NATIONAL INSTITUTE OF TECHNOLOGY WARANGAL

SCHEME OF INSTRUCTION AND SYLLABI

FOR

M.TECH PROGRAM IN POWER ELECTRONICS & DRIVES

Effective from 2019-20

DEPARTMENT OF ELECTRICAL ENGINEERING

VISION

Towards a Global Knowledge Hub, striving continuously in pursuit of excellence in Education, Research, Entrepreneurship and Technological services to the society

MISSION

- Imparting total quality education to develop innovative, entrepreneurial and ethical future professionals fit for globally competitive environment.
- Allowing stake holders to share our reservoir of experience in education and knowledge for mutual enrichment in the field of technical education.
- Fostering product oriented research for establishing a self-sustaining and wealth creating centre to serve the societal needs.

DEPARTMENT OF ELECTRICAL ENGINEERING

VISION

To excel in education, research and technological services in electrical engineering in tune with societal aspirations.

MISSION

- Impart quality education to produce globally competent electrical engineers capable of extending technological services.
- Engage in research & development in cutting edge and sustainable technologies.
- Nurture scientific temperament, professional ethics and industrial collaboration.

DEPARTMENT OF ELECTRICAL ENGINEERING

M.TECH IN POWER ELECTRONICS & DRIVES

PROGRAM EDUCATIONAL OBJECTIVES

PEO1	Design and develop independently innovative products and services in the field of Power Electronics & Drives
PEO2	Adopt and utilize latest technologies and tools in design of products and systems
PEO3	Communicate effectively to propagate ideas and promote teamwork
PEO4	Attain intellectual leadership skills to cater to the changing needs of power industry, academia, society and environment

Mapping of Mission statements with program educational objectives

Mission Statement	PEO1	PEO2	PEO3	PE04
MS1	3	3	2	3
MS2	3	3	2	2
MS3	3	3	2	3

PROGRAM OUTCOMES: At the end of the program the student will be able to:

PO1	Engage in critical thinking and pursue research/ investigations and development to solve practical problems.
PO2	Communicate effectively on complex engineering activities with the engineering community and with society at large, write and present substantial technical reports.
PO3	Demonstrate higher level of professional skills to tackle multidisciplinary and complex problems related to Power Electronics & Drives systems
PO4	Develop attitude for self-learning to deliver and develop eco-friendly and sustainable technologies for Power Electronics & Drive systems through innovative and entrepreneurial solutions by maintaining professional ethics.

Mapping of program outcomes with program educational objectives

Programme outcomes	PEO1	PEO2	PEO3	PEO4
PO1	3	3	2	3
PO2	2	2	3	3
PO3	3	3	2	3
PO4	3	3	2	3

CURRICULAR COMPONENTS

The total course package M.Tech. Degree program will typically consist of the following components.

a) Core Courses ≥ 24 Credits
b) Elective Courses ≥ 15 Credits
c) Dissertation = 27 Credits

Degree Requirements for M. Tech in POWER ELECTRONICS & DRIVES

Category of Courses	Credits Offered	Min. credits to be earned
Program Core Courses (PCC)	30	30
Departmental Elective Courses (DEC)	18	18
Dissertation	27	27
Total	75	75

SCHEME OF INSTRUCTION

M.Tech. (POWER ELECTRONICS & DRIVES) Course Structure

M. Tech. I - Year I - Semester

S No	Course Code	Course Title	L	T	P	Credits	Cat. Code
1.	EE5101	Analysis of Power Converters	3	0	0	3	PCC
2.	EE5102	Analysis and Modelling of Electrical Machines	3	0	0	3	PCC
3.	EE5103	Applications of Digital Signal Processors	3	0	0	3	PCC
4.		Elective – I	3	0	0	3	DEC
5.		Elective - II	3	0	0	3	DEC
6.		Elective – III	3	0	0	3	DEC
7.	EE5104	Power Electronics Lab	0	1	2	2	PCC
8.	EE5105	Power Electronic Simulation Lab	0	1	2	2	PCC
9.	EE5141	Seminar – I	0	0	2	1	PCC
		TOTAL	**18**	**2**	**6**	**23**	

M. Tech. I - Year II - Semester

S No	Course Code	Course Title	L	T	P	Credits	Cat. Code
1.	EE5151	Advanced Power Electronics	3	0	0	3	PCC
2.	EE5152	Advanced Electric Drives	3	0	0	3	PCC
3.	EE5153	Digital Control Systems	3	0	0	3	PCC
4.		Elective – IV	3	0	0	3	DEC
5.		Elective – V	3	0	0	3	DEC
6.		Elective – VI	3	0	0	3	DEC
7.	EE5154	Electric Drives Lab	0	1	2	2	PCC
8.	EE5155	Digital Signal Processing Lab	0	1	2	2	PCC
9.	EE5191	Seminar – II	0	0	2	1	PCC
		TOTAL	**18**	**2**	**6**	**23**	

M. Tech. II - Year I - Semester

S No	Course Code	Course Title	Credits	Cat. Code
		Industrial Training (8-10 Weeks) – Optional		
1	EE6142	Comprehensive Viva Voce	2	PCC
2	EE6149	Dissertation Part A	9	PCC
		Total	11	

M. Tech. II - Year II - Semester

S No	Course Code	Course Title	Credits	Cat. Code
1	EE6199	Dissertation Part B	18	PCC
		Total	18	

List of Electives

I Year I Semester

S.No	Course Code	Course Title
1.	EE5111	Modern Control Theory
2.	EE5112	Control & Integration of Renewable Energy Sources
3.	EE5113	Electromagnetic interference and compatibility
4.	EE5114	High Power Inverters
5.	EE5211	Data Science Applications in Power Engineering
6.	EE5213	HVDC Transmission
7.	EE5214	Smart Grid Technologies
8.	EE5216	Instrumentation and Automation
9.	EE5217	Machine Learning and Deep Learning

ELECTIVE -I : EE5111, EE5112, EE5214
ELECTIVE -II : EE5113, EE5213, EE5114
ELECTIVE -III : EE5211,EE5216, EE5217

I Year II Semester

S.No.	Course Code	Course Title
1.	EE5161	Applications of Power Converters
2.	EE5162	Design of Power Electronic Converters for Drives
3.	EE5163	Power Quality Improvement Techniques
4.	EE5164	Electric Vehicles
5.	EE5165	Nonlinear Control Systems
6.	EE5166	Digital Signal Processor Controlled Drives
7.	EE5263	Flexible AC Transmission Systems
8.	EE5265	Energy Auditing and Management
9.	EE5269	Evolutionary Algorithms Applications in Power Engineering

ELECTIVE -IV : EE5161, EE5162, EE5163
ELECTIVE -V : EE5263, EE5265, EE5269
ELECTIVE -VI : EE5164, EE5165, EE5166

Note: In addition to the above listed electives, a student can also register one elective per semester from other departments and two electives per semester from other specializations of the same department, based on suitability of timetable.

DETAILED SYLLABUS

EE 5101	Analysis of Power Converters	PCC	3 – 0 – 0	3 Credits

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

CO1	Select appropriate switching devices for power converters
CO2	Analyze and design power converter configurations for specific applications
CO3	Select control techniques for low and medium power converters
CO4	Design power electronic converters to improve power quality

CO-PO Mapping:

CO/PO	PO1	PO2	PO3	PO4
CO1	2	2	3	2
CO2	2	2	3	2
CO3	2	2	3	2
CO4	2	2	3	3

Overview of Switching Power Devices: Static and dynamic characteristics of switching devices: BJT, MOSFET, IGBT, GTO, Wide band gap devices (GaN, SiC) - Design of driver and snubber circuit

DC-DC Converters: Non-isolated DC-DC converters: buck, boost, buck-boost, CUK converters under continuous and discontinuous conduction operation - Isolated DC-DC converters: forward, fly-back, push-pull, half-bridge and full-bridge converters - Relationship between I/P and O/P voltages - design of filter inductor and capacitors

Inverters: Single-phase and three-phase inverters - PWM techniques: single, multiple and sinusoidal PWM techniques - selective harmonic elimination, space vector modulation, current source inverter-High power inverters: Multi-pulse inverters, multi-level inverters - Diode-clamped, cascaded and Flying capacitor types, Carrier and Vector based multi-level modulation schemes -Concept of active power filters- Introduction to Matrix Converters.

Front-End (AC-DC) Converters: Conventionalmethods of power factor improvements: Semi-converter, extinction angle control, symmetrical angle control – active front-end converters - Single phase: Boost, voltage doubler and PWM rectifiers –voltage and current controlled three-phase PWM rectifiers

Text books:

1. M.H. Rashid **:**Power Electronics Handbook,Butterworth-Heinemann, 4th edition, 2017.
2. N. Mohan, T.M. Undeland, W.P. Robbins**:** Power Electronics: Converters, Applicationsand Design**,** John Wiley & Sons, 3rd edition, 2003.

References:

1. Umanand, L.: Power Electronics: Essentials and Applications, John Wiley India, 1st Edition, 2009.
2. Jayant Baliga B: Fundamentals of Power Semiconductor Devices, Springer, 1st Edition 2008.
3. Bin Wu: High Power Converters and AC Drives, Wiley-Interscience, 2nd Edition, 2017.
4. Derek A Paice: Power Electronic Converter Harmonics Multipulse Method for Clean Power, IEEE Press, 1995

EE 5102	Analysis and Modeling of Electrical Machines	PCC	3 – 0 – 0	3 Credits

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

CO1	Develop models for linear and nonlinear magnetic circuits
CO2	Determine the developed torque in an electrical machine using the concepts of field Energy and co-energy and determine the dynamic model of a DC machine
CO3	Determine the dynamic model of induction and synchronous machines based on the dq0 transformation
CO4	Determine the dynamic torque developed in induction and synchronous motors

CO-PO Mapping:

CO/PO	PO1	PO2	PO3	PO4
CO1	2	2	3	2
CO2	2	2	2	2
CO3	3	2	3	2
CO4	3	2	3	2

Basic Principles for Electrical Machine Analysis: Magnetically coupled circuits: review of basic concepts, magnetizing inductance, Modeling linear and nonlinear magnetic circuits, Electromechanical energy conversion: principles of energy flow, concept of field energy and coenergy, Derivation of torque expression for various machines using the principles of energy flow and the principle of coenergy, Inductance matrices of induction and synchronous machines.

DC Machines: Theory of DC machines: Review of the theory of DC machine, model of a commutator, State-space model of a DC machine, reduced order model & transfer function of the DC machine

Reference Frame Theory: Concept of space vector, components of space vector, direct and quadrature axis variables, various types of transformation, condition for power invariance, Expression for power with various types of transformation, Transformations between reference frames, Clarke and Park's Transformations, Variables observed from various frames

Theory of symmetrical Induction Machines: Voltage and torque in machine variables, Derivation of *dq0* model for a symmetrical induction machine, Voltage and torque equation in arbitrary reference frame variables, Analysis of steady- state operation

Theory of synchronous machines: Equations in arbitrary reference frame, Park's transformation, Derivation of *dq0* model for a salient pole synchronous machine with damper windings, Torque expression of a salient pole synchronous machine with damper windings and identification of various components.

Text Books:

1. Paul C. Krause, Oleg W, Scott D. Sudhoff: Analysis of Electric Machinery & Drive systems, IEEE Press, 3rd ed., 2013.
2. Rama Krishnan: Electric motor drives: modeling, analysis, and control, Pearson Education India; 1st ed., 2015.

Reference Books:

1. A. E. Fitzgerald, Charles Kingsley, Stephen D. Umans: Electric Machinery, TMH, 6th ed., 2017.
2. Rik De Doncker, Duco W. J. Pulle, André Veltman: Advanced Electrical Drives: Analysis, Modeling, Control Springer, 2011.

EE 5103	Digital Signal Processors and Applications	PCC	3 – 0 – 0	3 Credits

Course Outcomes:

At the end of course, student will be able to

CO1	Develop Assembly Language Programs for the Digital Signal Processors
CO2	Configure and use Digital Input / Output lines and ADCs
CO3	Configure and use Interrupts and Event Managers for PWM generation
CO4	Employ DSPs & FPGAs for the real time control of Power Electronic Converters

CO-PO Mapping:

CO/PO	PO1	PO2	PO3	PO4
CO1	3	2	3	3
CO2	3	2	3	3
CO3	3	2	3	3
CO4	3	2	3	3

TMSLF2407 DSP Controller: Brief Introduction to Peripherals - Types of Physical Memory - Software Tools.

C2XX DSP CPU and instruction set: Introduction to the C2xx DSP Core and Code Generation - The Components of the C2xx DSP Core - Mapping External Devices to the C2xx Core and the Peripheral Interface -System Configuration Registers –Memory -Memory Addressing Modes -Assembly Programming Using the C2xx DSP Instruction Set.

Parallel and Serial Data Transfer: Pin Multiplexing (MUX) and General Purpose I/O Overview - Multiplexing and General Purpose I/O Control Registers - Using the General Purpose I/O Ports.

Interrupt system of TMS320LF2407: Introduction to Interrupts - Interrupt Hierarchy - Interrupt Control Registers - Initializing and Servicing Interrupts in Software, real time control with interrupts.

The analog-to-digital converter (ADC): ADC Overview - Operation of the ADC and programming modes.

Event Managers (EVA, EVB): Overview of the Event Manager (EV) - Event Manager Interrupts - General Purpose (GP) Timers- Compare Units - Capture Units and Quadrature Encoded Pulse (QEP) Circuitry - General Event Manager Information - PWM Signal Generation with Event Managers and interrupts, Measurement of speed with Capture Units, Implementation of Space Vector Modulation with DSP TMSLF2407A.
Introduction to TMS320F28335 DSP Controller, Architecture, Peripherals and Interrupts.

Field Programmable Gate Arrays: Introduction to Field Programmable Gate Arrays – CPLD Vs FPGA – Types of FPGA , Configurable logic Blocks (CLB), Input/Output Block (IOB) –Programmable Interconnect Point (PIP)- HDL programming –overview of Spartan 6 & ISE Design Suite, Implementation of PWM technique with SPARTAN-6 FPGA.

Text Books:

1. Hamid A. Tolyat**:** DSP based Electromechanical Motion Control**,** CRC press, 1st ed., 2003.
2. Wayne Wolf: FPGA based system design, Pearson Education,1st ed., 2005.

Reference books:

1. Philip Andrew Simpson: FPGA Design, Springer Nature; 2nd ed., 2015.
2. A. ArockiaBazil Raj: FPGA-Based Embedded System Developer's Guide, CRC Press, 1st ed., 2018.
3. Application Notes from Texas Instruments
4. Spartan-6 FPGA Configurable Logic
5. Xilinx Spartan 6 Data sheets

EE5104	Power Electronics Lab	PCC	0–1–2	2 Credits

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

CO1	Determine the characteristics of power devices and converters
CO2	Implement control circuits for power converters
CO3	Determine the performance of power converters

CO-PO Mapping:

CO/PO	PO1	PO2	PO3	PO4
CO1	2	2	2	3
CO2	2	2	2	3
CO3	3	2	2	3

List of Experiments

- Static characteristics of MOSFET and IGBT
- PV characteristics and Implementation of MPPT
- Analysis of DC-DC converters (a) Buck converter, (b) Boost converter, and (c) Buck-Boost converter
- Closed loop control of Buck and Boost converter
- Quasi-square wave control of a Single phase Full bridge VSI
- Unipolar and bipolar PWM techniques for single-phase half-bridge and full-bridge inverters.
- 120° and 180°operation of three-phase inverter and selective harmonic elimination for three-phase inverter
- Sine-PWM techniques for three-phase two-level inverters.
- Space vector modulation for a three-phase VSI
- Pulse width modulation control of Single phase AC voltage controller
- Single phase Five level cascaded H-Bridge inverter
- Hysteresis current control of a single phase inverter
- Control of Front-end active rectifiers/Bidirectional Converters
- Control of Z-source inverter
- Control of Resonant DC - DC converters

EE5105	Power Electronic Simulation Lab	PCC	0 – 1 – 2	2 Credits

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

CO1	Use simulators as a learning aid and gain insight regarding power electronic converters and drive systems
CO2	Validate the performance of power converters with different PWM schemes
CO3	Explore the behavior of new circuits for power conversion

CO-PO Mapping:

CO/PO	PO1	PO2	PO3	PO4
CO1	3	2	3	3
CO2	3	2	3	3
CO3	3	2	3	3

1. Study of the dynamics of second order system.
2. Study of the dynamic behavior of an electromechanical relay.
3. Study of the dynamics of magnetic circuits.
4. (a) Study of instantaneous power in various frames of reference.
   (b) Study of torque produced in an induction machine in '*abc'* and '*qd0'* frames.
5. Implementation of buck and boost dc-dc converters.
   (a) Design of various elements such as inductor, capacitor for continuous and discontinuous current operation.
   (b) State-space modelling.
   (c) Study the dynamic behavior of the DC-DC converters through numerical integration methods.
6. Study on the design of PI controllers and stability analysis for a DC-DC buck Converter.
7. Sine-PWM techniques for single-phase half-bridge, full-bridge and three-phase inverters.
8. Programming of sine-triangle PWM technique in simulation environment.
9. Space vector modulation (SVM) for three-phase two-level inverters using classical and Kim-Sul methods.
10. Closed-loop implementation single-phase high power factor rectifiers (Boost rectifier and PWM rectifier).
11. Multicarrier PWM techniques for three-phase diode clamped and cascade H-bridge multilevel inverters.
12. Study of the dynamic performance of a V/Hz controlled induction motor drive using the *dq0* model.

EE5111	Modern Control Theory	DEC	3 – 0 – 0	3 Credits

Course Outcomes:

At the end of the course, student will be able to

CO1	Develop mathematical models of physical systems
CO2	Design optimal controllers for power electronic converters and power systems
CO3	Analyze the issues related to the stability of automatic control systems
CO4	Design complex nonlinear systems with linearization

CO-PO Mapping:

CO/PO	PO1	PO2	PO3	PO4
CO1	1	2	2	3
CO2	2	2	2	3
CO3	2	2	3	3
CO4	2	2	3	3

Introduction:Introductionto linear control systems

System representation: Introduction to state and state variables - system representation in state variable form - transformations - Phase variable form - Canonical forms – Physical systems - Plant models – Representation using state function - Lagrange linearization

Time response: State transition matrix – Properties and methods of valuation - Time response of linear systems -State diagrams - Resolvant matrix - Resolvant algorithm

Controllability and observability: Definition and concepts - Criteria for controllability and observability - State variable feedback - Pole placement - Luenberg observer design

Stability: Introduction - definition of stability - stability in the sense of Lyapunov - stability of linear systems - transient response - Behavior of estimation - stability of non linear systems - generation of Lyapunov functions

Optimal control: Formulation of the optimal control problem - method of calculus of variations - use of Hamiltonian method - Pontryagin's minimum principle - Optimal control problem - Hamilton – Jacobi approach - Continuous time linear state regulator matrix riccati equation - Methods of solution – State variable feedback design.

Introduction to non-linear control systems

Text Books:

1. Katsuhiko Ogata: Modern control Engineering, Pearson Education India, 5th Edition, 2015
2. M. Gopal: Modern Control Systems Theory, New Age International Private Limited, 3rd Edition, 2014.

Reference Books:

1. Z. Bubnicki: Modern Control Theory, Springer, 1st Edition, 2010
2. Schultz &Melsa: State functions & linear control systems, McGraw Hill Book Co. New York, 1998.

EE5112	Control & Integration of Renewable Energy Sources	DEC	3 – 0– 0	3 Credits

Course Outcomes:

At the end of the course student will be able to

CO1	Understand different renewable energy sources and storage devices
CO2	Model and simulate renewable energy sources
CO3	Analyze and simulate control strategies for grid connected and off-grid systems
CO4	Develop converters to comply with grid standards to obtain grid integration

CO-PO Mapping:

CO/PO	PO1	PO2	PO3	PO4
CO1	2	2	2	2
CO2	3	2	3	3
CO3	3	2	3	3
CO4	3	2	3	3

Introduction: Electric grid, Utility ideal features, Supply guarantee, power quality, Stability and cost; Importance & Effects of Renewable Energy penetration into the grid, Boundaries of the actual grid configuration, Consumption models and patterns.

Dynamic Energy Conversion Technologies: Introduction, types of conventional and nonconventional dynamic generation technologies, principle of operation and analysis of reciprocating engines, gas and micro turbines, hydro and wind based generation technologies.

Static Energy Conversion Technologies: Introduction, types of conventional and nonconventional static generation technologies; Principle of operation and analysis of fuel cell, photovoltaic systems and wind generation technologies; MPPT techniques and its classifications, principle of operation and partial shading effects; Storage Technologies -batteries, fly wheels, super capacitors and ultra capacitors.

Control Issues and Challenges: Linear and nonlinear controllers, predictive controllers and adaptive controllers, Load frequency and Voltage Control, PLL, Modulation Techniques, Control ofDiesel, PV, wind and fuel cell based generators, Dimensioning of filters, Fault-ride through Capabilities.

Integration of Energy Conversion Technologies: Introduction & importance, sizing, Optimized integrated systems, Interfacing requirements, Distributed versus Centralized Control, Grid connected Photovoltaic systems –classifications, operation, merits & demerits; Islanding Operations, stability and protection issues, load sharing, operation & control of hybrid energy systems, Solar Photovoltaic applications. IEEE & IEC standards for renewable energy grid integrations.

Text books:

1. G. Masters, Renewable and Efficient Electric Power Systems, IEEE-John Wiley and Sons Ltd. Publishers, 2nd Edition, 2013.
2. S. Chowdhury, S. P. Chowdhury, P. Crossley, Microgrids and Active Distribution Networks, IET Power Electronics Series, 2012.
3. Ali Keyhani Mohammad Marwali and Min Dai, Integration and Control of Renewable Energy in Electric Power System, John Wiley publishing company, 2nd Edition, 2010.

References:

1. Chetan Singh Solanki, Solar Photovoltaic: Fundamentals, technologies & Applications, PHI Publishers, 3rd Edition, 2019.
2. Quing-Chang Zhong: Control of Power Inverters in Renewable Energy and Smart Grid Integration, IEEE-John Wiley and Sons Ltd. Publishers, 1St Edition, 2013.
3. Bin Wu, Yongqiang Lang, NavidZargari:Power Conversion and Control of Wind Energy Systems, IEEE- John Wiley and Sons Ltd. Publishers, 1st Edition, 2011.
4. Report on "Large Scale Grid Integration of Renewable Energy Sources - Way Forward" Central Electricity Authority, GoI, 2013.

EE5113	Electromagnetic Interference & Compatibility	DEC	3 – 0 – 0	3 Credits

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

CO1	Recognize the sources of Conducted and radiated EMI in Power Electronic Converters and consumer appliances and suggest remedial measures to mitigate the problems
CO2	Assess the insertion loss and design EMI filters to reduce the loss
CO3	Design EMI filters, common-mode chokes and RC-snubber circuits measures to keep the interference within tolerable limits
CO4	Develop suitable techniques to mitigate EMI/EMC issues in power converters

CO-PO Mapping:

CO/PO	PO1	PO2	PO3	PO4
CO1	1	2	2	3
CO2	1	2	2	3
CO3	2	2	2	3
CO4	2	2	2	3

Introduction: Sources of conducted and radiated EMI, EMC standardization and description, measuring instruments, conducted EMI references, EMI in power electronic equipment: EMI from power semiconductors circuits.

Noise suppression in relay systems: AC switching relays, shielded transformers, capacitor filters, EMI generation and reduction at source, influence of layout and control of parasites.

EMI filter elements: Capacitors, choke coils, resistors, EMI filter circuits. Ferrite breeds, feed through filters, bifilar wound choke filter, EMI filters at source, EMI filter at output

EMI filter design for insertion loss: Worst case insertion loss, design method for mismatched impedance condition and EMI filters with common mode choke-coils, IEC standards on EMI

EMI in Switch Mode Power Supplies: EMI propagation modes, power line conducted-mode inference, safety regulations (ground return currents), Power line filters, suppressing EMI at sources, Line impedance stabilization network (LISN), line filter design, common-mode line filter inductors-design& example, series –mode inductors and problems, EMI measurements.

Faraday Screens for EMI prevention: As applied to switching devices, transformers faraday screen and safety screens, faraday screens on output components, reducing radiated EMI on gapped transformer cores, metal screens, electrostatic screens in transformers

Text Books:

1. Laszlo Tihanyi: Electromagnetic Compatibility in Power Electronics, IEEE Press, 1st Edition, 1995.
2. Ficchi, Rocco F.: Practical Design for Electromagnetic Compatibility, Hayden Book Co., 1981

Reference:

1. Keith H Billings, Taylor Morey: Handbook on Switch-Mode power supplies, McGraw-Hill Publisher, 3rd Edition, 2011.
2. Abraham I. Pressman, Keith Billings, Taylor Morey: Switching Power Supply Design, McGraw Hill International, 3rd Edition, 2009.

EE5114	High Power Inverters	DEC	3 – 0 – 0	3 Credits

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

CO1	Analyze the Weighted THD and implement SVM based on instantaneous phase reference voltages
CO2	Implement level-shifted, phase-shifted, hybrid and Space Vector PWM schemes for Cascaded H-Bridge Multilevel Inverters
CO3	Develop PWM schemes to balance the neutral point, eliminate common mode voltage and reduce the switching power loss in diode clamped multilevel inverter
CO4	Develop reduced switch count MLIs and PWM current source inverters

CO-PO Mapping:

CO/PO	PO1	PO2	PO3	PO4
CO1	3	2	3	2
CO2	3	2	3	2
CO3	3	2	3	2
CO4	3	2	3	2

Introduction: Double Fourier integral analysis of two-level inverter PWM waveform, Weighted THD, effect of dead-time and compensation, space vector modulation (SVM) of two-level inverter, Implementation of SVM based on instantaneous phase reference voltages, even order harmonic elimination, overmodulation, and discontinuous SVM.

Cascade H-bridge (CHB) multilevel inverter (MLI): Symmetrical and asymmetrical topologies, level-shifted PWM, phase-shifted PWM, hybrid PWM and SVM. Concept of coupling transformer-less grid connected applications, Topologies of modular multilevel inverters (MMI).

Diode clamped multilevel inverter (DCMLI): 3, 4 and 5 level DCMLI, level-shifted PWM, Neutral point voltage balance, SVM and discontinuous SVM, Elimination of common mode voltage, Active Neutral Point Clamped Inverter (ANPCI).

Reduced switch count MLIs: Introduction, classification, operation of T-type, multilevel dc link, switched series parallel source and other topologies.

PWM current source inverters: Trapezoidal modulation, selective harmonic elimination and SVM, Load-commutated inverters (LCI).

Text books:

1. Bin Wu: High Power Converters and AC Drives, Wiley-Inter science, 2nd Edition, 2017.
2. D. Grahame Holmes and Thomas A. Lipo: Pulse Width Modulation for Power Converters: Principles and Practice, IEEE Press, 2003.

References:

1. Research publications.

EE5211	Data Science Applications in Power Engineering	DEC	3 – 0 – 0	3 Credits

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

CO1	Distinguish between Algorithmic based methods and Knowledge based Methods
CO2	Able to distinguish between Artificial Neural Networks and Fuzzy Logic
CO3	Adopt Soft Computing techniques for solving Power Systems and Power Electronics and Drives Problems
CO4	Apply appropriate AI frame work for solving power systems and Power Electronics & Drives Problems

CO-PO Mapping:

CO/PO	PO1	PO2	PO3	PO4
CO1	2	2	2	2
CO2	2	2	3	3
CO3	3	2	3	3
CO4	3	2	3	3

Artificial Neural Networks (ANN): Introduction to Artificial Neural Networks - Definition and Fundamental concepts -Biological Neural Network – Modeling of a Neuron -Activation functions – initialization of weights -Typical architectures-Leaning/Training laws - Supervised learning Unsupervised learning – Reinforcement learning-Perceptron – architectures-Linear Separability – XOR Problem - ADALINE and MADALINE.

ANN Paradigms: Multi – layer perceptron using Back propagation Algorithm (BPA)-Self-Organizing Map (SOM)- Learning Vector Quantization (LVQ) - Radial Basis Function Network -Functional link network -Hopfield Network -Bidirectional Associate Memory (BAM)

Fuzzy Logic: Introduction – Classical and Fuzzy sets- Properties, Operations and relations-Fuzzy sets – Membership function – Basic Fuzzy set operations -Properties of Fuzzy sets – Fuzzy cartesion Product - Operations on Fuzzy relations – Fuzzy logic – Fuzzy Cardinalities -Fuzzy Logic Controller (FLC): Fuzzy Logic System Components: Fuzzification- Inference Engine - Defuzzification methods.

Applications of ANN & Fuzzy Logic: Load flow studies -Economic load dispatch -Load frequency control – Single area system and two area systems -Reactive power control -Speed control of DC and AC Motors.- PWM Vector controlled drive -Speed estimation and flux estimation of induction motor

Text books:
1. S. Rajasekaran and G.A.V. Pai: Neural Networks, Fuzzy Logic & Genetic Algorithms, PHI, New Delhi, 2008.
2. T.J. Ross: “Fuzzy Logic with Fuzzy applications”, Mc Graw Hill Inc, 1997

Reference books:
1. Simon Haykin: Neural Networks: A Comprehensive Foundations, Pearson Edition, 2003
2. G.J. Klir and T.A. Folger: Fuzzy sets, Uncertainty and Information, PHI, Pvt.Ltd,1994.
3. Bart Kosko: Neural Network & Fuzzy System, Prentice Hall, 1992.
4. P.D. Wasserman: Neural Computing Theory & Practice, Van Nostrand Reinhold, New York, 1989.

EE5213	HVDC Transmission	DEC	3 – 0 – 0	3 Credits

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

CO1	Distinguish HVDC Transmission and EHVAC transmission system.
CO2	Analyze HVDC transmission with Current Source Converters and Voltage Source Converters.
CO3	Evaluate performance metrics for HVDC converter configuration.
CO4	Synthesize controllers for Voltage Source Converters based HVDC under DC fault conditions.

CO-PO mapping:

CO/PO	PO1	PO2	PO3	PO4
CO1	3	2	3	3
CO2	3	2	2	3
CO3	3	2	3	3
CO4	3	2	3	2

DC POWER TRANSMISSION TECHNOLOGY

Introduction, Comparison of AC&DC Transmission, Applications of DC Transmission, Description of DC Transmission System, Modern Trends in DC Transmission.

HVDC WITH CURRENT SOURCE CONVERTERS

ANALYSIS OF HVDC CONVERTERS: Choice of converter configuration, Simplified analysis of Graetz circuit: without overlap, with overlap, Converter Bridge characteristics. Equivalent circuit of HVDC link, power factor and reactive power of converters.

CONVERTER AND HVDC SYSTEM CONTROL: Principles of DC link control ,Converter control characteristics, power reversal in DC link, voltage dependent current order limit(VDCOL), System control hierarchy, Firing angle control , constant current control and Extinction angle control, Power control.

LCC HVDC System Harmonics: Harmonic Performance Criteria, Harmonic Limits, Harmonic Filters, Noncharacteristic Harmonic Reduction Using HVDC Controls.

HVDC WITH VOLTAGE SOURCE CONVERTERS

VSC HVDC Applications and Topologies, Performance and Cost Comparison with LCC HVDC: Voltage Source Converters (VSC), Comparison with Line-Commutated Converter (LCC) HVDC, Overhead and Subsea/Underground VSC HVDC Transmission, DC Cable Types with VSC HVDC, Monopolar and Bipolar VSC HVDC Systems, VSC HVDC Converter Topologies, VSC HVDC Station Components, AC Reactors, DC Reactors.

Two-Level PWM VSC HVDC Modelling, Control and Interaction with AC Systems: Various Two-Level Converter Models, VSC Converter Control Principles, Complete VSC Converter Controller. Power Exchange between Two AC Voltage Sources , Converter Phasor Model and Power Exchange with an AC System and Operation with Very Weak AC Systems.

VSC HVDC under AC and DC Fault Conditions and applications: Introduction, DC Faults with Two-Level VSC, Influence of DC Capacitors, VSC Converter Modelling under DC Faults conditions. VSC HVDC High-Level Controls and AC Grid Support, HVDC Embedded AC Grid, HVDC Connecting Two Separate AC Grids, HVDC in Parallel with a Passive AC System and VSC HVDC Operation with Offshore Wind Farms.

Text Books:

1. K.R. Padiyar: HVDC Power Transmission System, New Age Intl. Co, 2015.
2. Dragan Jovcic, Khaled Ahmed, High Voltage Direct Current Transmission: Converters, Systems and DC Grids, Wiley Publishers, 2015.

Reference Books:

1. Edward Wilson Kimbark: Direct Current Transmission, Vol-1, John Wiley & Sons,1971.
2. Jos Arrillaga, Yonghe H. Liu, Neville R. Watson, Nicholas J. Murray: Self-Commutating Converters for High Power Applications Wiley Publishers, 2009.
3. Chan-Ki Kim, Vijay K. Sood, Gil-Soo Jang, Seong-Joo Lim, Seok-Jin Lee: HVDC Transmission: Power Conversion Applications in Power Systems, Wiley Publishers 2009.

EE5214	Smart Grid Technologies	DEC	3– 0 –0	3 Credits

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

CO1	Understand the features of Smart Grid.
CO2	Assess the role of automation in Transmission and Distribution
CO3	Apply Evolutionary Algorithms for the Smart Grid and Distribution Generation.
CO4	Understand operation and importance of PMUs, PDCs, WAMS, Voltage and Frequency control in Micro Grids.

CO-PO mapping:

CO/PO	PO-1	PO-2	PO-3	PO-4
CO-1	3	2	2	2
CO-2	1	2	3	3
CO-3	2	2	3	2
CO-4	3	2	3	2

Introduction to Smart Grid: Introduction toSmart Grid - Working definitions of Smart Grid and Associated Concepts – Smart Grid Functions – Traditional Power Grid and Smart Grid – New Technologies for Smart Grid – Advantages – Indian Smart Grid – Key Challenges for Smart Grid.

Smart Grid Architecture: Components and Architecture of Smart Grid Design – Review of the proposed architectures for Smart Grid. The fundamental components of Smart Grid designs – Transmission Automation – Distribution Automation – Renewable Integration

Tools and Techniques for Smart Grid: Computational Techniques – Static and Dynamic Optimization Techniques – Computational Intelligence Techniques – Evolutionary Algorithms – Artificial Intelligence techniques.

Distribution Generation Technologies: Introduction to Renewable Energy Technologies – Micro grids – Storage Technologies –Electric Vehicles and plug – in hybrids – Environmental impact and Climate Change – Economic Issues.

Communication Technologies and Smart Grid: Introduction to Communication Technology – Synchro-Phasor Measurement Units (PMUs) – Wide Area Measurement Systems (WAMS)-Introduction to Internet of things (IOT)- Applications of IOT in Smart Grid

Control of Smart Power Grid System: Load Frequency Control (LFC) in Micro Grid System – Voltage Control in Micro Grid System – Reactive Power Control in Smart Grid. Case Studies and Test beds for the Smart Grids.

Text Books:

1. Stuart Borlase: Smart Grids, Infrastructure, Technology and Solutions, CRC Press, 1e, 2013
2. Gil Masters: Renewable and Efficient Electric Power System, Wiley–IEEE Press, 2e, 2013.

Reference Books:

1. A.G. Phadke and J.S. Thorp: Synchronized Phasor Measurements and their Applications, Springer Edition, 2e, 2017.
2. T. Ackermann: Wind Power in Power Systems, Hoboken, NJ, USA, John Wiley, 2e, 2012.

EE5216	Instrumentation and Automation	DEC	3-0-0	3 Credits

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

CO1	Analyze the performance of physical systems for measurement of physical quantities
CO2	Understand Signal Conditioning operations and design systems for measurement and instrumentation.
CO3	Synthesize Industrial Automation and Control technologies
CO4	Implement PLCs for Industrial Automation.

CO-PO mapping:

CO/PO	PO1	PO2	PO3	PO4
CO1	3	2	3	3
CO2	3	2	3	3
CO3	3	2	3	3
CO4	3	2	2	3

Introduction: Static and Dynamic characteristics of Instrument, measurement of translational and rotational displacement, resistive potentiometers, strain gauges, Linear Variable Differential Transformer (LVDT), Synchros, induction potentiometers, piezoelectric transducers, electro optical devices, digital displacement transducers (translational and rotary encoders), magnetic and photoelectric pulse counting for speed, transducers for torque, voltage, current, power, frequency, power factor and phase angle measurement and microprocessor based measurement.

Signal Conditioning: Instrumentation amplifiers: Basic characteristics. Chopped and Modulated DC Amplifiers-Isolation amplifiers - Opto couplers - Buffer amplifiers .Noise Reduction Techniques in Signal Conditioning- Fundamentals of 4-20 mA current loops, Regulators and power supplies for industrial instrumentation. Estimation of errors and Calibration, Bus standard for communication between instruments - GPIB (IEEE-488 bus), RS 232 and RS 485 interface, Optical Fiber Based Signal Transmission-Piezoelectric Couplers- Intelligent transmitters. Interrupt-based Data Acquisition. Software Design Strategies-Hardware Vs Software Interrupts-Foreground/ background Programming Techniques.

Impact of Automation on Manufacturing and Process Industries; Architecture of Industrial Automation Systems. Data Acquisition systems and PC based automation.

Automatic Control, P-I-D Control, Controller Tuning, Special Control Structures: Feed forward and Ratio Control, Predictive Control, Control of Systems with Inverse Response, Cascade Control. Process and Instrumentation Diagrams.

Sequence Control: PLCs and Relay Ladder Logic, Scan Cycle, RLL Syntax, Structured Design Approach, Advanced RLL Programming, Hardware environment, Timers and counters: Types of timers, programming timers, ON and OFF- delay timers, pulse timers, forms of counter, programming, up and down counters, timers with counters and sequencer.

Text Books:

1. S. Mukhopadhyay, S. Sen and A. K. Deb: Industrial Instrumentation, Control and Automation, Jaico Publishing House, 2013
2. Doebelin: Measurement Systems, Applications and Design, Tata McGraw Hill, 2008.
3. W Bolton: Programmable Logic controllers, Elsevier- newness, 5th edition, 2009.

Reference Books:

1. AlokBarua: Fundamentals of Industrial Instrumentation, Wiley India Pvt. Ltd., 2011.
2. M.K. Ghosh, S. Sen and S. Mukhopadhyay: Measurement & Instrumentation: Trends & Applications, Ane Books, 2010.
3. George Stephanopoulos: Chemical Process Control, An Introduction to Theory and Practice, Prentice Hall India, 2012.
4. Frank. D, Petruzella: Programmable Logic Controllers, Tata McGraw Hill Third Edition-2010

EE5217	Machine Learning and Deep Learning	DEC	3– 0 –0	3 Credits

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

CO1	understand basic concepts of Machine Learning and Deep Learning Techniques
CO2	distinguish between supervised learning, unsupervised learning and reinforced learning
CO3	Develop the skills in using machine learning and deep learning software for solving practical problems.
CO4	Apply Machine Learning and Deep Learning Algorithms for the Electrical Engineering problems.

CO-PO mapping:

CO/PO	PO1	PO2	PO3	PO4
CO1	3	2	3	3
CO2	3	2	3	3
CO3	2	2	3	3
CO4	3	2	3	3

LEARNING THEORY : Introduction to Machine Learning: What is Learning – Learning Objectives – Data needed – Bayesian inference and Learning – Bayes theorem – inference – naïve Bayes – Regularization – Bias-Variance Decomposition and Trade-off – Concentration Inequalities – Generalization and Uniform Convergence – VC –dimension- Types of Learning- Supervised Learning – Unsupervised Learning and Reinforcement Learning

SUPERVISED LEARNING : Simple linear Regression – Multiple Linear Regression- Logistic Regression – Exponential Family and Generalized Linear Models- Generative Models: Gaussian Discriminate Analysis, Naïve Bayes – Kernal Method: Support Vector Machine (SVM) – Kernal function – Kernal SVM - Gaussian Process – Tree Ensembles: Decision Trees- Random Forests – Boosting and Gradient Boosting.

UNSUPERVISED LEARNING (CLUSTERING) :K –means Clustering Algorithm – Gaussian Mixture Model (GMM) – Expectation Maximization (EM) – Variational Auto Encoder (VAE) – Factor Analysis – Principle Components Analysis (PCA) – Independent Component Analysis (ICA)

REINFORCEMENT LEARNING : Markov Decision Processes (MDP) – Bellman's Equations- Value Iteration and Policy Iteration - Value Function Approximation – Q – Learning

DEEP LEARNING : Neural Networks – Back propagation Algorithm (BPA) – Deep Architectures – Convolutional Neural Networks – Convolutional Layer – Pooling Layer – Normalization Layer- Fully Connected Layer – Deep belief Networks – Recurrent Neural Networks.

Text Books:
1. Christopher Bishop: Pattern Recognition and Machine Learning, Springer, 2011.
2. E. Alpaydin: Machine Learning, MIT Press, 2010.

References Books:
1. Ian Goodfelow, YoshuaBengio, and Aaron Courville: Deep Learning, MIT Press, Cambridge, Massachusetts, London, England, 2016.
2. Tom M. Mitchell: Machine Learning, McGraw Hill International Edition, 1997

EE5151	Advanced Power Electronics	PCC	3 – 0 – 0	3 Credits

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

CO1	Analyze and design resonant converters
CO2	Develop power converter models under steady state and small signal conditions
CO3	Design feedback control systems for power converters
CO4	Synthesize and design magnetic components for power converters

CO-PO Mapping:

CO/PO	PO1	PO2	PO3	PO4
CO1	3	2	3	3
CO2	2	2	3	3
CO3	2	2	3	3
CO4	3	2	3	3

Resonant Converters: Introduction, Basic resonant circuit concepts, Classification - Load resonant converters, Resonant switch converters, Zero voltage switching clamped voltage converters, Resonant DC link inverters High frequency link integral half cycle converters, Phase modulated resonant converters, Dual active bridge converters, High gain converters.

Modeling of DC-DC Converters: Basic ac modeling approach, State space averaging, Circuit averaging and averaged switch modeling, Canonical circuit modeling, Converter transfer functions for buck, boost and buck-boost topologies.

Current Mode Control: Introduction, types, advantages and disadvantages, Slope compensation, Determination of duty cycle and transfer functions for buck, boost and buck-boost converters.

Design of Closed Loop Control: Controller Design: Introduction, mechanism of loop stabilization, Shaping E/A gains vs frequency characteristics, Conditional stability in feed-back loop, Stabilizing a continuous mode forward and fly-back converter, Feed-back loop stabilization with current mode control, right plane zero.

Design of Power Converters Components: Design of magnetic components - design of transformer, design of inductor and current transformer - Selection of filter capacitors, Selection of ratings for devices, input filter design, Thermal design

Text books:

1. M.H. Rashid: Power Electronics-Circuits, Devices & Applications, Pearson, 4th edition, 2013.
2. N. Mohan, T.M. Undeland, W.P. Robbins: Power Electronics: Converters, Applications & Design, J.Wiley& Sons, 3rd edition, 2003.

References:

1. Abraham I. Pressman, Keith Billings &Taylor Morey: Switching Power Supply Design, McGraw Hill International, 3rd Edition, 2009.
2. R.W. Erickson and Dragan Maksimonic: Fundamentals of Power Electronics, Springer, 2nd Edition, 2001.
3. Umanand, L., Power Electronics: Essentials and Applications, John Wiley India, 1st Edition, 2009.

EE5152	Advanced Electric Drives	PCC	3 – 0 – 0	3 Credits

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

CO1	Design controllers for closed-loop operation of separately excited DC motor drives
CO2	Develop high performance induction motor drives using the principles of Scalar control, Vector control and Direct Torque Control
CO3	Develop the control strategies for doubly fed induction motor drives, VSI fed poly-phase induction motors.
CO4	Implement control schemes for PMSM, BLDC and Switched Reluctance Motor drives

CO-PO Mapping:

CO/PO	PO1	PO2	PO3	PO4
CO1	2	2	2	2
CO2	3	2	3	3
CO3	3	2	3	3
CO4	3	2	3	3

Separately Excited DC-motor Drives: Introduction, Review of DC-motor drives, Speed control of a Separately excited DC motor drive with controlled rectifiers and choppers, Review of controllers, need for anti-windup feature for integral controllers, Speed control of a separately excited DC drive with inner current loop and outer speed loop, Design of current loop with pole-zero cancellation, Design of speed loop with symmetrical optimization technique

Induction Motor drives: Implementation of V/f control with slip compensation scheme, Review of dq0 model of 3-Ph IM with simulation studies, Principle of vector control of IM, Direct vector control, Indirect vector control with feedback, Indirect vector control with feed-forward, Indirect vector control in various frames of reference, Decoupling of vector control with feed forward compensation, Direct Torque Control of IM, Control of wound rotor induction machine, introduction to five-phase induction motor drives.

Permanent Magnet Drives: Expression for torque, Model of PMSM, Implementation of vector control for PMSM, BLDC drives

Switched Reluctance Motor Drives: Torque expression, converters for SRM drives, Control of SRM drives

Text Books:

1. B.K. Bose: Modern Power Electronics & AC Drives, Pearson Education India; 1st ed., 2015.
2. R. Krishnan: Electric Motor Drives: Modeling, Analysis and Control; Pearson Education India; 1st ed., 2015.

Reference Books:

1. Bin-Wu: High-power Converters and AC Drives, Wiley-Blackwell, 2nd ed., 2017.
2. M.B. Patil, V. Ramanarayanan, V.T. Ranganathan: Simulation of Power Electronic Circuits, Narosa Publications, 2013.

EE5153	Digital Control Systems	PCC	3 – 0 – 0	3 Credits

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

CO1	Evaluate the output of a digital system for a given input.
CO2	Describe the dynamics of a Linear, Time Invariant and Causal digital systems through difference equations.
CO3	Analyze digital systems using the Z-transformation.
CO4	Design digital controllers for Power Electronic Systems.

CO-PO Mapping:

CO/PO	PO1	PO2	PO3	PO4
CO1	2	2	2	3
CO2	2	2	2	3
CO3	2	2	3	3
CO4	2	2	3	3

Introduction: Digital control systems - Quantizing and quantization error, Data acquisition, Conversion and distribution system

Z-Transform: Z-transform - Z-transforms of elementary functions, important properties and theorems, Inverse Z-transform, Z-transform method of solving difference equations

Z-Plane Analysis of Discrete-Time Control Systems: Impulse sampling and data hold, Pulse transfer function, Realization of digital controllers and digital filters, Mapping between s-plane and z-plane, Stability analysis of closed loop systems in z-plane, Transient and steady state analyses

State Space Analysis: State space representation of digital control systems - Solution of discrete time state space equations, Pulse transfer function matrix, Discritisation of continuous time state space equations, Lyapunov stability analysis

Pole Placement & Observer Design: Controllability, Observability

Quadratic Optimal Control Systems: Design via pole placement, State observers, Quadratic optimal control, Steady state quadratic optimal control, Quadratic optimal control of a servo system

Text Books:

1. M. Gopal: Digital control engineering**,** New Age Int. Ltd., 2nd Edition, 2014.
2. K. Ogata**:** Discrete time control systems**,** Pearson Education, 2nd Edition, 2006.

Reference Books:

1. Katsuhiko Ogata: Modern control Engineering, Pearson Education India, 5thEdition, 2015.
2. B.C. Kuo: Digital Control Systems, Oxford University Press, 2nd Edition, 2012.

EE5154	Electric Drives Lab	PCC	0 – 1 – 2	2 Credits

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

CO1	Implement speed control schemes for separately exited DC motor, induction motor
CO2	Develop control schemes for permanent magnet synchronous motor and Brushless DC motor drives
CO3	Develop control schemes using analog circuitry and digital control platform

CO-PO Mapping:

CO/PO	PO1	PO2	PO3	PO4
CO1	3	2	3	3
CO2	3	2	3	3
CO3	3	2	3	3

1) Open-loop control of separately excited DC motor using four-quadrant DC chopper.
2) Speed control of separately excited DC motor using single-phase dual converter.
3) Torque-speed characteristics of a 6-pulse fully controlled rectifier fed Separately Excited DC motor Drive.
4) Symmetrical angle and pulse width modulation control of 1-phase & 3-phase AC motor connected to AC voltage controller.
5) Open-loop speed control of three-phase induction motor using V/f control technique with analog controller.
6) Closed-loop speed control of three-phase induction motor using the slip-compensation technique.
7) Torque-Speed characteristics of a three-phase induction motor using IM-IM drive
8) Speed control of three-phase induction motor drive using three-level Neutral Point Clamped inverter.
9) Torque-Speed characteristics of a three-phase Permanent Magnet Synchronous Motor drive.
10) Implementation of space vector modulation with DSP TMS320LF2407A for V/Hz control of induction motor drive.
11) Speed control of Brushless DC motor drive.
12) Speed control of switched reluctance motor (SRM).

EE5155	Digital Signal Processors Lab	PCC	0 – 1 – 2	2 Credits

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

CO1	Configure the on-chip peripherals such as ADC, Digital I/O and QEP to suit the control requirements of Power Converters
CO2	Configure Interrupts and Event manager to implement Pulse Width Modulation
CO3	Develop Assembly AND C-programming Languages for DSP to achieve the real time control of Power Electronic Converters

CO-PO Mapping:

CO/PO	PO1	PO2	PO3	PO4
CO1	3	2	3	3
CO2	3	2	3	3
CO3	3	2	3	3

List of Experiments on TMS320LF2407A Processor (using Assembly Language)

1. General Programs to get familiarity with addressing modes, instruction set, arithmetic and logical operations such as:
   a. Arithmetic and logical operations
   b. Direct & Indirect Data Transfer
   c. Sorting of Data in Ascending order and Descending order
   d. Square root of positive integer
   e. Maximum and minimum of given set of numbers
2. Study of the phenomenon of Aliasing
3. Study of the on-chip ADC of TMS320LF2407 processor.
4. Study of the GPIO functionality.
5. Waveform generation with on board DAC of EVM TMS320LF2407
6. PWM signal generation using event manager with dead time
7. Study of the interrupts of TMS320LF2407 processor.
8. Space Vector Modulation of a 3-Phase VSI

List of Experiments on TMS320F2812 Processor (using C-Programming Language)

9. General Programs to get familiarity with syntax, arithmetic and logical operations (the list is similar to expt.1)
10. Solution of Difference equation
11. Study of interrupts & GPIO
12. Generation of Basic PWM signals
13. Study of Quadrature Encoder Pulse (QEP) Unit
14. Implementation of sine-triangle PWM scheme
15. Implementation of Sine-triangle PWM with Launch XL-F28069M
16. Implementation of SVPWM with Launch XL-F28377S
17. Control of BLDC motor with DRV8301

EE5161	Applications of Power Converters	DEC	3 – 0 – 0	3 Credits

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

CO1	Identify power converter configurations and improvise the existing control techniques to suit the application
CO2	Analyze and design inverters for Induction Heating applications
CO3	Develop improved power converters for Low voltage High current applications
CO4	Analyze and design converters for lighting, HV systems and Bi-directional converters for charge/discharge applications

CO-PO Mapping:

CO/PO	PO1	PO2	PO3	PO4
CO1	3	2	3	2
CO2	3	2	3	2
CO3	3	2	3	2
CO4	3	2	3	2

Inverters for Induction Heating: Inverters for induction cooking, induction hardening, melting, and welding applications.

Power Converters for Lighting, pumping and refrigeration Systems: Electronic ballast, LED power drivers for indoor and outdoor applications. PFC based grid fed LED drivers, PV / battery fed LED drivers. PV fed power supplies for pumping/refrigeration Applications.

High Voltage Power Supplies - Power supplies for X-ray applications - power supplies for radar applications - power supplies for space applications.

Low Voltage High Current Power Supplies: Power converters for modern microprocessor and computer loads .

Bi-directional DC-DC (BDC) converters: Electric traction, Automotive Electronics, Battery charging converters, UPS and its applications, Line Conditioners and Solar Charge Controllers, Solar PV tracking.

Text books:

1. Abraham I. Pressman, Keith Billings &Taylor Morey: Switching Power Supply Design, McGraw Hill International, 3rd Edition, 2009.
2. Ali Emadi, A. Nasiri, and S. B. Bekiarov: Uninterruptible Power Supplies and Active Filters, CRC Press, 1st Edition, 2005.

References:

1. Valery Rudnev, Don Loveless, Raymond L. Cook: Hand book of Induction Heating, CRC Press, 2nd Edition, 2017.
2. Steve Winder: Power Supplies for LED Driving, Newnes, 2nd Edition, 2016
3. William Ribbens: Understanding Automotive Electronics : An Engineering Perspective, Butterworth-Heinemann, 8th Edition, 2017.
4. M. Ehsani, Yimin Gao, Stefano Longo, K Ebrahimi: Modern Electric, Hybrid Electric and Fuel Cell Vehicles, 3rd Edition, CRC Press, 2018.

EE5162	Design of Power Electronic Converters for Drives	DEC	3 – 0 – 0	3 Credits

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

CO1	Apply numerical methods to develop simulation software for power electronic systems
CO2	Carryout transient simulation for power electronic systems
CO3	Apply switching functions to describe switching states of power converters
CO4	Develop effective models for power electronic converters

CO-PO Mapping:

CO/PO	PO1	PO2	PO3	PO4
CO1	2	3	3	3
CO2	2	3	3	3
CO3	3	2	3	3
CO4	2	2	3	3

Introduction: Computation challenges - Simulation process - mechanics of simulation, Solution techniques for time domain analysis -Equation solvers, circuit-oriented simulators.

Simulation of power electronic converters: MNA and ST Approaches- Nodal Analysis, Modified Nodal Analysis, Spare Tableau Approach, Nonlinear Circuits - Newton-Raphson Method, Computation Time, Convergence Issues, Nonlinear Circuit Equations.

Transient Simulation - Introduction, Discretization of Time, Transient Analysis, Accuracy and Stability, Explicit and Implicit Schemes, Methods for Transient Simulation - FE, BE and TRZ, Transient Analysis in Circuit Simulation, Equivalent Circuit Approach: RC Circuit, Buck Converter; Some Practical Aspects: Undamped Oscillations, Ringing, Global Error in Switching Circuits, Round-off Error, Assessment of Accuracy, Singular Matrix Problem, Trapezoidal integration, M & N method for simulating power electronic converters (with buck converter as a representative example).

Switching function: Introduction, Application of the switching function technique, Properties of the switching function, Voltage-Current relations in switched circuits - Single Switch, Parallel Switch. Pulse Width Modulation Modeling- Unipolar, PWM Signal of a composite function, bipolar square wave modulation, Mathematical Modeling of Buck Converter, Modeling using switching function-buck converter, Rectifier, 3-phase VSI inverter, matrix converter, m-phase rectifier. PWM rectifier topologies

Modeling of power electronic converters - PWM rectifier in different frames- abc, alpha-beta and d-q using switching function, Inverters.

Text book:

1. M. B. Patil, V. Ramnarayanan, V.T. Ranganathan**:** Simulation of Power Electronic Converters**,** 1st ed., Narosa Publishers, 2010.
2. De Russo, P. M., Roy, R. J., Close, C. M., Desrochers, A: State Variables For Engineers, John Wiley, New York, 2nd Edition, 1998.

Reference book:

1. N. Mohan, T.M. Undeland, W.P. Robbins: Power Electronics: Converters, Applications, 3rd edition, John Wiley & Sons, 2009.
2. Smith, J. M.: Mathematical modeling and digital simulation for engineers and scientists, John Wiley, New York, 2nd edition, 1987.

EE5163	Power Quality Improvement Techniques	DEC	3 – 0 – 0	3 Credits

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

CO1	Identify power quality problems in distribution system
CO2	Evaluate power quality indices in distribution system
CO3	Develop mitigation techniques for compensating devices to improve power quality in distribution system
CO4	Suggest compensating devices to improve power quality in distribution system

CO-PO Mapping:

CO/PO	PO1	PO2	PO3	PO4
CO1	1	2	2	2
CO2	1	2	2	3
CO3	3	2	2	3
CO4	3	2	2	3

Power Quality: Significance of power quality, Power quality terms: Transients, Long-duration voltage variations, Short-duration voltage variations, Voltage imbalance, Waveform distortion, Voltage fluctuation, CBEMA and ITI curves

Waveform Distortion: Introduction, Voltage versus current distortion, Harmonics versus transients, Harmonics indices: Total Harmonics Distortion (THD) and Total Demand distortion (TDD); Harmonic standards; Harmonic analysis; Harmonic phase sequence; Triplen harmonics; Interharmonics.

Harmonic Sources: Introduction; Harmonics generated from electrical machines such as transformers and rotating machines; Arcing devices; Static power conversion: Phase controlled and uncontrolled rectifiers, AC voltage regulators, Cycloconverters, Pulse width modulated inverters; Converter fed ac and dc drives;

Effects of Harmonic Distortion: Introduction; Resonances; Effects of harmonics on rotating machines; Effect of harmonics on static power plant; Power assessment with distorted waveforms; Effect of harmonics on measuring instruments; Harmonic interference with ripple control systems; Harmonic interference with power system protection; Effect of harmonics on consumer equipment; Interference with communication systems.

Harmonic Elimination: Introduction; Passive power filters: Design, A Shunt active power filters: Configurations, State of the art, Design and control strategies. Three-phase four-wire shunt active power filters

Voltage Quality: Introduction; Sources of Sags, Swell, Unbalance and Flicker; Voltage quality standards; Effects of sags, Swell, Unbalance and Flicker; Voltage sag magnitude due to fault; Voltage sag magnitude calculation based on influence of cross section of conductor, transformer and fault levels; Critical distance for a voltage sag magnitude; Causes of phase-angle jumps in voltage; Classification of voltage sags, voltage sag transformation due to transformers.

Methods for improving Voltage Quality: Introduction; Dynamic Voltage Restorer (DVR): Operating principle, Configurations, State of the art, Design and control strategies. Three-phase four-wire DVR.

Unified Power Quality Conditioner (UPQC): Introduction; design and control; Three-phase three-wire UPQC and three-phase four-wire UPQC topologies, Multilevel inverters based UPQC topologies, Mitigation of Flicker

Text Books:

1. Bhim Singh, Ambrish Chandra, Kamal Al-Haddad: Power Quality: Problems and Mitigation Techniques, Wiley, 2015.
2. Math H. J. Bollen: Understanding power quality problems, Ist edition, Wiley-IEEE Press, 2000
3. Ghosh Arindam, Ledwich Gerard: Power Quality Enhancement Using Custom Power Devices, Springer, 2009.

References:

1. Hirofumi Akagi, Edson Hirokazu Watanabe, Mauricio Aredes: Instantaneous Power Theory and Applications to Power Conditioning, Wiley-IEEE Press, 2017.
2. Roger C. Dugan, Mark F. McGranaghan, Surya Santoso and H. Wayne Beaty: Electrical Power Systems Quality, McGraw Hill, 3rd edition, 2012.
3. J. Arrillaga, N.R. Watson: Power System Harmonics, Wiley, 2nd Edition, 2003.

EE5164	Electric Vehicles	DEC	3 – 0 – 0	3 Credits

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

CO1	Understand the concepts of electric vehicles, hybrid electric vehicles and their impact on environment
CO2	Analyze the drive-train topologies and advanced propulsion techniques
CO3	Analyze hybrid energy storage methodologies
CO4	Select suitable power converter topologies for motor control and hybrid energy storage

CO-PO Mapping:

CO/PO	PO1	PO2	PO3	PO4
CO1	3	2	2	1
CO2	1	2	2	2
CO3	1	2	3	3
CO4	2	2	3	3

Introduction: Conventional vehicle, basics of vehicle performance, History of electric vehicles, social and environmental importance of electric vehicles, impact of modern drive-trains on energy supplies.

Hybrid Electric Vehicles: Micro hybrid vehicles, mild hybrid vehicles, full hybrid vehicles, Parallel hybrid vehicles, series Hybrid Vehicles, Series-Parallel Hybrid vehicles, plug-in hybrid vehicles, power flow diagrams for various operating modes. Plug-in Hybrid Vehicles: Operating principle, architectures: series-parallel-series-parallel, challenges related to grid connection. Range-extended Electric Vehicles: Classification and configurations, Fuel Cell Electric Vehicles, Solar electric Vehicles, Electric Bi-cycles and their propulsion systems, Vehicle-to-grid, vehicle-to-home concepts, Concept of Hybrid Electric Vehicles.

Electric drive-trains: Basic concept of electric traction, introduction to various electric drive-train topologies, power flow control in electric drive-train topologies, fuel efficiency analysis

Electric propulsion unit: Electric components used in electric vehicles, Configuration and control of DC Motor drives, Induction Motor drives, Permanent Magnet Motor drives, Switch Reluctance Motor drives, Drive system efficiency.

Energy Storage: Storage requirements for Electric Vehicles, Battery based energy storage, Fuel Cell based energy storage, Super Capacitor based energy storage and their analysis. Power pack management systems, Cell balancing techniques, Flywheel based energy storage and its analysis, Hybridization of different energy storage devices, compressed air storage systems, super conducting magnetic storage systems and Energy management systems.

Converters for Hybrid Energy Storage Systems: Converter configurations for hybrid energy systems based on Battery and Ultra Capacitors-cascaded converter, multiple parallel-connected converter, dual-active-bridge converter, multiple-input converter,-multiple modes single converter, interleaved converter, switched capacitor converter, converters for coupled inductor based hybridization. Fundamentals of Chargers: Charger classifications and standards, selection of AC charging systems, DC charging systems, Converter topologies for charging, wireless chargers.

Text books:

1. Ali Emadi,Advanced Electric Drive Vehicles, CRC Press, Taylor & Francis Group 2015.
2. Iqbal Hussein, Electric and Hybrid Vehicles: Design Fundamentals, CRC Press, Second Edition 2003.

References:

1. MehrdadEhsani, YimiGao, Sebastian E. Gay, Ali Emadi, Modern Electric, Hybrid Electric and Fuel Cell Vehicles: Fundamentals, Theory and Design, CRC Press, 2005.
2. James Larminie, John Lowry, Electric Vehicle Technology Explained, Wiley, 2003.

EE5165	Nonlinear Control Systems	DEC	3– 0 – 0	3 Credits

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

CO1	Understand the behavioral properties of nonlinear controlled systems
CO2	Analyze stability analysis of nonlinear systems, feedback linearization control method, Lyapunov design and sliding mode control method.
CO3	Formulate and solve basic robust and nonlinear controller design problems.
CO4	Develop methods of synthesis for nonlinear systems

CO,PO Mapping:

CO/PO	PO1	PO2	PO3	PO4
CO1	2	2	2	3
CO2	2	2	2	3
CO3	2	2	2	3
CO4	2	2	2	3

Introduction and classical techniques: Characteristics of nonlinear systems, classification of equilibrium points, limit cycles, analysis of systems with piecewise constant inputs using phase plane analysis, perturbation techniques, periodic orbits, stability of periodic solutions, singular perturbation model, slow and fast manifolds.

Lyapunov Stability and Design: Stability of Nonlinear Systems - Lyapunov stability, local stability, local linearization and stability in the small, Direct method of Lyapunov, generation of Lyapunov function for linear and nonlinear systems, variable gradient method, Centre manifold theorem, region of attraction, Invariance theorems - Input output stability, L stability, L stability of state models, L2 stability, Lyapunov based design, Lyapunonv redesign, Robust stabilization, Nonlinear Damping, back stepping, sliding mode control, adaptive control, Model controller, model reference adaptive control.

Harmonic Linearization and Describing Function Method: Harmonic linearization, filter hypothesis, describing function of standard nonlinearities, study of limit cycles (amplitude and frequency) using SIDF, Dual Input Describing function, study of sub-harmonic oscillations, correction on describing functions.

Feedback Control and Feedback Stabilization: Analysis of feedback systems, Circle Criterion, Popov Criterion, simultaneous Lyapunov functions, Feedback linearization, stabilization, regulation via integral control, gain scheduling, input stat linearization, input output linearization, state feedback control, stabilization, tracking, integral control.

Text Books:

1. A Isidori: Nonlinear Control systems, Springer verlag, 3rd Edition, 2013.
2. Hassan K. Khalil: Nonlinear Systems, Pearson, 3rd Edition, 2001.
3. Slotine& W. LI: Applied Nonlinear Control, Pearson, 1st Edition, 1991

References:

1. H. Nijmeijer& A.J. Vander Schaft: Nonlinear Dynamic control Systems, Springer, 1st Edition, 2016.
2. S. Wiggins: Introduction to Applied Nonlinear Dynamical Systems and chaos, Springer, 2nd Edition, 2010.

EE5166	Digital Signal Processor Controlled Drives	DEC	3 – 0 – 0	3 Credits

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

CO1	Interface the DSP platform with sensors such as hall-effect voltage sensors, hall-effect current sensors, shaft encoder for data acquisition for motor drive applications
CO2	Scale and normalize the data to suit the requirements of the drive system
CO3	Exploit the architectural features of the DSP platform to design and implement algorithms for the realization of controllers, Pulse Width Modulators and observers
CO4	Develop software modules to accomplish individual tasks and integrate them to build electrical drive systems.

CO-PO Mapping:

CO/PO	PO1	PO2	PO3	PO4
CO1	2	2	2	2
CO2	3	2	3	3
CO3	3	2	3	3
CO4	3	2	3	3

Overview of TMS320LF2407 DSP controller: Review of Instruction Set, Interrupts, normalization and number formatting.

Clarke's and Park's transformations: Review of Clarke's and Park's transformations, Implementation of Clarke's and Park's transformation using TMS320LF2407 DSP

Implementation of PWM Techniques for 3-Ph VSI: Implementation of Sine-triangle and SVPWM with TMS320LF2407 DSP using the concept of imaginary switching time

Control of BLDC Motor: Principle of operation with Drive control system, implementation of control system using TMS320LF2407 DSP

Control of PMSM: Principle of operation with drive control system, implementation of vector control using TMS320 LF2407DSP

Control of Induction Motor: Implementation of field oriented control for the speed control of Induction Motor using TMS320LF2407 DSP.

Implementation of PWM Techniques and Control of AC and DC drives using TMS320FLF2812 DSP

Text Books:

1. Hamid A. Toliyat: DSP Based Electromechanical Motion Control, 1st Edition, CRC Press, 2003
2. Ned Mohan, T.M. Undeland and William P. Robbins: Power Electronics: Converters, Applications, 3rd Edition, John Wiley & Sons, 2009

Reference:

Application Notes from Texas Instruments

EE5263	Flexible AC Transmission Systems	DEC	3 – 0 –0	3 Credits

Course Outcomes:

At the end of course, student will be able to

CO1	Understand the need for control of Real and Reactive power flows.
CO2	Identify the objectives of series and shunt compensation of power systems.
CO3	Analyse the performance of Series, Shunt and combined FACTS controllers
CO4	Evaluate the performance and stability of power systems with FACTS controllers

CO-PO mapping:

CO/PO	PO1	PO2	PO3	PO4
CO1	3	2	3	2
CO2	3	2	2	2
CO3	3	2	3	3
CO4	3	2	3	3

Introduction:Need for power system interconnections, Evolution of AC and DC transmission systems, Comparison of HVDC and HVAC Transmission systems, Power flow in AC systems, Relative importance of controllable parameters, Basic types of FACTS controllers, shunt and series controllers. Overview of power converters used in FACTS controllers.

Objectives of shunt compensation, Methods of controllable VAR generation, Static Var Compensator, its characteristics, TCR, TSC, FC-TCR configurations, STATCOM, basic operating principle, control approaches and characteristics

Objectives of series compensator, variable impedance type of series compensators, switching converter type compensators, TCSC, TSSC- operating principles and control schemes, SSSC, Power Angle characteristics, Control range and VAR rating

Static Phase Angle Regulators – power flow control by phase angle regulator and improvement of transient stability.

Introduction to Unified Power Flow Controller, Basic operating principles, Conventional control capabilities, Control structure of UPFC, Interline power flow controller.

Text Books:

1. Yong Hua Song & Allan T Johns: Flexible AC Transmission Systems (FACTS), IEE power and energy series, 2008.
2. NarainG.Honorani, Laszlo Gyugyi: Understanding FACTS – Concepts and Technology of Flexible AC Transmission Systems, Wiley-IEEE Press, 1999.

Reference:

1. K.R. Padiyar: Facts Controllers in Power Transmission and Distribution, New Age International Publishers, 2016.
2. R. Mohan Mathur and Rajiv K. Varma: Thyristor- Based FACTS controllers for electrical transmission systems, IEEE Press, 2002.

EE5265	Energy Auditing and Management	DEC	3 – 0 –0	3 Credits

Course Outcomes:

At the end of the course, student will be able to

CO1	Understand the need and significance of energy audit and management
CO2	Identify the equipment and domain of energy conservation and audit in power system
CO3	Assess the need and type of instruments for energy audit and energy management
CO4	Design, analyze and evaluate an energy audit and the benefits of different energy management techniques

CO-PO mapping:

CO/PO	PO1	PO2	PO3	PO4
CO1	2	1	2	3
CO2	1	3	2	2
CO3	2	2	3	3
CO4	1	3	3	3

ENERGY AUDIT AND DEMAND SIDE MANAGEMENT (DSM) IN POWER UTILITIES: Energy Scenario & Conservation -Demand Forecasting Techniques- Integrated Optimal Strategy for Reduction of T&D Losses - DSM Techniques and Methodologies- Loss Reduction in Primary and Secondary Distribution system and capacitors - Energy Management – Role of Energy Managers - Energy Audit - Metering

ENERGY AUDIT: Energy audit concepts, Basic elements and measurements, Mass and energy balances, Scope of energy auditing in industries,

ENERGY AUDIT OF ELECTRICAL EQUIPMENT: Evaluation of energy conservation opportunities and environmental management- Preparation and presentation of energy audit reports, case studies for Induction motors, Transformers, Cables, Lighting, AC systems, Pumps, Capacitor banks and potential energy savings.

INSTRUMENTATION: Evaluation and instrumentation techniques for renewable energy systems (solar thermal, photovoltaic and wind energy); energy management devices; micro controller based systems.

ENERGY CONSERVATION: Energy conservation in HVAC systems and thermal power plants, Solar systems, Fan and Lighting Systems - Different light sources and luminous efficacy, Energy conservation in electrical devices and systems, Economic evaluation of energy conservation measures, Electric motors and transformers, Inverters and UPS, Voltages stabilizers,

Text books :

1. AmlanChakrabarti: Energy Engineering and management, PHI, 2018.
2. Rajiv Shanker: Energy auditing in Electrical utilities, Viva books Pvt. Ltd., 2015.

Reference Books:

1. Larry C. Witte, Schmidt & Brown: Industrial energy management and utilization. Hemisphere publishing, Co. New York, 1988.
2. Wayne. C Turner: Energy management handbook, Wiley Inter-science publications. New York, 1982.
3. Hodge B.K, Analysis and Design of Energy Systems, Prentice Hall, 2002.

EE 5269	Evolutionary Algorithms application in Power Engineering	DEC	3 – 0 – 0	3 Credits

Course Outcomes:

After completion of the course, the student will be able to

CO1	Discriminate the capabilities of bio-inspired system and conventional methods in solving optimization problems.
CO2	Examine the importance of exploration and exploitation of evolutionary algorithm to attain near global optimal solution.
CO3	Distinguish the functioning of various evolutionary algorithms.
CO4	Employ various bio-inspired algorithms for Power systems engineering applications.

CO-PO mapping:

CO/PO	PO-1	PO-2	PO-3	PO-4
CO-1	3	2	3	2
CO-2	2	2	2	2
CO-3	1	2	2	3
CO-4	2	2	2	3

FUNDAMENTALS OF SOFT COMPUTING TECHNIQUES: Definition-Classification of optimization problems- Unconstrained and Constrained optimization Optimality conditions- Introduction to intelligent systems- Soft computing techniques- Conventional Computing versus Swarm Computing - Classification of meta-heuristic techniques - Single solution based and population based algorithms – Exploitation and exploration in population based algorithms - Properties of Swarm intelligent Systems - Application domain - Discrete and continuous problems - Single objective and multi-objective problems.

GENETIC ALGORITHM and PARTICLE SWARM OPTIMIZATION: Genetic algorithms- Genetic Algorithm versus Conventional Optimization Techniques - Genetic representations and selection mechanisms; Genetic operators- different types of crossover and mutation operators -Bird flocking and Fish Schooling – anatomy of a particle- equations based on velocity and positions -PSO topologies - control parameters – GA and PSO algorithms for solving ELD problem.

ARTIFICIAL BEE COLONY ALGORITHM and DIFFERENTIAL EVOLUTION: Artificial bee colony (ABC) algorithms-binary ABC algorithms – ACO and ABC algorithms for solving Economic Dispatch of thermal units. The Motivation for Differential Evolution (DE), Introduction to Parameter Optimization, Single-Point, Derivative-Based Optimization, Local Versus Global Optimization, Differential Mutation, Recombination, Selection, Benchmarking Differential Evolution, DE Versus Other Optimizers, DE on Parallel Processors

SHUFFLED FROG-LEAPING ALGORITHM and BAT OPTIMIZATION ALGORITHM: Bat Algorithm- Echolocation of bats- Behaviour of microbats- Acoustics of Echolocation-Movement of Virtual Bats- Loudness and Pulse Emission- Shuffled frog algorithm-virtual population of frogs-comparison of memes and genes -memeplex formation-memeplexupdation- BA and SFLA algorithms for solving ELD and optimal placement and sizing of the DG problem.

MULTI OBJECTIVE OPTIMIZATION: Multi-Objective optimization Introduction- Concept of Pareto optimality - Non-dominant sorting technique-Pareto fronts-best compromise solution-min-max method-NSGA-II algorithm and applications to power systems.

Text Books:

1. Xin-She Yang: Recent Advances in Swarm Intelligence and Evolutionary Computation, Springer International Publishing, Switzerland, 1e, 2015.
2. Kalyanmoy Deb: Multi-Objective Optimization using Evolutionary Algorithms, John Wiley & Sons, 1e, 2001.

Reference Books:

1. Eric Bonabeau, Marco Dorigo and Guy Theraulaz: Swarm Intelligence-From natural to Artificial Systems, Oxford university Press, 1999.
2. James Kennedy and Russel E Eberheart: Swarm Intelligence, The Morgan Kaufmann Series in Evolutionary Computation, 2001.
3. N P Padhy: Artificial Intelligence and Intelligent Systems, Oxford University Press, 2005.