ANNA UNIVERSITY

NON-AUTONOMOUS COLLEGE

AFFILIATED TO ANNA UNIVERSITY

M.E., POWER ELECTRONICS AND DRIVES

REGULATIONS 2025

PROGRAMME OUTCOMES (POs)

On successful completion of the programme, the graduate would have	
PO1	An ability to independently carry out research / investigation and development work to solve practical problems.
PO2	An ability to write and present a substantial technical report / document.
PO3	Students should be able to demonstrate a degree of mastery in power electronics and drives.

PROGRAMME SPECIFIC OUTCOMES (PSOs)

On successful completion of the PG programme, the graduate would have	
PSO 1	Apply knowledge of basic science and engineering science to analyze, design and testing of power electronic systems and drives to achieve high power density and high efficiency.
PSO 2	Design analog and digital controllers for power electronic systems and extracting maximum energy and utilization of renewable energy system.

ANNA UNIVERSITY, CHENNAI

POST GRADUATE CURRICULUM (NON.AUTONOMOUS AFFILIATED INSTITUTIONS)

Programme: M.E., Power Electronics and Drives **Regulations:** 2025

Abbreviations:

BS – Basic Science (Mathematics, Physics, Chemistry)
ES – Engineering Science (General (**G**), Programme Core (**PC**), Programme Elective (**PE**))
SD – Skill Development
SL – Self Learning
OE – Open Elective

L – Laboratory Course
T – Theory
LIT – Laboratory Integrated Theory
PW – Project Work
TCP – Total Contact Period(s)

Semester I

S. No.	Course Code	Course Title	Type	Periods per week L	T	P	TCP	Credits	Category
1.	MA25101	Applied Mathematics for Power Engineers	T	3	1	0	4	4	BS
2.	PX25101	Modelling and Analysis of Electrical Machines	LIT	2	1	2	5	4	ES (PC)
3.	PX25C01	Analysis of Power Converters	LIT	3	0	2	5	4	ES (PC)
4.	PX25102	Digital Controllers in Power Electronics Applications	LIT	3	0	2	5	4	ES (PC)
5.	PX25103	Advanced Power Semiconductor Devices	T	2	0	0	2	2	ES (PC)
6.	PX25104	Technical Seminar	-	0	0	2	2	1	SD
						Total Credits	**23**	**19**	

Semester II

S. No.	Course Code	Course Title	Type	Periods per week			TCP	Credits	Category
				L	T	P			
1.	PX25201	Modeling and Design of SMPS	LIT	2	1	2	5	4	ES (PC)
2.	PX25202	Analysis of Electrical Drives	LIT	2	1	2	5	4	ES (PC)
3.	PX25203	Computer Aided Design of Electrical Machines	LIT	3	0	2	5	4	ES (PC)
4.	--	Programme Elective I	T	3	0	0	3	3	ES (PE)
5.	--	Industry Oriented Course I	--	1	0	0	1	1	SD
6.	--	Self-Learning Courses	--	--	-	--	--	1	SD
						Total Credits	**19**	**17**	

Semester III

S. No.	Course Code	Course Title	Type	Periods per week			TCP	Credits	Category
				L	T	P			
1.	--	Programme Elective II	T	3	0	0	3	3	ES (PE)
2.	--	Programme Elective III	T	3	0	0	3	3	ES (PE)
3.	--	Programme Elective IV	T	3	0	0	3	3	ES (PE)
4.	--	Open Elective	--	3	0	0	3	3	-
5.	--	Industry Oriented Course II	--	1	0	0	1	1	SD
6.	PX25301	Project Work I	--	0	0	12	12	6	SD
7.	PX25302	Industrial Training	--	-	-	-	-	2	SD
						Total Credits	**25**	**21**	

Semester IV

S. No.	Course Code	Course Title	Type	Periods per week			TCP	Credits	Category
				L	T	P			
1.	PX25401	Project Work II	--	0	0	24	24	12	SD
						Total Credits	**24**	**12**	

Programme Elective Courses (PE)

S. No.	Course Code	Course Title	Periods Per Week			Total Contact Periods	Credits
			L	T	P		
1.	PX25C05	Wind Energy Conversion systems	3	0	0	3	3
2.	PX25001	Embedded Systems for Power Electronic Applications	3	0	0	3	3
3.	PX25002	EMI and EMC in Power Converters	3	0	0	3	3
4.	PX25003	FPGA based control for Power Electronic converters	3	0	0	3	3
5.	PX25004	Power Electronics for Renewable Energy systems	3	0	0	3	3
6.	PS25C01	Distributed Generation and Micro Grids	3	0	0	3	3
7.	PS25C02	FACTS	3	0	0	3	3
8.	PX25005	Non-Linear Control of Power Electronic Circuits	3	0	0	3	3
9.	PX25006	Non-Linear Dynamics in Power Electronic Circuits	3	0	0	3	3
10.	PX25007	Smart Grid Technologies	3	0	0	3	3
11.	PX25008	Modern Rectifiers and Resonant Converters	3	0	0	3	3
12.	PX25009	Soft Computing Techniques	3	0	0	3	3
13.	PX25010	High Power Converters	2	0	2	4	3
14.	PX25011	Grid Integration of Renewable Energy Sources	3	0	0	3	3
15.	PX25CO3	Power Quality	3	0	0	3	3
16.	PX25012	Linear System Theory	3	0	0	3	3
17.	PX25013	Special Electrical Machines	3	0	0	3	3
18.	PX25014	Advanced Power Converters	3	0	0	3	3
19.	PX25015	Advanced Battery Technology	3	0	0	3	3
20.	PX25C02	Electric Vehicles and Power Management	3	0	0	3	3
21.	PX25016	PCB Design for Power Converters and Drives	3	0	0	3	3
22.	PX25017	AI for Power Electronics	3	0	0	3	3
23.	ET25CO3	Python Programming for Machine Learning	3	0	0	3	3
24.	ET25C02	Machine Learning and Deep Learning	3	0	0	3	3
25.	ET25C01	IoT for Smart Systems	3	0	0	3	3

Semester I

MA25101	Applied Mathematics for Power Engineers	L	T	P	C
		3	1	0	4

Course Objectives:

- Use the linear algebra concepts in Electrical Engineering problems
- To familiarize the students in the field of differential equations to solve boundary value problems associated with engineering applications.
- Formulate and solve engineering problems involving random variables
- To develop the ability to using Z-transform, Fourier series and Fourier transforms.

Linear Algebra: Vector spaces, norms, Inner Products, The Cholesky decomposition, Generalized Eigen vectors, Canonical basis, QR factorization, Singular value decomposition (SVD), Pseudo inverses, least squares method.

Activities: SVD to an engineering problem.

Calculus of Variations: Concept of variation and its properties, Euler's Equation, Functionals dependent on first and higher order derivatives, Functionals dependent on functions of several independent variables, Variational problems with moving boundaries, Direct methods: Ritz and Kantorovich methods

Activities: Optimal signal trajectories, Minimizing energy in communication channel models, Antenna design optimization, Variational methods for radiation pattern shaping, Control systems in electronics, Energy functional minimization for stable system design.

One Dimensional Random Variable: Random variables, Probability function, moments, moment generating functions and their properties, Binomial, Poisson, Geometric, Uniform, Exponential, Gamma and Normal distributions, Function of a Random Variable.

Activities: Failure probability of beams/columns modelled using Binomial and Poisson distributions, Modelling vehicle arrivals at intersections using Poisson/Exponential random variables, Normal distribution applications in concrete compressive strength testing, with mean/variance modelling.

Z – Transforms: Definition, Standard Z-transforms, damping rule, Shifting rule, Initial value and Final value theorems (without proofs) and problems, Inverse Z-transform, Simple problems.

Activities: Solutions of difference equations.

Fourier Series: Fourier series: Periodic function as power signals, Convergence of series, Even and odd function: cosine and sine series, non-periodic function: Extension to other intervals, Power signals: Exponential Fourier series, Parseval's theorem and power spectrum.

Activities: Frequency spectrum and examples from engineering field.

Fourier Transforms: Infinite Fourier transforms. Fourier Sine and Cosine transforms. Inverse Fourier transforms, and simple problems. Dirac delta function –

Convolution theorem.

Activities: Heat equation, Analyzing transient heat conduction in long rods.

References:

1. Bronson, R. (2011). Matrix operation. McGraw Hill.
2. Elsgolts, L. D. (2007). Calculus of variations. Dover Publications Inc.
3. Grewal, B. S. (2018). Higher engineering mathematics. Khanna Publishers.
4. Andrews, L. C., & Phillips, R. L. (2005). Mathematical techniques for engineers and scientists. Prentice Hall.
5. Papoulis, A., & Pillai, S. U. (2019). Probability, random variables and stochastic processes. McGraw Hill.

	Description OF CO	**PO**	**PSO1**	**PSO2**
CO1	To apply the linear algebra concepts in Electrical Engineering problems	PO1(2) PO3(3)		
CO2	To familiarize the students in the field of differential equations to solve boundary value problems associated with engineering applications.	PO1(2) PO3(2)		
CO3	Able to formulate and solve engineering problems involving random variables and random process	PO1(2) PO3(2)		
CO4	To develop Z-transform techniques for discrete time systems	PO1(3) PO3(2)		
CO5	To develop the ability to solve problems using Fourier series and Fourier transforms in Engineering applications	PO1(3) PO3(3)		

<table>
<tr><td rowspan="2">PX25101</td><td rowspan="2">Modeling and Analysis of Electrical Machines</td><td>L</td><td>T</td><td>P</td><td>C</td></tr>
<tr><td>2</td><td>1</td><td>2</td><td>4</td></tr>
<tr><td colspan="6">Course Objectives:
• To provide knowledge about the fundamentals of magnetic circuits & analyze the steady state and dynamic state operation of DC machine through mathematical modeling and simulation in digital computer.
• To provide the knowledge of theory of transformation of three phase variables to two phase variables & analyze the steady state and dynamic state operation of three-phase induction machines using transformation theory based mathematical modeling
• To analyze the steady state and dynamic state operation of three-phase synchronous machines using transformation</td></tr>
<tr><td colspan="6">Principles of Electro Magnetic Energy Conversion: Magnetic circuits, permanent magnet, stored magnetic energy, co-energy, force and torque in singly and doubly excited systems, machine windings and air gap mmf, determination of winding and mechanical parameters of a machine.
Practical: Development of program for evaluating the parameters of machines in software environment</td></tr>
<tr><td colspan="6">DC Machines: Elementary DC machine and analysis of steady state operation, Voltage and torque equations, dynamic characteristics of DC motors, Time domain block diagrams, transfer function of DC motor, responses.
Practical: Simulation of mathematical model of DC Machines in software environment</td></tr>
<tr><td colspan="6">Reference Frame Theory: Historical background of Clarke and Park transformations, power invariance and phase transformation and commutator transformation, transformation of variables from stationary to arbitrary reference frame- variables observed from several frames of reference.
Practical: Simulation of mathematical model of transformation scheme in software environment</td></tr>
<tr><td colspan="6">Induction Machines: Three phase induction machine, equivalent circuit and analysis of steady state operation free acceleration characteristics, voltage and torque equations in machine variables and arbitrary reference frame variables, analysis of dynamic performance for load torque variations, Multiphase Machines: Advantages, modelling of multiphase machines, applications
Practical: Simulation of mathematical model of Induction machines in software environment.</td></tr>
<tr><td colspan="6">Synchronous Machines: Three phase synchronous machine and analysis of steady state operation- voltage and torque equations in machine variables and rotor reference frame variables (Park’s equations), analysis of dynamic performance for load torque variations
Practical: Simulation of mathematical model of synchronous machines in software environment.</td></tr>
<tr><td colspan="6">Weightage: Continuous Assessment: 50%, End Semester Examinations: 50%</td></tr>
<tr><td colspan="6">Assessment Methodology: Quiz (5%), Assignments (10%), Review of Question Papers (IES, GATE, SSC Questions) (20%), Projects (20%), Flipped Class (5%), Internal Examinations (40%).</td></tr>
</table>

References:
1. Krause, P. C., Wasyzczuk, O., & Sudhoff, S. (2010). *Analysis of electric machinery and drive systems*. John Wiley.
2. Ramanujam, R. (2018). *Modelling and analysis of electrical machines*. I.K. International Publishing Pvt. Ltd.
3. Bimbhra, P. S. (2008). *Generalized theory of electrical machines*. Khanna Publishers.
4. Fitzgerald, A. E., Kingsley, C. Jr., & Umans, S. D. (1999). *Electric machinery*. Tata McGraw Hill.

	Description of CO	**PO**	**PSO1**	**PSO2**
CO1	Ability to optimally design magnetics required in power supplies and drive systems.	PO1(3) PO3(3)	3	1
CO2	Ability to acquire and apply knowledge of mathematics of machine dynamics in Electrical engineering.	PO1(3) PO3(3)	3	1
CO3	Ability to model, simulate and analyze the dynamic performance of electrical machines using computational software.	PO1(3) PO3(3)	3	1
CO4	Ability to verify the results of the dynamic operation of electrical machine system	PO1(3) PO2(2) PO3(3)	3	1

PX25C01	Analysis of Power Converters	L	T	P	C
		3	0	2	4

Course Objectives:

- To provide a comprehensive understanding of the operation, design, and control of hard switched and soft switched power electronic converters.
- To analyse and evaluate the performance of single-phase and three-phase power converters under various load conditions.
- To enhance practical skills through laboratory experiments that reinforce theoretical concepts and provide exposure to real-world converter operation and analysis.

Single-Phase Controlled Rectifiers: Semi and fully controlled rectifiers with R, RL, and RLE loads. Freewheeling diode effects: Continuous and discontinuous conduction modes. Inversion operation; Dual converter operation. PWM rectifiers. Performance parameters: Harmonics, ripple, distortion, power factor. Effect of source inductance.

Practical: Simulation and Experimention of single-phase half and fully controlled converters. / Gate drivers and firing circuits for single phase rectifiers./ Waveform analysis under various load conditions./ Input power factor and harmonic analysis.

Three-Phase Controlled Rectifiers: Three-phase semi and fully controlled rectifiers with R, RL, RLE loads. Freewheeling diode, inversion operation, continuous/discontinuous modes. Multi-pulse (6 and 12 pulse) and dual converters. Effect of source inductance and commutation overlap. Performance parameters

Practical: Simulation and Experimentation of three-phase line-commutated converters.

DC-DC Converters: Non-isolated topologies: Buck, Boost, Buck-Boost, Cuk. Isolated topologies: Single and multiple switch converters. Operation in CCM and DCM; Synchronous and interleaved converters.

Practical: Design and testing of driver circuits for DC-DC converters (totem pole/transformer based/boot strap/opto coupler based)

DC-AC Inverters: Single-phase and three-phase VSI and CSI; 120° and 180° conduction modes. PWM techniques: Sine PWM, Space Vector PWM, 60° PWM, Third harmonic PWM. Multilevel inverters: Diode-clamped, flying capacitor, cascaded H-bridge. Voltage control methods and harmonic elimination. Filter design and device selection.

Practical: Simulation and analysis of single phase and three-phase inverters / Generation of PWM pulses with different modulation techniques/ Harmonic spectrum and THD analysis.

AC-AC Converters: AC voltage controllers: Single-phase and three-phase with R, RL loads. Phase angle control and integral cycle control. Working principle of Resonant converters: ZVS, ZCS, quasi, and multi-resonant types.

Practical: Simulation and Experimentation of AC voltage regulators / Simulation and experimentation of resonant converters

Weightage: Continuous Assessment: 50%, End Semester Examinations: 50%

Assessment Methodology: Quiz (5%), Assignments (10%), Review of Question Papers (IES, GATE, SSC Questions) (20%), Projects (20%), Flipped Class (5%), Internal Examinations (40%).
References: 1. Rashid, M. H. (2017). *Power electronics: Circuits, devices and applications* (4th ed.). Prentice Hall India. 2. Bose, B. K. (2003). *Modern power electronics and AC drives* (2nd ed.). Pearson Education. 3. Umanand, L. (2010). *Power electronics: Essentials & applications* (1st ed.). Wiley. 4. Mohan, N., Undeland, T. M., & Robbins, W. P. (2007). *Power electronics: Converters, applications and design* (3rd ed.). John Wiley and Sons. 5. Bimbhra, P. S. (2022). *Power electronics* (7th ed.). Khanna Publishers.
E-resources: 1. https://onlinecourses.nptel.ac.in/noc24_ee88/preview.

	Description of CO	PO	PSO1	PSO2
CO1	Analyze the operation and performance of single-phase and three-phase rectifiers under various load conditions.	PO1(3) PO3(3)	3	2
CO2	Design and evaluate isolated and non-isolated DC-DC converter topologies for specific applications.	PO1(2) PO3(2)	3	3
CO3	Implement PWM techniques in single and three-phase inverters and assess performance.	PO1(3) PO3(2)	3	3
CO4	Examine and compare multilevel inverters and resonant converter architectures for high-power applications.	PO1(3) PO2(2) PO3(2)	3	1
CO5	Conduct experiments and simulations to validate theoretical concepts and evaluate real-time converter behaviour.	PO1(3) PO2(2) PO3(3)	3	3

PX25102	Digital Controllers in Power Electronics Applications	L	T	P	C
		3	0	2	4

Course Objectives:

- This course offers an understanding of dsPIC 30F4011 and TMS320F28379D microcontroller architectures, programming, and peripherals for digital control applications.
- To develop skills in interfacing, signal processing, and signal conditioning.
- Practical knowledge of PWM generation techniques and the control of power electronic converters using digital controllers.

Introduction to PIC Microcontrollers: dsPIC 30F4011 microcontroller – device overview-architecture, memory organisation, pin diagrams, I/O ports, Timers, Capture/Compare/PWM modules (CCP), Serial Communication, Analog-to-digital converter module, interrupts, simple programs, Device Programming using MPLAB.
Practicals: A to D conversion and PWM generation with PICkit4 or PICkit5 and Development board.

Introduction to DSP Based Digital Controller: Introduction to the Texas Instruments C2000 microcontroller platform; Architecture of the TMS320F28379D including CPU core and Control Law Accelerator (CLA); Basic memory types – Flash and RAM; Getting started with Code Composer Studio (CCS); Basic programming concepts and GPIO overview; Introduction to interrupts and simple Interrupt Service Routines (ISRs).
Practicals: A to D conversion, voltage sensing and PWM generation using TI Launchpad and CCS.

Interfacing, Signal Processing and Signal Conditioning: ADC module configuration and sampling techniques; DAC operations and interfacing methods; PWM generation and synchronization using ePWM modules; Event Capture (eCAP) and Quadrature Encoder Pulse (eQEP) modules. Signal conditioning circuit, Signal Conditioning - Necessity, Instrumentation amplifiers, isolation amplifier, Noise problems, shielding and grounding- Filters, Dynamic compensation, Linearization, sample and hold circuits- A/D and D/A Converters.
Practicals: Verifying practically quadrature Encoder pulse module usage, Instrumentation amplifier and other signal conditioning circuit using OPAMPs.

PWM Generation Techniques using Digital Controllers: PWM generation techniques: single pulse width, multiple pulse width, and sinusoidal pulse width, Interfacing digital controller with power converters for open and closed loop control.
Practicals: Sinusoidal and space vector PWM generation using PIC Microcontroller and suitable digital signal processors.

Weightage: Continuous Assessment: 50%, End Semester Examinations: 50%

Assessment Methodology: Quiz (5%), Assignments (10%), Review of Question Papers (IES, GATE, SSC Questions) (20%), Projects (20%), Flipped Class (5%), Internal Examinations (40%).

References:
1. Milivojevic, Z., & Saponjic, D. (n.d.). *Programming dsPIC microcontrollers in C*. Mikroelektronika.
2. Toliyat, H. A., & Campbell, S. (2004). *DSP based electromechanical motion control*. CRC Press.
3. Kuo, S. M., Lee, B. H., & Tian, W. (n.d.). *Real-time digital signal processing: Implementations and applications* (2nd ed.).
4. Singh, A., & Srinivasan, S. (2004). *Digital signal processing implementation*. Thomson Press.
5. Texas Instruments. (n.d.). *C2000 real-time microcontrollers peripherals reference guide* [Technical manual].
6. Texas Instruments. (n.d.). *TMS320F2837xD dual-core real-time microcontrollers technical reference manual: LAUNCHXL-F28379D overview user's guide* [User guide].

	Description of CO	PO	PSO1	PSO2
CO1	Ability to understand dsPIC30F4011 architecture and programming, including memory, timers, communication, ADC, interrupts, and use of MPLAB.	PO1(3) PO2(1) PO3(2)	3	3
CO2	Ability to understand TMS320F28379D architecture and develop basic programs using CCS and C2000Ware.	PO1(3) PO3(2)	3	3
CO3	Configure ADC, DAC, PWM, Event Capture, and QEP modules in TMS320F28379D.	PO1(3) PO3(3)	3	3
CO4	Ability to develop signal conditioning using amplifiers, filters, and sample-and-hold circuits.	PO1(3) PO3(2)	3	3
CO5	Ability to develop PWM techniques and open and closed loop control of power converters using a digital controller.	PO1(3) PO3(2)	3	3

PX25103	Advanced Power Semiconductor Devices	L	T	P	C
		2	0	0	2

Course Objectives:

- To provide knowledge about wide bandgap devices, their characteristics and applications in DC-DC and DC-AC converters .
- To perform electrical and thermal modeling of wide bandgap devices and design EMI filters for high-frequency power converters.
- To understand general guidelines and best practices for single-layer and multilayer PCB design according to industrial standards.

Wide Band Gap Devices: Introduction to basic power devices, characteristics, advantages, and challenges in designing converters - Silicon Power MOSFETs, SiC Planar Power MOSFETs, SiC Trench-Gate Power MOSFETs, Need for GaN devices, basic GaN transistor structure, GaN vertical power HEMTs, and horizontal power HEMTs.

Activity: Assignment ; Selection of power devices for various applications.

SiC Power Device: Planer SiC Power Mosfets: Blocking characteristics, On, Resistance, Threshold voltage, Reliability- Shielded SiC Planner Power Mosfet, Device structure blocking mode, channel structure & On-Resistance- SiC Trench Power Mosfets: Blocking characteristics, On-Resistance, Threshold voltage, Reliability- Shielded Trench Power Mosfets characteristics - Introduction to silicon bipolar transistor (BJT) for achieving ultra-high voltage.

Activity: Visual Demonstration between Si and SiC device.

GaN Power Device: Pulsed static characterization: Turn-ON and Turn-OFF switching characteristics of GaN devices, hard switching loss analysis, Junction capacitance characterization, Gate drive for dynamic characterization: gate driver design, impact of gate resistance, dv/dt and di/dt immunity, etc. - protection design for double pulse test setup, Electrical and thermal modeling of GaN transistors, Cross-talk considerations, High-frequency design complexity, EMI filter design for high-frequency power converters - Heat sink design.

Activity: Quiz on Thermal design for power devices.

PCB Design: Power circuit design, driver circuit design considerations, single, layer and multilayer PCBs, separation of power and driver circuits, high-frequency power loop optimization - design examples.

Activity: schematic capture and PCB layout for buck, boost, and buck-boost DC-DC converter using industry standard EDA tools.

Applications of WBG Device : GaN in AC/DC and DC/AC power converters, GaN in switched, mode power amplifiers, wireless energy transfer, electric vehicle applications, and renewable energy applications.

Weightage: Continuous Assessment: 40%, End Semester Examinations: 60%

Assessment Methodology: Quiz (5%), Assignments (10%), Review of Question Papers (IES, GATE, SSC Questions) (20%), Projects (20%), Flipped Class (5%), Internal Examinations (40%).

References:

1. Lidow, A., Strydom, J., de Rooij, M. D., & Reusch, D. (2014). *GaN transistors for efficient power conversion*. Wiley.
2. Baliga, B. J. (2017). *Gallium nitride and silicon carbide power devices*. World Scientific Publishing Company.
3. Wang, F., Zhang, Z., & Jones, E. A. (2018). *Characterization of wide bandgap power semiconductor devices*. IET.
4. Di Polo Emilio, M. (2024). *GaN and SiC power devices*. Springer.
5. Hu, R. (2019). *PCB design and layout fundamentals for EMC*. Independently Published.

E-resources: https://nptel.ac.in/courses/108106480

	Description of CO	PO	PSO1	PSO2
CO1	Explain the fundamentals and applications of wide-bandgap semiconductor devices.	PO1(1) PO2(1)	3	2
CO2	Analyze the electrical characteristics of wide bandgap devices and design suitable driver circuits.	PO1(2) PO3(2)	3	2
CO3	Perform electrical and thermal modeling of wide bandgap devices and design effective EMI filters for high-frequency power converters.	PO1(3) PO3(1)	3	2
CO4	Apply best practices and industry standards in designing single-layer and multilayer PCBs.	PO1(2) PO2(1) PO3(2)	2	2
CO5	Design and evaluate DC-DC and DC-AC converters utilizing wide bandgap devices for real-time applications.	PO1(2) PO2(2) PO3(1)	3	3

PX25201	MODELLING AND DESIGN OF SMPS	L	T	P	C
		3	0	2	4

Course Objectives:

- To perform steady state analysis of isolated & Non-Isolated DC-DC converter.
- To understand and design controller for different converter
- To design magnetic core for SMPS applications.

DESIGN OF CONVERTER CIRCUITS

Revision of Buck, Boost, Buck-boost and Cuk converters - Discontinuous conduction mode – Derivation of current ripple and voltage ripple formulae based on volt-sec balance and charge balance concepts - Design of critical inductance – Selection of capacitors

Practicals: Simulation & Experimental verification of Buck, Boost, Buch-Boost & Cuk Converter

ANALYSIS OF ISOLATED DC-DC CONVERTERS

Introduction - classification- forward- flyback- pushpull- halfbridge- fullbridge topologies- design of SMPS

Practicals: Simulation & Experimental verification of forward- flyback- pushpull- half-bridge topology**.**

MODELING CONTROL OF SMPS CONVERTERS

AC equivalent circuit analysis – State space averaging – Circuit averaging – Averaged switch modeling – Transfer function model for buck, boost, buck-boost and cuk converters – Input filters, Controller Design - Review of P, PI, and PID control concepts – gain margin and phase margin – Bode plot based analysis – Design of controller for buck, boost, buck-boost and cuk converters.

Practicals: Transfer function model of Buck, Boost, Buch-Boost converter, Design of controller for Buck, Boost, Buch-Boost in software environment, Transfer function model of Buck, Boost, Buch-Boost converter.

DESIGN OF MAGNETICS

Basic magnetic theory revision – Inductor design – Design of mutual inductance – Design of transformer for isolated topologies – Ferrite core table and selection of area product – wire table – selection of wire gauge – Amorphous core for filter application.

Practicals: Design of core for isolated topology and verify using software environment.

Weightage:	Continuous Assessment: 60%	End Semester Theory

	I. Activities: 15% II. Internal Theory Examinations: 30% III. Internal Laboratory Examinations: 15%	Examination: 40%

Mandated Activities with marks:

Assignments (30), Quiz (10), Virtual demonstration (25), Flipped Classroom (10),

Internal Examinations: TWO tests

References:

1. Robert W. Erickson & Dragon Maksimovic, " Fundamentals of Power Electronics", Second 2. Edition, 2001 Springer science and Business media
2. John G. Kassakian, Martin F. Schlecht, George C. Verghese, "Principles of Power Electronics",
3. Pearson, India, New Delhi, 2010. Philip T Krein, " Elements of Power Electronics", Oxford University Press, 2017.
4. Ned Mohan, "Power Electronics: A first course", John Wiley,2012.
5. Issa Batarseh, Ahmad Harb, "Power Electronics- Circuit Analysis and Design, Second edition.

	CO Description	PO1	PO2	PO3	PO4	PO5	PO6
CO1	Ability to understand the operation and design of non-isolated DC-DC converters.	2	2	1	3	2	1
CO2	Ability to understand the operation and design of isolated DC-DC converters.	.2	2	1	2	3	2
CO3	Ability to derive transfer function of different converters.	2	2	1	2	3	2
CO4	Ability to design controllers for DC DC converters.	3	2	1	3	2	1
CO5	Ability to design magnetics core for SMPS applications	2	2	2	2	3	2

PX25202	ANALYSIS OF ELECTRICAL DRIVES	L	T	P	C
		2	1	2	4

Course Objective:

This course aims to provide an in-depth understanding of the modeling, control, and dynamic analysis of electrical drives used in industrial and high-performance applications. Students will explore the behavior of DC, induction, and permanent magnet machines under various control strategies and operating conditions. Emphasis is placed on analytical methods, simulation tools, and real-time control concepts to design efficient and robust drive systems for modern engineering challenges.

Electric Drives & System Components

Dynamics of electric drives: steady-state and transient behaviour- Components of an electric drive system: converter, motor, controller, and load - Load torque characteristics and drive system stability

DC Drives – Analysis and Control

Modeling of DC motors (separately excited, series, and shunt)-Closed-loop control: armature voltage and field current control-Chopper-fed DC drives- Dynamic response and transfer function approach – Applications.

Practicals: Modeling and Simulations of DC Drives.

Induction Motor Drives

Modeling of three-phase induction motors (IM) in d-q reference frame- Scalar control (V/f control), vector control, and direct torque control (DTC)- Inverter-fed IM drives: PWM techniques- Dynamic performance under load disturbances and transients – Applications.

Practicals: Modeling and Simulations of Induction Motor Drives.

Synchronous Motor Drives

Modeling of three-phase Synchronous Motors in d-q reference frame, vector control, and direct torque control (DTC), Dynamic performance under load disturbances and transients – Applications.

Practicals: Modeling and Simulations of Synchronous Motor Drives.

Permanent Magnet Motor Drives

Dynamic modeling of permanent magnet synchronous motors (PMSM), Control strategies: open-loop, vector control, field-oriented control (FOC)-Brushless DC motor drives (BLDC): d-q modeling and commutation control –

Practicals: Modeling and Simulations of Permanent Magnet Motor Drives.

Weightage:	Continuous Assessment: 40%	

	(i). Activities: 10% (ii). Internal Theory Examinations: 30% (iii).Internal Laboratory Examinations:15%	End Semester Theory Examination: 40%
Assessment Weightage:		
Internal Examinations: TWO tests		

References:

1. “Electric Motor Drives: Modeling, Analysis, and Control”, Author: R. Krishnan, Publisher: Pearson Education, Published Year: 2001
2. **“Vector Control of AC Drives”, Author:** Ion Boldea & S.A. Nasar, **Publisher:** CRC Press, **Published Year: 1992**
3. **"Analysis of Electric Machinery and Drive Systems" Authors:** Paul C. Krause, Oleg Wasynczuk, Scott D. Sudhoff, **Publisher:** Wiley-IEEE Press, **Published Year:** 2013 (3rd Edition)
4. **"Power Electronics and Motor Drives: Advances and Trends", Editor:** Bimal K. Bose, **Publisher:** Academic Press (Elsevier), **Published Year:** 2006

	CO Description	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
CO1	**Analyze** the dynamic behavior of electric drive systems under various loading and operating conditions	1	3	2	3	3	2
CO2	Design and implement control strategies to achieve optimal performance of electrical drives.	3	2	1	3	3	2
CO3	Evaluate and compare drive system performance based on suitability for specific applications	1	3	2	3	2	3
CO4	Develop research capability to innovate for next-generation electric drive systems	2	2	1	1	1	2

PX25203	COMPUTER AIDED DESIGN OF ELECTRICAL MACHINES	L	T	P	C
		3	0	2	4

Course Objective:

The Computer-Aided Design (CAD) of Electrical Machines course aims to equip M.Tech students with advanced knowledge and practical skills in utilizing computational tools for the design, analysis, and optimization of various electrical machines. Students will learn to apply finite element analysis (FEA) and other numerical methods to model electromagnetic, thermal, and mechanical aspects, enabling them to predict machine performance accurately. The ultimate objective is for students to independently design and optimize electrical machines for specific applications, considering efficiency, cost, and material utilization.

Introduction to CAD for Electrical Machines and Numerical Methods

Introduction to Computer-Aided Design, Overview of Electrical Machine Design Principles, Introduction to Numerical Methods in Electrical Engineering, Software Tools for CAD in Electrical Machines

Electromagnetic Field Analysis using FEA

Governing Equations of Electromagnetism: Maxwell's equations in differential and integral forms, vector potential formulation for magnetic fields, scalar potential for electric fields; **Application of FEM to Magnetostatics:** Formulation for 2D and 3D problems, sources (currents, permanent magnets), materials (linear and non-linear, isotropic and anisotropic); **Application of FEM to Magnetodynamics:** Time-harmonic and transient analysis, eddy currents, skin effect, motion modeling (rotor movement, sliding mesh); **Post-processing of FEA Results:** Flux density plots, magnetic field lines, inductance calculation, force calculation (Maxwell stress tensor, virtual work method), core losses; **Case Studies**

Thermal and Mechanical Analysis in Electrical Machines

Heat Transfer Mechanisms in Electrical Machines: Conduction, convection, radiation. Sources of heat (core losses, copper losses, mechanical losses);

Thermal Modeling using FEA: Governing equations for heat transfer, boundary conditions (convective heat transfer coefficients), steady-state and transient thermal analysis;

Coupled Field Analysis (Electro-Thermal): Iterative approaches for considering temperature-dependent material properties; **Mechanical Aspects and Stress Analysis:** Vibrations, noise, structural integrity, stress and strain analysis using FEA (introduction to structural mechanics); **Multiphysics Coupling:** Introduction to methods for coupling electromagnetic, thermal, and mechanical simulations for a comprehensive machine analysis; **Case Studies**

Design Optimization and Performance Prediction

Optimization Techniques in Electrical Machine Design: Single-objective and multi-objective optimization, classical optimization methods (gradient-based), evolutionary algorithms (Genetic Algorithms, Particle Swarm Optimization); **Surrogate Modeling and Response Surface Methodology:** Creating approximate models for computationally expensive simulations; **Design of Experiments (DOE):** Planning simulations to efficiently explore the design space; **Performance Prediction from CAD Models:** Efficiency mapping, torque-speed characteristics, power factor, thermal limits, demagnetization analysis of PMs, etc.; **Parametric Design and Sensitivity Analysis:** Analyzing the impact of design variables on performance; **Case Studies**

Advanced Topics and Emerging Trends

Artificial Intelligence and Machine Learning in Electrical Machine Design, Materials for Electrical Machines, Design for Manufacturing and Assembly (DFMA), Reliability and Fault Diagnosis, Emerging Machine Topologies and Applications

Weightage:	Continuous Assessment: 60% (i). Activities: 15% (ii). Internal Theory Examinations: 30% (iii). Internal Laboratory Examinations: 15%	End Semester Theory Examination: 40%

Mandated Activities with marks: Assignments (30), Quiz (10), Virtual demonstration (25), Flipped Classroom (10),

Internal Examinations: TWO tests

1. **Salon, S. J.**,Finite Element Analysis of Electrical Machines,Publisher: Kluwer Academic Publishers (now part of Springer Science+Business Media), Year: 1995
2. **Silvester, P. P., & Ferrari, R. L.,** Finite Elements for Electrical Engineers, Publisher: Cambridge University Press, Year: 1996 (3rd Edition, first edition 1983)
3. **Hameyer, K., & Hanitsch, R.,** Electrical Machine Design using FEA, Publisher: Wiley-VCH (for "Electrical Machine Design using FEA") / WIT Press (for "Numerical Modelling and Design of Electrical Machines and Devices"), Year: 2000.
4. **Bianchi, N.,** Electrical Machine Analysis using Finite Elements, Publisher: CRC Press / Taylor & Francis Group, Year: 2005.

	CO Description	**PO 1**	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
CO1	Understand the principles of CAD for electrical machines and the role of numerical methods.	1	1	3		1	2
CO2	Apply the Finite Element Method to formulate and solve magnetostatic and magneto dynamic problems in electrical machines.	2	2	3		2	3
CO3	Model and simulate the thermal behavior of electrical machines using FEA,	1	1	2		3	2

	CO Description	PO 1	PO2	PO3	PO4	PO5	PO6
	considering various heat transfer mechanisms.						
CO4	Employ optimization techniques to improve the performance metrics (e.g., efficiency, torque density) of electrical machine designs.	2	2	3		3	1
CO5	Evaluate the potential and challenges of applying Artificial Intelligence and Machine Learning techniques in electrical machine design.	3	1	2		3	1

PROGRAM ELECTIVE COURSES (PEC)

PX25C05	WIND ENERGY CONVERSION SYSTEMS	L	T	P	C
		3	0	0	3

Course Objectives:

- To introduce the various electrical generators and appropriate power electronic controllers employed in wind energy systems.
- To teach the students the steady-state analysis and operation of different existing configurations of electrical systems in wind energy and also the recent developments taking place in this field

Wind turbine system:

Wind statics - Wind energy – energy in the wind – forces developed by blades - turbine power characteristics – classification of wind turbine generator systems - aerodynamics - rotor types –- Aerodynamic models – parts of wind turbines - braking systems – tower - control and monitoring system - design considerations power curve - power speed characteristics – Large scale integration and power quality issues.

Grid Connected Induction Generators (GCIGs):

Principle of operation – steady-state analysis-characteristics of GCIGs- Need for single-phase operation –typical configurations for the single-phase operation of three-phase GCIGs - operation of single-phase and three-phase GCIGs with different power electronic configurations.

Self-Excited Induction Generators (SEIGs) :

Process of self-excitation – steady-state equivalent circuit of SEIG and its analysis - performance equations - widening the operating speed-range of SEIGs by changing the stator winding connection with suitable solid state switching schemes - power electronic controllers used in standalone systems.

Doubly-Fed Induction Generators (DFIGs):

Different operating modes- steady-state equivalent circuit- performance analysis- DFIG for standalone applications- operation of DFIGs with different power electronic configurations for standalone and grid-connected operation.

Permanent Magnet Synchronous Generators (PMSGs):

Operation of PMSGs- steady-state analysis- performance characteristics- operation of PMSGs with different power electronic configurations for standalone and grid-connected operation.

Weightage:	Continuous Assessment: 40%	End Semester Theory Examination: 60%
	(iv). Activities: 10% (v). Internal Theory Examinations: 30%	

Mandated Activities with marks: Assignments (30), Quiz (10), Virtual demonstration (25), Flipped Classroom (10),
Internal Examinations: TWO tests
References: 1. Ion Boldea, 'The Electric Generators Handbook- Variable Speed Generators', CRC Press, 2010. 2. M. Godoy Simoes and Felix A. Farret, 'Alternative Energy Systems: Design and Analysis with Induction Generators', CRC Press, 2nd Edition, 2008. 3. *Marcelo Godoy Simões and Felix A. Farret, '**Renewable Energy Systems: Design and Analysis with Induction Generators**', CRC Press, ISBN 0849320313, 2004.* 4. *S.N. Bhadra, D.Kastha and S.Banerje, **'Wind Electrical Systems'**, Oxford University Press,* 2005. 5. Bin Wu, Yongqiang Lang, Navid Zargari, Samir Kouro, 'Power Conversion and Control of Wind Energy Systems', IEEE Press Series on Power Engineering, John Wiley & Sons, 2011.

	CO Description	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
CO1	Attain knowledge on the basic concepts of Wind energy conversion system.	1		2	2		2
CO2	Analyze the electrical characteristics of various wind-driven electrical generators	.3	1	2	2	2	2
CO3	Identify and design suitable power electronic converters for wind energy conversion system	3	1	3	3	2	3
CO4	Study about the need of Variable speed system and its modelling.	3	2	3	3	2	3
CO5	Learn about Grid integration issues and current practices of wind interconnections with power system.	3	2	3	2	2	3

PX25001	EMBEDDED SYSTEMS FOR POWER ELECTRONIC APPLICATIONS	L	T	P	C
		3	0	0	3

Course Objective:

To enable the learner to understand the concepts of embedded controllers with its application to power electronics

Introduction:

Embedded system design – Definition – development life cycle – typical architectures – ISA architectural models – architectural design – memory units - memory organization -data operation-bus configurations. System on-chip, scalable bus architectures.

Data Acquisition:

Sensor and Actuator, I/O – ADC, DAC, timers, DMA, Servos, Relays, stepper motors, H-Bridge, CODECs, FPGA, ASIC, diagnostic port.

Real-time Operating systems:

Real time operating systems (RTOS) – real time kernel – OS tasks – task states – task scheduling – interrupt processing – clocking communication and synchronization – control blocks – memory requirements and control – kernel services.

Embedded Networks:

Embedded Networks – Distributed Embedded Architecture – Hardware and Software Architectures, Networks for embedded systems– I2C, CAN Bus, Ethernet, Internet, Network based design– Communication Analysis, system performance Analysis, Hardware platform design, Allocation and scheduling.

Real-time control applications:

Sensors and Special ICs – Voltage Sensor, Current Sensor, Speed Sensor, RMS calculation IC, Battery Management IC, Opto-couplers and Current amplification transistors. PWM pulse generation - Open loop and closed control of power converters and inverters.

Weightage:	Continuous Assessment: 40%	End Semester Theory Examination: 60%
	(i). Activities: 10% (ii). Internal Theory Examinations: 30%	

Mandated Activities with marks:

Assignments (30), Quiz (10), Virtual demonstration (25), Flipped Classroom (10),

References:

1. Wayne Wolf, ‘Computers as Components: Principles of Embedded Computing System Design’, Morgan Kaufman Publishers,3rd Edition, 2012.
2. C. M. Krishna, Kang G. Shin ,‘Real time systems’, McGrawHill,2010.

3. Herma K., Real Time Systems: Design for Distributed Embedded Applications, Kluwer Academic, 2ndEdition, 2011.

4. Nazzareno Rossetti, “Managing Power Electronics: VLSI and DSP-driven Computing systems:, WileyInterscience Publications, 2006.

	CO Description	PO1	PO2	PO3	PO4	PO5	PO6
CO1	Understand the basics of the embedded systems.	2	2	2	1	3	1
CO2	Identify the suitable peripherals for a particular application	2	2	2	1	2	2
CO3	Understand the requirements of the real time OS and embedded networks	2	2	1	1	1	1
CO4	Apply the concepts of embedded control for power applications.	2	1	3	2	2	1

PX25002	EMI and EMC in POWER CONVERTERS	L	T	P	C
		3	0	0	3

Course Objectives:

- To understand the concept of EMI, EMC problems & Grounding & cabling issues and measurement techniques.
- To Design a filtering, shielding of cables and learn testing techniques.

INTRODUCTION

Definitions of EMI/EMC -Sources of EMI- Inter systems and Intra system- Conducted and radiated interference- Characteristics - Designing for electromagnetic compatibility (EMC)- EMC regulationtypical noise path- EMI predictions and modelling, Methods of eliminating interferences and noise mitigation

GROUNDING AND CABLING

Cabling- types of cables, mechanism of EMI emission / coupling in cables –capacitive coupling, inductive coupling- shielding to prevent magnetic radiation- shield transfer impedance, Grounding – safety grounds – signal grounds- single point and multipoint ground systems -hybrid grounds- functional ground layout –grounding of cable shields- -guard shields- isolation, neutralizing transformers, shield grounding at high frequencies, digital grounding- Earth measurement Methods.

BALANCING, FILTERING AND SHIELDING

Power supply decoupling- decoupling filters-amplifier filtering –high frequency filtering- EMI filters characteristics of LPF, HPF, BPF, BEF and power line filter design -Choice of capacitors, inductors, transformers and resistors, EMC design components -shielding – near and far fields shielding effectiveness- absorption and reflection loss- magnetic materials as a shield, shield discontinuities, slots and holes, seams and joints, conductive gaskets-windows and coatings - grounding of shields.

EMI TESTING METHODOLOGY

LISN, Test setup for conducted emission and standards-Bi-conical Antenna, Log periodic Antenna, Test set-up for radiated emission and standards, Test setup for conducted susceptibility standards, Test setup for radiated susceptibility and standards, EFT standard: IEC61000**.**

ELECTROSTATIC DISCHARGE, STANDARDS AND TESTING TECHNIQUES

Static Generation- human body model- static discharges- ESD versus EMC, ESD protection in equipment- standards - FCC requirements – EMI measurements – Open area test site measurements and precautions- Radiated and conducted interference measurements, Control requirements and testing.

Weightage:	Continuous Assessment: 40%	End Semester Theory Examination: 60%
	Activities: 10% Internal Theory Examinations: 30%	

Mandated Activities with marks:

Assignments (30), Quiz (10), Virtual demonstration (25), Flipped Classroom (10),

Internal Examinations: TWO tests

References:

1. V.P. Kodali, "Engineering Electromagnetic Compatibility", S. Chand, 1996.
2. Henry W.Ott, " Noise reduction techniques in electronic systems", John Wiley & Sons, 1989.
3. Bernhard Keiser, "Principles of Electro-magnetic Compatibility", Artech House, Inc. (685 canton street, Norwood, MA 020062 USA) 1987.
4. Bridges, J.E Milleta J. and Ricketts.L.W., "EMP Radiation and Protective techniques", John Wiley and sons, USA 1976.
5. William Duff G., & Donald White R. J, "Series on Electromagnetic Interference and Compatibility",
6. Weston David A., "Electromagnetic Compatibility, Principles and Applications", 1991.

	CO Description	PO1	PO2	PO3	PO4	PO5	PO6
CO1	Ability to understand the types and sources of EMI.	3	2	2	1	1	2
CO2	Ability to understand the needs of grounding and cabling.	3	2	2	3	2	2
CO3	Ability to understand the design concept of filtering and shielding.	3	2	2	2	1	3
CO4	Ability to study the effect of EMI in elements and circuits.	3	2	2	2	2	2
CO5	Ability to know about the effects of electrostatic discharge and testing techniques.	3	2	2	3	2	3

PX25003	FPGA BASED CONTROL FOR POWER ELECTRONIC CONVERTERS	L	T	P	C
		3	0	0	3

Course Objective:

To enable the learner to understand the concepts of FPGA with its application to power electronics

FPGA

Introduction to Field Programmable Gate Arrays – CPLD Vs FPGA, Development and evolution of digital devices - design and verification tools, Abstraction levels of digital system design - Configurable logic Blocks (CLB), Input/Output Block (IOB) – programmable Interconnect Point (PIP) – Xilinx 4000 series -overview of Spartan and Virtex FPGA boards. Significance of FPGA in Power Electronics.

Verilog HDL

Introduction to Verilog HDL and simulation using Xilinx Webpack - Modeling styles: Behavioral, Dataflow, and Structural Modeling, gate delays, switch-level Modeling, Hierarchal structural modeling.

Verilog Programming for Logic Circuits

Verilog HDL program for combinational logic circuits – Adder/subtractor – Multiplexers – Demultiplexers – Encoders – Priority Encoder - Decoders – Comparators, generating triggering pulses for power converters. Verilog HDL program for sequential logic circuits - Flip-Flops, Shift Registers, Counters, Clock divider circuit – Generation of multi-phase clock - Finite State Machine Modelling.

Interfacing Peripherals with FPGA Board

Fixed point implementation using Verilog HDL (P, PI, PID, etc.) – Modelling phase locked loop using Verilog HDL. Interface ADC and DAC blocks with FPGA – closed loop control of power converters.

FPGA Applications to Power Electronic System

Gate Pulse generation for AC-AC converter, AC-DC converter, PWM generation for Buck Converter, SPWM generation. DC motor control, Induction Motor Control.

Course Outcomes: upon completion of the course, the students will be able to:

1. Understand the basics of the FPGA.
2. Appraise the use of Verilog HDL for the logic circuit design
3. Understand the requirements of the peripherals in FPGA boards.
4. Apply the concepts of FPGA control for power applications.

Weightage:	Continuous Assessment: 40%	**End Semester Theory Examination: 60%**
	(i). Activities: 10% (ii). Internal Theory Examinations: 30%	

Mandated Activities with marks: Assignments (30), Quiz (10), Virtual demonstration (25), Flipped Classroom (10),
Internal Examinations: TWO tests

References:

1. Samir Palnitkar, “Verilog HDL: A Guide to Digital Design and Synthesis” Pearson, Second Edition, 2009.
2. Wayne Wolf, “FPGA-Based System Design”, Prentice Hall India Pvt. Ltd., 2005.
3. Ming-Bo Lin., Digital System Designs and Practices Using Verilog HDL and FPGAs. Wiley, 2008.
4. Woods, R., McAllister, J., Yi, Y. and Lightbody, G. FPGA-based implementation of signal processing systems. John Wiley & Sons, 2017.
5. M. H. Rashid, “Power Electronics: Circuits, Devices and Applications. Pearson 3rd edition, 2013.

	CO Description	PO1	PO2	PO3	PO4	PO5	PO6
CO1	Understand the basics of the FPGA.	2	2	1	1	2	2
CO2	Appraise the use of Verilog HDL for the logic circuit design	2	1	2	2	1	2
CO3	Understand the requirements of the peripherals in FPGA boards.	2	2	1	2	2	2
CO4	Apply the concepts of FPGA control for power applications	2	2	1	2	2	2

PX25004	POWER ELECTRONICS FOR RENEWABLE ENERGY SYSTEMS	L	T	P	C
		3	0	0	3

Course Objectives:

- To provide knowledge about different types of renewable energy systems.
- To analyze the various electrical Generators used for the Wind Energy Conversion Systems.
- To design a power converter used in renewable energy systems such as AC-DC, DC-DC, and AC-AC converters.
- To understand the importance of standalone, grid-connected, and hybrid operation in renewable energy systems.
- To analyse various maximum power point tracking algorithms.

Introduction to Renewable Energy Systems

World energy sources – Potential of renewable energy in India's future power generation – Advantages and disadvantages of conventional and non-conventional dynamic generation technologies – Need for power electronics in renewable energy-based power generation – Islanding mode and grid-connected mode operations. IEEE & IEC standards for renewable energy grid integrations.

Wind Energy Conversion Systems

Wind energy conversion – Wind turbine characteristics – Principle of operation and analysis of Squirrel Cage Induction Generator (SCIG) and Doubly Fed Induction Generator (DFIG) – Permanent Magnet Synchronous Generator (PMSG) – Three-phase AC voltage Controllers – AC-DC-AC converters: uncontrolled rectifiers, PWM inverters, Grid-interactive inverters – Matrix converter – Stand-alone operation of fixed and variable speed WECS – Grid-integrated SCIG and PMSG-based WECS.

Photovoltaic Power Conversion Systems

Photovoltaic (PV) systems – Solar PV modeling and characteristics – Maximum Power Point Tracking (MPPT): algorithms and MPP tracking under shading conditions – Grid requirements for PV systems – Power electronic converters used in solar PV – Line-commutated converters (in inversion mode) – Boost and buck-boost converters – Control techniques – Battery charging in PV systems.

Fuel Cell and Energy Storage Systems

Principle of operation of fuel cells – Classifications – Modeling and characteristics – Power electronic converters for fuel cells – Hydrogen production – Storage technologies: batteries, flywheels, supercapacitors, and ultracapacitors – Selection of inverter, battery sizing, and array sizing.

Hybrid Renewable Energy Systems

Need for Hybrid Systems – Range and types of hybrid systems – Case studies of Diesel-PV, Wind-PV, Microhydel-PV, Biomass-Diesel, and Fuel Cell-PV-Battery systems.

<table>
<tr><td rowspan="2">Weightage:</td><td>Continuous Assessment: 40%</td><td rowspan="2">End Semester Theory Examination: 60%</td></tr>
<tr><td>i. Activities: 10%
ii. Internal Theory Examinations: 30%</td></tr>
<tr><td colspan="3">Mandated Activities with marks:Assignments (30), Quiz (10), Virtual demonstration (25), Flipped Classroom (10),</td></tr>
<tr><td colspan="3">Internal Examinations: TWO tests</td></tr>
<tr><td colspan="3">References:
1. G. Masters, Renewable and Efficient Electric Power Systems, IEEE-John Wiley and Sons Ltd. Publishers, 2nd Edition, 2013.
2. Rai. G.D, “Non-conventional energy sources”, Khanna Publishers, 2010.
3. Rashid, M. H, “Power Electronics Handbook, Academic press, 2nd Edition, 2006.
4. Gray, L. Johnson, “Wind energy system”, Prentice Hall of India, 1995.
5. B.H. Khan “Non-conventional Energy sources”, Tata McGraw-Hill Publishing Company, New Delhi, 2017</td></tr>
</table>

	CO Description	PO1	PO2	PO3	PO4	PO5	PO6
CO1	Analyze the environmental impacts of renewable energy technologies and demonstrate their application in harnessing electrical power	2		1	1	1	2
CO2	Select suitable electrical machines for Wind Energy Conversion Systems.	3	2	3		2	3
CO3	Design power converters such as AC-DC, DC-DC, and AC-AC converters for wind energy systems.	3	2	3	3	2	3
CO4	Design power converters such as DC-DC and DC-AC converters for solar energy and fuel cell systems.	3	2	3	1	3	3
CO5	Interpret stand-alone, grid-connected, and hybrid renewable energy systems with Maximum Power Point Tracking (MPPT).	3	2	3	1	3	3

PS25C01	DISTRIBUTED GENERATION AND MICRO-GRIDS	L	T	P	C
		3	0	0	3

Course Objectives:

- To understand the planning and operational issues related to Distributed Generation
- To understand various configurations of Micro-grids
- To analyse the various operating conditions of Micro-grids with and without DGs

INTRODUCTION

Need for Distributed generation, renewable sources in distributed generation, current scenario in Distributed Generation, Planning of DGs – Siting and sizing of DGs – optimal placement of DG sources in distribution systems, Load Flow for Distribution Systems with and without DGs.

DISTRIBUTED ENERGY SOURCES

Grid integration of DGs – Different types of interfaces - Inverter based DGs and rotating machine based interfaces - Aggregation of multiple DG units. Energy storage elements: Batteries, ultra-capacitors, flywheels. Technical impacts of DGs – Transmission systems, Distribution systems

DG PLANNING & PROTECTION

De-regulation – Impact of DGs upon protective relaying – Impact of DGs upon transient and dynamic stability of existing distribution systems. Transients in micro-grids - Protection of micro-grids – Reliability of DG based systems – Steady-state and Dynamic analysis**.**

MICRO GRIDS

Introduction to micro-grids – Types of micro-grids – autonomous and non-autonomous grids. Sizing of micro-grids- modelling & analysis- Micro-grids with multiple DGs – Micro- grids with power electronic interfacing units.

CONTROL TECHNIQUES

Case studies - Economic and control aspects of DGs –Market facts, issues and challenges - Limitations of DGs. Voltage control techniques, Reactive power control, Harmonics, Power quality issues.

Weightage:	Continuous Assessment: 40%	End Semester Theory Examination: 60%
	(iv). Activities: 10% (v). Internal Theory Examinations: 30%	

Mandated Activities with marks:

Assignments (30), Quiz (10), Virtual demonstration (25), Flipped Classroom (10),

Internal Examinations: TWO tests

References:

1. H. Lee Willis, Walter G. Scott ,'Distributed Power Generation – Planning and Evaluation', Marcel Decker Press, 2000.
2. M.GodoySimoes, Felix A.Farret, 'Renewable Energy Systems – Design and Analysis with Induction Generators', CRC press.
3. Robert Lasseter, Paolo Piagi, ' Micro-grid: A Conceptual Solution', PESC 2004, June 2004.

4. F. Katiraei, M.R. Iravani, 'Transients of a Micro-Grid System with Multiple Distributed Energy Resources', International Conference on Power Systems Transients (IPST'05) in Montreal, Canada on June 19-23, 2005.
5. Z. Ye, R. Walling, N. Miller, P. Du, K. Nelson 'Facility Microgrids', Subcontract report, May 2005,

	CO Description	PO1	PO2	PO3	PO4	PO5	PO6
CO1	Understand the current scenario and need for the implementation of DGs.	1			1		
CO2	Investigate the types of interfaces and control schemes for the grid integration of DGs	1	1	1	2	1	1
CO3	Evaluate the technical and economic impacts of DGs	1	2	2	1	2	
CO4	Understand different configurations of micro-grid and its modelling.	1	1	2	2	1	1

PS25C02	FACTS	L	T	P	C
		3	0	0	3

Course Objectives:

- To Understand the concepts of Flexible Power Transmission & describe the principles of shunt & series reactive power compensation to enhance the power flows in conventional power systems.
- To understand the capability of Combined Compensators with reference to exchange of active and reactive power with the power system network.

INRODUCTION
Fundamentals of ac power transmission, Load Compensation, Steady-State and Dynamic Reactive Power Control in Electric Transmission and Distribution Systems, FACTS Concept and Basic Types of FACTS Devices. Relative Importance of Controllable Parameters.

SHUNT COMPENSATOR

Principles of Static shunt Compensation and Control. Variable Impedance type & switching types VAR Generation, Static VAR Compensator (SVC) and STATCOM, Comparison between STATCOM and SVC: V-I and V-Q Characteristic, Transient Stability, Capability to exchange real power and Response.

SERIES COMPENSATOR

Principles of Static Series Compensation and Control. Variable Impedance type & switching types of VAR Generation: GCSC, TCSC and TSSC – applications – Static Synchronous Series Compensator (SSSC). V-I and V-Q Characteristic, Transient Stability, Capability to exchange real power.

COMPENSATION

Angle Compensation: Static Voltage and Phase angle Regulators: Objective of Voltage and phase angle regulators, Approaches to Thyristor-controlled voltage and phase angle regulators, switching converter-based voltage and phase angle regulators, Hybrid phase angleregulators.

UPFC
Unified power flow controller (UPFC): Principles of operation and characteristics - independent active and reactive power flow control - comparison of UPFC with the controlled series compensators and phase shifters. Introduction to Interline power flow controller (IPFC) .

Weightage:	Continuous Assessment: 40% I. Activities: 10% II. Internal Theory Examinations: 30%	End Semester Theory Examination: 60%

Mandated Activities with marks: Assignments (30), Quiz (10), Virtual demonstration (25), Flipped Classroom (10),

Internal Examinations: TWO tests

References:

1. P. Kundur, “Power System Stability and Control”, McGraw-Hill, 2006.
2. K.R.Padiyar, “HVDC Power Transmission Systems”, New Age International (P)Ltd., NewDelhi, 2002.

3. Mohan Mathur, R., Rajiv. K. Varma, "Thyristor – Based Facts Controllers for Electrical Transmission Systems", IEEE press and John Wiley& Sons, Inc.
4. K.R.Padiyar," FACTS Controllers in Power Transmission and Distribution", New Age International(P) Ltd., Publishers, New Delhi, Reprint 2008.
5. J.Arrillaga, , "High Voltage Direct Current Transmission", Peter Pregrinus, London, 1983
6. Erich Uhlmann, " Power Transmission by Direct Current", BS Publications,2004.
7. V.K.Sood, HVDC and FACTS controllers – Applications of Static Converters in Power System, APRIL 2004 , Kluwer Academic Publishers.
8. A.T.John, "Flexible AC Transmission System", Institution of Electrical and Electronic Engineers (IEEE), 1999.
9. NarainG.Hingorani, Laszio. Gyugyl, "Understanding FACTS Concepts and Technology of Flexible AC Transmission System", Standard Publishers, Delhi 2001

	CO Description	PO1	PO2	PO3	PO4	PO5	PO6
CO1	Analyze the problems in AC transmission systems and understand the need for Flexible AC transmission systems	1		3	2		3
CO2	Analyze the operation and control of SVC and its applications to enhance the stability and damping.	3	1	3	2	2	3
CO3	Analyze the different modes of operation TCSC and to model it for power flow and stability studies.	3	1	3	3	2	3
CO4	Analyze basic operation and control of voltage source converter based FACTS controllers.	3	2	3	3	2	3
CO5	Analyze the interaction between the FACTS controllers	3	2	3	2	2	3

PX25005	NONLINEAR CONTROL OF POWER ELECTRONIC CIRCUITS	L	T	P	C
		3	0	0	3

Course Objectives:

- To understand the design and implementation of sliding mode controller for power electronic circuits
- To the design and implementation of model predictive control for power electronic circuits
- To introduce the concept of adaptive control techniques for power electronic circuits

BASICS OF NONLINEAR DYNAMICS

Introduction to nonlinear systems – nonlinear system analysis- Analysis using perturbation theory, phase plane trajectories, and Describing functions- stability and convergence- Lyapunov direct and indirect methods-limit cycles.

SLIDING MODE CONTROL

Variable Structure Systems, Concept of Sliding Surface, Reachability Conditions, Switching control action, Design of sliding mode controllers using feedback linearization for non-linear dynamic systems - Sliding mode motion on switching surface - Design of stable switching surfaces for nonlinear systems - discrete-time sliding mode control. Chattering phenomena in sliding mode control

SLIDING MODE CONTROL FOR POWER ELECTRONIC CIRCUITS

DC-DC converter modelling-sliding mode controller design for buck, boost, and buck-boost converters-sliding mode implementation of PID controller-stability analysis-chattering reduction. Sliding mode control for single phase inverters.

MODEL PREDICTIVE CONTROL FOR POWER ELECTRONIC CIRCUITS

Introduction to Model predictive control, problem formulation, optimization in MPC, Constraints handling in MPC - Formulation, design and implementation of MPC for Buck, Boost and Buck-Boost converters, introduction to implementation of MPC using microcontroller, DSP and FPGA

ADAPTIVE CONTROL OF POWER ELECTRONIC CIRCUITS

Model Reference Adaptive Control (MRAC) and Self- Tuning Regulators (STR), direct and indirect approaches. Development of MRAC adaptive control algorithms for the control of buck, boost and buck-boost power converters.

Weightage:	Continuous Assessment: 40%	End Semester Theory Examination: 60%
	(i). Activities: 10% (ii). Internal Theory Examinations: 30%	

Mandated Activities with marks: Assignments (30), Quiz (10), Virtual demonstration (25), Flipped Classroom (10),
Internal Examinations: TWO tests
References: 1. Hassan. K. Khalil, Nonlinear systems, Prentice Hall Inc., 2002 2. Azaykumar Mehta, Brijesh Naik, Sliding mode controllers for power converters, springer, 2019 3, Shankar Sastry, Marc Bodson, Adaptive Control- Stability, Convergence and Robustness, Prentice Hall Inc., 2011. 4, Marian P. Kazmierkowski, R Krishnan and Frede Blaabjerg, Control in Power Electronics, Academic Press, 20023.

	CO Description	PO1	PO2	PO3	PO4	PO5	PO6
CO1	Ability to. understand, model and analyse the nonlinear systems	**3**	**3**	**2**		**2**	**1**
CO2	Ability to understand, model and simulate sliding mode controllers for power converters.	3	3	2		2	2
CO3	Ability to understand, model and simulate model predictive controllers for power converters.	.3	1	2		2	2
CO4	Ability to understand, model and simulate adaptive controllers for power converters.	3	2	2		2	1

PX25006	NONLINEAR DYNAMICS FOR POWER ELECTRONIC CIRCUITS	L	T	P	C
		3	0	0	3

Course Objectives:

- To understand and investigate the non-linear behaviour of power electronic converters
- To analyse the nonlinear phenomena in DC-to-DC converter & AC and DC Drives.
- To introduce the control techniques for control of nonlinear behaviour in power electronic Systems.

BASICS OF NONLINEAR DYNAMICS

Basics of Nonlinear Dynamics: System, state, and state space model, Vector field- Modeling of Linear, nonlinear and Linearized systems, Attractors , chaos, Poincare map, Dynamics of Discrete time system, Lyapunov Exponent, Bifurcations, Bifurcations of smooth map, Bifurcations in piece wise smooth maps, border crossing and border collision bifurcation.

TECHNIQUES FOR INVESTIGATION OF NONLINEAR PHENOMENA

Techniques for experimental investigation, Techniques for numerical investigation, Computation of averages under chaos, Computations of spectral peaks, Computation of the bifurcation and analyzing stability.

NONLINEAR PHENOMENA IN DC-DC CONVERTERS

Border collision in the Current Mode controlled Boost Converter, Bifurcation and chaos in the Voltage controlled Buck Converter with latch, Bifurcation and chaos in the Voltage controlled Buck Converter without latch, Bifurcation and chaos in Cuk Converter. Nonlinear phenomenon in the inverter under tolerance band control.

NONLINEAR PHENOMENA IN DRIVES

Nonlinear Phenomenon in Current controlled and voltage-controlled DC Drives, Nonlinear

Phenomenon in PMSM Drives.

CONTROL OF CHAOS

Hysteresis control, Sliding mode and switching surface control, OGY Method, Pyragas method, Time Delay control. Application of the techniques to the Power electronics circuit and drives.

Weightage:	Continuous Assessment: 40% (iii). Activities: 10% (iv). Internal Theory Examinations: 30%	End Semester Theory Examination: 60%

Mandated Activities with marks: Assignments (30), Quiz (10), Virtual demonstration (25), Flipped Classroom (10),
Internal Examinations: TWO tests
References: 1. George C. Vargheese, July 2001 Wiley – IEEE Press S Banerjee, Nonlinear Phenomenon Power Electronics, IEEE Press 2. Steven H Strogatz, Nonlinear Dynamics and Chaos, Westview Press 3. C.K.TSE Complex Behaviour of Switching Power Converters, CRC Press,2003 4. Alfredo Medio, Marji Lines, "Non Linear Dynamics: A primer", Cambridge University Press, 2003.

	CO Description	PO1	PO2	PO3	PO4	PO5	PO6
CO1	Ability to understand, model and simulate chaotic behavior in power electronic systems.	3	1	2	2	1	3
CO2	Ability to investigate the various techniques of non linear phenomena	.1	2		3	3	
CO3	Ability to analyse the nonlinear phenomena in DC-DC converter	3		1	3	1	
CO4	Ability to analyse the nonlinear phenomena in Drives	3		1	1	3	
CO5	Ability to mitigate chaotic behavior noticed in power system.	3		1	1	2	

PX25007	Smart Grid Technologies	L	T	P	C
		3	0	0	3

Course Objective:

This course equips students with core concepts and evolving technologies in smart grids, integrating power systems, renewable energy, communication, and control. It aims to prepare postgraduates for modern grid challenges through the application of intelligent control, secure communication, and sustainable practices. The course builds skills aligned with current industrial demands and research frontiers in energy systems.

Smart Grid Fundamentals and Architecture

Evolution to Smart Grid, Characteristics and Smart Grid Architectures: Transmission, Distribution, and Consumer Interfaces, Functional Elements: Smart Meters, AMI, Smart Substations, Microgrid Concept: Grid-Connected & Islanded Mode, Benefits and Challenges of Smart Grid Adoption, Smart Grid Maturity Model

Communication Technologies and Cybersecurity in Smart Grids

Communication Requirements for Real-time Control in Power Electronics Systems, Smart Grid Communication Technologies: PLC, ZigBee, 6LoWPAN, 5G, Protocols Relevant to Converter and Drive Systems: IEC 61850, Modbus, DNP3, IoT in PED Devices for Condition Monitoring and Remote Control, SCADA Integration with Power Converters and Drives, Cybersecurity Threats for Converter-Controlled Grids, Blockchain for Secure Energy Transactions

Advanced Metering and Demand Side Control with Drives

AMI Architecture and Real-time Data Acquisition from power electronic drive systems, Bi-directional Metering in systems with Smart Converters, Net Metering and Drive-based Load Control, Demand Response: Smart Load Control with Drives (Direct/Indirect), Demand Side Management using Power Electronic based Controllers in Industrial Loads, Time-of-Use Pricing, Load Curtailment, and Response Optimization, Standards: OpenADR, IEEE 2030.5

Electric Vehicles and Smart Charging Infrastructure

Overview of EV Drives and Powertrain Topologies, PE-based Charging Infrastructure: AC, DC, Bidirectional, Wireless, Vehicle-to-Grid (V2G), Grid-to-Vehicle (G2V), and V2H Interfacing, Role of Bidirectional Converters in Energy Exchange, Charging Control Strategies, Standards: IEC 61851, ISO 15118, Impact on Grid Stability and Power Quality

Smart Charger Design and Integration with EMS

Smart Grid Policies, Standards, and Future Trends National Smart Grid Mission (NSGM), MoP, CEA, BIS, CERC Frameworks, International Standards: IEEE 1547, IEEE 2030, IEC TC 57, NIST, Smart Cities, Financing Models for PE-based Smart Grid Projects, Emerging Trends: Digital Twin for Converter Systems, AI & IoT (AIoT) in Power Electronics Monitoring, Edge Computing in Drives, Quantum Communication and Blockchain Integration, Simulation Tools: MATLAB/Simulink, OPAL-RT, PSCAD, OpenDSS, Typhoon HIL,Case Studies: India's PED-enabled Smart Grid Pilots		
Weightage:	Total Internal Assessment: 40 I. Activity :10 II. Internal Assessment: 30	End Semester Theory Examination: 60
Mandated Activities with marks: Assignments (30), Quiz (10), Virtual demonstration (25), Flipped Classroom (10),		
Internal Examinations: TWO tests		

References

1. James Momoh, *Smart Grid: Fundamentals of Design and Analysis*, Wiley-IEEE Press, 2012.
2. Janaka Ekanayake, Nick Jenkins, Kithsiri Liyanage, J.B. Wu, Akihiko Yokoyama, *Smart Grid: Technology and Applications*, Wiley, 2012.
3. Ali Keyhani, *Design of Smart Power Grid Renewable Energy Systems*, 3rd Edition, Springer, 2022.
4. Ekram Hossain, Zhu Han, H. Vincent Poor, *Smart Grid Communication and Networking*, Cambridge University Press, 2012.
5. O. A. Mohammed (Ed.), *Cyber-Physical Systems for Smart Grids*, Springer, 2018.
6. Stuart Borlase, *Smart Grids: Infrastructure, Technology and Solutions*, CRC Press, 2017.
7. S. K. Salman, *Electric Power Grid Modernization using Smart Grid Technologies,* Wiley-IEEE Press, 2022.
8. IEEE PES, *Smart Grid Handbook*, Wiley-IEEE Press, 2016.
9. Rodrigo Garcia-Valle & João A. Peças Lopes, *Electric Vehicle Integration into Modern Power Networks*, Springer, 2013.
10. Fei Tao & Ang Liu, *Digital Twin Driven Smart Design*, Elsevier, 2020.

E-resources:

1. NPTEL Course on Smart Grid – IIT Kharagpur: https://nptel.ac.in/courses/108105101
2. IEEE Xplore Digital Library – Journals, Conference Papers, and Standards https://ieeexplore.ieee.org
3. U.S. Department of Energy – Smart Grid Portal https://www.smartgrid.gov
4. International Energy Agency (IEA) – Smart Grid Section https://www.iea.org/topics/smart-grids

5. Open Energy Information (OpenEI) – Data & Case Studies
   https://openei.org
6. National Smart Grid Mission (NSGM)
   https://www.nsgm.gov.in
7. Indian Smart Grid Forum (ISGF)
   https://www.indiasmartgrid.org
8. OpenDSS Simulation Tool: https://sourceforge.net/projects/electricdss
9. GridLAB-D Simulation Platform: https://www.gridlabd.org
10. Typhoon HIL Microgrid & Inverter Testing Resources: https://www.typhoon-hil.com

	CO Description	PO1	PO 2	PO3	PO4	PO5	PO6
CO1	Understand the components, architecture, and operation of smart grids and microgrids.	1			1		
CO2	Understanding of Smart Grid Policies, Standards, and Future Trends	1	2		1	1	1
CO3	**Illustrate** the communication technologies, protocols, and cybersecurity measures used in smart grid systems.	1	2		1	2	
CO4	**Apply** demand side management and advanced metering infrastructure techniques for efficient energy usage.	1			1	1	2
CO5	**Demonstrate** the working of EV integration, smart charging infrastructure, and analyze future trends and standards.	1	2	2	1		2

PX25008	Modern Rectifiers and Resonant Converters	L	T	P	C
		3	0	0	3

Course Objectives:

- To impart knowledge on the design of pulse width modulated rectifiers and its supply current control strategies.
- To introduce the concept of resonant converters and focuses on the dynamic analysis of DC-DC converters.
- To introduce the control techniques applied for DC-DC converter.

PWM Rectifiers

ulse width modulation rectifiers – Properties of ideal rectifiers – Realization of near ideal rectifiers – CCM and DCM boost converter – Losses and efficiency in CCM high quality rectifiers – Device selection for rectifiers.

Source Current Shaping of Rectifiers

Need for current shaping – power factor – input current shaping methods – passive shaping methods – active methods – boost rectifier employing peak current control – average current control – Hysteresis control – Nonlinear carrier control – Sensor less current control.

Quasi Resonant DC-DC Converters

Introduction to Soft Switching – Difference between hard switched and soft switched converters – classification of resonant converters – Basics of ZVS and ZCS – operation and analysis of ZVS buck and boost converter – operation and analysis of ZCS buck and boost converter – Design of ZVS/ZCS (buck/boost) converters.

Class-D Resonant Converters

Introduction – Basic operation of Class-D series resonant converter- parallel resonant converter – series-parallel resonant converter – CLL resonant converter – LLC resonant converter.

Dynamic Analysis of Switching Converters

State Space Averaging – Steps involved in State Space Average Model – State Space Averaged model for an ideal Buck Converter, ideal Boost Converter, ideal Buck-Boost Converter – Pulse Width modulation – Voltage Mode PWM-Scheme – Current Mode PWM Scheme.

Weightage:	Continuous Assessment: 40%	End Semester Theory Examination: 60%
	(i). Activities: 10% (ii). Internal Theory Examinations: 30%	

Mandated Activities with marks:

Assignments (30), Quiz (10), Virtual demonstration (25), Flipped Classroom (10),

Internal Examinations: TWO tests

Text Books:

- Robert W. Erickson and Dragon Maksimovic, 'Fundamentals of Power Electronics', Second Edition, Springer science and Business media, 2001. 2. Marian.K. Kazimierczuk and Dariusz Czarkowski, 'Resonant Power Converters', John Wiley & Sons limited, 2011.

References:

- Simon Ang and Alejandro Oliva, 'Power Switching Converters', Taylor & Francis Group, 2010.
- John G. Kassakian, Martin F. Schlecht, George C. Verghese, 'Principles of Power Electronics', Pearson, India, New Delhi, 2010.
- Issa Batarseh, Ahmad Harb, 'Power Electronics – Circuit Analysis and Design', Second edition, 2018.
- Keng C.Wu, 'Switch Mode Power Converters – Design and Analysis', Elsevier academic press, 2006.
- Mohan, Undeland and Robins, 'Power Electronics – Concepts, Applications and Design', Wiley, 2007.

	CO Description	PO1	PO2	PO3	PO4	PO5	PO6
CO1	Illustrate the concept of pulse-width modulated rectifier and its characteristics.	3	3	3	3		1
CO2	Analyse the various source current shaping methods for AC-DC PFC rectifiers.	3	3	3	3		1
CO3	Demonstrate the concept of quasi-resonant DC-DC converters.	3	3	3	3		1
CO4	Explain the concept of Class-D resonant power converters.	3	3	3	3	3	1
CO5	Analyse the state -space average modelling of DC-DC converters and control Methods.	3	3	3	3	3	1

PX25009	Soft Computing Techniques	L	T	P	C
		3	0	0	3

Course Objective:

The objective of this course is to provide students with a comprehensive understanding of soft computing methodologies such as fuzzy logic, artificial neural networks, genetic algorithms, and hybrid systems. The course aims to equip students with the theoretical knowledge and practical skills needed to model, analyze, and solve complex real-world problems in power electronics, control systems, and engineering applications using intelligent computing techniques.

Introduction to Soft Computing

Concept and characteristics of Soft Computing, Differences between Soft and Hard Computing, Components: Fuzzy Logic, Evolutionary Computation, Genetic Algorithms, Swarm Intelligence, Neural Networks; Machine Learning, Introduction to Deep Learning, applications of soft computing techniques

Fuzzy Logic Systems

Fuzzy Sets and operations, Membership Functions, Linguistic Variables, Fuzzy Rule Base, Inference Mechanisms, Fuzzification and Defuzzification techniques, Fuzzy Controllers in Engineering Systems

Artificial Neural Networks (ANN)

Biological Neuron and artificial neuron Model and ANN Architectures: Single layer, multilayer, feedforward, feedback, Learning rules: Hebbian, Perceptron, Delta, Backpropagation, Training and testing of neural networks, ANN Applications

Genetic Algorithms (GA) and Evolutionary Techniques

GA Terminology, Population, Fitness Function, Selection, Crossover, Mutation Techniques, Convergence and elitism, Applications in Optimization and Scheduling, Other Evolutionary Algorithms: DE, PSO basics

Hybrid Soft Computing Systems and Case Studies

Neuro-Fuzzy Systems, GA-ANN Integration, Hybrid Models and Optimization in Engineering Design, MATLAB/Simulink-based Implementation, Case studies: Fuzzy logic for speed control of DC motor, ANN for classification of load patterns, GA for tuning PI controllers in converter circuits

Weightage:	Continuous Assessment: 40%	End Semester Theory Examination: 60
	i. Activities: 10% ii. Internal Theory Examinations: 30%	

Mandated Activities with marks: Assignments (30), Quiz (10), Virtual demonstration (25), Flipped Classroom (10),
Internal Examinations: TWO tests
References 1. J.-S.R. Jang, C.-T. Sun, E. Mizutani, *Neuro-Fuzzy and Soft Computing*, Pearson Education, 2019. 2. Simon Haykin, *Neural Networks and Learning Machines*, 3rd Edition, Pearson Education, 2009. 3. Timothy J. Ross, *Fuzzy Logic with Engineering Applications*, 4th Edition, Wiley, 2020. 4. David E. Goldberg, *Genetic Algorithms in Search, Optimization and Machine Learning*, Addison-Wesley, 1989. 5. S. N. Sivanandam, S. N. Deepa, *Principles of Soft Computing*, 3rd Edition, Wiley India, 2018. 6. *Soft Computing with MATLAB Programming* by **N. P. Padhy and S. P. Simon**, Oxford University Press, 2019. 7. **S. Rajasekaran, G. A. Vijayalakshmi Pai**, *Neural Networks, Fuzzy Logic and Genetic Algorithms: Synthesis and Applications*, PHI Learning, 2017.
E- Resources: 1. NPTEL Course: Soft Computing by Prof. D.K. Pratihar (IIT Kharagpur) 2. NPTEL: Artificial Neural Networks by Prof. S. Sengupta (IIT Kharagpur) 3. Coursera: Neural Networks and Deep Learning by Andrew Ng 4. MIT OpenCourseWare – Artificial Intelligence

	CO Description	PO1	PO2	PO3	PO4	PO5	PO6
CO1	Understand and explain the fundamental concepts of soft computing and its components.		2	1			
CO2	Design and implement fuzzy logic systems for intelligent control and decision-making.	.	2	1			
CO3	Develop neural network models for solving real-world problems.		1				
CO4	Apply genetic algorithms and other evolutionary approaches for optimization in engineering problems.	3	2		2		
CO5	Understand how different soft computing techniques can work together and simulate basic models using MATLAB/Simulink.		1		1	1	3

PX25010	HIGH POWER CONVERTERS	L	T	P	C
		2	0	2	3

Course Objectives:

To provide an in-depth understanding of various multilevel inverter (MLI) topologies, their modulation strategies, and practical applications in advanced power electronic systems.

Review of two-level inverters

Review of Power circuits and working principle of: single-phase square-wave inverter, single-phase PWM inverter and three-phase PWM inverter. Review of the principle of sine-triangle PWM for single-phase and three-phase two-level inverters. Review of concepts of blocking voltage and conduction current ratings of power switches in inverter, dv/dt stress, harmonic profile, total harmonic distortion (THD) and filtering components

Practical: Simulation/Experimental study of CHBMLI for a given application

Cascaded H-Bridge Multilevel Inverter (CHBMLI)

Working of a three-level H-bridge cell; realization of five-level inverter by cascading two H-bridge cells; advantages of multilevel inverters (MLIs) in terms of topological features (e.g. reduced blocking voltage) and waveform (e.g. reduced dv/dt stress); limitations of MLIs; advantages and limitations of CHBMLI; level-shifted and phase-shifted sine-triangle PWM for CHBMLI; selective harmonic elimination technique for CHBMLI; typical applications of CHBMLI.

Practical: Simulation/Experimental study of diode-clamped MLI for a given application

Neutral Point Clamped MLIs

Power circuit and working principle of diode clamped MLI; level-shifted sine-triangle PWM and space-vector PWM for diode clamped MLIs; advantages and limitations of diode clamped MLIs; power circuit and working principle of active neutral point clamped (ANPC) MLI; advantages and limitations of ANPC MLI; typical applications of neutral point clamped MLIs.

Practical: Simulation/Experimental study of ANPC MLI for a given application

Flying Capacitors based MLI

Power circuit and working principle of flying capacitors based MLI; study of redundant states, various mechanisms for voltage balancing of flying capacitors, level-shifted sine-triangle PWM and space-vector PWM for diode clamped multilevel inverters; advantages and limitations of diode clamped MLIs; power circuit and working principle of active neutral point clamped (ANPC) MLI; advantages and limitations of ANPC MLI; typical applications of neutral point clamped MLIs.

Practical: Simulation/Experimental study of flying capacitors based MLI for a given application

Advanced MLIs

Power circuits and working principle of Modular Multilevel Converter (MMC), T-Type inverter, Packed U Cell (PUC) MLI and Nested Neutral Point Converter (NNPC); Basic principle of working of Switched Capacitors based MLIs (SCMLIs), advantages and limitations of SCMLIs; Typical applications of non-conventional MLIs

Practical: Simulation/Experimental study of advanced MLIs for a given application (e.g. MMC for HVDC, T-type MLI for high power EV drive-train, PUC for PV application, NNPC for EV charging, SCMLI for fuel cell based power generation etc.)		
Weightage:	Continuous Assessment: 60% i. Activities: 15% ii. Internal Theory Examinations: 30% iii. Internal Laboratory Examinations: 15%	End Semester Theory Examination: 40%

Mandated Activities with marks:

Assignments (30), Quiz (10), Virtual demonstration (25), Flipped Classroom (10), mini project (25).

Internal Examinations: TWO tests

References:

1. Multilevel Inverters" by Krishna Kumar Gupta and Pallavee Bhatnagar, Academic Press (Elsevier), ISBN 9780128124482 (2017)

2.“Modular Multilevel Converters” by Sixing Du, Apparao Dekka, Bin Wu and Navid Zargari, Wiley-IEEE Press, ISBN 1119366305 (2018)

3.“High Power Converters and AC Drives” by Bin Wu and Mehdi Narimani, Wiley-IEEE Press, ISBN 1119156033 (2017)

4. Ersan Kabalcı, Multilevel Inverters Introduction and Emergent Topologies, Academic Press, 2021.

5. Iftekhar Maswood, Dehghani Tafti, Advanced Multilevel Converters and Applications in Grid Integration, Wiley, 2018.

6. S. Ganesh Kumar, Marco Rivera Abarca, S. K. Patnaik, Power Converters, Drives and Controls for Sustainable Operations, Wiley, 2023.

E-resources:

(1) Baker, R.H.,; “Switching circuit,” U.S.Patent 4210826,1980. “Modular Multilevel Converters” by Sixing Du, Apparao Dekka, Bin Wu and Navid Zargari, Wiley-IEEE Press, ISBN 1119366305 (2018)
(2) Nabae, A.; Takahashi, I.; Akagi, H.;, “A neutral-point-clamped PWM inverter,” in Conf. Rec. IEEE IAS Annual Meeting, Cincinnati, OH, vol. 3, pp. 761–766,Sep. 28–Oct. 3, 1980.
(3) Meynard, T.A.; Foch, H.; "Multi-level Conversion: High Voltage Choppers and Voltage-source Inverters," Proceedings of the IEEE Power Electronics Specialist Conference, pages 397-403, 1992.
(4) Lavieville, J.P.; Carrere, P.; Meynard, T.;, “Electronic circuit for converting electrical energy and a power supply installation making use thereof,” U.S. Patent 5 668 711,1997.
(5) K. K. Gupta, A. Ranjan, P. Bhatnagar, L. K. Sahu and S. Jain, "Multilevel Inverter Topologies With Reduced Device Count: A Review," in IEEE Transactions on Power Electronics, vol. 31, no. 1, pp. 135-151, Jan. 2016.

(6) V. Dargahi, K. A. Corzine, J. H. Enslin, A. K. Sadigh, J. Rodriguez and F. Blaabjerg, "Logic-Equations Method for Active Voltage-Control of a Flying-Capacitor Multilevel Converter Topology," IECON 2018 - 44th Annual Conference of the IEEE Industrial Electronics Society, Washington, DC, USA, 2018, pp. 1291-1298,
(7) Hinago, Y.; Koizumi, H.;, "A Single-Phase Multilevel Inverter Using Switched Series/Parallel DC Voltage Sources," Industrial Electronics, IEEE Transactions on , vol.57, no.8, pp.2643-2650, Aug. 2010.

	CO Description	PO1	PO2	PO 3	PO4	PO5	PO6
CO1	Analyze and compare the performance characteristics of conventional two-level and multilevel inverter topologies.	3	3	3	3	3	2
CO2	Employ appropriate modulation technique(s) for a given multilevel inverter.	3	3	3	3	3	2
CO3	Evaluate application-specific merits and limitations of various topologies of multilevel power inverters	3	3	3	3	3	22
CO4	Investigate recent advancements/patents/industry applications in MLI technology and effectively communicate the findings through technical reports and/or presentations.	3	3	3	3	3	2

PX25011	GRID INTEGRATION OF RENEWABLE ENERGY SOURCES	L	T	P	C
		3	0	0	3

Course Objectives:

- To study about the integration of various renewable energy sources into the grid.
- To analyse various grid issues due to renewable energy sources & the dynamics of network due to wind farm
- To provide knowledge about power system stabilizers, grid connected and standalone PV system

NTRODUCTION

Introduction to Renewable Energy (RE) based grid integration - Concept of mini/micro/nano grids and Smart grids - Different types of grid interfaces - Issues related to grid integration of small and large scale of synchronous generator based - induction generator based and converter-based sources together - Influence of WECS on system transient response.

NETWORK INFLUENCE OF GENERATION TYPE

Interconnection standards and grid code requirements for grid integration – starting – Network voltage management – Thermal/Active Power management – Network power quality management – Transient system performance – Fault level issues –Low Voltage Fault Ride Through (LVRT) – Protection – Study of Blackouts and Brownouts – Causes, effects and mitigation.

GRID INTEGRATION OF WIND POWER

Introduction-Electric Grid- Embedded Generation- Functional Requirements of Wind Power Plant (WPP) in Electric Grid- Types of WPP and Wind Farm Grid Connections - Interface Issues - Operational Issues: Power System Stability, Frequency Control, Short Term Balancing, Long Term Balancing, Transmission and Distribution System Impacts, Economic Dispatch and Unit Commitment – Sitting WPPs for Effective Grid Integration - Grid Integration issues in India – Challenges for Grid Integration – Wind Power Integration Standards – Super Grid Strategy.

GRID- CONNECTED SPV SYSTEM

Introduction- Configurations-Components of Grid-connected SPV system– Grid-connected PV System Design: Small Power Applications and Power Plants–Safety in installation of SPV system– Installation and troubleshooting of SPV power plants - International PV programs.

GRID CODE COMPLIANCE AND GRID INTEGRATION STANDARDS

IEC TS 63102-2021: Compliance assessment methods – Operating area – Control performance – Fault ride through – Power Quality – IEEE standards: IEEE 2800-2022, IEEE 1547-2018- CEA standards: technical standards for connectivity to grid, Distributed Energy Resources- RE Policies and Regulations in India.

Weightage:	Continuous Assessment: 40%	End Semester Theory Examination: 60%
	i. Activities: 10% ii. Internal Theory Examinations: 30%	

Mandated Activities with marks: Assignments (30), Quiz (10), Virtual demonstration (25), Flipped Classroom (10),
Internal Examinations: TWO tests
References: 1. Joshua Earnest, "Wind power technology", II Edition, PHI, 2015. 2. Brenden Fox, Damian Flynn and Leslie Bryans, "Wind Power Integration Connection and system operational aspects", The Institute of Engineering and Technology, London, United Kingdom, 2007. 3. Chetan Singh Solanki, "Solar Photovoltaic Technology and Systems" – A Manual for Technicians, Trainees and Engineers, PHI, 2014. 4. Stuart R.Wenham, Martin A. Green, Muriel E. Watt and Richard Corkish, "Applied Photovoltaics", Earthscan, UK, 2007. 5. Heier, Siegfried, "Grid Integration of Wind Energy Conversion Systems", Germany, Wiley, 2006. 6. Joshua Earnest, Tore Wizelius, "Wind Power Plants and Project Development", Second Edition, PHI learning, 2017. 7. IEC TS 63102:2021 Grid code assessment methods for grid connection of wind and PV power plants 8. CEA technical standards for connectivity to the grid 9. CEA technical standards for connectivity of the distributed generation resources 10. IEEE Std 2800-2022 IEEE standard for interconnection and interoperability of inverterbased resources (IBRS) interconnecting with associated transmission electric power systems 11. IEEE Std 1547-2018 IEEE standard for interconnection and interoperability of distributed energy resources with associated electric power systems interface.

	CO Description	PO1	PO2	PO3	PO4	PO5	PO6
CO1	Know about the integration of various renewable energy sources into the grid.	3	1	2	1	2	2
CO2	Able to analyze various grid issues due to renewable energy sources.	3	1	2	1	2	2
CO3	Able to analyze the dynamics of network due to windfarm	3	1	2	1	2	2
CO4	Know about power system stabilizers.	3	1	2	1	2	2
CO5	Able to design the grid connected and standalone PV system.	3	1	2	1	2	2

PX25C03	POWER QUALITY	L	T	P	C
		3	0	0	3

Course Objective:

- Understand the various power quality phenomenon, their origin, impact and monitoring methods.
- Equip the necessary skills to handle power quality problems.

Electric power quality phenomena: Introduction to power quality, IEEE and IEC - EMC standards, overview, sources and impact of power quality disturbances – RMS voltage variations, interruptions, voltage fluctuation, transients, waveform distortion and power frequency variations.

Harmonics: Harmonic sources, measurement of harmonic distortion, current and voltage limits of distortion, harmonic analysis using Fourier transform, effects of harmonic distortion and harmonic filters

Power definitions: Instantaneous power and other power definitions for single-phase system under sinusoidal and non-sinusoidal conditions, three-phase balanced and unbalanced systems under sinusoidal and non-sinusoidal conditions

Power Quality Monitoring: importance and introduction to power quality monitoring, overview of power quality disturbance classification, signal processing of disturbances, power quality indices estimation and case studies.

Custom Power Devices: Introduction to shunt and series compensators, DSTATCOM, Dynamic Voltage Restorer (DVR) and Unified Power Quality Conditioner (UPQC) – case studies.

Weightage	Continuous Assessment: 40%	End Semester Theory Examination: 60%
	(i). Activities: 10% (II) Internal Theory Examinations: 30%	

Mandated Activities with marks:

Assignments (30), Quiz (10), Virtual demonstration (25), Flipped Classroom (10), Review of GATE & IES questions (25)

Internal Examinations: TWO tests

Reference Books:

1. Dugan R. C., Mc Granaghan M. F. Surya Santoso, and Beaty H. W., 'Electrical Power System Quality', McGraw-Hill 2003.

2. Bollen, M. H. J., 'Understanding Power Quality Problems; Voltage sags and interruptions', IEEE Press, New York, 2000.

3. Mishra, Mahesh Kumar, 'Power Quality in Power Distribution Systems Concepts and Applications', CRC Press, Taylor & Francis, New York, 2024.

4. Ghosh, Arindam, and Gerard Ledwich, 'Power quality enhancement using custom power devices' Springer Science & Business Media, 2012.

5. Arrillaga, J., Watson, N. R., Chen, S., 'Power System Quality Assessment', Wiley, New York, 2011.

	CO Description	PO1	PO2	PO3	PO4	PO5	PO6
CO1	Understand different types of power quality problems with their source of generation.	3	1	1	1	2	2
CO2	Interpret and analyse the results of power quality monitoring equipment	3	1	2	1	1	2
CO3	Develop different methodologies for detection and classification of power quality problems.	3	1	3	3	3	2
CO4	Interpret and analyse the results of power quality monitoring equipment	3	1	3	3	2	2

PX25012	LINEAR SYSTEM THEORY	L	T	P	C
		3	0	0	3

Course Objectives:

To understand the concept of state space and to obtain the state space model.

To obtain the solution of state equations in both continuous and discrete domains.

To test controllability and observability of systems

To design state controller and observer using pole-placement technique.

To analyze stability of a systems using Lyapunov criterion

STATE SPACE MODEL: System properties: Causality – Linearity, Linearization. LTI system, Concept of state and state models, state diagram, state space and state trajectory. State space representation of physical systems - Representation using state space approach- phase variable and canonical variables. Modelling of electrical systems. Discretisation of continuous time model. Comparison of input-output description and state variable description. MIMO systems.

STATE SPACE ANALYSIS: Solution of continuous time state equation, state transition matrix and its properties. Eigen values, Eigen vectors, modal matrix, diagonalization, generalized Eigen vectors. Computation of state transition matrix using Laplace Transformation, power series method, Cayley-Hamilton method. Similarity transformation. Solution of discrete time state equation.

CONTROLLABILITY AND OBSERVABILITY: Kalman`s and Gilbert`s test for controllability – – Controllability of discrete LTI systems – Kalman`s and Gilbert`s test for observability –– Observability of discrete LTI Systems– Controllability and Observability Canonical Forms - Duality.

POLE PLACEMENT TECHNIQUES: Controller design by state feedback, necessary and sufficient condition for arbitrary pole placement. State regulator problem and state regulator design. Pole placement controller design for discrete time systems. State observer – full order observer, reduced order observer, observer based state feedback control. Observer design for discrete time systems.

STABILITY ANALYSIS: Lyapunov’s stability analysis: Stability in the sense of Lyapunov, Construction of Lyapunov function, asymptotic stability of linear time invariant continuous and discrete systems.

Weightage:	Continuous Assessment: 40% i. Activities: 10% ii. Internal Theory Examinations: 30%	End Semester Theory Examination: 60%

Mandated Activities with marks: Assignments (30), Quiz (10), Virtual demonstration (25), Flipped Classroom (10),
Internal Examinations: TWO tests
References: 1) Katsuhiko Ogata, 'Modern Control Engineering', Fifth Edition, Prentice-Hall of India, 2015. 2) Nagarath and M. Gopal, 'Control System Engineering', Eigth Edition, New Age International, 2024. 3) Benjamin C. Kuo and Farid Golnaraghi, 'Automatic Control Systems', Eigth Edition, John Wiley &Sons, 2017. 4) Chen CT, "Linear System Theory and Design", Fourth Edition, Oxford University Press, 2014.
E-resources: 1. https://archive.nptel.ac.in/courses/107/106/107106081/ 2. https://archive.nptel.ac.in/courses/108/106/108106098

	CO Description	PO1	PO2	PO3	PO4	PO5	PO6
CO1	Understand the concept of state space and to obtain the state space model.	1	1	3	3	2	2
CO2	Solve the state equations in both continuous and discrete domains.	2	1	1	3	2	2
CO3	Understand and test controllability and observability of systems	3	1	2	3	3	3
CO4	Design state controller and observer using pole-placement technique.	3	2	3	3	3	2
CO5	Analyze stability of a system using Lyapunov criterion.	2	3	2	2	2	2

*

<table>
<tr><td rowspan="2">PX25013</td><td rowspan="2">Special Electrical Machines</td><td>L</td><td>T</td><td>P</td><td>C</td></tr>
<tr><td>2</td><td>0</td><td>2</td><td>3</td></tr>
</table>

Course Objective:

The course aims to equip students with the analytical, simulation and development skills necessary to model and evaluate the performance of various special electrical machines in modern electric drive systems. It emphasizes the integration of special machines with power electronic converters, advanced control techniques, and their role in high-performance applications such as electric vehicles, robotics, automation, and renewable energy systems. By fostering a strong foundation in machine dynamics and control strategies, the course also encourages research and innovation in the design and development of energy-efficient and high-precision drive systems.

Stepper Motors

Construction and Principle of Operation – Types - Modes of Excitation, Characteristics - Driver Circuits - Digital Control – Simulations and Programming - Applications - Design and Performance Analysis

Switched Reluctance Motors (SRM)

Construction and Principle of Operation – Power Converters and their Controllers – Methods of Rotor Position Sensing – Sensor-Less Operation – Characteristics – Applications - Simulations - Design and Performance Analysis

Permanent Magnet Brushless DC Motors (PMBLDC)

Magnetic Circuit Analysis – Emf and Torque Equations – Commutation – Power Converter and their Controllers – Characteristics – Applications; Axial Flux Motors; Simulations - Design and Performance Analysis

Permanent Magnet Synchronous Motors (PMSM)

Principle of Operation - Ideal PMSM-Emf and Torque Equations - Armature MMF - Synchronous Reactance - Sine Wave Motor with Practical Windings - Phasor Diagram - Characteristics - Power Converter and their Controllers - Applications - Simulations - Design and Performance Analysis

Advanced Synchronous Motors

Synchronous Reluctance Motors - Flux Switching Motors - Linear Motors - Construction and Torque Production – Characteristics - Applications Simulations - Design and Performance Analysis

<table>
<tr><td rowspan="2">Weightage:</td><td>Continuous Assessment: 60%</td><td rowspan="2">End Semester Theory Examination: 40%</td></tr>
<tr><td>I. Activities: 15%
II. Internal Theory Examinations: 30%
III. Internal Laboratory Examinations:15%</td></tr>
</table>

Mandated Activities with marks: Assignments (30), Quiz (10), Virtual demonstration (25), Flipped Classroom (10),
Internal Examinations: TWO tests
References: 1. **"Stepper Motors: Fundamentals, Applications and Design"** V.V. Athani, Publisher: New Age International, 1997 2. **"Stepper Motors and Their Microprocessor Controls"** Author: Takashi Kenjo, Publisher: Oxford University Press, 1984 3. **"Switched Reluctance Motors and Their Control"**, Author: T.J.E. Miller, Published: 1993, **Publisher:** Magna Physics Publishing and Clarendon Press (Oxford University Press) 4. **"Switched Reluctance Motor Drives: Modeling, Simulation, Analysis and Control", Author: R. Krishnan, Published Year: 2001, Publisher: CRC Press** 5. **"Permanent Magnet Motor Technology: Design and Applications", Author: Jacek F. Gieras, Published Year: 2010 (3rd Edition), Publisher: CRC Press** 6. **"Permanent Magnet Synchronous Machines: Design and Analysis", Author: Sandra Eriksson, Published Year: 2015, Publisher: Lund University Publications (also available as an academic e-book)** 7. **"Flux-Switching Machines: Principles, Performance, and Applications", Author: Wenxiang Zhao, Published Year: 2013 (also reprinted in 2016), Publisher: Tsinghua University Press & Springer.**

	CO Description	PO1	PO2	PO3	PO4	PO5	PO6
CO1	Articulate construction, operating principles, and electromagnetic behaviour	3	1	2	2	3	2
CO2	Develop and solve dynamic machine models	1	2	2	2	3	2
CO3	Apply control strategies to enhance the precision and efficiency of drive systems	2	3	2	1	3	1
CO4	Specify and size power-electronic converters	2	3	2	2	3	1
CO5	Develop research capability to innovate for next-generation drive systems.	1	3	2	2	3	2

PX25014	ADVANCED POWER CONVERTERS	L	T	P	C
		3	0	0	3

Course Objectives:

- To provide conceptual knowledge in advanced power electronic converters and its applications in the field of electrical drives and utility grid interconnection.
- To understand the operation of voltage lift converters, super lift converters and ultra lift converters.
- To design the bidirectional dual active bridge DC-DC converters and impedance
- source converter.
- To impart knowledge on multilevel inverters and modulation techniques

Voltage-Lift Converters

Introduction - P/O Luo converters and N/O Luo Converters - Elementary Circuit, Self-Lift Circuit, Re-Lift Circuit, Multiple Lift Circuit - Continuous conduction and discontinuous conduction mode.

Super Lift and Ultra Lift Luo Converters

Positive Output Super Lift Luo Converters, Negative Output Super Lift Luo Converters - Main Series, Additional Series, Enhanced Series.

Ultra-Lift Luo-Converter: Operation - Continuous conduction and discontinuous conduction mode - Instantaneous Values.

Bidirectional Dual Active Bridge DC–DC Converters

Non-Isolated and Isolated DC–DC Converter - Working Principle of Hybrid-Bridge-Based Dual active bridge (DAB) converter- Converter performance with voltage match control- Principle and operation of Dual-Transformer based DAB converter- Three-Level bidirectional DC–DC converter.

Impedance Source Converter

Voltage-fed Z-source/ Quazi-Z-source inverters - Topologies – Steady state and dynamic model - Current-fed Z-source/ Quazi-Z-source inverters - Topology modification and operational principles. Modulation Methods - Sine PWM - SVPWM and Pulse width Amplitude Modulation.

Multilevel Inverters with Reduced Switch Count

Multilevel inverter (MLI) with reduced switch count-structures, working principles - pulse generation methods for the inverter with carrier signals and without carrier signals.

Weightage:	Continuous Assessment: 40% Activities: 10% Internal Theory Examinations: 30%	End Semester Theory Examination: 60%

Mandated Activities with marks: Assignments (30), Quiz (10), Virtual demonstration (25), Flipped Classroom (10),
Internal Examinations: TWO tests
References: 1. Fang Lin Luo, Hong Y, "Advanced DC/DC Converters", Second Edition, CRC Press, 2017. 2. Yushan Liu, Haitham Abu-Rub, "Impedance Source Power Electronic Converters", First Edition, Wiley, 2016. 3. Deshang Sha, Guo Xu, "High-Frequency Isolated Bidirectional Dual Active Bridge DC– DC Converters with Wide Voltage Gain", Springer, 1st Edition, 2019. 4. Fang Lin Luo, Hong Ye, "Essential DC/DC Converters", CRC Press, 1st Edition, 2005. 5. Fang Lin Luo, Hong Ye, "Power Electronics Advanced Conversion Technologies", CRC press, 2nd Edition, 2018. 6. Bin Wu, Mehdi Narimani, "High-Power Converters and AC Drives", Wiley, 2nd Edition, 2017. 7. Rashid M.H., "Power Electronics Circuits, Devices and Applications", Pearson, 4th Edition, 2021.

	CO Description	PO1	PO2	PO3	PO4	PO5	PO6
CO1	Understand the working of voltage lift converters	3	3	3		3	
CO2	Understand the operation of super lift and ultra-lift Luo converters	3	3	3		3	
CO3	Design the bidirectional dual active bridge DC-DC converters	3	3	3		3	
CO4	Design the voltage fed and current fed impedance source converters	3	3	3		3	
CO5	Describe the working of multilevel inverters and understand various modulation techniques	3	3	3		3	

PX25015	ADVANCED BATTERY TECHNOLOGY	L	T	P	C
		3	0	0	3

Course Objectives:

- Understand the principles of electrochemical energy storage systems and battery chemistries.
- Analyze battery characteristics, performance, degradation mechanisms, and modeling.
- Explore battery charging techniques, safety standards, and protective mechanisms.
- Understand BMS architecture, functions, and system-level integration.
- Implement state estimation, balancing, diagnostics, and communication protocols.
- Apply battery and BMS knowledge in electric vehicles, renewable systems, and grid storage.

FUNDAMENTALS OF BATTERIES AND ENERGY STORAGE

Electrochemical principles – Electrodes, electrolytes, separators. Battery parameters – Cell voltage, capacity, C-rate, energy/power density, DoD, self-discharge, Battery classifications – Primary vs. secondary, construction and working of Lead-acid, NiMH, Li-ion, Charge/discharge cycles and degradation basics

BATTERY CHEMISTRIES, MODELING, AND CHARACTERISTICS

Battery chemistries: Lead-acid, NiMH, Li-ion, Flow batteries, Battery comparison – Cost, cycle life, energy/power density, Battery modeling – Battery testing:Pulse testing, EIS, Thermal behavior, and degradation mechanisms.

BMS ARCHITECTURE, MONITORING, AND PROTECTION

Introduction to BMS: Functions and components, Hardware architecture – Sensors, controllers, data acquisition, BMS topologies: Centralized, modular, distributed, Monitoring: Voltage, current, temperature, Protection: Over/under voltage, current, thermal.

STATE ESTIMATION AND CELL BALANCING

SOC estimation – Coulomb counting, Open circuit voltage and Kalman filtering, SOH estimation – Capacity fade, resistance growth, Remaining Useful Life(RUL) estimation and interpretation, Cell balancing methods: Passive vs. active.

CHARGING, COMMUNICATION AND APPLICATIONS

Charging methods – CC, CV, CCCV, pulse charging, Communication: CAN, I2C, SPI protocols in BMS, Safety standards: IEC, BIS, ISO 26262, IEC 62133, Applications: EVs, hybrids, grid storage, battery recycling and sustainability.

<table>
<tr><td rowspan="2">Weightage:</td><td>Continuous Assessment: 40%</td><td rowspan="2">End Semester Theory Examination: 60%</td></tr>
<tr><td>Activities: 10%

Internal Theory Examinations: 30%</td></tr>
<tr><td colspan="3">Mandated Activities with marks: Assignments (30), Quiz (10), Virtual demonstration (25), Flipped Classroom (10),</td></tr>
<tr><td colspan="3">Internal Examinations: TWO tests</td></tr>
<tr><td colspan="3">References:

1. Chris Mi, M. Abul Masrur – Hybrid Electric Vehicles: Principles and Applications,Wiley IEEE Press,2011.
2. Gregory L. Plett – Battery Management Systems, Vol. 1 and 2,Artech House, 2015.
3. J. Garche – Electrochemical Energy Storage for Renewable Sources and Grid Balancing,Elseiveir, 2015.
4. D. Linden and T. B. Reddy – Handbook of Batteries, McGraw-Hill,2002.</td></tr>
<tr><td colspan="3">E-Resources:

❖ https://standards.ieee.org</td></tr>
</table>

	CO Description	PO1	PO2	PO 3	PO4	PO5	PO6
CO1	Understand the battery principles, electrochemistry, and evaluate chemistries for applications.	2	2	1	2	2	2
CO2	Understand the modelling of batteries considering electrical, thermal, and aging behavior.	.1	3	3	2	3	3
CO3	Design BMS with appropriate architecture and protection mechanisms.	3	2	2	2		3
CO4	To apply estimation and cell balancing techniques in BMS systems.	3	1	2	3	2	3
CO5	Demonstrate integration of BMS in EVs and apply relevant standards.	2	2		2		3

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PX25C02	ELECTRIC VEHICLES AND POWER MANAGEMENT	L	T	P	C
		3	0	0	3

Course Objective:

This course aims to equip students with a comprehensive understanding of electric vehicle (EV) architecture, propulsion systems, and energy storage technologies. It focuses on power management strategies that optimize performance, efficiency, and battery life under varying load and driving conditions. Students will also explore smart charging, regenerative braking, grid integration, and the role of power electronics in advancing sustainable transportation systems.

Introduction to Electric Vehicles (EVs)

EV evolution and classification (BEV, HEV, PHEV, FCEV) - EV configurations and architecture -Vehicle dynamics: tractive effort, energy consumption, gradability - Driving cycles: EPA, NEDC, WLTP, and custom profiles

Electric Propulsion and Drive Systems

Types of electric motors used in EVs: PMSM, BLDC, IM, SRM - Motor characteristics and drive selection - Motor control strategies: Field-Oriented Control (FOC), Direct Torque Control (DTC) - Regenerative braking – Torque Vs. Speed Control

Energy Storage Systems and Battery Management

Battery types: Li-ion, NiMH, Lead-acid – comparison and characteristics - Battery modeling and performance parameters - Battery Management Systems (BMS): SoC, SoH, cell balancing - Supercapacitors and hybrid storage systems

Power Electronics and Energy Conversion

DC-DC converters, inverters, and onboard chargers - Bidirectional power flow and energy recuperation - Charging infrastructure: AC vs DC, wireless charging, V2G systems - Safety, thermal management, and EMI issues

Power Management Strategies and Future Trends

Power flow optimization and energy scheduling in EVs - Smart energy management using AI and predictive algorithms - Integration with smart grids and renewable sources - Trends in EV policy, standardization, and sustainable mobility

Weightage:	Continuous Assessment: 40% i. Activities: 10% ii. Internal Theory Examinations: 30%	End Semester Theory Examination: 60%

Assessment Weightage: Internal Assessment 1 – 15%; Internal Assessment 2 – 15%; Digital Assignments/Simulations (minimum 2) – 10%; Seminar/International Conference – 10%; Final Assessment – 50%

Internal Examinations: TWO tests

References:

1. **“Advanced Electric Drive Vehicles”, Authors:** Ali Emadi, Mehrdad Ehsani, John M. Miller, **Publisher: CRC Press, Published Year: 2014**
2. **“Modern Electric Vehicle Technology”**, Authors: C.C. Chan, K.T. Chau, Publisher: Oxford University Press, Published Year: 2001
3. ***“Battery Management Systems for Large Lithium-Ion Battery Packs”,*** **Author:** Philip Weicker, **Publisher:** SAE International, **Published Year: 2013**
4. ***“Power Electronics for Electric Vehicles and Energy Storage Systems”,*** **Author:** Shuai Jiang, **Publisher:** Springer, **Published Year: 2022**
5. **“Electric and Hybrid Vehicles: Technologies, Modeling and Control – A Mechatronics Approach”, Authors:** Amir Khajepour, M. Saber Fallah, Avesta Goodarzi, **Publisher: Wiley, Published Year: 2014**

	CO Description	PO1	PO2	PO3	PO4	PO5	PO6
CO1	**Understand** the architecture of EV powertrains and identify the role of various subsystems in power and energy flow management.	1	1	2	1		3
CO2	**Analyze** battery systems, charging infrastructure, and battery management techniques to ensure safety, efficiency, and longevity of EVs.	2	2	2	1		3
CO3	**Apply** power electronics converters and control strategies for energy conversion, bidirectional charging, and regenerative braking in electric vehicles.	3	3	2	1		3
CO4	**Evaluate** real-time power management strategies under different driving conditions using performance metrics such as efficiency, thermal stability, and cost-effectiveness.	3	3	2	1		3
CO5	**Design** intelligent energy management systems using rule-based, fuzzy logic, and optimization-based algorithms for hybrid and battery electric vehicles.	3	3	2	1		3

PX25016	PCB DESIGN FOR POWER CONVERTERS AND DRIVES	L	T	P	C
		3	0	0	3

Course Objectives:

To design proper power electronic hardware, simulation tools, proper designing of power PCB, designing protection, reducing electromagnetic interference.

Fundamentals of PCB Design and CAD Tools

PCB structure and terminology - Layers, vias, pads, traces, solder mask, silkscreen, Types of PCBs (single-sided, double-sided, multilayer, metal-core), Selection of PCB stack-up based on power density and thermal needs, Schematic capture and netlist generation, Creation of custom footprints, Understanding and applying design rule checks (DRC/ERC), Overview of commonly used EDA tools such as Altium Designer, KiCad, Eagle, and LTspice (simulation only), Generation of fabrication-ready files (Gerber, drill, BOM), Trace impedance and layer assignment for signal integrity, IPC Standards and Guidelines- IPC-2221, IPC-2222, IPC-6012, IPC-A-600 (relevant to power applications).

Power Circuit Layout and Thermal Design

Trace width calculation as per IPC-2152 - Calculation of current-carrying capacity and trace width for external and internal layers, Thermal design using copper pours, thermal vias, and heat spreading, Optimization of gate driver signal paths to minimize dv/dt loops, Placement of snubbers and bootstrap circuits for switching node stability, Component derating, trace clearance, and spacing considerations under thermal and voltage stress, Strategies for paralleling devices and interleaving currents.

Safety, Insulation, and High Voltage Design

Determining clearance and creepage based on operating voltage and pollution degree (IEC/UL), Application of insulation classes (basic, reinforced, supplementary, functional), Layout for galvanic isolation in mixed-voltage circuits, Selection and placement of safety-rated components (Class Y/X capacitors, opto-isolators), Safety considerations for moisture, dust, and condensation-prone environments**.**

EMI/EMC and ESD Protection

Identification of EMI sources in high-speed switching circuits, Design of differential and common-mode filters, Layout strategies to reduce loop area and parasitic inductance, Component placement to meet conducted emission standards, Use of ESD protection devices near I/O and control lines, Use of LISN and oscilloscope to validate conducted EMI compliance, Selection of filter topology based on impedance matching.

Grounding, Mixed-Signal Layout and Final Validation

Design of grounding systems for mixed-signal PCBs (analog, digital, and power domains), Planning return current paths for high-frequency signals, Star grounding vs split-plane implementation, Handling ground bounce and cross-talk in fast switching systems, Design for manufacturability (DFM) and testability (DFT), Peer review techniques to reduce debugging time, Final layout checklist for EMC, thermal, and safety compliance.

Weightage:	Continuous Assessment: 40%	End Semester Theory Examination: 60%
	(i). Activities: 10% (ii). Internal Theory Examinations: 30%	

Mandated Activities with marks: Assignments / Quizzes: 20%, • Laboratory Exercises / Reports: 30%, Midterm Exam (Theory): 20%, • Final Design Project (Report + Viva): 30%

Internal Examinations: TWO tests

References:

1. Douglas Brooks & Johannes Adam, PCB Design Guide to Via and Trace Currents and Temperatures, 1st Ed., Artech House, 2021.
2. Peter Dalmaris, KiCad Like a Pro: Learn the World's Favourite Open Source PCB Design Tool, 3rd Ed., Tech Explorations, 2022.
3. Henry Ott, Electromagnetic Compatibility Engineering, Wiley, 2009.
4. Mark Montrose, Practical EMC Design Techniques, IEEE Press, 2004.
5. Kraig Mitzner, Complete PCB Design Using OrCAD Capture and PCB Editor, 1st Ed., Newnes, 2009.
6. Bruce R. Archambeault, PCB Design for Real World EMI Control, 1st Ed., Springer, 2002
7. Tim Williams, EMC for Product Designers, 5th Ed., Newnes (Elsevier), 2016.
8. Kazimierz Gajda & Jerzy Baranowski, Electromagnetic Compatibility in Design and Construction of Electronic Products, 1st Ed., Springer, 2017.
9. Nihal Kularatna, Power Electronics Design Handbook, 2nd Ed., Newnes (Elsevier), 2018.
10. Yong Liu, Power Electronic Packaging: Design, Assembly Process, Reliability and Modeling, Springer, 2012.
11. Altium Designer 25 and 24 Technical Documentation.
12. KiCad Documentation.
13. Application Notes from Texas Instruments, Analog Devices, and Infineon Technologies covering gate-driver layout, EMI suppression, thermal strategies, and standards.

	CO Description	PO1	PO2	PO3	PO4	PO5	PO6
CO1	Ability to understand the basic PCB design and CAD tool.	2	2	2		2	3
CO2	Ability to understand the product architecture and layout development	2	2	1		1	2
CO3	Ability to understand the safety concern and high voltage design the product as suitability of Industrial applications	1	2	2		1	1
CO4	Ability to design for manufacturing and product development with EMI & EMC filters.	2	2	2	1	2	3

PX25017	AI FOR POWER ELECTRONICS	L	T	P	C
		3	0	0	3

Course Objectives:

Industrial Applications & AI Integration in Power Electronics

Industrial Power Electronics Applications

SMPS, UPS, static switches, solid-state relays, switchgear, AC phase controllers & inverters, Example: TRIAC-based dimmers and motor drives

Electric Drives

Integration of power converters in industrial motor drives, Role of AI in optimizing performance and reliability

AI in Converter Design & Control

AI algorithms (ANN, fuzzy logic, GA, reinforcement learning) for converter parameter optimization, control, and fault detection

Condition Monitoring & Health Management

AI-driven systems to predict failures and enable maintenance of power electronic equipment, Condition Monitoring Techniques

Renewable Integration & Smart Grids

AI-enabled converters for renewable energy systems and microgrids, Adaptive control to handle intermittency and power quality issues

Weightage:	Continuous Assessment: 40%	End Semester Theory Examination: 60%
	(iii).Activities: 10% (iv). Internal Theory Examinations: 30%	

Mandated Activities with marks: Assignments, Quiz

Internal Examinations: TWO tests

References:

- **Rashid, M.H.** - *Power Electronics: Circuits, Devices & Applications, Princeton Publications,2021*

- **Hu, W., Zhang, G., Zhang, Z., Blaabjerg, F., et al.** – *AI for Power Electronics and Renewable Energy Systems* (IET, 2024)
- Ahteshamul Haque, Azra Malik, Saad Mekhilef, - AI for Power Electronics, Wiley IEEE Publictions,2025

E-resources:

1. **Zhao, S., Blaabjerg, F., & Wang, H.** – “Overview of AI Applications for Power Electronics,” *IEEE Trans. Power Electronics*, Apr 2021
2. **Zhao, S., Blaabjerg, F., & Wang, H.** – “Overview of AI Applications for Power Electronics,” *IEEE Trans. Power Electronics*, Apr 2021

	CO Description	PO1	PO2	PO3	PO4	PO5	PO6
CO1	A review of Industrial application of Power Electronics	2	2	2		2	3
CO2	Demonstrate the implementation of AI techniques Power Electronics Application	3	2	1		3	2
CO3	Demonstrate the AI based condition monitoring of power electronics system	3	2	2		3	3
CO4	Understand the AI based Renewable Integration & Smart Grids	2	2	2		2	3

ET25C03	PYTHON PROGRAMMING FOR MACHINE LEARNING	L	T	P	C
		3	0	0	3

Course Objectives:

- To learn Python syntax, data structures, and libraries essential for machine learning.
- To understand the basics to preprocess structured and numerical data for machine learning using NumPy arrays and Pandas DataFrames,
- To learn techniques to clean, transform, and optimize datasets for ML models, including handling missing data and feature scaling.
- To understand the techniques to build, evaluate, and tune supervised/unsupervised models using Scikit-learn
- To get a knowledge to design and train neural networks (MLP, CNN, RNN) using TensorFlow/Keras and apply transfer learning.

Python Fundamentals for ML

Python Basics: Syntax, Variables, Data Types, and Operators, Control Structures: if-else, loops (for, while), Functions and Lambda expressions - Data Structures: Lists, Tuples, Dictionaries, Sets- File handling in Python, Exception Handling, Basic Object-Oriented Programming (Classes and Objects)

Python for Data Handling

NumPy: Arrays, Slicing, Broadcasting, indexing Math Operations- Pandas: DataFrames, Series, Data Cleaning, GroupBy- File Handling (CSV, JSON), merging, filtering, sorting, Data Visualization (Matplotlib, Seaborn)

Data Preprocessing & Feature Engineering

Handling Missing Data: Imputation, Dropping-Categorical Data Encoding: One-Hot, Label Encoding-Feature Scaling: Standardization, Normalization-Feature Extraction: PCA, Feature Selection-Time-Series Data Handling: Resampling, Rolling Windows

Implementing ML Algorithms in Python

Scikit-learn Workflow: Train-Test Split, Pipelines, Cross Validation, Supervised Learning: Linear/Logistic Regression (Sklearn), Decision Trees & Random Forests, SVM & k-NN, Unsupervised Learning: k-Means Clustering, Hierarchical Clustering, Model Evaluation Metrics: Confusion Matrix, ROC Curve, Model performance tuning: Grid Search, Random Search, Bias-variance trade-off

Deep Learning with Python (TensorFlow/Keras) Neural Networks with Keras: Layers, Activations, Loss Functions, Building & Training MLP: Multi-Layer Perceptron, CNNs for Image Classification: MNIST, CIFAR-10, RNNs/LSTMs for Sequential Data: Time-Series, Text, Transfer Learning: Fine-tuning Pre-Trained Models, Flask/Django API for ML Models, Cloud Deployment (AWS SageMaker, Google AI Platform)		
Weightage:	Continuous Assessment: 40 (i). Activities: 10% (ii). Internal Theory Examinations: 30%	End Semester Theory Examination:60
Mandated Activities with marks: Assignments (30), Quiz (10), Virtual demonstration (25), Flipped Classroom (10),		
Internal Examinations: TWO tests		

References:

1. **Géron, A.** (2022). Hands-On Machine Learning with Scikit-Learn, Keras, and TensorFlow (3rd ed.). O’Reilly Media.
2. **McKinney, W.** (2022). Python for Data Analysis: Data Wrangling with pandas, NumPy, and Jupyter (3rd ed.). O’Reilly Media.
3. **Goodfellow, I., Bengio, Y., & Courville, A.** (2016). Deep Learning. MIT Press.
4. **Nielsen, M. A.** (2015). Neural Networks and Deep Learning. Determination Press.
5. **Matthes, E.** (2023). *Python Crash Course: A Hands-On, Project-Based Introduction to Programming* (3rd ed.). No Starch Press.
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8. **Hapke, H., & Nelson, C.** (2020). *Building Machine Learning Pipelines: Automating Model Life Cycles with TensorFlow* (1st ed.). O’Reilly
9. **Media.Raschka, S., & Mirjalili, V.** (2023). Python Machine Learning (3rd ed.). Packt Publishing.

	CO Description	PO1	PO2	PO3	PO4	PO 5	PO6
CO1	Develop Python code for machine learning workflows using industry best practices.			2	3	3	
CO2	Process and optimize tabular/numerical data for machine learning using NumPy and Pandas.	3	1	3		3	1
CO3	Preprocess raw datasets by handling missing values, encoding categorical variables, and reducing dimensionality (PCA).	2	1	2		3	3
CO4	Train and evaluate ML models using Scikit-learn, including hyperparameter tuning (GridSearchCV) and performance analysis (ROC, confusion matrix).	3	2	3	3	3	3
CO5	Build and optimize deep learning models for tasks like image classification (CNNs) and sequence prediction (RNNs/LSTMs).					3	

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ET25C02	MACHINE LEARNING AND DEEP LEARNING	L	T	P	C
		3	0	0	3

Course Objectives:

1. **Learn** the differences between supervised, unsupervised, and reinforcement learning, and **understand** how they are used in real-world applications.
2. **Get knowledge** of data preprocessing techniques and **learn** how to train and evaluate machine learning models using Scikit-learn.
3. **Understand** how to implement and fine-tune supervised algorithms and unsupervised methods for practical problems.
4. **Learn** how to design and train neural networks with TensorFlow/PyTorch.

Get knowledge of transfer learning and model deployment to lay models into production

Introduction to Machine Learning

Overview of AI, ML, and DL-Applications of ML and DL in real-world Scenarios-Types of Machine Learning: Supervised Learning, Unsupervised Learning, Reinforcement Learning, ML Workflow-Data collection, preprocessing, training, evaluation, deployment, Basics of Python for ML: Numpy, Pandas, Matplotlib, Scikit-learn

Classical Machine Learning Algorithms

Data preprocessing techniques: Handling missing values, encoding categorical variables, Scaling-Feature selection and dimensionality reduction (PCA), Supervised Learning Models: Linear Regression, Logistic Regression, Decision Trees, Random Forests, Support Vector Machines (SVM), K-Nearest Neighbors (KNN), Unsupervised Learning Models: K-Means Clustering, Hierarchical Clustering, Ensemble methods: Bagging, Boosting (AdaBoost, XGBoost), Hyper parameter tuning: Grid SearchCV, Randomized SearchCV, Model evaluation metrics: Confusion Matrix, Accuracy, Precision, Recall, F1-Score, ROC-AUC

Fundamentals of Neural Networks and Deep Learning

Introduction to Neural Networks, Perceptron and Multilayer Perceptron (MLP), forward propagation, cost functions, error backpropagation, training by gradient descent, bias/variance, Activation functions: ReLU, Sigmoid, Tanh, Loss functions: MSE, Cross-Entropy, Backpropagation and optimization: SGD, Adam, Overfitting and Regularization techniques: Dropout, Early Stopping, Building basic ANN with TensorFlow/Keras or PyTorch

Convolutional and Recurrent Neural Networks

Neural network architectures: MLPs, CNNs, RNNs, and LSTMs, Convolutional Neural Networks (CNNs): Architecture: Convolutional layers, Pooling, Flatten, Fully connected layers, Image classification tasks, Pre-trained models and transfer learning: VGG, ResNet, Recurrent Neural Networks (RNNs): Sequence modeling concepts, LSTM and GRU networks, Applications: Text classification, Time series prediction, Training deep networks: Loss functions, optimizers (SGD, Adam), regularization (Dropout, BatchNorm)

Advanced Deep Learning and Deployment

Introduction to advanced DL models: Autoencoders, Variational Autoencoders (VAE), Generative Adversarial Networks GANs, VAEs – basic architecture, Transformers and Attention Mechanism Model- GPT, BERT, Reinforcement learning basics- Q-Learning, Deep Q-Networks, Evaluation and fine-tuning, Model deployment: Saving/loading models, Serving models using Flask or FastAPI, Intro to Docker and cloud deployment (Heroku/AWS), Complete ML/DL pipeline: data processing, model building, evaluation, and deployment

Weightage:	Continuous Assessment: 40 (i). Activities: 10% (ii). Internal Theory Examinations: 30%	End Semester Theory Examination:60

Mandated Activities with marks:

Assignments (30), Quiz (10), Virtual demonstration (25), Flipped Classroom (10),

Internal Examinations: TWO tests

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1. **Alpaydin, E.** (2015). *Introduction to Machine Learning* (3rd ed.). Prentice Hall India.
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3. **Nielsen, M. A.** (2015). *Neural Networks and Deep Learning*. Determination Press.
4. **Bengio, Y.** (2009). *Learning Deep Architectures for AI*. Now Publishers Inc.
5. **Duda, R. O., Hart, P. E., & Stork, D. G.** (2007). *Pattern Classification* (2nd ed.). Wiley India.
6. **Bishop, C. M.** (2006). *Pattern Recognition and Machine Learning*. Springer.
7. **Bhuyan, M. K.** (2019). *Computer Vision and Image Processing: Fundamentals and Applications*. CRC Press.
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10. **McKinney, W.** (2022). *Python for Data Analysis: Data Wrangling with pandas, NumPy, and Jupyter* (3rd ed.). O'Reilly Media.
11. **Haykin, S. O.** (2016). *Neural Networks and Learning Machines* (3rd ed.). Pearson Education India.

	CO Description	PO1	PO2	PO3	PO4	PO5	PO6
CO1	Explain supervised, unsupervised, and reinforcement learning paradigms with real-world examples.	1	3	1			
CO2	Pre-process data and train ML models using Scikit-learn.	2	3	2			
CO3	Implement and tune supervised/unsupervised algorithms for real-world problems.	3		3		3	
CO4	Design and train neural networks (CNNs, RNNs) with TensorFlow/PyTorch.	2	3	3		2	
CO5	Transfer learning and deploy models in production environments.	3	3	3		3	

ET25C01	IOT FOR SMART SYSTEMS	L	T	P	C
		3	0	0	3

Course Objectives:

- To describe about Smart Objects and IoT Architectures
- To learn about various IOT-related protocols
- To develop simple IoT Systems using Arduino and Raspberry Pi.
- To explain data analytics and cloud in the context of IoT
- To develop IoT infrastructure for popular applications

Fundamentals of IoT

Evolution of Internet of Things - Enabling Technologies – IoT Architectures: M2M, IoT World Forum (IoTWF) and Alternative IoT models – Simplified IoT Architecture and Core IoT Functional Stack -– Fog, Edge and Cloud computing in IoT – Functional blocks of an IoT ecosystem – Sensors, Actuators, Smart Objects and Connecting Smart Objects- Industrial IoT

IoT Protocols

IoT Access Technologies: Physical and MAC layers, topology – Network Layer: IP versions, Constrained Nodes and Constrained Networks – Optimizing IP for IoT: WiFi (IEEE 802.11), Bluetooth/Bluetooth Smart, ZigBee/ZigBee Smart, From 6LoWPAN to 6Lo, Lora WAN, Routing over Low Power and Lossy Networks – Application Transport Methods, Application Layer Protocols: CoAP and MQTT.

Design and Development

Design Methodology - Embedded computing logic - Microcontroller, System on Chips - IoT system building blocks - Arduino - Board details, IDE programming - Raspberry Pi - Interfaces and Raspberry Pi with Python Programming– STM32

Data Analytics, Cloud and Supporting Services

Structured Vs Unstructured Data and Data in Motion Vs Data in Rest – A framework for data-driven decision making, Descriptive, Predictive and Prescriptive Analytics, NoSQL Databases – Hadoop Ecosystem – Apache Kafka, Apache Spark – Edge Streaming Analytics and Network Analytics – Thing speak, Ubidot and Xively Cloud for IoT, Blynk app, Python Web Application Framework – Django – AWS for IoT.

Case Studies/Industrial Applications

Home Automation, Building Energy Management, Smart Grid – Industry 4.0- Smart and Connected Cities: Layered architecture, Smart Lighting, Smart Parking Architecture, Smart Traffic Control, Agriculture and Healthcare productivity application.

Weightage:	Continuous Assessment: 40% (i). Activities: 10% (ii). Internal Theory Examinations: 30%	End Semester Theory Examination: 60%

Mandated Activities with marks:

Assignments (30), Quiz (10), Virtual demonstration (25), Flipped Classroom (10),

Internal Examinations: TWO tests

References:

1. David Hanes, Gonzalo Salgueiro, Patrick Grossetete, Rob Barton and Jerome Henry, ―IoT Fundamentals: Networking Technologies, Protocols and Use Cases for Internet of Things, Cisco Press, 2017.
2. Arshdeep Bahga, Vijay Madisetti, ―Internet of Things – A hands-on approach‖, Universities Press, 2015.
3. Olivier Hersent, David Boswarthick, Omar Elloumi, ―The Internet of Things – Key applications and Protocols‖, Wiley, 2012 (for Unit 2).
4. Jan Ho¨ ller, Vlasios Tsiatsis, Catherine Mulligan, Stamatis, Karnouskos, Stefan Avesand. David Boyle, "From Machine-to-Machine to the Internet of Things - Introduction to a New Age of Intelligence", Elsevier, 2014.
5. Dieter Uckelmann, Mark Harrison, Michahelles, Florian (Eds), ―Architecting the Internet of Things‖, Springer, 2011.

	CO Description	PO1	PO2	PO3	PO4	PO5	PO6
CO1	Explain the concepts of IoT	1	2	1			
CO2	Analyze various protocols for IoT.	.	2				
CO3	Design an IoT system using Rasperry Pi, Arduino, STM32	1	2		1	3	3
CO4	Apply data analytics and use cloud offerings related to IoT	2	2	3	3	3	3
CO5	Apply IoT for real time systems	3	2	3	3	3	3

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