings:

1. Raghunathan Rengaswamy and Resmi Suresh, Data Science for Engineers, CRC Press, 2022.
2. Ethem Alpaydin, Introduction to Machine Learning, MIT Press, 4th Edition, 2020.
3. Ian Goodfellow, Yoshua Bengio, Aaron Courville, Deep Learning, MIT Press, 2016.

Suggested Readings:

1. Christopher M. Bishop, Pattern Recognition and Machine Learning, Springer, 2006.
2. Aurélien Géron, Hands-On Machine Learning with Scikit-Learn, Keras, and TensorFlow, O'Reilly, 3rd Edition, 2022.

Practical Component: ***(30 Hours)***

List of Experiments:

1. Basic Statistics Visualization: Compute sample/population mean, covariance, and correlation on electrical load datasets; plot results to analyze grid stability relationships.
2. Fit linear regression on historical power demand data, evaluate R-squared and confidence intervals for EE predictive maintenance.
3. Train ridge/LASSO models on noisy transmission line fault data; compare overfitting via bias-variance plots.
4. K-Means Clustering: Cluster renewable energy output (solar/wind) data into demand patterns; visualize with EE scatter plots.
5. PCA Dimensionality Reduction: Apply PCA/SVD on high-dimensional smart grid sensor data; compare variance retention for anomaly detection.
6. Build decision trees/random forests for fault classification in power systems; tune via grid search/cross-validation.
7. Use support vector regression to predict energy consumption; test on transmission line datasets.
8. Train feed-forward NN with Adam optimizer for solar power forecasting; evaluate loss on EE time-series data.

(Note: Course instructor may add/delete/update new experiments in addition to the above suggested practical exercise.)

Real Time Embedded System (DSE-09/ GE-09)

(Credit Distribution and Pre-Requisites of the Course)

Course title	Credits	Credit distribution of the course			Prerequisite of the course (if any)
		Lecture	Tutorial	Practical	
Real Time Embedded Systems	4	3	0	1	Fundamentals of Computer Programming

Course Objectives:

1. To understand the concept of embedded system design and analysis.
2. To expose the basic concepts of embedded programming.
3. To learn real time operating systems.
4. To acquire knowledge about real time processors and operating systems.

Course Outcomes:

At the end of this course, students will demonstrate the ability to:

1. Apply the concepts of embedded systems and its features.
2. Analyze various Real Time Operating system is used in Embedded System.
3. Design the flow &Techniques to develop Software for embedded system networks.
4. Analyze Real-time applications using embedded System Products.

UNIT-I ***(12 hours)***

Introduction to Embedded System Design: Complex systems and microprocessors– Embedded system design process –Design example: Model train controller- Design methodologies- Design flows - Requirement Analysis – Specifications-System analysis and architecture design – Quality Assurance techniques - Designing with computing platforms – consumer electronics architecture – platform-level performance analysis.

UNIT-II ***(10 hours)***

Embedded Programming: Components for embedded programs- Models of programs- Assembly, linking and loading – compilation techniques- Program level performance analysis – Software performance optimization – Program level energy and power analysis and optimization – Analysis and optimization of program size- Program validation and testing.

UNIT-III ***(08 hours)***

Real Time Systems: Structure of a Real Time System — Estimating program run times – Task Assignment and Scheduling – Fault Tolerance Techniques – Reliability, Evaluation – Clock Synchronization.

UNIT-IV ***(15 hours)***

Processes and Operating Systems: Introduction – Multiple tasks and multiple processes – Multirate systems-Preemptive real time operating systems-Priority based scheduling- Interprocess communication mechanisms – Evaluating operating system performance- power optimization strategies for processes – Example Real time operating systems-POSIX-Windows CE. - Distributed embedded systems – MPSoCs and shared memory multiprocessors. – Design Example - Audio player, Engine control unit – Video accelerator.

Essential Readings:

1. Marilyn Wolf, “Computers as Components - Principles of Embedded Computing System Design”, Third Edition, Morgan Kaufmann Publisher (An imprint from Elsevier), 2012.

2. Jane W. S. Liu, “Real Time Systems”, Pearson Education, Third Indian Reprint, 2003.
3. Lyla B. Das, “Embedded Systems: An Integrated Approach”, Pearson Education, 2013.

Suggested Readings:

1. Jonathan W. Valvano, “Embedded Microcomputer Systems Real Time Interfacing”, Third Edition Cengage Learning, 2012.
2. David. E. Simon, “An Embedded Software Primer”, 1st Edition, Fifth Impression, Addison-Wesley Professional, 2007

Practical Component: ***(30 hours)***

List of Experiments:

Conduct the following experiments on an ARM CORTEX M3 evaluation board to learn Assembly Language Program and using evaluation version of Embedded 'C' & Keil uVision-4 tool/compiler

1. Write a program to find the factorial of a number.
2. Write a program to add an array of 16 bit numbers and store the 32 bit result in internal RAM.
3. Write a program to find the square of a number (1 to 10) using a look-up table.
4. Write a program to find the largest or smallest number in an array of 32 numbers.
5. Write a program to arrange a series of 32 bit numbers in ascending/descending order.
6. Write a program to count the number of ones and zeros in two consecutive memory locations.
7. Interface a Stepper motor and rotate it in clockwise and anti-clockwise direction.
8. Interface a DAC and generate Triangular and Square waveforms.

(Note: Course instructor may add/delete/update new experiments in addition to the above suggested practical exercise.)

Process Control (DSE-09/ GE-09)

(Credit Distribution and Pre-Requisites of the Course)

Course title	Credits	Credit distribution of the course			Prerequisite of the course (if any)
		Lecture	Tutorial	Practical	
Process Control	4	3	0	1	Introduction to Electrical and Electronics Engineering, Mathematics-I

Course Objectives:

1. To understand the fundamentals of non-linear systems.
2. To understand the modeling concepts of non-linear systems.
3. To understand the stability of non-linear systems.
4. To acquire the knowledge of various non-linear control techniques.

Course Outcomes:

At the end of this course, students will demonstrate the ability to:

1. Understand the basic design techniques in process control.
2. Understand different types of controllers used in process control.
3. Understand the various processes and their control in industries.
4. Develop the knowledge of advanced control strategies with their applications.

UNIT-I ***(15 hours)***

Sensors and Transducers: Basic concepts and working principles of sensors and transducers for measuring process variables like pressure, temperature, level and flow; electromechanical, capacitive, inductive, resistive and photoelectric type proximity sensors.

Concepts of System and Process: Response of first order systems including transfer function and transient response to different forcing functions, introduction to process control loop and salient components, process control terminology, modeling basics, degree of freedom, mass balance, energy Balance equations, linearization of nonlinear systems, modeling of level tank system, continuous Stirred Tank Heater, continuous stirred Tank Reactor, transfer function.

UNIT-II ***(12 hours)***

Controller Principles: Process characteristics, Process Characteristics, Constraints in implementation of process control, terms used in process control, process measurement, control system parameters, discontinuous controller modes, continuous controller modes, composite control modes.

Analog Controllers: General features, electronic controllers, pneumatic controllers, design considerations.

Digital Controllers: Digital simulation of control systems, microprocessor-based controller.

UNIT-III ***(10 hours)***

Control Loop Characteristics: Control system configuration, multivariable control system, control system quality and stability, process loop tuning.

Control Equipment and Final Control Elements: Details of controllers including measurement unit, comparator, actuator and final control elements; pneumatic, hydraulic and electronic actuators; control valve characteristic, pneumatic to electric and electric to pneumatic converters, hydraulic and pneumatic power supply system.

UNIT-IV ***(08 hours)***

Advanced control strategies with case studies: Use of DDC and PLC, introduction to supervisory control, conversion of existing control schemes in operating plants, data loggers.

Essential Readings:

1. Process Control by Harriott Peter, Tata McGraw-Hill Publishing Company Limited, 2008.
2. Process Controls: Principles and Applications by S. Bhanot, Oxford Higher Educations, 2008.
3. Process control: a practical approach. John Wiley & Sons, Myke King, 2016.

Suggested Readings:

1. Process Systems Analysis and Control by Coughanowr and LeBlanc, Third Edition, McGrawHill , 2009.
2. Process Control Instrumentation Technology by C.D. Johnson, 8thEd.,Prentice Hall of India Private Limited, 2008.

Practical Component: ***(30 Hours)***

List of Experiments:

1. Design and Simulation of Sampled Data Control System with Deadbeat Controller.
2. Design and Simulation of Sampled Data Control System with Dahlin’s Controller.
3. Implementation of Cascade Control System.
4. Dead Time Compensation Using Smith Predictor Algorithm Simulation Using Simulink.
5. Design and Testing Of Inverse Response Compensator Using Simulink.
6. Air Temperature Control System.
7. Study of Labview Software.
8. Simulation of a temperature process Using Labview.
9. Study of Programmable Logic Controller.
10. Direction control of a DC Motor Using Programmable Logic Controller.
11. Process Identification using Least Square Estimation.
12. Understanding FOPTD and SOPTD modeling of systems with MATLAB.
13. PC based control of simulated process.
14. Study of Fuzzy Tool Box and design of Fuzzy Logic Controller for a given process.

(Note: Course instructor may add/delete/update new experiments in addition to the above suggested practical exercise.)

Smart Energy Storage System (DSE-09/ GE-09)

(Credit Distribution and Pre-Requisites of the Course)

Course title	**Credits**	**Credit distribution of the course**			**Prerequisite of the course (if any)**
		Lecture	**Tutorial**	**Practical**	
Smart Energy Storage System	4	3	0	1	Introduction to Electrical and Electronics Engineering, Mathematics-I

Course Objectives:

1. To understand the need, characteristics, and techno-economic role of energy storage in modern power systems.
2. To study advanced energy storage technologies and their performance metrics.
3. To analyze smart integration of storage with grids, microgrids, and renewable energy systems.
4. To introduce control, communication, and management architectures for intelligent energy storage operation.

Course Outcomes:

At the end of this course, students will demonstrate the ability to:

1. Explain the role of smart energy storage in renewable-rich power systems.
2. Classify and compare different energy storage technologies based on technical and operational criteria.
3. Analyze storage deployment for grid, microgrid, and electric mobility applications.
4. Understand control, monitoring, and aggregation of distributed storage systems.

UNIT-I ***(15 hours)***

Fundamentals of Smart Energy Storage Systems: Characteristics of electrical energy and challenges in power system operation, Need for energy storage in conventional and renewable-based systems, Peak demand, grid congestion, intermittency, and reliability issues, Evolution from conventional storage to smart energy storage systems, Role of storage in smart grids, microgrids, and prosumer-based energy systems, Key performance parameters: power rating, energy capacity, efficiency, response time, lifecycle, and cost.

UNIT-II ***(12 hours)***

Energy Storage Technologies and Classification: Overview and classification of energy storage systems, Mechanical Storage: Pumped Hydro Storage (PHS), Compressed Air Energy Storage (CAES), Flywheel Energy Storage (FES), Electrochemical Storage: Lead-acid, Lithium-ion, Sodium-sulfur, Flow batteries, Electrical Storage: Supercapacitors (DLC), Superconducting Magnetic Energy Storage (SMES), Chemical and Thermal Storage: Hydrogen energy storage, Synthetic Natural Gas (SNG), thermal energy storage, Comparative assessment of technologies for smart applications.

UNIT-III ***(10 hours)***

Smart Integration, Control, and Standards: Integration of storage with renewable energy sources (solar, wind), Storage roles from utility, consumer, and renewable generator perspectives, Power electronics interfaces for energy storage systems, Battery Management Systems (BMS) and Energy Management Systems (EMS), Communication, monitoring, and control architectures, Standards, safety, and grid codes for smart energy storage deployment.

UNIT-IV *(8 hours)*

Applications and Advanced Concepts in Smart Energy Storage: Utility-scale applications: frequency regulation, peak shaving, load leveling, Storage in smart grids and smart microgrids, Residential and commercial storage: smart homes and buildings, Energy storage for electric vehicles and charging infrastructure, Emerging trends and future research directions in smart energy storage.

Essential Readings:

1. D. Linden and T. B. Reddy, *Handbook of Batteries*, 4th Edition, McGraw-Hill, 2011.
2. Ibrahim Dincer and Marc A. Rosen, *Thermal Energy Storage: Systems and Applications*, 2nd Edition, Wiley, 2010.
3. Sean Daly, Drew Lebowitz, and Swetha Sundaram, *The BESS Book: A Cell to Grid Guide to Utility-Scale Battery Energy Storage Systems* (Bess Book, 2024).

Suggested Readings:

1. Xisheng Tang, Zhiping Qi , Li Kong, *Electrical Energy Storage Technologies and Applications*, Springer, 2025.
2. A. A. Akhil, G. Huff, A. B. Currier, et al., *Energy Storage Systems: Fundamentals, Classification and a Technical Comparative*. Albuquerque, NM, USA: Sandia National Laboratories, 2013.

Practical Component: ***(30 Hours)***

List of Experiments:

1. To study charge–discharge characteristics of a battery energy storage system and evaluate its efficiency and state of charge.
2. To model and analyze lithium-ion battery behavior using equivalent circuit models under dynamic operating conditions
3. To study battery management system functions, including state of charge estimation, state of health assessment, and cell balancing.
4. To analyze the integration of energy storage systems with a solar PV system for power smoothing and peak shaving.
5. To model and analyze high-power energy storage systems such as flywheels and supercapacitors for short-duration applications.
6. To study the operation of energy storage systems in grid-connected and islanded microgrid modes.
7. To analyze thermal and safety aspects of battery energy storage systems under different operating conditions.
8. To analyze the techno-economic feasibility of energy storage systems for renewable energy integration.

(Note: The Course instructor may add/delete/update new experiments in addition to the above suggested practical exercise.)

Wind and Small Hydro Power Generation (DSE-09/ GE-09)

(Credit Distribution and Pre-Requisites of the Course)

Course title	Credits	Credit distribution of the course			Prerequisite of the course (if any)
		Lecture	Tutorial	Practical	
Wind and Small Hydro Power Generation	4	3	0	1	Introduction to Electrical and Electronics Engineering

Course Objectives:

1. Understand wind and small hydro fundamentals, resource assessment, and site selection.
2. Analyze wind turbine aerodynamics, generators, and farm design.
3. Learn small hydro classification, hydrology, turbines, and components.
4. Evaluate hybrid integration, grid challenges, environmental, and economic aspects.

Course Outcomes:

At the end of this course, students will demonstrate the ability to:

1. To appraise basic principles of wind energy conversion, various wind parameter measuring instruments and to estimate potential of wind energy resource
2. To appraise concept of aerodynamics geometry, design and performance of HWAT and concepts of VAWT
3. To make calculations of the economics of the wind energy system.
4. To appraise small hydro system components and design, hybrid systems and controls.

UNIT-I ***(12 hours)***

Introduction to Renewable Energy and Wind Power Basics

Overview of renewable energy sources: Global and Indian energy scenario, potential, advantages, and limitations of wind and hydro power. Wind energy fundamentals: Nature of wind, wind data analysis (Weibull distribution), power in the wind, Betz limit, wind resource assessment, site selection criteria. Wind energy program in India: Status, potential sites, and policies. Types of wind turbines: Horizontal axis (HAWT) and vertical axis (VAWT), components (blades, rotor, gearbox, generator, tower).

UNIT-II ***(15 hours)***

Wind Energy Conversion Systems

Aerodynamics of wind turbines: Blade design, number of blades, pitch control, tip speed ratio (λ), power coefficient (Cp-λ curves). Wind turbine generators: Fixed-speed vs. variable-speed systems, induction generators, synchronous generators, doubly-fed induction generators (DFIG). Performance characteristics: Power curve, capacity factor, cut-in/cut-out speeds, efficiency. Wind farm design: Layout, wake effects, offshore wind energy, environmental impacts, and economic aspects.

UNIT-III ***(10 hours)***

Small Hydro Power Fundamentals

Introduction to hydropower: Classification (large, small, micro, mini, pico hydro), potential in India, advantages, and limitations. Hydrology basics: Resource assessment, flow duration curves, head and flow rate measurement, site selection. Components of small hydro systems: Intake, penstock, turbines, generators, tailrace, and control systems. Types of turbines for small hydro: Pelton (impulse), Francis (reaction), Kaplan, propeller, cross-flow; selection criteria based on head and flow.

UNIT-IV

Small Hydro Power Systems and Integration *(8 hours)*

Performance and efficiency: Effect of head, flow rate, and load on power output; specific speed, voltage regulation. Small hydro plant design: Civil works, speed and voltage control, standalone vs. grid-connected systems. Environmental and economic aspects: Impacts on ecology, siltation issues, cost-benefit analysis, tariffs, and subsidies in India. Hybrid systems: Integration of wind and small hydro with other renewables (e.g., solar), energy storage, and grid interconnection challenges.

Essential Readings:

1. J. F. Manwell, J. G. McGowan, and A. L. Rogers, Wind Energy Explained: Theory, Design and Application, John Wiley & Sons Ltd., 2010.
2. L. L. Freris, Wind Energy Conversion Systems, Prentice Hall, 1990.
3. Martin O. L. Hansen, Aerodynamics of Wind Turbines, Earthscan, 2008.
4. Adam Harvey, Micro-Hydro Design Manual: A Guide to Small-Scale Water Power Schemes, Intermediate Technology Publications, 1993.

Suggested Readings:

1. J. F. Walker, *Wind Energy Technology*, John Wiley, 1997.
2. G. L. Johnson, *Wind Energy Systems*, Prentice Hall, 1985.
3. Roman Ritter, *Good and Bad of Mini Hydro Power*, 2009.

Practical Components: ***(30 hours)***

List of Experiments:

1. Wind measurement for a month and Statistical Analysis of Wind data.
2. To study the construction and working of various types of HAWT.
3. To study the construction and working of various types of VAWT.
4. To study the wind farm planning and development.
5. Case study on wind energy economics.
6. Study of the generator used in wind power plants (PMDC / Induction generator.
7. To draw the performance curves of a horizontal-axis wind turbine using lamps as an electrical load.
8. To draw the performance curves of a horizontal-axis wind turbine using a battery (Accumulator) as an electrical load.
9. To study and design of small hydro turbine.
10. To study and design mini and micro hydro turbines.

(Note: Course instructor may add/delete/update new experiments in addition to the above suggested practical exercise.)

Embedded Based Smart System Design (DSE-09/ GE-09)

(Credit Distribution and Pre-Requisites of the Course)

Course title	Credits	Credit distribution of the course			Prerequisite of the course (if any)
		Lecture	Tutorial	Practical	
Embedded Based Smart System Design	4	3	0	1	Introduction to Electrical and Electronics Engineering

Course Objectives:

1. To introduce the fundamental concepts and architecture of embedded systems used in automotive engineering, with emphasis on electric and hybrid vehicles.
2. To enable students to design and develop embedded solutions for vehicle control, communication, diagnostics, and safety systems.
3. To provide hands-on experience in programming, testing, and integrating embedded hardware and software for automotive applications.
4. To develop the ability to analyze performance, reliability, and safety requirements of embedded systems deployed in automotive environments.

Course Outcomes:

At the end of this course, students will demonstrate the ability to:

1. Explain embedded system fundamentals and their application in automotive and electric vehicle subsystems.
2. Design and implement embedded programs for vehicle control and monitoring applications.
3. Interface sensors, actuators, and communication modules used in automotive embedded systems.
4. Analyze and evaluate the performance, reliability, and safety aspects of embedded systems in automotive environments.
5. Integrate multidisciplinary knowledge to develop embedded solutions for real-world challenges in vehicle automation and smart mobility.

UNIT-I ***(10 hours)***

Introduction to Embedded Systems in EHV: Overview of embedded systems and their role in automotive engineering, electric and hybrid vehicle system architecture, role of embedded systems in EV subsystems: battery management system (BMS), vehicle control unit (VCU), motor control unit and charger controller, fundamentals of microcontrollers and microprocessors used in automotive applications, automotive-grade embedded hardware requirements, introduction to real-time operating systems (RTOS), importance of RTOS in safety-critical automotive and EV applications.

UNIT-II ***(12 hours)***

Automotive Communication Protocols: Need for in-vehicle communication networks, overview of automotive communication protocols: CAN bus, LIN bus, and FlexRay, CAN frame structure and arbitration mechanism, applications of CAN communication in EHV, embedded communication between BMS, VCU, and motor controller.

UNIT-III ***(12 hours)***

Embedded Systems for Vehicle Diagnostics and Maintenance: Introduction to onboard diagnostics (OBD) systems, OBD-II architecture and standards, overview of ISO 15765 CAN-based diagnostics, embedded monitoring of vehicle performance, battery health, and fault conditions, diagnostic trouble code (DTC) generation, retrieval, and interpretation, introduction to remote diagnostics and over-the-air (OTA) software updates in modern electric vehicles.

UNIT-IV ***(11 hours)***

Automotive Infotainment, Human–Machine Interface, and Vehicle Safety: Introduction to automotive infotainment systems and human–machine interface (HMI) design principles, embedded displays, warning indicators, and driver information systems, overview of advanced driver assistance systems (ADAS), embedded systems for collision warning, lane departure warning, and adaptive cruise control, case studies of embedded system applications in vehicle safety and driver assistance systems.

Essential Readings:

1. R. Zurawski, Embedded Systems Handbook: Embedded systems design and verification, CRC press, 2018.
2. J. Wang, Real-time embedded systems, John Wiley & Sons, 2017.
3. R. Zurawski, Embedded Systems Handbook 2-Volume Set, CRC press, 2018.

Suggested Readings:

1. M. Kathiresh, R. Neelaveni, Automotive Embedded Systems, Springer International Publishing, 2021.
2. N. Subhashini, K. Mohanaprasad, M. Murugan, Intelligent embedded systems, D. Thalmann (Ed.). Springer, 2018.
3. G. Nicolescu, P. J. Mosterman, Model-based design for embedded systems, CRC Press, 2018.

Practical Components: ***(30 hours)***

List of Experiments:

1. Study of Automotive Embedded System Architecture.
2. Microcontroller Programming for Automotive Applications.
3. Battery Voltage and Current Measurement Using ADC.
4. Battery Temperature Monitoring and Protection System.
5. PWM-Based DC/BLDC Motor Speed Control.
6. Relay and Contactor Control for EV Power Management.
7. CAN Bus Communication Between Automotive ECUs.
8. On-Board Diagnostics (OBD) and Fault Code Generation.
9. State of Charge (SOC) Estimation Using Embedded System.
10. Embedded HMI for Electric Vehicle Monitoring.
11. Mini Embedded Project for Electric/Hybrid Vehicle Application.

(Note: Course instructor may add/delete/update new experiments in addition to the above suggested practical exercise.)

Computer Aided Design of Electric Machines (DSE-09/ GE-09)

(Credit Distribution and Pre-Requisites of the Course)

Course title	Credits	Credit distribution of the course			Prerequisite of the course (if any)
		Lecture	Tutorial	Practical	
Computer Aided Design of Electric Machines	4	3	0	1	Electrical Machines I, Electrical Machines II

Course Objectives:

1. To develop a strong analytical understanding of modern electric motor topologies used in electric vehicle traction.
2. To enable students to mathematically model torque production, magnetic circuits, and electromechanical energy conversion in advanced electric motors.
3. To train students in step-by-step electromagnetic design methodology of EV traction motors considering performance, thermal, and mechanical constraints.
4. To expose students to computer-aided design, FEM-based analysis, and optimization techniques for modern electric motors through case studies.

Course Outcomes:

At the end of this course, students will demonstrate the ability to:

1. Analyze and compare advanced electric motors for electric vehicle applications based on torque density, efficiency, and control requirements.
2. Develop mathematical models and equivalent circuits of BLDC, PMSM, SynRM, and SRM using dq-axis theory, co-energy method, and nonlinear magnetic modeling.
3. Design EV traction motors from given specifications by calculating magnetic, electrical, thermal, and mechanical parameters using analytical design procedures.
4. Apply FEM tools to evaluate magnetic field distribution, torque, losses, and saturation effects in electric machines.
5. Optimize machine performance using parametric studies and basic optimization techniques while interpreting practical design trade-offs in EV applications.

UNIT-I ***(12 hours)***

Design of Synchronous Reluctance: Introduction and role of reluctance machines in EV traction, comparison of EV motors, torque production mechanisms, dq-axis modeling, saliency ratio and reluctance torque, equivalent circuit representation, power drive motor design requirements, step-by-step design methodology, EV traction case study.

Design of PM-Assisted Motors: Motivation for PM-assisted SynRM, magnetic saturation effects, permanent magnet placement strategies, linear start motor design, parameterization.

UNIT-II ***(12 hours)***

Design of Brushless Permanent Magnet Motors: Historical evolution, applications in electric vehicles, aerospace and industrial drives, permanent magnet materials and characteristics, magnetic circuit modeling, demagnetization and thermal considerations.

Design of Permanent Magnet Synchronous Motors: Configurations and mathematical modeling, fundamental design relationships, winding design and EMF equations, design scope and constraints, optimal design with case studies.

Design of Brushless DC Motors: Mathematical modeling, surface-mounted motor construction and design, design guidelines, numerical problem on motor design.

UNIT-III ***(11 hours)***

Design of Switched Reluctance Motors: Introduction, applications in EVs and harsh environments, construction and operating principle, phase voltage equations, electromagnetic torque equations, nonlinear inductance modeling, co-energy method for torque computation, analytical flux linkage computation, air-gap permeance modeling, aligned and unaligned inductance calculation, design specifications, stator design parameters, rotor pole design, winding design and current profiling, performance calculation, mechanical stress considerations, thermal design considerations, design workflow from specifications to performance evaluation.

UNIT-IV ***(10 hours)***

Advanced Motors: Axial flux motors: Introduction, torque and force equations, performance characteristics, design scope; axial flux switched reluctance motors (AFSRM): introduction, applications and classification, operating principle, analytical design equations.

computer aided designing and analysis method (Case-Study): FEM-based design methodology, FEM problem formulation for EV motors, critical simulation settings for FEA, meta model-based simulation optimization, overview of optimization algorithms: genetic algorithm and particle swarm optimization.

Essential Readings:

1. A. K. Sawhney, A Course in Electrical Machine Design, Dhanpat Rai and Co., 2016.
2. J. R. Hendershot and T. J. E. Miller, Design of Brushless Permanent – Magnet Motors, Motor Design Books LLC, 2nd edition, 2010.
3. R. Krishnan, Switched Reluctance Motor Drives, CRC Press LLC, USA, 2001.

Suggested Readings:

1. T. A. Lipo, Introduction to AC Machine Design, IEEE Press – Wiley Publications, 2017.
2. J. Pyrhonen, T. Jokinen, and V. Hrabovcova, Design of Rotating Electrical Machines, John Wiley and Sons Inc., 2nd edition, 2013.

Practical Components: ***(30 hours)***

List of Experiments:

1. Performance comparison of PMSM, SynRM, and SRM based on torque–speed and efficiency characteristics.
2. Computation of reluctance torque using saliency ratio and current angle variation in a synchronous reluctance motor.
3. Analytical design of a synchronous reluctance motor for EV traction based on given power and speed specifications.
4. Analysis of torque enhancement and saturation using different PM placement strategies in a synchronous reluctance motor.
5. Calculation of air-gap flux density and demagnetization limits of permanent magnet motors.
6. Determination of PMSM winding turns, back-EMF constant, and torque constant.
7. Simulation of BLDC motor phase currents, back-EMF, and electromagnetic torque.
8. Analytical calculation of surface-mounted BLDC motor dimensions, torque, and losses.
9. Flux linkage and torque computation of SRM using the co-energy method.
10. Determination of switched reluctance motor stator and rotor pole arcs, inductances, and torque profile.

(Note: Course instructor may add/delete/update new experiments in addition to the above suggested practical exercise.)

Clean Energy Technologies (DSE-10/ GE-10)

(Credit Distribution and Pre-Requisites of the Course)

Course title	Credits	Credit distribution of the course			Prerequisite of the course (if any)
		Lecture	Tutorial	Practical	
Clean Energy Technologies	4	3	1	0	Introduction to Electrical and Electronics Engineering, Physics

Course Objectives:

1. To introduce clean energy concepts and the need for sustainable technologies.
2. To explain clean production from fossil fuels and bioenergy sources.
3. To describe solar and wind energy systems and their applications.
4. To cover other renewable technologies and economic/environmental aspects.

Course Outcomes:

At the end of this course, students will demonstrate the ability to:

1. Understand the principles of clean energy and its importance in sustainability.
2. Analyze clean coal technologies and biofuel production processes.
3. Explain solar photovoltaic and thermal systems, including performance calculations.
4. Describe wind, hydro, and geothermal energy conversion and evaluate economic viability.

UNIT-I ***(11 hours)***

Introduction to Clean Energy: Global energy scenario, environmental impacts of fossil fuels, need for clean technologies; Clean coal technologies: gasification, fluidized bed combustion, carbon capture and storage (CCS); Supercritical and ultra-supercritical power plants.

UNIT-II ***(11 hours)***

Bioenergy Technologies: Biomass resources, thermochemical conversion (pyrolysis, gasification); Biochemical conversion (anaerobic digestion, fermentation); Biofuels: biodiesel production (transesterification), bioethanol; Biogas plants and applications.

UNIT-III ***(10 hours)***

Solar Energy Technologies: Solar radiation, measurement, and models; Solar thermal systems - collectors, concentrators, solar water heating, power cycles; Solar photovoltaic: cell types, efficiency, PV modules, inverters, grid integration.

UNIT-IV ***(13 hours)***

Wind and Other Renewables: Wind energy: turbine types, power curves, Betz limit, site assessment; Hydroelectric: small hydro, tidal, and ocean energy basics; Geothermal energy: resources, binary cycles; Economic analysis: levelized cost of energy, payback period; Policy and sustainability issues.

Essential Readings:

1. Godfrey Boyle, Renewable Energy: Power for a Sustainable Future, Oxford University Press, 3rd Edition, 2012.
2. Bent Sorensen, Renewable Energy: Physics, Engineering, Environmental Impacts, Economics and Planning, Academic Press, 5th Edition, 2017.
3. Chetan Singh Solanki, Renewable Energy Technologies: A Practical Guide for Beginners, PHI Learning, 2019.

Suggested Readings:

1. G.D. Rai, Non-Conventional Energy Sources, Khanna Publishers, 5th Edition, 2010.
2. John Twidell and Tony Weir, Renewable Energy Resources, Routledge, 3rd Edition, 2015.
3. Sukhatme and Nayak, Solar Energy: Principles of Thermal Collection and Storage, McGraw Hill Education, 4th Edition, 2018.

Tutorial Component: ***(15 Hours)***

List of Tutorial Tasks:

1. Comparison of environmental impacts and efficiency of conventional vs. clean coal technologies (gasification, FBC, CCS).
2. Calculation of efficiency improvement in supercritical/ultra-supercritical plants using Rankine cycle modifications.
3. Selection criteria for site and technology in clean coal power plants (case-study discussion).
4. Classification and comparison of thermochemical vs. biochemical biomass conversion routes with yield calculations.
5. Design considerations and performance evaluation of biogas plants (digester sizing and methane yield).
6. Biodiesel/bioethanol production process flow and transesterification efficiency calculations.
7. Solar radiation measurement, tilt-angle optimization, and insolation calculations for a given location.
8. Performance analysis and efficiency comparison of flat-plate vs. concentrating solar thermal collectors.
9. PV module sizing, I-V curve interpretation, and grid integration challenges (sketching and discussion).
10. Wind turbine power curve analysis, Betz limit application, and site assessment using wind data.
11. Classification and basic power output calculations for small hydro, tidal, and geothermal systems.
12. Economic evaluation (LCOE, payback period) and policy comparison of different clean energy technologies (group discussion/case study).

(Note: The course instructor may add/delete/update new tutorial tasks in addition to the above suggested tutorial tasks.)

Introduction to Smart Grid (DSE-10/ GE-10)

(Credit Distribution and Pre-Requisites of the Course)

Course title	Credits	Credit distribution of the course			Prerequisite of the course (if any)
		Lecture	Tutorial	Practical	
Introduction to Smart Grid	4	3	1	0	Introduction to Electrical and Electronics Engineering

Course Objectives:

1. To introduce the concept of smart grid and its evolution from traditional power systems.
2. To explain the architecture, components, and enabling technologies of smart grids.
3. To describe communication infrastructure and standards in smart grids.
4. To familiarize students with applications, renewable integration, microgrids, and challenges in smart grid implementation.

Course Outcomes:

At the end of this course, students will demonstrate the ability to:

1. Differentiate between conventional grids and smart grids, and explain the need for smart grids.
2. Describe the functional components and architecture of smart grids.
3. Understand communication technologies and standards used in smart grids.
4. Analyze applications of smart grids in renewable integration, microgrids, and demand-side management.

UNIT-I ***(10 hours)***

Introduction to Smart Grids: Evolution of electric power systems; Limitations of traditional grids; Concept and definition of smart grid; Drivers and need for smart grids; Smart grid functions and benefits; Opportunities and challenges in smart grid implementation.

UNIT-II ***(14 hours)***

Smart Grid Architecture and Components: Conceptual model and domains (generation, transmission, distribution, customer); Key components: advanced metering infrastructure (AMI), phasor measurement units (PMU), wide area monitoring systems (WAMS); Distributed energy resources (DER) integration; Energy storage systems.

UNIT-III ***(10 hours)***

Communication and Standards: Communication technologies in smart grids: wired (PLC, optical fiber) and wireless (ZigBee, Wi-Fi, cellular); IEC 61850 standard for substation automation; Cyber security basics in smart grids; Interoperability and standards.

UNIT-IV ***(11 hours)***

Applications and Advanced Concepts: Renewable energy integration in smart grids; Microgrids: AC/DC types, operation modes (grid-connected, islanded); Demand-side management and demand response; Electric vehicles and vehicle-to-grid (V2G); Smart grid initiatives in India.

Essential Readings:

1. James Momoh, Smart Grid: Fundamentals of Design and Analysis, Wiley-IEEE Press, 2012.
2. Janaka Ekanayake, Nick Jenkins, Kithsiri Liyanage, Jianzhong Wu, Akihiko Yokoyama, Smart Grid: Technology and Applications, Wiley, 2012.

3. Clark W. Gellings, The Smart Grid: Enabling Energy Efficiency and Demand Response, Fairmont Press, 2009.

Suggested Readings:

1. Stuart Borlase, Smart Grids: Infrastructure, Technology, and Solutions, CRC Press, 2nd Edition, 2017.
2. Tony Flick and Justin Morehouse, Securing the Smart Grid: Next Generation Power Grid Security, Syngress, 2010.
3. Vehbi C. Güngör and Dilan Sahin, Smart Grid Communications and Networking, Cambridge University Press, 2012.

Tutorial Component: ***(15 Hours)***

List of Tutorial Tasks:

1. Comparison of conventional grids vs. smart grids (features, limitations, and benefits).
2. Identification of drivers, opportunities, and challenges in smart grid adoption (case-study discussion).
3. Listing smart grid functions and benefits with real-world examples.
4. Conceptual modelling of smart grid domains and key component identification.
5. Sizing and application of AMI, PMU, and WAMS in sample power systems.
6. Integration of DER and energy storage systems in smart grid architecture (sketching and discussion).
7. Selection of communication technologies (wired vs. wireless) for different smart grid layers.
8. Interpretation of IEC 61850 standards in substation automation scenarios.
9. Basic cyber-security risk assessment and interoperability issues in smart grid communication.
10. Renewable energy integration and microgrid operation modes (grid-connected vs. islanded).
11. Demand response strategies, V2G calculations, and electric vehicle integration.
12. Economic and policy analysis of smart grid initiatives (group discussion/case study).

(Note: The course instructor may add/delete/update new tutorial tasks in addition to the above suggested tutorial tasks.)

Optimal and Robust Control (DSE-10/ GE-10)

(Credit Distribution and Pre-Requisites of the Course)

Course title	Credits	Credit distribution of the course			Prerequisite of the course (if any)
		Lecture	Tutorial	Practical	
Optimal and Robust Control	4	3	0	1	Introduction to Electrical and Electronics Engineering, Mathematics-I.

Course Objectives:

1. To acquire the fundamental knowledge of optimal control framework.
2. To understand the designs of optimal control techniques.
3. To acquire the fundamental knowledge of robust control theory.
4. To understand the robust control techniques.

Course Outcomes:

At the end of this course, students will demonstrate the ability to:

1. Design and analyze the closed loop system with linear state feedback control laws.
2. Design the observer based controllers.
3. Analyze robustness of the control systems.
4. Design robust control algorithms on the engineering systems.

UNIT-I ***(08 hours)***

Introduction to Optimal Control: Introduction to optimal control issues and framework, state feedback for regulation and tracking, observer based compensators and separation property, steady state tracking with observer based compensators, related examples.

UNIT-II ***(12 hours)***

Optimal control general mathematical procedures: Formulation of optimal control problem, performance indices, calculus of variation, minimum principle, dynamic programming, related examples, optimal feedback control linear state regulator, continuous time linear state regulator, use of linear regulator to solve other linear optimal control problems, minimum time control of LTI systems, stability analysis, related examples.

UNIT-III ***(15 hours)***

Introduction to robust control: Vector spaces, linear subspaces, invariant subspaces, vector norms and matrix norms, singular value decomposition, semi-definite matrices, description of linear systems, operations on systems, state space realizations for transfer matrices.

Feedback interconnection & stability: Well-posedness, internal stability, co-prime factorization, stabilizing controllers, Linear Quadratic Regulators: Return ratio and difference, design of LQR and robustness analysis.

UNIT-IV ***(10 hours)***

Other Robust Control Techniques: LQG/LTR Design and its robustness analysis, related examples, H_2 and $H\infty$ control techniques and their design formulations.

Essential Readings:

1. Modern Control System Theory by M Gopal, New Age International (P) Limited, 2015.

2. Linear State-space Control Systems by Robert L Williams II & Douglas A. Lawrence, John Wiley & Sons, INC, 2007.
3. Essentials of Robust Control by Kemin Zhou and J C Doyle, Prentice Hall, 1998.

Suggested Readings:

1. Multivariable Feedback Design by J M Maciejowski, Addison-Wesley Publishing Company, 1989.
2. Linear Optimal Control by B D O Anderson and J B Moore, Prentice Hall, 1990.

Practical Component: ***(30 Hours)***

List of Experiments:

1. State Space realization of SISO system and implementation of optimal control for the same.
2. State Space realization of MIMO system and implementation of optimal control for the same.
3. To obtain the various norms of matrix, signals, vectors and systems.
4. To implement LQR control for SISO system.
5. To implement LQR control for MIMO system.
6. To implement LQG/LTR control for SISO system.
7. To implement LQG/LTR control for MIMO system.
8. To implement $H\infty$ control technique for SISO system.
9. Applications of robust control techniques in real problems.
10. Case Study1: Implementation of optimal control for any practical application.
11. Case Study2: Implementation of robust control for any practical application.

(Note: Course instructor may add/delete/update new experiments in addition to the above suggested practical exercise.)

Robotics in Biomedical Engineering (DSE-10/ GE-10)

(Credit Distribution and Pre-Requisites of the Course)

Course title	Credits	Credit distribution of the course			Prerequisite of the course (if any)
		Lecture	Tutorial	Practical	
Robotics in Biomedical Engineering	4	3	1	0	Introduction to Robotics and Mechatronics

Course Objectives:

1. To explore the medical robots and their uses in rehabilitation purpose.
2. To investigate recent developments and emerging trends in biomedical robots and interpret localization and navigation techniques for mobile robots.
3. To identify the fundamental parameters of medical and mobile robots and examine their typical applications.

Course Outcomes:

At the end of this course, students will demonstrate the ability to:

1. Design and implement robotic assistants for Minimally Invasive Surgery and Image-Guided Interventions and analyze key design parameters of medical robots.
2. Evaluate the parameters of rehabilitation systems, exoskeletons, and explore locomotion aspects of mobile robots.
3. Analyze the core applications of specialized surgical robots and assess their advantages and limitations.

UNIT-I ***(12 hours)***

Introduction to Medical Robots: Introduction to Bio-medical robots, Types of Medical Robots, Navigation and paradigms of BioMedical Robots, Forward kinematics, Inverse, Typical applications and benefits of robots in health care sectors. Design of Medical Robots, Characterization of gestures to the design of robot-design methodology- technological choices-security

UNIT-II ***(12 hours)***

Rehabilitation Robotics: Introduction, Exoskeletons-Design concepts, Development and control-Human hand-Biomechanics, Rehabilitation for Limbs-Brain-Machine-Interfaces, Redundancy resolution, Introduction to Rehabilitation Strategies, Robotic prosthetics. Mobile Robot locomotion: Types of locomotion and its salient characteristics of hopping robots, legged robots, wheeled robots, stability, aerial robots, maneuverability, controllability.

UNIT-III ***(11 hours)***

Mobile Robot Localization and Navigation: Introduction, the challenges of localization, localization based navigation versus programmed solutions, map representation, probabilistic map, map based localization, autonomous map building. Planning and navigation: Planning and reaction, D* algorithm obstacle avoidance.

UNIT-IV ***(10 hours)***

Current Topics in Bio-Medical Robotics: Haptic Augmentation in Exoskeletons, Robotic Catheters for percutaneous interventions, Unsupervised learning for mapping in Bio-Robots, Reven–II Robots. Future Trends of Robotics in the Medical Field.

Essential Readings:

1. Paula Gomes, “Medical robotics- Minimally Invasive surgery”, Woodhead Publishing, 2012
2. Jocelyne Troccaz, “Medical Robotics”, Wiley-ISTE, 2012.
3. Vanja Bonzovic, “Medical Robotics”, I-tech Education publishing, Austria, 2008.

Suggested Readings:

1. Daniel Faust, “Medical Robots”, Rosen Publishers, 2016.
2. Jacob Rosen, Blake Hannaford & Richard M Satava, “Surgical Robotics: System Applications & Visions”, Springer 2011.

Tutorial Component: ***(15 Hours)***

(Note: The course instructor will design tasks to complete the tutorial component of the course.)

Smart Grid Technologies (DSE-10/ GE-10)

(Credit Distribution and Pre-Requisites of the Course)

Course title	Credits	Credit distribution of the course			Prerequisite of the course (if any)
		Lecture	Tutorial	Practical	
Smart Grid Technologies	4	3	0	1	Introduction to Electrical and Electronics Engineering, Mathematics-I

Course Objectives:

1. To introduce the fundamental concepts, architecture, standards, and enabling technologies of Smart Grid systems.
2. To understand distributed generation resources, energy storage technologies, and battery management systems for Smart Grid applications.
3. To study wide-area monitoring, phasor measurement, protection schemes, and islanding detection techniques in Smart Grids.
4. To analyze the operation, control, and energy management of AC, DC, and hybrid AC–DC microgrids with practical case studies.

Course Outcomes:

At the end of this course, students will demonstrate the ability to:

1. Explain Smart Grid concepts, architectures, standards, cybersecurity issues, and demand-side management strategies.
2. Analyze distributed generation and energy storage systems, including modelling, sizing, siting, and BMS operation.
3. Apply wide-area monitoring systems, PMU-based phasor estimation, digital protection, and islanding detection techniques in Smart Grids.
4. Analyze the operation, control, and protection of AC, DC, and hybrid microgrids under grid-connected and islanded modes.

UNIT-I ***(15 hours)***

Smart Grid Fundamentals, Architecture, and Enabling Technologies: Introduction to Smart Grid, Architecture of Smart Grid System, Standards of Smart Grid System, Elements and Technologies of Smart Grid System, Cybersecurity and resiliency of Smart Grid, Demand Side Management (DSM) of Smart Grid, Demand Response Analysis of Smart Grid, Virtual inertia and ancillary support in Smart Grid.

UNIT-II ***(10 hours)***

Distributed Generation and Energy Storage Systems: Distributed Generation Resources, Introduction to energy storage devices, Types of energy storage technologies, Analytical modelling of energy storage devices, Modelling of storage devices, Optimal sizing and siting of energy storage systems, Battery Management System (BMS).

UNIT-III ***(10 hours)***

Monitoring, Protection, and Islanding in Smart Grids: Wide Area Monitoring Systems (WAMS), Phasor Estimation, Phasor Measurement Unit (PMU) placement, Digital relays for Smart Grid protection, Islanding Detection Techniques, Smart Grid Protection, Harmonic effects and mitigation techniques.

UNIT-IV ***(10 hours)***

Microgrids, Energy Management, and Advanced Applications: Modelling of DC Smart Grid components, Operation and control of: AC Microgrid, DC Microgrid, AC–DC Hybrid Microgrid, Hierarchical control techniques in hybrid AC–DC microgrids, Energy management design of Smart Grid, System analysis of AC/DC Smart Grid.

Essential Readings:

1. Janaka Ekanayake, Nick Jenkins, Kithsiri Liyanage, and Jianzhong Wu, *Smart Grid: Technology and Applications*, John Wiley & Sons, 1st Edition, 2012.
2. Stuart Borlase (Ed.), *Smart Grid: Infrastructure, Technology, and Solutions*, CRC Press, 1st Edition, 2013.
3. James Momoh, *Smart Grid: Fundamentals of Design and Analysis*, John Wiley & Sons, 1st Edition, 2012.

Suggested Readings:

1. Hatim G. Shaker, Ahmed F. Zobaa, *Wide Area Monitoring, Protection and Control Systems: The Enablers for Smarter Grids*, IET, 1st Edition, 2015.
2. Nikos Hatziargyriou (Ed.), *Microgrids: Architectures and Control*, Wiley–IEEE Press, 1st Edition, 2014.

Practical Component: ***(30 Hours)***

List of Experiments:

1. To model and simulate distributed generation resources in a Smart Grid using software tools.
2. To perform analytical modelling, optimal sizing, and siting of energy storage systems.
3. To simulate phasor estimation techniques and PMU placement in a Smart Grid network.
4. To simulate the operation and control of an AC microgrid under grid-connected and islanded modes.
5. To simulate the operation and control of a DC microgrid and a grid-connected DC microgrid.
6. To analyze harmonic effects in Smart Grids and implement mitigation techniques.
7. To perform a simulation and case study of AC, DC, and AC–DC hybrid microgrids.
8. To demonstrate energy management in a microgrid using real-time or simulation-based platforms.

(Note: Course instructor may add/delete/update new experiments in addition to the above suggested practical exercise.)

Energy Management Systems and SCADA (DSE-10/ GE-10)

(Credit Distribution and Pre-Requisites of the Course)

Course title	Credits	Credit distribution of the course			Prerequisite of the course (if any)
		Lecture	Tutorial	Practical	
Energy Management Systems and SCADA	4	3	0	1	Introduction to Electrical and Electronics Engineering, Mathematics-I

Course Objectives:

1. To understand the functions, architectures, and recent developments of Energy Management Centers and their role in power system operation.
2. To analyze power generation characteristics, economic dispatch, unit commitment, generation scheduling, and interchange costing in interconnected power systems.
3. To study the principles, architectures, components, and communication protocols of SCADA systems for power system monitoring and control.
4. To understand the architecture, control functions, and applications of Energy Management Systems (EMS), including AGC, LFC, VQC, security assessment, and dispatch.

Course Outcomes:

At the end of this course, students will demonstrate the ability to:

1. Acquire and demonstrate knowledge of energy management centers, power system operation, and generation characteristics.
2. Apply principles of economic dispatch, unit commitment, and generation scheduling, considering operational constraints and regional interchanges.
3. Analyze Energy Management System (EMS) architectures, online and offline functions, and real-time control applications in power systems.
4. Understand and analyze SCADA system components, configurations, communication requirements, and protocols used for power system monitoring and automation.
5. Analyze advanced EMS and SCADA applications such as AGC, LFC, VQC, security assessment, contingency analysis, power flow, and state estimation in modern power systems.

UNIT-I ***(13 hours)***

Energy Management and Generation Scheduling: Energy Management Centers: functions, architectures, and recent developments, Characteristics of power-generating units, Economic dispatch of generating units, Unit commitment: spinning reserve, thermal, hydro, and fuel constraints, Solution techniques for unit commitment, Generation scheduling with limited energy, Energy production cost: cost models, budgeting, planning, and practical considerations, Interchange evaluation for regional power system operations, Types of power interchanges and exchange costing techniques.

UNIT-II ***(12 hours)***

Supervisory Control and Data Acquisition (SCADA) Fundamentals: Introduction to SCADA systems, SCADA functional requirements and components, General features, functions, applications, and benefits of SCADA, SCADA configurations and system architectures, Remote Terminal Units (RTUs): hardware and connections, SCADA communication requirements, SCADA communication protocols: past, present, and future, Structure of a SCADA communication protocol.

UNIT-III ***(10 hours)***

Energy Management Systems (EMS) Architecture and Control: Introduction and evolution of EMS: control centers, energy control centers, and EMS, Functions and benefits of EMS, State

Electricity Boards (SEBs) monitoring and control, EMS architectures and applications, On-line and offline functions of EMS, Real-time modeling and applications of EMS, EMS control functions: Automatic Generation Control (AGC), Load Frequency Control (LFC), Voltage and Reactive Power Control (VQC).

UNIT-IV ***(10 hours)***

SCADA, EMS Applications, and Power System Automation: EMS case studies: Security assessment Economic dispatch, Contingency analysis, Study-mode applications: Forecasting, Power flow and optimal power flow, State estimation, Security assessment, SCADA evolution, architectures, modules, and components, SCADA hardware: RTUs, IEDs, and Substation Automation Systems (SAS), SCADA software and standards: IEC 61850, GOOSE protocol, Applications of SCADA: Power systems, Railways, Renewable energy systems, Smart grid, Power SCADA applications: automation, protection, and relay interoperability

Essential Readings:

1. Handschin, E. “Energy Management Systems”, Springer Verlag, 1990.
2. Handschin, E. “Real Time Control of Electric Power Systems”, Elsevier, 1972.
3. John D McDonald, “Electric Power Substation Engineering”, CRC press, 2001.

Suggested Readings:

1. Wood, A. J, and Wollenberg, B. F, “Power Generation Operation and Control”, 2nd Edition, John Wiley and Sons, 2003.
2. Green, J. N, Wilson, R, “Control and Automation of Electric Power Distribution Systems”, Taylor and Francis, 2007.
3. Turner, W. C, “Energy Management Handbook”, 5th Edition, 2004.

Practical Component: ***(30 Hours)***

List of Experiments:

1. To study the Energy Management Center (EMC) architecture and functions using simulation tools.
2. Simulation of the economic dispatch problem for thermal generating units without transmission losses.
3. Simulation of economic dispatch with transmission losses using the penalty factor method.
4. Unit commitment analysis considering spinning reserve and generator constraints.
5. Evaluation of energy production cost using different generator cost models.
6. Simulation of Automatic Generation Control (AGC) for single-area and multi-area power systems.
7. Simulation and analysis of Load Frequency Control (LFC) and Voltage Reactive Power Control (VQC).

(Note: The Course instructor may add/delete/update new experiments in addition to the above suggested practical exercise.)

EV Charging Infrastructure (DSE-10/ GE-10)

(Credit Distribution and Pre-Requisites of the Course)

Course title	Credits	Credit distribution of the course			Prerequisite of the course (if any)
		Lecture	Tutorial	Practical	
EV Charging Infrastructure	4	3	0	1	Introduction to Electrical and Electronics Engineering

Course Objectives:

1. Understand the architecture of EV charging infrastructure and applicable Indian and international charging standards.
2. Analyze and design AC–DC and DC–DC power converter topologies with appropriate control strategies for efficient EV charging applications.
3. Understand and apply communication protocols, testing methodologies, and EMI/EMC considerations essential for reliable and compliant EV charging systems.
4. Develop the ability to apply theoretical concepts to practical EV charger design problems and real-world deployment scenarios, including Indian charging ecosystem case studies.

Course Outcomes:

At the end of this course, students will demonstrate the ability to:

1. Explain EV charging infrastructure, EVSE types, charging modes, and Indian and international charging standards.
2. Analyze and simulate AC–DC PFC converters for single-phase and three-phase EV chargers.
3. Design and evaluate isolated DC–DC converters with soft-switching techniques for EV charging applications.
4. Implement and analyze communication protocols and testing methodologies used in EV chargers and EVSE.
5. Evaluate EMI/EMC issues and apply mitigation techniques in EV charging systems.

UNIT-I ***(10 hours)***

Introduction: introduction to EV systems, EV benefits, battery charging modes, types of EV supply equipment (EVSE), components of EV battery chargers, charging infrastructure challenges.

Charger Classification and standards: classification based on charging levels (region-wise), modes, plug types, architecture and specifications of Bharat AC001 and DC001 chargers, standards related to: connectors, communication, supply equipments, electromagnetic interference (EMI)/ electromagnetic compatibility (EMC).

UNIT-II ***(12 hours)***

AC-DC Converter: types of AC-DC converters; working principles, modulation, design, and closed loop control of power factor correction converters (PFC): Boost type PFC, Totem-pole PFC, active front-end converter, three-phase PFCs; working principles, modulation, design, and closed loop control of single-stage AC-DC converters; G2V, V2X operations.

UNIT-III ***(10 hours)***

DC-DC Converter: Types of DC-DC converter used for EV chargers; working principles, modulation, design, modelling and closed loop control of dual active bridge, LLC converter, high frequency magnetics, soft-switching criteria.

UNIT-IV ***(13 hours)***

Protocols and communication: Open charge point protocol (OCPP), Open System Interconnection-Layer-Model (OSI), adapted PWM signal based low-level communication, PLC based high level communication, CAN communication, testing methodology for EV battery chargers and EVSE.

EMI/EMC considerations: sources of EMI, differential mode noise, common mode noise, LISN, measuring of EMI/EMC spectrum, design of DM filters, CM filters.

Case study: deployment of Bharat DC-001 and AC-001 chargers in Indian charging ecosystem.

Essential Readings:

1. Iqbal Husain, Electric and Hybrid Vehicles: Design Fundamentals, CRC Press. 2021.
2. L. Umanand, Power Electronics: Essentials and Applications, Wiley India, 2012.
3. N. Mohan, T.M. Underland and W.P. Robbins, Power Electronics – Converters, Applications and Design, 3rd Ed., Wiley India, 2008.

Suggested Readings:

1. Tom Denton, Automotive Electrical and Electronic Systems, Routledge, 5th Edition, 2018.
2. Robert W. Erickson, and Dragan Maksimovic, Fundamentals of Power Electronics, 3rd Ed., Springer, 2020.
3. Christoph Marscholik and Peter Subke, Road Vehicles - Diagnostic Communication, University Science Press, 2009.
4. Wolfhard Lawrenz, CAN System Engineering: From Theory to Practical Applications, Springer, 2013.

Practical Component: ***(30 Hours)***

List of Experiments:

1. Study of EV Charging Infrastructure and Standards.
2. Analysis of Impact of EV Charging Load on Distribution System.
3. Simulation of Single-Phase AC–DC Rectifier with and without Power Factor Correction.
4. Design and Simulation of Single-Phase Boost PFC Converter for EV Charger.
5. Simulation and Performance Evaluation of Totem-Pole PFC Converter.
6. Analysis of Bidirectional AC–DC Converter for G2V and V2X Operation.
7. Design and Simulation of Dual Active Bridge (DAB) DC–DC Converter.
8. Design and Analysis of LLC Resonant DC–DC Converter for EV Charger.
9. High-Frequency Transformer Design for Isolated EV Charger.
10. Study and Implementation of EV Charger Communication Protocols.
11. EMI/EMC Analysis and Filter Design for EV Chargers.

(Note: Course instructor may add/delete/update new experiments in addition to the above suggested practical exercise.)

Electrical Vehicle System Design (DSE-10/ GE-10)

(Credit Distribution and Pre-Requisites of the Course)

Course title	Credits	Credit distribution of the course			Prerequisite of the course (if any)
		Lecture	Tutorial	Practical	
Electrical Vehicle System Design	4	3	0	1	Introduction to Electrical and Electronics Engineering

Course Objectives:

1. To understand vehicle fundamentals and dynamics relevant to electric vehicles.
2. To analyze and design EV powertrain systems and configurations.
3. To model, simulate, and size EV subsystems for performance and efficiency.
4. To integrate mechanical, electrical, and control aspects of EV design.

Course Outcomes:

At the end of this course, students will demonstrate the ability to:

1. Analyze vehicle forces and performance parameters.
2. Compare conventional and electric vehicle powertrain configurations.
3. Design and size EV powertrain components.
4. Model EV systems and evaluate range and energy consumption.
5. Understand chassis, braking, steering, suspension, and their control in EVs.

UNIT-I ***(10 hours)***

Vehicle Fundamentals and Dynamics: Vehicle movement, rolling resistance, aerodynamic drag, grading resistance, tractive effort and power requirements, vehicle performance, acceleration characteristics, maximum speed and gradeability, slip ratio and traction limits, calculation of normal tire forces, effective tire radius and load transfer, static forces, longitudinal and cornering forces, interaction between longitudinal and lateral forces.

UNIT-II ***(12 hours)***

Conventional Vehicle Systems and Powertrain Fundamentals: Overview of conventional vehicle systems, IC engine components, operation of four-stroke engines, engine performance, supercharging and turbocharging techniques, combustion in spark ignition engines, engine emissions and emission control methods, automotive powertrain components; clutch, gearbox, torque converter, powertrain analysis, powertrain configurations; rear-wheel drive (RWD), front-wheel drive (FWD), and all-wheel drive (AWD).

UNIT-III ***(11 hours)***

Electric Vehicle Systems and Powertrain Design: Electric vehicle architecture and classifications, EV powertrain configurations and components, traction motors: DC, Induction, PMSM, SRM – characteristics and selection, tractive effort calculation, drive cycles, range modeling of battery electric vehicle, vehicle control unit (VCU) and system integration, auxiliary systems in EV, powertrain component sizing: motor, battery, inverter, Auxiliary control functions: start-stop, anti-roll, traction control.

UNIT-IV ***(12 hours)***

Chassis and vehicle structure: Vehicle and body center of gravity, mass moments of inertia, chassis stiffness, strength, and vibration behavior, external loads and structural considerations, multi-body vehicle models, ride comfort and NVH.

Steering, braking, and suspension: Steering systems: manual and power steering, brake systems: hydraulic, air brakes, braking analysis and weight transfer, Antilock Braking System (ABS), regenerative braking, suspension systems: dependent and independent.

Vehicle control systems: Steering control, braking control and electronic brake distribution, vehicle stability control, brake assist system, anti-spin regulation, suspension control: trim, damping, and roll control.

Essential Readings:

1. Mehrdad Ehsani et al., Modern electric, hybrid electric, and fuel cell vehicles, CRC press, 2018.
2. Iqbal Husain, Electric and hybrid vehicles: design fundamentals, CRC press, 2010.
3. Reza N. Jazar, Vehicle dynamics: theory and application, Springer, 2017.

Suggested Readings:

1. G. Genta, L. Morello, The Automotive Chassis, Volume 1: Components Design, Springer Nature, 2009.
2. Rajesh Rajamani, Vehicle Dynamics and Control, Springer, 2012.

Practical Component: ***(30 Hours)***

List of Experiments:

1. Calculation of road load forces and tractive effort using MATLAB.
2. Vehicle acceleration and gradeability analysis.
3. Modeling of IC engine torque-speed characteristics.
4. EV motor selection based on drive cycle requirements.
5. Battery pack sizing and range estimation for a BEV.
6. Simulation of regenerative braking and energy recovery.
7. EV powertrain modeling in MATLAB/Simulink.
8. Drive cycle-based energy consumption analysis.
9. Vehicle dynamics simulation for braking and steering.
10. Comparative study of ICE vs EV powertrain performance.

(Note: Course instructor may add/delete/update new experiments in addition to the above suggested practical exercise.)