JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY - GURAJADA - VIZIANAGARAM
VIZIANAGARAM – 535 003 Andhra Pradesh (India)
(Established by Andhra Pradesh Act No.22 of 2021)

DEPARTMENT OF ELECTRICAL & ELECTRONICS ENGINEERING

M.TECH COURSE STRUCTURE & SYLLABUS
Common to

I. **Power Electronics (Course Code: 43)**
II. **Power and Industrial Drives (Course Code: 52)**
III. **Power Electronics & Electrical Drives (Course Code: 54)**

(Applicable for batches admitted from 2025-2026)

COURSE STRUCTURE

I Year MTech (Power Electronics Group) I – Semester

S. No.	Course Code	Course Title	L	T	P	C
1	M254301	Electrical Machine Modeling and Analysis	3	1	0	4
2	M254302	Power Electronic Converters	3	1	0	4
3	M254303	Electric Vehicle Technology	3	1	0	4
4	M254304	**Program Elective – I** Modern Control Theory	3	1	0	4
	M254305	Power Quality Enhancement using Custom Power Devices				
	M254306	Industrial Control Electronics				
5	M254307	**Program Elective – II** Artificial Intelligence Techniques	3	1	0	4
	M254308	Renewable Energy Technologies				
	M254309	HVDC Transmission and Flexible AC Transmission Systems				
6	M254310	**Laboratory – 1** Power Converters Simulation Laboratory	0	1	2	2
7	M254311	**Laboratory – 2** Power Converters Laboratory	0	1	2	2
8	M254312	Seminar-I	0	0	2	1
		TOTAL	**15**	**7**	**6**	**25**

I Year MTech (Power Electronics Group) II – Semester

S. No.	Course Code	Course Title	L	T	P	C
1	N254301	Switched Mode Power Conversion	3	1	0	4
2	N254302	Power Electronic Control of Electrical Drives	3	1	0	4
3	N254303	Digital Controllers for Power Electronic Applications	3	1	0	4
4	N254304	Program Elective – III Control & Integration of Renewable Energy Systems	3	1	0	4
	N254305	Digital Control Systems				
	N254306	Battery Management Systems and Charging Stations				
	N254307	Program Elective – IV Advanced Digital Signal Processing	3	1	0	4
	N254308	Applications of Power Converters				
	N254309	Industrial Internet of Things				
6	N254310	Laboratory – 3 Electric Drives Simulation Laboratory	0	1	2	2
7	N254311	Laboratory – 4 Digital Controllers and Electric Drives	0	1	2	2

		Laboratory				
8	N254312	Seminar – II	0	0	2	1
		TOTAL	15	7	6	25

II Year MTech (Power Electronics Group) I – Semester

Sl. No.	Course Code	Course Title	L	T	P	C
1	O254301	Research Methodology and IPR / *Swayam 12 week MOOC course – RM&IPR*	2	0	0	2
2	O254302	Summer Internship/ Industrial Training (8-10 weeks)*	-	-	-	2
3	O254303	Dissertation Part – A$	-	-	20	10
		TOTAL	**2**	**-**	**20**	**14**

* Student attended during summer / year break and assessment will be done in 3rd Sem.

$ Dissertation – Part A, internal assessment

II Year MTech (Power Electronics Group) II – Semester

Sl. No.	Course Code	Course Title	L	T	P	C
1	P254301	Dissertation Part – B%	-	-	32	16
		TOTAL	**-**	**-**	**32**	**16**

% External Assessment

I- Semester	Electrical Machines Modeling and Analysis (Program Core – 1)	Category PC	L-T-P 3-1-0	Credits 4

Pre-requisite: Electric Circuits & Electrical Machines.

Course Objectives:

- To impart knowledge of fundamental modeling concepts and reference frame transformations for the analysis of induction, synchronous, and special machines.
- To provide proficiency in formulating mathematical and state-space models for various electrical machines using modern transformation and circuit analysis techniques.
- To enable critical analysis of machine performance in steady-state and transient conditions using various operational scenarios.

Course Outcomes:

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

- Explain the fundamental modeling principles and reference frame transformations for DC, induction, synchronous, and special electrical machines.
- Develop mathematical and state-space models for various electrical machines using transformation and circuit equations.
- Analyze steady-state and transient machine performance under varying operational conditions.

UNIT– I

Basic Concepts of Modeling & DC Machine Modeling :

Basic two-pole D.C. machine - Primitive 2-axis machine – Voltage and Current relationship – Torque equation. Mathematical model of separately excited D.C. motor and D.C. Series motor in state variable form – Mathematical model of D.C. shunt motor and D.C. Compound motor in state variable form, Steady state analysis – Transient state analysis, Transfer function of the D.C. motor, Sudden application of inertia load.

UNIT– II

Reference Frame Theory & 3-phase Induction Motor dq model:

Linear transformation – Phase transformation (abc to αβ0) – Power equivalence, Active transformation (αβ0 to dq0), transformations in complex plane, Commonly used reference frames and transformation between reference frames, Circuit model of a 3 phase Induction motor – Flux linkage equation – dq transformation of flux linkages in the complex plane – voltage equations

UNIT– III

Modeling of 3-phase Induction motor in various reference frames

Voltage equation transformation to a synchronous reference frame, dq model of induction motor in the stator reference frame, rotor reference frame and arbitrary reference frame, power equation, electromagnetic torque equation, state space model in induction motor with flux linkages as variables and current-flux variables

UNIT– IV

Modeling of 3-phase Synchronous Motor

Synchronous machine inductances – Circuits model of a 3-phase synchronous motor – derivation of voltage equations in the rotor's dq0 reference frame electromagnetic torque – State space model with flux linkages as variables.

UNIT– V

Special Machines:

Modeling of Permanent Magnet Synchronous motor – Modeling of Brushless DC Motor, Modeling of Switch Reluctance Motors

Text Books

1. Generalized theory of Electrical Machines -Fifth edition, Khanna Publishers P. S. Bimbhra, 1985.
2. AC Motor control and electric vehicle applications – Kwang Hee Nam – CRC press, Taylor & Francis Group, 2010.
3. Analysis of Electric Machinery and Drive Systems, 3rd Edition-Wiley-IEEE Press- Paul Krause, Oleg Wasynczuk, Scott D. Sudhoff, Steven Pekarek, Junr 2013.

Reference Books:

1. Dynamic simulation of Electric machinery using MATLAB / Simulink –CheeMunOng- Prentice Hall, 2003.
2. Magneto electric devices transducers, transformers and machines-G. R. Slemon- Wiley in New York, London, 1966.
3. Electric Motor Drives - Modeling, Analysis& control -R.Krishnan- Pearson Publications.

I- Semester	Power Electronic Converters (Program Core – 2)	Category PC	L-T-P 3-1-0	Credits 4

Pre-Requisite: Power Electronics.

Course Objectives:

- To understand the static and dynamic characteristics of power switching devices including MOSFET, IGBT, GTO, GaN devices, and their gate drive circuit requirements.
- To apply operational principles and control techniques of single-phase and three-phase fully controlled AC-DC converters, including power factor evaluation and harmonic analysis.
- To analyze various PWM inverter modulation schemes for single-phase and three-phase voltage and current source inverters, including sinusoidal, third harmonic, and space vector PWM. Analyze advanced PWM modulation techniques for multi-level inverters.
- To understand multilevel inverter topologies such as diode-clamped, cascaded H-bridge, and modular multilevel converters.

Course Outcomes:

- Understandthe characteristics and switching behavior of modern power devices and corresponding gate driver circuits. Understand the operation of AC-DC converters, two-level inverters and various multilevel inverter configurations.
- Apply various control strategies to improve input power quality and perform harmonic reduction in AC-DC conversion systems.
- Analyze and compare different PWM techniques for two-level and multi-level inverters to reduce harmonics.

UNIT– I

Overview of Switching Devices

Power MOSFET, IGBT, GTO, GaN devices-static and dynamic characteristics, gate drive circuits for switching devices.

UNIT– II

AC-DC converters

Single phase fully controlled converters with RL load– Evaluation of input power factor and harmonic factor- Continuous and Discontinuous load current, Power factor improvements, Extinction angle control, symmetrical angle control, PWM control, Single-phase single stage boost power factor corrected rectifier.

Three Phase AC-DC Converters, fully controlled converters feeding RL load with continuous and discontinuous load current, Evaluation of input power factor and harmonic factor-three phase dual converters.

UNIT– III

PWM Inverters: Voltage control of single-phase inverters employing phase displacement Control, Bipolar PWM, Unipolar PWM. Three-phase Voltage source inverters: Six stepped VSI operation-Voltage Control of Three-Phase Inverters employing Sinusoidal PWM, Third Harmonic PWM, Space Vector Modulation- Comparison of PWM Techniques- Three phase current source inverters.

UNIT– IV

Multilevel Inverters:

Introduction, Multilevel Concept, Types of Multilevel Inverters, Diode-Clamped Multilevel Inverter, Principle of Operation, Features of Diode-Clamped Inverter, Improved Diode Clamped Inverter, Cascaded H-bridge Multilevel Inverter, Principle of Operation, Features of Cascaded H-bridge Inverter, Fault tolerant operation of CHB Inverter, Comparison of DCMLI & CHB, Modular multilevel converters, principle of operation.

UNIT– V

PWM Multilevel Inverters:

CHB Multilevel Inverter: Stair case modulation-SHE PWM- Phase shifted Multicarrier modulation-Level shifted PWM- Diode clamped Multilevel inverter: SHE PWM-Sinusoidal PWM- Space vector PWM-Capacitor voltage balancing.

Text Books

1. Power Electronics: Converters, Applications, and Design- Ned Mohan, Tore M. Undeland, William P. Robbins, John Wiley&Sons, 2nd Edition ,2003.
2. Power Electronics-Md.H.Rashid –Pearson Education Third Edition- First IndianReprint-2008.

Reference Books:

1. Power Electronics Semiconductor Switches – Ram Shaw, 1993.
. Power Electronics Daniel W. Hart - McGraw-Hill, 2011.
2. Elements of Power Electronics – Philip T. Krein, Oxford University press, 2014.
3. Power Converter Circuits – William Shepherd & Li Zhang-Yes Dee CRC Press, 2004.

I-Semester	Electric Vehicle Technology (Program Core – 3)	Category PC	L-T-P 3-1-0	Credits 4

Pre-requisite: Knowledge of Power Electronics and Electric Drives

Course Objectives:
- To understand the fundamental components of conventional vehicles, propulsion loads, drive cycles, and terrains along with concepts of electric and hybrid vehicles.
- To apply hybridization techniques in automobiles, including the design and comparison of HEV, PHEV, and fuel cell vehicles.
- To analyze motor control strategies, power electronic converters, and regenerative braking systems used in electric and hybrid electric vehicles.
- To analyze different energy storage systems such as batteries, ultra-capacitors, flywheels, and other advanced technologies for their suitability in electric and hybrid vehicles.

Course Outcomes:
At the end of the course, student will be able to,
- Understand the key components of conventional vehicles and contrast them effectively with electric and hybrid vehicles.
- Apply knowledge of hybrid vehicle architectures, motor control startegies and energy management systems to design or select appropriate ev's.
- Analyze the functionality of motor controllers, power electronic devices, and regenerative braking to optimize electric vehicle performance.
- Analyze various energy storage technologies and their integration into electric and hybrid vehicles to improve overall system efficiency.

UNIT– I
Introduction:
Fundamentals of vehicle, components of conventional vehicle and propulsion load; Drive cycles and drive terrain; Concept and classification of electric vehicle and hybrid electric vehicle; History of electric and hybrid vehicles, Comparison of conventional vehicle with electric and hybrid vehicles.

UNIT– II
Hybridization of Automobile:
Fundamentals of vehicle, components of conventional vehicle and propulsion load; Drive cycles and drive terrain; Concept of electric vehicle and hybrid electric vehicle; Plug-in hybrid vehicle, constituents of PHEV, comparison of HEV and PHEV; Fuel Cell vehicles and its constituents.

UNIT– III
Motor Control in Electric Vehicles:
Role of motors in Electric Vehicles, factors to choose motors for EV, Comparison of motors for EV power train, Motor Controller Unit (MCU)- need and components, Motor control units of two- and four –wheel EVs, Regenerative braking.

UNIT– IV

Power Electronics in HEVs:

Rectifiers used in HEVs, voltage ripples; Buck converter used in HEVs, non-isolated bidirectional DC-DC converter, regenerative braking, voltage source inverter, current source inverter, isolated bidirectional DC-DC converter, PWM rectifier in HEVs, EV and PHEV battery chargers.

UNIT– V

Battery and Storage Systems

Energy Storage Parameters; Lead–Acid Batteries; Ultra capacitors; Flywheels - Superconducting Magnetic Storage System; Pumped Hydroelectric Energy Storage; Compressed Air Energy Storage - Storage Heat; Energy Storage as an Economic Resource

Text Books

1. Ali Emadi, Advanced Electric Drive Vehicles, CRC Press, 2014.
2. Iqbal Hussein, Electric and Hybrid Vehicles: Design Fundamentals, CRC Press, 2003.

Reference Books:

1. MehrdadEhsani, YimiGao, Sebastian E. Gay, Ali Emadi, Modern Electric, Hybrid Electric and Fuel Cell Vehicles: Fundamentals, Theory and Design, CRC Press, 2004.
2. James Larminie, John Lowry, Electric Vehicle Technology Explained, Wiley, 2003.
3. H. Partab: Modern Electric Traction – Dhanpat Rai & Co, 2007.

Research Books:

1. Pistooa G., “Power Sources , Models, Sustanability, Infrastructure and the market”, Elsevier 2008.
2. Mi Chris, Masrur A., and Gao D.W., “ Hybrid Electric Vehicle: Principles and Applications with Practical Perspectives” 1995.

I-Semester	Modern Control Theory (Program Elective – I)	Category PE	L-T-P 3-1-0	Credits 3

Pre-requisite: Control Systems, differential equations.

Course Objectives:

- To understand the concepts of state variables, state equations, controllability, and observability for linear time-invariant dynamic systems and their canonical forms.
- To apply state variable techniques to design state feedback controllers, including pole placement using Ackermann's formula, and develop full and reduced order state observers.
- To analyze nonlinear systems through classification, describing function analysis, phase plane methods, and stability, including Lyapunov stability and related theorems.
- To assess optimal control problems using calculus of variations, Euler-Lagrange equations, and quadratic performance criteria to design optimal regulators and controllers.

Course Outcomes:

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

- Understand state-space modeling, solution of state equations, and the concepts of controllability and observability in linear systems .
- Apply state feedback design and observer design techniques to control dynamic systems effectively.
- Analyze stability and dynamic behavior of nonlinear systems using describing functions, phase plane analysis, and Lyapunov's methods.
- Assess optimal control solutions for constrained and unconstrained control problems with quadratic cost functions using minimum principle and Euler-Lagrange techniques.

UNIT– I

State Variable Analysis

The concept of state – State Equations for Dynamic systems– Solution of Linear Time Invariant Continuous-Time State Equations, State transition matrix and it's properties. Controllability and Observability of state model in Jordan Canonical form - Controllability and Observability Canonical forms of State model

UNIT– II

Design using state variable technique

Design of state feedback controller through pole placement technique-Necessary and sufficient condition- Ackermann's formula. Concept of observer-Design of full order state observer-reduced order observer.

UNIT– III
Non Linear Systems
Classification of Nonlinearities- common physical nonlinearities– Characteristics of nonlinear systems - Singular Points –Linearization of nonlinear systems– Describing function – describing function analysis of nonlinear systems- Stability analysis of Nonlinear systems through describing functions, Introduction to phase plane analysis, Method of Isoclines for Constructing Trajectories.

UNIT– IV
Stability Analysis
Stability in the sense of Lyapunov, Lyapunov's stability and Lyapunov's instability theorems – Stability Analysis of Linear Continuous time invariant systems by Lyapunov method – Generation of Lyapunov functions – Variable gradient method – Krasooviski's method.

UNIT– V
Introduction to Optimal Control
Minimization of functional of single function – Constrained minimization – Minimum principle – Control variable inequality constraints – Control and state variable inequality constraints – Euler lagrangine equation. Typical optimal control performance measures-optimal control based on Quadratic performance measures- Quadratic optimal regulator systems- State regulator problems –Output regulator problems.

Text Books:
1. Modern Control Engineering – by K. Ogata, Prentice Hall of India, 3rd edition, 1998.
2. Automatic Control Systems by B.C. Kuo, Prentice Hall Publication.

Reference Books:
1. Modern Control System Theory – by M. Gopal, New Age International Publishers, 2nd edition,1996
2. Control Systems Engineering by I.J. Nagarath and M.Gopal, New Age International (P) Ltd.
3. Digital Control and State Variable Methods – by M. Gopal, Tata McGraw–Hill Companies, 1997.
4. Systems and Control by Stainslaw H. Zak , Oxford Press, 2003.
5. Optimal control theory: an Introduction by Donald E.Kirk by Dover publications.
6. Modern control systems, Richard C. Dorf and Robert H. Bishop, 11th Edition, Pearson Edu, India, 2009

I-Semester	POWER QUALITY ENHANCEMENT USING CUSTOM POWER DEVICES (Program Elective – I)	Category PE	L-T-P 3-1-0	Credits 4

Pre requisite: Knowledge on electric circuit analysis, power systems and power electronics and concept of reactive power compensation techniques.

Course Educational Objectives:

- To understand significance of power quality and power quality parameters.
- To analyze types of transient over voltages and protection of transient voltages.
- To examine harmonics, their effects, harmonic indices and harmonic minimization techniques.
- To know the importance of power devices and their applications.
- To understand different compensation techniques to minimize power quality disturbances.

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

- Identify the issues related to power quality in power systems.
- Address the problems of transient and long duration voltage variations in power systems.
- Analyze the effects of harmonics and study of different mitigation techniques.
- Identify the importance of custom power devices and their applications.
- Acquire knowledge on different compensation techniques to minimize power quality disturbances.

UNIT– I

Introduction to power quality: Overview of Power Quality, Concern about the Power Quality, General Classes of Power Quality Problems, Voltage Unbalance, Waveform Distortion, Voltage fluctuation, Power Frequency Variations, Power Quality Terms, Voltage Sags, swells, flicker and Interruptions - Sources of voltage and current interruptions, Nonlinear loads.

UNIT– II

Transient and Long Duration Voltage Variations: Source of Transient Over Voltages - Principles of Over Voltage Protection, Devices for Over Voltage Protection, Utility Capacitor Switching Transients, Utility Lightning Protection, Load Switching Transient Problems.

Principles of Regulating the Voltage, Device for Voltage Regulation, Utility Voltage Regulator Application, Capacitor for Voltage Regulation, End-user Capacitor Application, Regulating Utility Voltage with Distributed generation

UNIT– III

Harmonic Distortion and solutions: Voltage vs. Current Distortion, Harmonics vs. Transients - Power System Quantities under Non-sinusoidal Conditions, Harmonic Indices, Sources of harmonics, Locating Sources of Harmonics, System Response Characteristics, Effects of Harmonic

Distortion, Inter harmonics, Harmonic Solutions Harmonic Distortion Evaluation, Devices for Controlling Harmonic Distortion, Harmonic Filter Design, Standards on Harmonics

UNIT– IV

Custom Power Devices: Custom power and custom power devices, voltage source inverters, reactive power and harmonic compensation devices, compensation of voltage interruptions and current interruptions, static series and shunt compensators, compensation in distribution systems, interaction with distribution equipment, installation considerations.

UNIT– V

Application of custom power devices in power systems: Static and hybrid Source Transfer Switches, Solid state current limiter - Solid state breaker. P-Q theory – Control of P and Q, Dynamic Voltage Restorer (DVR), Operation and control of Interline Power Flow Controller (IPFC), Operation and control of Unified Power Quality Conditioner (UPQC), Generalized power quality conditioner.

Text Books:

1. Electrical Power Systems Quality, Dugan R C, McGranaghan M F, Santoso S, and Beaty H W, Second Edition, McGraw-Hill, 2002.
2. Understanding Power Quality Problems: Voltage Sags and Interruptions, Bollen M H J, First Edition, IEEE Press; 2000.
3. Guidebook on Custom Power Devices, Technical Report, Published by EPRI, Nov 2000
4. Power Quality Enhancement Using Custom Power Devices – Power Electronics and Power Systems, Gerard Ledwich, ArindamGhosh, Kluwer Academic Publishers, 2002.

Reference Books:

1. Power Quality Primer, Kennedy B W, First Edition, McGraw-Hill, 2000.
2. Power System Harmonics, Arrillaga J and Watson N R, Second Edition, John Wiley & Sons, 2003.
3. Electric Power Quality control Techniques, W. E. Kazibwe and M. H. Sendaula, Van Nostrad Reinhold, New York.
4. Power Quality c.shankaran, CRC Press, 2001
5. Harmonics and Power Systems –Franciso C.DE LA Rosa-CRC Press (Taylor & Francis).

6. Power Quality in Power systems and Electrical Machines-EwaldF.fuchs, Mohammad A.S. Masoum-Elsevier
7. Power Quality, C. Shankaran, CRC Press, 2001
8. Instantaneous Power Theory and Application to Power Conditioning, H. Akagiet.al., IEEE Press, 2007.
9. Custom Power Devices - An Introduction, ArindamGhosh and Gerard Ledwich, Springer, 2002
10. A Review of Compensating Type Custom Power Devices for Power Quality Improvement, Yash Pal et.al., Joint International Conference on Power System Technology and IEEE Power India Conference, 2008. POWERCON 2008.

I-Semester	INDUSTRIAL CONTROL ELECTRONICS (Program Elective – I)	Category	L-T-P 3-1-0	Credits 4

Pre-requisite: Knowledge on relay logic and digital electronics.

Course Objectives:
- To understand the principles and characteristics of power supplies including UPS topologies, energy storage systems, and sensor technologies used in industrial applications.
- To apply controllers such as analog PID and signal conditioning techniques to regulate power systems and sensor signals effectively.
- To analyze power sources for welding and heating by evaluating volt-ampere characteristics, control methods, and advanced pulsing techniques.
- To apply PLC and SCADA architectures and their role in industrial automation and energy saving within electrical drive systems.

Course Outcomes:
At the end of the course, student will be able to,
- Understanding of UPS systems, energy storage options, and various sensors utilized in industrial power environments.
- Apply knowledge of control strategies and signal conditioning to design and implement reliable power and sensor control systems.
- Analyze the operating principles and control techniques of welding and heating power sources to optimize performance and quality.
- Apply PLC and SCADA systems for effective supervisory control and energy-efficient electrical drive management in industrial processes.

UNIT– I
Power Supplies:
Review of uninterrupted power supplies - offline and on-line topologies - analysis of UPS topologies, solid state circuit breakers and solid-state tap changing of transformer - advance energy storage systems, battery, ultra-capacitors, flywheel energy storage, fuel cells characteristics and applications.

UNIT– II
Sensors:
Overview of sensors in industrial applications – current sensors, current transformer, hall effect sensors - voltage sensors, non-isolated measurement, hall effect, temperature sensors, thermal protection of power components – speed sensors – position sensors.

UNIT– III
Controllers:
Analog controllers - proportional controllers, proportional – integral controllers, PID controllers, derivative overrun, integral windup, cascaded control, feed forward control. Signal conditioners - instrumentation amplifiers – voltage to current, current to voltage, voltage to frequency, frequency to voltage converters

UNIT– IV
Power Sources for Welding & Heating:
Solid state welding power source - introduction, classification, basic characteristics, volt ampere relationship and its measurements, control of volt ampere characteristics, volt control, slope control and dual control– pulsing techniques – testing of welding power source. Introduction to heating, classification, characteristics – applications

UNIT– V
PLC & SCADA:
Introduction to programmable logic controllers, architecture, programming. Supervisory control and data acquisition (SCADA) Systems, components of SCADA systems, SCADA basic functions, SCADA application functions in electrical engineering. Energy saving in electrical drive systems.

Text Books:

1. Michael Jacob, 'Industrial Control Electronics – Applications and Design', Prentice Hall, 1995
2. Thomas E. Kissell, 'Industrial Electronics', Prentice Hall India, 2003 2. Curtis D. Jhonson 'Process Control Instrumentation technology' Pearson New International Eighth edition,2014

Reference Books:

1. Mehrdad Ehsani, Yimin Gao, Sebastien E. Gay, Ali Emadi 'Modern Electric, Hybrid Electric and Fuel Cell Vehicles Fundamentals, Theory and Design' CRC Press 2004.
2. Mini S. Thomas, John D McDonald, Power Systems SCADA and Smart Grid, CRC Press, Taylor and Francis.
3. Welding Handbook, Volume-2, Seventh Edition, American Welding Society.
4. Power Electronics Applied to Industrial Systems and Transports. Volume
5. Measurement Circuits, Safeguards and Energy Storage, Imprint - ISTE Press – Elsevier.

Pre –requisite: Fundamentals of Neural networks and Fuzzy Logic

I-Semester	Artificial Intelligence Techniques (Program Elective – II)	Category PE	L-T-P 3-1-0	Credits 4

Course Objectives:

- To understand the fundamentals of artificial neural networks, biological inspiration, activation functions, and learning strategies including perceptron, ADALINE, and MADALINE models.
- To apply various ANN paradigms such as backpropagation, RBF networks, self-organizing maps, associative memories, and bidirectional networks for pattern recognition and data classification.
- To analyze classical and fuzzy set theories along with fuzzy logic components including fuzzification, inference, and defuzzification processes in intelligent control systems.
- To evaluate the application of AI techniques such as neural networks and fuzzy logic controllers in advanced motor control and harmonic elimination in power electronics.

Course Outcomes:

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

- Understanding of neural network architectures, learning algorithms, and fuzzy set fundamentals for intelligent system modeling.
- Apply neural network paradigms and fuzzy logic techniques to develop solutions for classification, clustering, and control problems.
- Analyze the structure and behavior of ANN models and fuzzy logic controllers to optimize control strategies and system performance.
- Evaluate AI-based applications such as neural network-based PWM and fuzzy logic motor controls for improved automation and power quality.

UNIT– 1

Introduction

Artificial Neural Networks (ANN) – Humans and computers – Biological neural networks – ANN Terminology – Models of Artificial neuron – activation functions –typical architectures – biases and thresholds – learning strategy(supervised, unsupervised and reinforced) learning rules, perceptron training and classification using Discrete and Continuous perceptron algorithms, ADALINE and MADLINE – linear separability and non-separability with examples.

UNIT– II

ANN Paradigms

Generalized delta rule – Back Propagation algorithm- Radial Basis Function (RBF) network. Kohonen’s self-organizing feature map (KSOFM), Learning Vector Quantization (LVQ) – Functional Link Networks (FLN) – Bidirectional Associative Memory (BAM) – Hopfield Neural Network.

UNIT– III
Classical and Fuzzy Sets
Introduction to classical sets - properties, Operations and relations; Fuzzy sets, Membership, Uncertainty, Operations, properties, fuzzy relations, cardinalities, membership functions.

UNIT– IV
Fuzzy Logic Controller (FLC)
Fuzzy logic system components: Fuzzification, Inference engine (development of rule base and decision-making system), Defuzzification to crisp sets- Defuzzification methods.

UNIT– V
Application of AI Techniques: Selected Harmonic Elimination PWM using feed forward neural network, instantaneous current control PWM using neural network, Speed control of DC motor using Fuzzy logic, Speed control of Induction motor using Fuzzy logic.

Text Books:

1. Fundamentals of Neural Networks: Architectures, Algorithms and Applications by Laurene Fausett, Pearson Education, 2008.
2. Introduction to Artificial Neural Systems - Jacek M. Zuarda, Jaico Publishing House, 1997.
3. Fuzzy logic with Fuzzy Applications – T.J Ross – McGraw Hill Inc, 1997.
4. Modern Power Electronics and AC Drives, Bimal K Bose, 1st Edition, Pearson Education,2002

Reference Books:

1. Neural Networks, Fuzzy logic, Genetic algorithms: synthesis and applications by Rajasekharanand Pai – PHI Publication.
2. Introduction to Neural Networks using MATLAB 6.0 by S N Sivanandam,S Sumathi,S N Deepa TMGH
3. Introduction to Fuzzy Logic using MATLAB by S N Sivanandam,S Sumathi,S N Deepa Springer, 2007.

I-Semester	Renewable Energy Technologies (Program Elective -II)	Category PE	L-T-P 3-1-0	Credits 4

Pre requisite: UG power Electronics.

Course Objectives:

- To understand the fundamental principles of renewable energy sources, distributed generation, and economic aspects including electricity generation cost and management options.
- To apply operational principles and mathematical models of induction generators including self-excitation, speed, and voltage control for renewable power systems.
- To analyze key factors in wind and photovoltaic power plant design, including site evaluation, turbine classification, PV cell characteristics, and maximum power point tracking techniques.
- To explore fuel cell technologies, their performance modeling, practical implementation challenges, and integration considerations for sustainable energy conversion and storage.

Course Outcomes:

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

- Understanding of renewable energy fundamentals, distributed generation concepts, and the economic/environmental impact of renewable power systems.
- Apply knowledge of induction generator operation and controls to model and control renewable energy conversion systems effectively.
- Analyze wind and solar energy system components, including turbine types, PV cell models, and MPPT algorithms, to optimize system performance.
- Explore fuel cell technologies, hydrogen storage issues, and system integration strategies for advancing renewable energy utilization.

UNIT– 1

Introduction: Renewable Sources of Energy; Distributed Generation; Renewable Energy Economics - Calculation of Electricity Generation Costs; Demand-Side Management Options; Supply-Side Management Options; Control of renewable energy based power Systems

UNIT– II

Induction Generators: Principles of Operation; Representation of Steady-State Operation; Power and Losses Generated - Self-Excited Induction Generator; Magnetizing Curves and Self-Excitation - Mathematical Description of the Self-Excitation Process; Interconnected and Stand-alone operation - Speed and Voltage Control.

UNIT– III

Wind Power Plants: Site Selection; Evaluation of Wind Intensity; Topography; Purpose of the Energy Generation- General Classification of Wind Turbines; Rotor Turbines; Multiple-Blade Turbines; Drag Turbines; Lifting Turbines - Generators and Speed Control Used in Wind Power Energy; Analysis of Small wind energy conversion system.

UNIT– IV

Photovoltaic Power Plants: Solar Energy; Generation of Electricity by Photovoltaic Effect; Dependence of a PV Cell on Temperature and irradiance input-output Characteristics - Equivalent Models and Parameters for Photovoltaic Panels; MPPT schemes: P&O,INC, effect of partial shaded condition. Applications of Photovoltaic Solar Energy-Economical Analysis of Solar Energy

UNIT– V

Fuel Cells: The Fuel Cell; Low- and High-Temperature Fuel Cells; Commercial and Manufacturing Issues - Constructional Features of Proton Exchange-Membrane Fuel Cells; Reformers; Electrolyzer Systems; Advantages and Disadvantages of Fuel Cells - Fuel Cell Equivalent Circuit; Practical Determination of the Equivalent Model Parameters; Aspects of Hydrogen for storage

Text Books:

1. Felix A. Farret, M. Godoy Simo` es, Integration of Alternative Sources of Energy, John Wiley & Sons, 2006.
2. Remus Teodorescu, Marco Liserre, Pedro Rodríguez, Grid Converters for Photovoltaic and Wind Power Systems, John Wiley & Sons, 2011.

Reference Books:

1. Gilbert M. Masters, Renewable and Efficient Electric Power Systems, John Wiley & Sons, 2004

I-Semester	HVDC Transmission and Flexible AC Transmission Systems (Program Elective -II)	Category PE	L-T-P 3-1-0	Credits 4

Pre-requisite: Knowledge on Power Electronics, Power Systems and High Voltage Engineering

Course Objectives:

- To understand the fundamentals, components, and evolution of HVDC transmission systems, their advantages over HVAC, and basic FACTS concepts.
- To apply analysis techniques for HVDC converters including Graetz circuits, conduction modes, voltage waveforms, and converter control methods.
- To analyze control strategies for DC links, harmonic generation and filtering, as well as the operation and control of static shunt and series compensators in FACTS devices.
- To analyze the performance and control of advanced FACTS devices like STATCOM, SSSC, and Unified Power Flow Controllers for improving system stability and reactive power compensation.

Course Outcomes:

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

- Understanding of HVDC system components, types of DC links, and the basics of FACTS controllers and transmission system interconnections.
- Apply knowledge of HVDC converter configurations, firing angle control, and harmonic filter design to enhance power quality and control.
- Analyze DC link control schemes, harmonic effects, and the operational characteristics of shunt and series static compensators in power systems.
- Analyze the design, operation, and control of FACTS devices including DVR, STATCOM, and UPFC to optimize power flow and voltage stability in electrical networks.

UNIT– 1

HVDC Transmission: DC Power Transmission: Need for power system interconnections, Evolution of AC and DC transmission systems, Comparison of HVDC and HVAC Transmission systems, Types of DC links, relative merits, Components of a HVDC system, Modern trends in DC Transmission systems.

UNIT– II

Analysis of HVDC Converters: Pulse number, choice of converter configurations, Analysis of Graetz circuit with and without overlap, voltage waveforms, Analysis of two and three valve conduction mode, Converter Bridge characteristics, Inverter mode of operation, voltage waveforms.

UNIT– III

HVDC Control: Principles of DC link control, Converter Control characteristics, Control hierarchy Constant current Control, CEA Control, firing angle control of valves, starting and stopping of a dc link, Power control.AC-DC power flow.

Harmonics and Filters: effects of Harmonics, sources of harmonic generation, Types of filters –Design examples.

UNIT– IV

Flexible AC Transmission Systems (FACTS): FACTS concepts and general system conditions: Power flow in AC systems, Relative importance of controllable parameters, Basic types of FACTS controllers, shunt and series controllers, Current source and Voltage source converters.

UNIT– V

Static Shunt Compensators: Objectives of shunt compensation, Methods of controllable VAR generation, Static Var Compensator, its characteristics, TCR, TSC, STATCOM, basic operating principle, control approaches and characteristics

Static Series Compensators: Objectives of series compensator, variable impedance type of series compensators, TCSC, TSSC-operating principles and control schemes, SSSC, Power Angle characteristics, Control range and VAR rating, Capability to provide reactive power compensation, external control

Introduction to Unified Power Flow Controller, Basic operating principles, Conventional control capabilities, Independent control of real and reactive power.

Text Books:

1. NarainG.Honorani, Laszlo Gyugyi: Understanding FACTS –Concepts and Technology of Flexible AC Transmission Systems, Wiley-IEEE Press, 2000.
2. K.R.Padiyar: HVDC Power Transmission Systems –Technology and System Interactions, New Age International Publishers, 2011.

Reference Books:

1. Kimbark: Direct Current Transmission, 1971.
2. Jos Arrillaga: High Voltage Direct Current Transmission, The Institution of electrical Engineers, 1998.
3. Yong Hua Song, Allan T Johns: Flexible AC Transmission Systems, The Institution of electrical Engineers, 1999.

I-Semester	Power Converters Simulation Laboratory	CATEGORY Lab	L-T-P 0 -1-2	CREDITS 2

Course Objectives:

- To understand the switching characteristics and operational principles of power MOSFETs and IGBTs including their structural differences and performance parameters.
- To apply driver circuit design concepts for power MOSFET and IGBT to enable effective gate control and switching operations.
- To analyze the simulation results of various power converter topologies such as three-phase full converters, dual converters, and PWM-based inverters to understand waveforms and conduction modes.
- To evaluate different PWM techniques including unipolar, bipolar, space vector, third harmonic injection, and multilevel inverter modulation schemes for improving inverter output quality.

Course Outcomes:

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

- Understanding of power MOSFET and IGBT switching behavior, including their advantages and limitations in power electronic applications (Level 2).
- Capable of applying driver circuit designs for effective control of MOSFET and IGBT power devices in switching converters (Level 3).
- Analyze the performance of simulated converter and inverter circuits under various load conditions and modulation schemes for improved power electronic system design.
- Analyze multilevel inverter configurations through simulation to improve power quality and system performance in advanced applications.

Any 10 of the following experiments are to be conducted.

List of Experiments:

1. Illustrate the switching characteristics of power MOSFET and power IGBT
2. Illustrate the use of Driver circuit for power MOSFET and power IGBT
3. Simulation of three phase full converter with RL & RLE loads.
4. Simulation of three-phase dual converter.
5. Simulation of single-phase full bridge inverter using unipolar & bipolar PWM techniques.
6. Simulation of three-phase two-level inverter for 120º & 180º mode of conduction.
7. Simulation of three phase two-level inverter using SPWM.
8. Simulation of three phase two-level inverter using Third Harmonic PWM,
9. Simulation of three phase two-level inverter using space vector PWM.
10. Simulation of three phase three-level NPC inverter using SPWM
11. Simulation of three phase five-level diode clamped inverter using SPWM
12. Simulation of Stair case modulation and SHE PWM for single-phase seven-level cascaded H-bridge inverter.
13. Simulation of Multicarrier PWM techniques for three-phase five-level cascaded H-bridge inverter.
14. Simulation of Modular Multilevel Converter.

I-Semester	Power Converters Laboratory	CATEGORY Lab	L-T-P 0 -1-2	CREDITS 2

Course Objectives:

- To understand the switching characteristics and operational principles of power MOSFETs and IGBTs including their structural differences and performance parameters.
- To apply driver circuit design concepts for power MOSFET and IGBT to enable effective gate control and switching operations.
- To analyze the various power converter topologies such as three-phase full converters, dual converters, and PWM-based inverters to understand waveforms and conduction modes.
- To evaluate different PWM techniques including unipolar, bipolar, space vector, third harmonic injection, and multilevel inverter modulation schemes for improving inverter output quality.

Course Outcomes:

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

- Understanding of power MOSFET and IGBT switching behavior, including their advantages and limitations in power electronic applications.
- Capable of applying driver circuit designs for effective control of MOSFET and IGBT power devices in switching converters.
- Analyze the performance of converter and inverter circuits under various load conditions and modulation schemes for improved power electronic system design.
- Analyze multilevel inverter configurations to improve power quality and system performance in advanced applications.

Any 10 of the following experiments are to be conducted.

List of Experiments:

1. Illustrate the switching characteristics of power MOSFET and power IGBT
2. Illustrate the use of Driver circuit for power MOSFET and power IGBT
3. Analysis of single phase full converter with RL & RLE loads.
4. Analysis of three phase full converter with RL & RLE loads.
5. Analysis of three-phase dual converter.
6. Analysis of single-phase full bridge inverter using unipolar & bipolar PWM techniques.
7. Analysis of three-phase two-level inverter for 120º & 180º mode of conduction.
8. Analysis of three phase two-level inverter using SPWM.
9. Analysis of three phase two-level inverter using Third Harmonic PWM,
10. Analysis of three phase two-level inverter using space vector PWM.
11. Analysis of three phase three-level NPC inverter using SPWM
12. Analysis of three phase five-level diode clamped inverter using SPWM
13. Analysis of Stair case modulation and SHE PWM for single-phase seven-level cascaded H-bridge inverter.
14. Analysis of Multicarrier PWM techniques for three-phase five-level cascaded H-bridge inverter.
15. Analysis of Modular Multilevel Converter.

I-Semester	**Seminar-I**	**PC**	**L-T-P 0-0-2**	**Credits 1**

II-Semester	Switched Mode Power Conversion (Program Core – 4)	Category PC	L-T-P 3-1-0	Credits 4

Pre-requisite: Concepts of electrical circuit analysis and power electronics.

Course Educational Objectives:

- To understand the fundamental principles, topologies, and operating modes of non-isolated, isolated, and resonant power converters, including essential design considerations for components and control.
- To apply appropriate modeling techniques and analytical methods to design, simulate, and implement dc-dc converter circuits and their control systems.
- To analyze and interpret the effects of non-ideal components, magnetic and thermal considerations, and control strategies on the performance of power converters.

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

- Explain the operation of non-isolated, isolated, and resonant DC-DC converters.
- Design power converter circuits with appropriate selection of components, magnetic designs, and control techniques.
- Develop averaged large signal, steady state and small signal mathematical models for controller design

UNIT– 1
Non-isolated switch mode converters:
Control of DC-DC converters: Buck converters, Boost converters, Buck-Boost converter, CUK Converter, continuous and discontinuous operation, Converter realization with non-ideal components.

UNIT– II
Isolated switched mode converters:
Forwarded converter, flyback converter, push-pull converter, half-bridge converter, full bridge converter.

UNIT– III
Resonant converters:
Basic resonant circuit concepts, series resonant circuits, parallel resonant circuits, zero current switching quasi-resonant buck converter, zero current switching quasi-resonant boost converter, zero voltage switching quasi-resonant buck converter, zero voltage switching quasi-resonant boost converter, load resonant converter.

UNIT– IV
Design of Power Converters Components: Magnetic concepts - design of inductor, design of transformer, Selection of filter capacitors, Selection of ratings for devices, input filter design, Thermal design

UNIT– V

Modeling and Controller design:

Circuit averaging method and average switch model technique to obtain averaged large signal model, steady state model, small signal models of buck, boost, buck-boost converters, Derivation of converter transfer functions for buck, boost and buck-boost topologies. Voltage mode control, Current mode control, current mode control instability, slope compensation, Controller design using Bode approach.

Text Books:

1. Fundamentals of Power Electronics-Erickson, Robert W., Maksimovic, Dragan, Springer, 2011.
2. Power switching converters-Simon Ang, Alejandro Oliva, CRC Press, 2010.
3. Power Electronics: Essentials and applications- L. Umanand, Wiley publications

Reference Books:

1. Design of Magnetic Components for Switched Mode Power Converters- Umanand, S.P. Bhat, John Wiley&Sons Australia, 1992.
2. Switching Power Supply Design-Abraham I. Pressman, McGraw-Hill Ryerson, Limited, 1991.
3. Power Electronics – IssaBatareseh, Jhon Wiley publications, 2004.
4. Power Electronics: converters Applications & Design – Mohan, Undeland, Robbins-Wiley publications.

II-Semester	Power Electronic Control of Electrical Drives (Program Core – 5)	Category PC	L-T-P 3-1-0	Credits 4

Pre-requisite: Knowledge of Power Electronics and Electrical Machines.

Course Educational Objectives:

- To understand the principles and working of different control methods for induction motor drives including V/f control, vector control, and direct torque control techniques.
- To apply sensorless control methods and state observers such as MRAS and Kalman filters to estimate motor parameters without speed sensors in induction motor drives.
- To analyze the control strategies and performance trade-offs of Permanent Magnet Synchronous Machines, Brushless DC motors, and Switched Reluctance Motors for efficient torque and speed control.

Course Outcomes: After the completion of the course, student will be able to

- Explain the concepts of vector control, sensorless speed estimation, DTC, and their significance in the operation of induction motor and permanent magnet motor drives.
- Demonstrate the implementation of rotor and stator field-oriented control and adapt sensorless control algorithms for real-time motor speed and torque control.
- Compare and analyze different motor control schemes including direct torque control and vector control techniques based on steady-state accuracy and dynamic response.
- Analyze the effectiveness of control strategies for the performance evaluation of Permanent Magnet Synchronous Machines, Brushless DC motors, and Switched Reluctance Motors for efficient torque and speed control.

UNIT– 1
Vector Control of Induction Motor Drive:
Open loop and closed loop V/f control, Principle of vector control – direct and indirect vector control, implementation of direct and indirect vector control, rotor field-oriented control, implementation of rotor field-oriented control, stator field-oriented control, field weakening control of induction motor.

UNIT– II
Sensor less Control of induction Motor Drive:
Advantages of speed sensor less control, voltage current based speed sensor less control, MRAS-model reference adaptive systems, state equation of an induction motor, state observers, full-order observer, reduced order observer, Extended Kalman filter observers.

UNIT– III
Direct Torque Control of Induction Motor Drive:
Principle of Direct torque control (DTC), concept of space vectors, DTC control strategy of induction motor, comparison between vector control and DTC, modified DTC of induction motor with constant switching frequency, space vector modulation based DTC of induction motors.

UNIT– IV
Control of Permanent Magnet Synchronous Machines (PMSM) and Brushless DC (BLDC) Motor Drives:
Advantages and limitations of Permanent magnet machines, operating principle of PMSM, vector control for PMSM, operating principle of BLDC, modeling of BLDC, similarities and difference between PMSM and BLDC, need for position sensing in BLDC motors, control strategies for PMSM and BLDC, methods of reducing torque ripples of BLDC motor.

UNIT– V
Control of Switched Reluctance Motor (SRM) Drive:
SRM structure, Merits and limitations, stator excitation, converter topologies, SRM waveforms, Torque control schemes, speed control of SRM, torque ripple minimization, instantaneous - torque control using current controllers and flux controllers.

Text Books:
1. Bose B. K., "Power Electronics and Variable Frequency Drives', IEEE Press, Standard Publisher Distributors. 2001.
2. Kwang Hee Nam, "AC Motor Control and Electrical Vehicle Applications" Second Edition, CRC Press.

Reference Books:

1. Seung-Ki Sul, "Control of Electric Machine Drive Systems" IEEE Press, A John Wiley & Sons, Inc. Publications. 2011.
2. Krishnan R., "Electric Motor Drives – Modeling, Analysis and Control", Prentice Hall of India Private Limited.
3. Switched Reluctance Motors and Their Control-T. J. E. Miller, Magna Physics, 1993.
4. Power electronic converters applications and design-Mohan, Undeland, Robbins-Wiley publications.

II-semester	DIGITAL CONTROLLERS FOR POWER ELECTRONIC APPLICATIONS (Program Core – 6)	Category PC	L-T-P 3-1-0	Credits 4

Pre-requisite: Digital Electronics, Digital Signal Processing, Computer Architecture.

Course Educational Objectives:

- To understand the architecture and components of the C2xx DSP core, including memory types, addressing modes, and system configuration.
- To apply programming concepts for assembly and C code generation on the C2xx DSP core, and manage pin multiplexing, interrupts, and peripheral control.
- To analyze the operation of ADCs, event managers, timers, and PWM generation techniques for embedded control applications.
- To evaluate control strategies for power converters and motor drives using DSP-based digital controllers and FPGA integration.

Course Outcomes: After the completion of the course, student will be able to

- Describe the architectural features of the C2xx DSP core, including memory, peripherals, and interrupt systems.
- Develop assembly and embedded C programs to initialize and service interrupts, configure peripherals, and implement control loops on the DSP core.
- Analyze signal acquisition and generation methods using ADCs, event managers, PWM units, and timers for real-time digital control.
- Design and critically assess DSP-based controllers for switched-mode power converters and electric motor drives, incorporating FPGA-based enhancements where applicable.

UNIT– 1

Introduction to the C2xx DSP core and code generation - The components of the C2xx DSP core - Mapping external devices to the C2xx core - peripherals and Peripheral Interface - System configuration registers - Memory - Types of Physical Memory - Memory Addressing Modes - Assembly Programming using C2xx DSP - Instruction Set - Software Tools

UNIT– II

Pin Multiplexing (MUX) and General Purpose I/O Overview - Multiplexing and General Purpose I/O Control Registers - Introduction to Interrupts - Interrupt Hierarchy - Interrupt Control Registers - Initializing and Servicing Interrupts in Software.

UNIT– III

ADC Overview - Operation of the ADC in the DSP - Overview of the Event manager (EV) - Event Manage interrupts - General Purpose (GP) Timers - Compare Units - Capture Units and Quadrature Enclosed Pulse (QEP) Circuitry - General Event Manager Information

UNIT– IV

Code composer studio, Embedded Coding through MATLAB and other modern simulation tools, PWM Generation, Dead band unit, Phase shifted PWM for full bridge converters, PWM for interleaved converters.

UNIT– V

Controlled Rectifier - Switched Mode Power Converters - PWM Inverters - DC motor control – Induction, Motor Control.

Text Books:

1. Hamid.A.Toliyat and Steven G.Campbell, 'DSP Based Electromechanical Motion Control' CRC Press New York , 2004.
2. TMS320F28004x Real-Time Microcontrollers- Technical Reference Manual
3. Getting Started With C2000™ Real-Time Control Microcontrollers (MCUs)- Technical reference Manual

Reference Books:

1. Dragan Maksimovic, Luca Corradini, Paolo Mattavelli, Regan Zane 'Digital Control of High-Frequency Switched-Mode Power Converters' Wiley-IEEE Press, 2015.
2. C2000™ Microcontroller Workshop guide Manual, Texas Instruments https://softwaredl.ti.com/trainingTTO/trainingTTO_public_sw/c28x28069/C28x_Microcontroller_MDW _5-0.pdf

II-Semester	Control & Integration of Renewable Energy Systems (Elective -III)	Category PE	L-T-P 3-1-0	Credits 4

Pre-requisite: Power Electronics

Course Educational Objectives:

- To understand the fundamental concepts of electric power grids, including supply guarantee, power quality, and the impact of renewable energy penetration on grid stability and operation.
- To apply the principles and operational characteristics of both dynamic and static energy conversion technologies, such as turbines, fuel cells, photovoltaic systems, and energy storage devices, for effective grid integration.
- To analyze the challenges and control strategies for real and reactive power management in various energy conversion systems, implementing advanced controllers and modulation techniques to maintain grid stability.
- To analyze and design integrated hybrid energy conversion systems, assessing trade-offs in distributed versus centralized control, interfacing requirements, and stability and protection aspects for optimized grid-connected and islanding operations.

Course Outcomes: After the completion of the course, student will be able to

- Explain the structure and operational principles of electric grids including supply guarantees, power quality standards, and the impact of renewable energy sources on grid performance.
- Demonstrate the ability to model and apply control techniques for various dynamic and static energy conversion technologies, and integrate storage solutions to support stable and reliable grid operation.
- Critically analyze power control issues using advanced controllers and modulation techniques in diesel, PV, wind, and fuel cell based systems to maintain voltage and frequency stability under variable load and fault conditions.
- Analyze integrated hybrid energy systems for effective resource integration, determine appropriate control architectures (distributed vs centralized), and recommend solutions for load sharing, fault ride-through, and islanding to optimize grid reliability and resilience.

UNIT-I

Introduction: Electric grid introduction, Supply guarantee and power quality, Stability, Effects of renewable energy penetration into the grid, Boundaries of the actual grid configuration, Consumption models and patterns, static and dynamic energy conversion technologies, interfacing requirements.

UNIT-II

Dynamic Energy Conversion Technologies: Introduction to different conventional and nonconventional dynamic generation technologies, principle of operation and analysis of reciprocating engines, gas and micro turbines, hydro and wind based generation technologies, control and integrated operation of different dynamic energy conversion devices.

UNIT-III

Static Energy Conversion Technologies: Introduction to different conventional and nonconventional static generation technologies, principle of operation and analysis of fuel cell, photovoltaic based generators, and wind based generation technologies, different storage technologies such as batteries, fly wheels and ultra-capacitors, plug-in-hybrid vehicles, control and integrated operation of different static energy conversion devices.

UNIT-IV

Real and reactive power control: Control issues and challenges in Diesel, PV, wind and fuel cell based generators, PLL, Modulation Techniques, Dimensioning of filters, Linear and nonlinear controllers, predictive controllers and adaptive controllers, Fault-ride through Capabilities, Load frequency and Voltage Control.

UNIT-V

Integration of different Energy Conversion Technologies: Resources evaluation and needs, Dimensioning integration systems, Optimized integrated systems, Interfacing requirements, integrated Control of different resources, Distributed versus Centralized Control, Synchro Converters, Grid connected and Islanding Operations, stability and protection issues, load sharing, Cases studies

Text Books:

1. G. Masters, Renewable and Efficient Electric Power Systems, IEEE-John Wiley and Sons Ltd. Publishers, 2013, 2nd Edition.
2. A. Mahaboob Subahani, G. R. Kanagachidambaresan, M. Kathiresh, Integration of Renewable Energy Sources with Smart Grid, Willey 2021.
3. Felix A. Farret, M. Godoy Simoes, Integration of Renewable Sources of Energy, Wiley, 2017, 2nd Edition.

Reference Books:

1. Chetan Singh Solanki, Fundamentals, Technologies & Applications, Solar Photovoltaic, PHI Publishers, 2019, 3rd Edition.
2. Quing-Chang Zhong, Control of Power Inverters in Renewable Energy and Smart Grid Integration, IEEE-John Wiley and Sons Ltd. Publishers, 2013, 1st Edition.
3. Bin Wu, Yongqiang Lang, Navid Zargari, Power Conversion and Control of Wind Energy Systems, IEEE- John Wiley and Sons Ltd. Publishers, 2011, 1st Edition.
4. S. Chowdhury, S. P. Chowdhury, P. Crossley, Microgrids and Active Distribution Networks, IET Power Electronics Series, 2012.

Other Suggested Readings:

1. https://nptel.ac.in/courses/108/102/108102145/
2. https://nptel.ac.in/courses/103/103/103103206/

II-Semester	Digital Control Systems (Program Elective – III)	CATEGORY PE	L-T-P 3-1-0	CREDITS 4

Pre-Requisite: Control Systems, digital control systems.

Course Educational objectives:

- To understand the fundamental concepts of analog and digital control systems, including sampling theorem, Z-transforms, and state-space representation of discrete-time systems.
- To apply state-space methods and stability criteria like Jury's test, Lyapunov's analysis, and root locus techniques to analyze and design discrete-time control systems.
- To analyze controllability and observability properties of control systems and evaluate system stability through pole placement and state-feedback controller design.
- To analyze and design state observers and controllers using advanced techniques such as Ackermann's formula, deadbeat response controllers, and minimum-order observers for optimal system performance.

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

- Explain the advantages of digital control systems, sampling processes, and the mathematical tools like Z-transforms for system modeling.
- Utilize state-space representation and solve discrete-time state equations to model and discretize continuous systems effectively.
- Assess controllability, observability, and system stability using Routh, Jury's stability tests and state-space criteria to design appropriate control strategies.
- Design and implement state feedback controllers and observers, including deadbeat and minimum-order observers, to achieve desired system response and stability.

UNIT– 1

Introduction

Introduction to analog and digital control systems – Advantages of digital systems – Typical examples– Sample and hold devices – Sampling theorem and data reconstruction-Transfer functions and frequency domain characteristics of zero order hold and first order hold. Review of Z–transforms and Inverse Z–transforms- solving differential equations. Mapping between the S–Plane and the Z–Plane – Primary strips and Complementary Strips.

UNIT– II

State space analysis and the concepts of Controllability and observability

State Space Representation of discrete time systems – State transition matrix properties and evaluation – Solution of state equations- Discretization of continuous-time state equations – controllability and observability – concepts, conditions and tests, Principle of duality.

UNIT– III

Stability Analysis

Stability criterion – Modified Routh's stability criterion and Jury's stability test, Lyapunov's stability analysis, Root locus technique in the z–plane.

UNIT– IV

State feedback controller design

Design of state feedback controller through pole placement techniques, Necessary and sufficient conditions, Ackermann's formula, controller for deadbeat response, control system with reference input.

UNIT– V

State Observer

Necessary and sufficient condition for state observation-Full order state observer- error dynamics – design of prediction observers- Ackermann's formula-effect of the addition of observer on closed loop system-Current observer- minimum order observer observed – state feedback control system with minimum order observer -control system with reference input.

Text Book:

1. Discrete–Time Control systems – K. Ogata, Pearson Education/PHI, 2nd Edition.
2. B. C. Kuo, "Digital control systems"- Holt Saunder's International Edition, 1991.

Reference Books:

1. M. Gopal: Digital control engineering**,** New Age Int. Ltd., India, 1998.
2. K. Ogata, **"**Modern control engineering"**-** PHI, 1991.

II-semester	Battery Management Systems and Charging Stations (Program Elective – III)	Category PE	L-T-P 3-1-0	Credits 4

Pre-Requisite: Basic knowledge of electrochemistry, circuit theory, and electrical energy systems.

Course Objectives:

- To understand the fundamental types, characteristics, and chemistry of various EV batteries including lead-acid, nickel-based, sodium-based, and lithium-ion batteries.
- To apply diverse battery charging algorithms and balancing techniques to safely and efficiently manage battery pack charging under different operational conditions.
- To analyze the design and functional requirements of battery management systems, sensing and control elements, and the architecture of domestic and public EV charging infrastructure.
- To evaluate electrochemical battery models and simulation techniques to predict performance, state of charge, and optimize battery system design and operation.

Course Outcomes:

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

- Understanding of EV battery types, nominal ratings, and special characteristics relevant to electric vehicle applications.
- Apply appropriate charging algorithms and balancing strategies to improve battery life, safety, and efficiency across various battery chemistries.
- Analyze BMS components, communication protocols, and charging infrastructure configurations to design robust EV battery systems.
- Evaluate battery simulation models and diagnostic methods for enhancing EV battery performance and management strategies in practical scenarios.

Unit - I:

EV Batteries

Cells & Batteries, Nominal voltage and capacity, C rate, Energy and power, Cells connected in series, Cells connected in parallel. **Lead Acid Batteries:** Lead acid battery basics, special characteristics of lead acid batteries, battery life and maintenance, Li-ion batteries. **Nickel-based Batteries:** Nickel cadmium, Nickel metal hydride batteries. **Sodium-Based Batteries:**

Introduction, sodium sulphur batteries, sodium metal chloride (Zebra) batteries.

Lithium Batteries: Introduction, the lithium polymer battery, lithium ion battery.

Unit - II:

Battery charging strategies

Charging algorithms for a single battery: Basic terms for charging performance evaluation and characterization, CC charging for NiCd/NiMH batteries, CV charging for lead acid batteries, CC/CV charging for lead acid and Li-ion batteries, MSCC charging for lead acid, NiMH and Li-ion batteries, TSCC/CV charging for Li-ion batteries, CVCC/CV charging for Li-ion batteries, Pulse charging for lead acid, NiCd/NiMH and Li-ion batteries, Charging termination techniques, Comparisons of charging algorithms and new development; Balancing methods for battery pack charging: Battery sorting Overcharge for balancing, Passive balancing, Active balancing.

Unit -III:
Charging Infrastructure
Domestic Charging Infrastructure, Public charging Infrastructure, Normal Charging Station, Occasional Charging Station, Fast Charging Station, Battery Swapping Station, Move-and-charge zone.

Unit - IV:
Battery-Management-System Requirements
Battery-pack topology, BMS design requirements, Voltage sense, Temperature sense, Current sense, Contactor control, Isolation sense, Thermal control, Protection, Charger control, Communication via CAN bus, Log book, SOC estimation, Energy estimation, Power estimation, Diagnostics .

Unit - V:
Battery Modelling
General approach to modelling batteries, simulation model of rechargeable Li-ion battery, simulation model of a rechargeable NiCd battery, Parameterization of NiCd battery model, Simulation examples.

Text Books

1. Electric Vehicles Technology Explained by James Larminie Oxford Brookes University, Oxford, UK John Lowry Acenti Designs Ltd., Uk. (Unit-1)
2. Energy Systems for Electric and Hybrid Vehicles by K.T. Chau, IET Publications, First edition, 2016. (Unit-2)

Reference Books:

1. Modern Electric Vehicles Technology by C.C.Chan, K.T Chau, Oxford University Press Inc., New york , 2001. (Unit-3)
2. Battery Management Systems Vol. – II Equivalent Circuits and Methods, by Gregory L.Plett, Artech House publisher, First edition 2016. (Unit-4)
3. Battery Management Systems: design by Modelling by Henk Jan Bergveld, Wanda S. Kruijt, Springer Science & Business Media, 2002. (Unit-5)

II-semester	Advanced Digital Signal Processing (Program Elective – IV)	Category PE	L-T-P 3-1-0	Credits 4

Pre-requisite: Signals & Systems

Course Educational Objectives:

- To understand fundamental digital signal processing concepts, including discrete signals, transforms, and filter structures.
- To apply design techniques for FIR and IIR digital filters using various methods like bilinear transform and windowing.
- To analyze the effects of finite word length, quantization errors, and implement DSP algorithms efficiently.
- To evaluate power spectrum estimation methods and optimize DSP filter implementations for computational complexity.

Course Outcomes:

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

- Explain the principles of discrete-time signals, digital filter structures, and transform domain analysis.
- Design and implement FIR and IIR filters for given specifications using appropriate algorithms and tools.
- Analyze finite precision effects and stability issues in digital filters and DSP systems.
- Assess different spectral estimation techniques and computational trade-offs in practical DSP applications.

UNIT– 1

Digital Filter Structure: Block diagram representation-Equivalent Structures-FIR and IIR digital filter Structures All pass Filters-tunable IIR Digital Filters-IIR tapped cascaded Lattice Structures-FIR cascaded Lattice structures-Parallel-Digital Sine-cosine generator-Computational complexity of digital filter structures.

UNIT– II

Digital filter design: Preliminary considerations-Bilinear transformation method of IIR filter design-design of lowpass, high pass-band pass, and band stop- IIR digital filters-Spectral transformations of IIR filters, FIR filter design-based on windowed Fourier series- design of FIR digital filters with least –mean- square-error-constrained least-square design of FIR digital filters

UNIT– III

DSP algorithm implementation: Computation of the discrete Fourier transform- number representation-arithmetic operations handling of overflow-tunable digital filters-function approximation.

UNIT– IV

Analysis of finite Word length effects: The quantization process and errors- quantization of fixed -point and floating -point Numbers-Analysis of coefficient quantization effects, Analysis of arithmetic round-off errors, dynamic range scaling-signal- to- noise ratio in low -order IIR filters-low-sensitivity digital filters-Reduction of Product round-off errors using error feedback-Limit cycles in IIR digital filters, Round-off errors in FFT Algorithms.

UNIT– V

Power Spectrum Estimation: Estimation of spectra from finite duration observations signals – Non-parametric methods for power spectrum estimation – parametric method for power spectrum estimation, estimation of spectral form-finite duration observation of signals-non-parametric methods for power spectrum estimation-Walsh methods-Blackman & torchy method.

Text Books:

1. Digital signal processing-Sanjit K. Mitra-TMH second edition, 2002.
2. Discrete Time Signal Processing – Alan V.Oppenheim, Ronald W.Shafer - PHI-1996 1st edition-9th reprint

Reference Books:

1. Digital Signal Processing and principles, algorithms and Applications – John G.Proakis - PHI –3rd edition-2002.
2. Digital Signal Processing – S.Salivahanan, A.Vallavaraj, C. Gnanapriya – TMH - 2nd reprint-2001
3. Theory and Applications of Digital Signal Proceesing-LourensR. Rebinar&Bernold.
4. Digital Filter Analysis and Design-Auntonian-TMH.

II-Semester	Applications of Power Converters (Program Elective – IV)	Category PE	L-T-P 3-1-0	Credits 4

Pre-requisites: Analysis of Power Electronic Converters

Course Educational Objectives:

- To understand inverter applications for induction heating and power conditioning systems.
- To analyze power converters for lighting, pumping, and refrigeration systems including PV-based drivers.
- To compare and contrast high voltage and low voltage high current power supplies for specialized industrial and computing loads.
- To develop and evaluate bi-directional DC-DC converters and active power filters for automotive and power quality applications.

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

- Describe the functioning and control of power electronic inverters and converters for various industrial applications.
- Analyze and interpret the performance of power supplies and converter circuits for lighting, HVAC, X-ray and space applications.
- Design power electronic converters including bidirectional DC-DC converters and power conditioners.
- Critically analyze power quality improvement techniques including active and hybrid power filters and UPS systems in practical scenarios.

UNIT-I
Inverters for Induction Heating: For induction cooking, induction hardening, melting, and welding applications.

UNIT-II
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.

UNIT-III
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

UNIT-IV
Bi-directional DC-DC (BDC) converters: Electric traction, automotive Electronics and charge/discharge applications, Line Conditioners and Solar Charge Controllers

UNIT-V
Power Conditioners:
Uniterupted Power Supplies - Active Power Filters - Shunt active power filters - Series active power filters - Hybrid active power filters - UPQC

Text Books:

1. Ali Emadi, A. Nasiri, and S. B. Bekiarov: Uninterruptible Power Supplies and Active Filters, CRC Press, 2005.
2. M. Ehsani, Y. Gao, E. G. Sebastien and A. Emadi: Modern Electric, Hybrid Electric and Fuel Cell Vehicles, 1st Edition,CRC Press, 2004.

References Books:

1. William Ribbens: Understanding Automotive Electronics, Newnes, 2003.

II-Semester	Industrial Internet of Things (Program Elective – IV)	Category PE	L-T-P 3-1-0	Credits 4

Pre-requisites:

Course Objectives:

- To understand IoT architectures, protocols, and communication principles.
- To apply programming skills for IoT device integration using Arduino and Raspberry Pi.
- To analyze domestic and industrial appliance technologies and embedded IoT solutions.
- To evaluate cloud and edge computing approaches for IoT data management and smart applications.

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

- Explain IoT communication models and interoperability.
- Develop IoT applications with sensors and actuators integration.
- Investigate IoT-enabled devices and optimize power and control systems.
- Critically assess IoT data analytics, SDN, and AI/ML applications in IoT.
  Course Objectives:

UNIT-I

IoT Communication Technologies: Introduction to IoT, Sensing, Actuation, Basics of Networking, Communication Protocols, Sensor Networks, Machine-to-Machine Communications. Interoperability in IoT.

UNIT-II

IoT Control Technologies and Programming: Introduction to Arduino Programming, Integration of Sensors and Actuators with Arduino, Internet of Things Open-Source Systems. Introduction to Python programming, Introduction to Raspberry. Implementation of IoT with Raspberry Pi, Smart Grid Hardware Security.

UNIT-III

Domestic & Industrial Appliances (Part-1): Solid State Lamps: Introduction - Review of Light sources - white light generation techniques-Characterization of LEDs for illumination application. Power LEDs - High brightness LEDs - Electrical and optical properties. LED driver considerations-Power management topologies -color issues of white LEDs- Dimming of LED sources,

UNIT-IV

Domestic & Industrial Appliances (Part-2): BLDC motors for pumping and domestic fan appliances, inverter technology-based home appliances, Smart devices and equipment. Industrial IoT applications Factories and Assembly Line- Power Plants, Plant Safety and Security (Including AR and VR safety applications)- Oil and chemical Industry- Applications of UAVs in Industries.

UNIT-V

IoT Cloud Computation and Applications: Introduction to SDN. SDN for IoT, Data Handling and Analytics, Cloud Computing, Sensor- Cloud. Fog Computing, Smart Cities and Smart Homes, Electric Vehicles, Industrial IoT, Case Study: Agriculture, Healthcare, Activity Monitoring, Role of ML and AI in IoT.

Text Books:

1. Sudip Misra, Chandana Roy, Anandarup Mukherjee, Introduction to Industrial Internet of Things and Industry 4.0, CRC press, 2021.
2. Kostas Siozios, Dimitrios Anagnostos, Dimitrios Soudris, Elias Kosmatopoulos, IoT for Smart Grids: Design Challenges and Paradigms, Springer publishers, 2019.
3. Vinod Kumar Khanna, Fundamentals of Solid-State Lighting: LEDs, OLEDs, and Their Applications in Illumination and Displays, CRC press, 2014, 1st Edition.

Reference Books:

1. Alasdair Gilchrist, Industry 4.0: The Industrial Internet of Things, Apress Publishers, 2016.
2. Craig Di Louie, Advanced Lighting Controls: Energy Savings, Productivity, Technology and Applications, River publishers, 2006, e-book, 2021,1st Edition.
3. Chang-liang Xia, Permanent Magnet Brushless DC Motor Drives and Controls, John Wiley & Sons Singapore Pte. Ltd., 2012, 1st Edition.

Other Suggested Readings:

1. https://nptel.ac.in/courses/106105166

II-Semester	Electric Drives Simulation Laboratory (Laboratory – 3)	Category Lab	L-T-P 0-1-2	Credits 2

Pre-requisite: Power electronics & Drives

Course Educational Objectives:

- To understand and explain the modeling and control techniques of induction motors.
- To apply V/f control and vector control methods for speed control of induction motors.
- To analyze the performance of vector control and direct torque control techniques.
- To design sensorless speed estimation techniqueslike MRAS and observer-based flux estimation for high-performance drives.

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

- Describe induction motor models and control schemes in synchronous reference frames.
- Implement speed control algorithms using open loop and closed loop V/f methods.
- Analyze and simulate vector control and direct torque control for improved motor dynamics.
- Evaluate sensorless speed estimation and field weakening techniques for efficient motor drive operation.

Any 10 of the following experiments are to be conducted.

List of Experiments:

1. Modeling and Simulation of induction motor in synchronous reference frame
2. Speed control of induction motor in open loop and closed loop using V/f method
3. Indirect vector control of induction motor with rotor field-oriented scheme.
4. Direct vector control of induction motor with rotor field-oriented scheme.
5. Field weakening control for vector control of induction motor.
6. MRAS based speed estimation for vector control of induction motor.
7. Full order observer for rotor flux estimation in the vector control of induction motor.
8. Simulation of switching table based direct torque control of induction motor.
9. Simulation of modified direct torque control of induction motor with constant switching frequency
10. Simulation of space vector modulation based direct torque control of induction motor.
11. Vector control of permanent magnet synchronous motor.
12. Simulation of brushless DC motor drive using the Hall effect sensor for speed control.
13. Simulation of switched reluctance motor drive for speed control.

II-Semester	Digital Controllers and Electric Drives Laboratory (Laboratory – 4)	Category	L-T-P 0-1-2	Credits 2

Course Educational Objectives:

- To understand interfacing techniques of peripherals like ADC, DAC, LEDs, and switches with C2xx controllers.
- To apply PWM generation and control methods for motor drives using timers and modulation schemes.
- To analyze vector and direct torque control strategies for induction and synchronous motors.
- To evaluate performance of speed estimation and control methods in different motor drive systems.

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

- Explain peripheral interfacing and device communication protocols with C2xx series DSPs.
- Implement PWM and SPWM generation techniques for motor control applications.
- Analyze and troubleshoot vector control and speed control algorithms for induction and synchronous motors.
- Assess motor control performance using advanced control schemes like MRAS and direct torque control.

Any 10 of the following experiments are to be conducted.

List of experiments:

1. Interfacing of LED with C2xx Series controller
2. Interfacing of push button switch with C2xx Series controller
3. Interfacing of ADC/DAC with C2xx Series controller
4. PWM generation using basic timer with C2xx Series controller
5. Generation of SPWM pulses with soft start using C2xx Series controller
6. Speed control of induction motor in open loop and closed loop using V/f method
7. Indirect vector control of induction motor with rotor field-oriented scheme.
8. Direct vector control of induction motor with rotor field-oriented scheme.
9. Field weakening control for vector control of induction motor.
10. MRAS based speed estimation for vector control of induction motor.
11. Switching table based direct torque control of induction motor.
12. Space vector modulation based direct torque control of induction motor.
13. Vector control of permanent magnet synchronous motor.
14. Speed control of brushless DC motor drive
15. Speed control of switched reluctance motor drive.

II-Semester	Seminar-II	PC	L-T-P 0-0-2	Credits 1

III-Semester	Research Methodology and IPR	Category	L-T-P 2-0-0	Credits 2

III-Semester	**Summer Internship/ Industrial Training (8-10 weeks)**	**PC**	**L-T-P 0-0-0**	**Credits 2**

III-Semester	**Dissertation Part – A**	**PC**	**L-T-P 0-0-20**	**Credits 10**

IV-Semester	Dissertation Part – B	PC	L-T-P 0-0-32	Credits 16