

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) **L** – Laboratory Course
- ES** – Engineering Science (General (**G**), Programme Core (**PC**), Programme Elective (**PE**)) **T** – Theory
- SD** – Skill Development **LIT** – Laboratory Integrated Theory
- SL** – Self Learning **PW** – Project Work
- TCP** – Total Contact Period(s)

Semester I

S. No.	Course Code	Course Title	Type	Periods per week			TCP	Credits	Category
				L	T	P			
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.	--	Programme Elective V	T	3	0	0	3	3	ES (PE)
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.	PX25C04	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.	PX25C03	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.	ET25C03	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: <ul style="list-style-type: none"> • 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)		

PX25101	Modelling and Analysis of Electrical Machines	L	T	P	C
		2	1	2	4
<p>Course Objectives:</p> <ul style="list-style-type: none"> 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 					
<p>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</p>					
<p>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</p>					
<p>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</p>					
<p>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.</p>					
<p>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.</p>					
<p>Weightage: Continuous Assessment: 50%, End Semester Examinations: 50%</p>					
<p>Assessment Methodology: Quiz (5%), Assignments (10%), Review of Question Papers (IES, GATE, SSC Questions) (20%), Projects (20%), Flipped Class (5%), Internal Examinations (40%).</p>					

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
<p>Course Objectives:</p> <ul style="list-style-type: none"> 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. 					
<p>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.</p> <p>Practical: Simulation and Experimentation 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.</p>					
<p>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</p> <p>Practical: Simulation and Experimentation of three-phase line-commutated converters.</p>					
<p>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.</p> <p>Practical: Design and testing of driver circuits for DC-DC converters (totem pole/transformer based/boot strap/opto coupler based)</p>					
<p>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.</p> <p>Practical: Simulation and analysis of single phase and three-phase inverters / Generation of PWM pulses with different modulation techniques/ Harmonic spectrum and THD analysis.</p>					
<p>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.</p> <p>Practical: Simulation and Experimentation of AC voltage regulators / Simulation and experimentation of resonant converters</p>					
<p>Weightage: Continuous Assessment: 50%, End Semester Examinations: 50%</p>					

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
<p>Course Objectives:</p> <ul style="list-style-type: none"> • 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. 					
<p>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.</p>					
<p>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.</p>					
<p>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.</p>					
<p>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.</p>					
<p>Weightage: Continuous Assessment: 50%, End Semester Examinations: 50%</p>					
<p>Assessment Methodology: Quiz (5%), Assignments (10%), Review of Question Papers (IES, GATE, SSC Questions) (20%), Projects (20%), Flipped Class (5%), Internal Examinations (40%).</p>					

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
<p>Course Objectives:</p> <ul style="list-style-type: none"> • 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. 					
<p>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.</p>					
<p>Activity: Assignment ; Selection of power devices for various applications.</p>					
<p>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.</p>					
<p>Activity: Visual Demonstration between Si and SiC device.</p>					
<p>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.</p>					
<p>Activity: Quiz on Thermal design for power devices.</p>					
<p>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.</p>					
<p>Activity: schematic capture and PCB layout for buck, boost, and buck-boost DC-DC converter using industry standard EDA tools.</p>					
<p>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.</p>					
<p>Weightage: Continuous Assessment: 40%, End Semester Examinations: 60%</p>					
<p>Assessment Methodology: Quiz (5%), Assignments (10%), Review of Question Papers (IES, GATE, SSC Questions) (20%), Projects (20%), Flipped Class (5%), Internal Examinations (40%).</p>					

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

Semester II

PX25201	MODELING AND DESIGN OF SMPS	L	T	P	C
		2	1	2	4
<p>Course Objectives:</p> <ul style="list-style-type: none"> 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. 					
<p>DESIGN OF CONVERTER CIRCUITS</p> <p>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</p> <p>Practicals: Simulation & Experimental verification of Buck, Boost, Buch-Boost & Cuk Converter</p> <p>ANALYSIS OF ISOLATED DC-DC CONVERTERS</p> <p>Introduction - classification- forward- flyback- pushpull- halfbridge- fullbridge topologies- design of SMPS</p> <p>Practicals: Simulation & Experimental verification of forward- flyback- pushpull- half-bridge topology.</p> <p>MODELING CONTROL OF SMPS CONVERTERS</p> <p>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.</p> <p>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.</p> <p>DESIGN OF MAGNETICS</p> <p>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.</p> <p>Practicals: Design of core for isolated topology and verify using software environment.</p>					
<p>Weightage: Continuous Assessment: 50%, End Semester Examinations: 50%</p>					

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. 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 of CO	PO	PSO1	PSO2
CO1	Explain the operation and design principles of non-isolated DC–DC converters	-	-	-
CO2	Analyze the operation and design of isolated DC–DC converters	PO1(2) PO3(2)	3	2
CO3	Derive small-signal models and transfer functions for DC–DC converters	PO1(3) PO3(1)	3	2
CO4	Design controllers for DC–DC converters using appropriate control strategies	PO1(2) PO2(1) PO3(2)	2	2
CO5	Design magnetic components for SMPS including core selection and loss estimation	PO1(2) PO2(2) PO3(1)	3	3

PX25202	ANALYSIS OF ELECTRICAL DRIVES	L	T	P	C
		2	1	2	4
<p>Course Objective:</p> <p>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.</p>					
<p>Electric Drives & System Components</p> <p>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</p> <p>DC Drives – Analysis and Control</p> <p>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.</p> <p>Practicals: Modeling and Simulations of DC Drives.</p> <p>Induction Motor Drives</p> <p>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.</p> <p>Practicals: Modeling and Simulations of Induction Motor Drives.</p> <p>Synchronous Motor Drives</p> <p>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.</p> <p>Practicals: Modeling and Simulations of Synchronous Motor Drives.</p> <p>Permanent Magnet Motor Drives</p> <p>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 –</p> <p>Practicals: Modeling and Simulations of Permanent Magnet Motor Drives.</p>					

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

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 of CO	PO	PSO1	PSO2
CO1	Analyze the dynamic behavior of electric drive systems under various loading and operating conditions	PO1(1) PO3(2)	3	2
CO2	Design and implement control strategies to achieve optimal performance of electrical drives	PO1(2) PO2(2) PO3(2)	3	3
CO3	Evaluate and compare drive system performance based on suitability for specific applications	PO1(2) PO3(1) PO4(1)	2	2
CO4	Develop research capability to innovate next-generation electric drive systems	PO1(3) PO3(3) PO5(2)	3	3

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

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 of CO	PO	PSO1	PSO2
CO1	Understand the principles of CAD for electrical machines and the role of numerical methods	PO1(2) PO2(2) PO5(2)	3	2
CO2	Apply the Finite Element Method to formulate and solve magnetostatic and magnetodynamic problems in electrical machines	PO1(3) PO2(3) PO3(2) PO5(3)	3	3
CO3	Model and simulate the thermal behavior of electrical machines using FEA considering various heat transfer mechanisms	PO1(3) PO2(2) PO3(2) PO5(2)	3	3
CO4	Employ optimization techniques to improve performance metrics (efficiency, torque density) of electrical machine designs	PO1(3) PO2(2) PO3(3) PO5(3)	3	3
CO5	Evaluate the potential and challenges of applying AI and ML techniques in electrical machine design	PO1(2) PO2(2) PO5(3)	2	3

Program Elective Courses

PX25C04	WIND ENERGY CONVERSION SYSTEMS	L	T	P	C
		3	0	0	3
<p>Course Objectives:</p> <ul style="list-style-type: none"> ➤ 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 					
<p>Wind turbine system:</p> <p>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.</p> <p>Grid Connected Induction Generators (GCIGs):</p> <p>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.</p> <p>Self-Excited Induction Generators (SEIGs) :</p> <p>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.</p> <p>Doubly-Fed Induction Generators (DFIGs):</p> <p>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.</p> <p>Permanent Magnet Synchronous Generators (PMSGs):</p> <p>Operation of PMSGs- steady-state analysis- performance characteristics- operation of PMSGs with different power electronic configurations for standalone and grid-connected operation.</p>					
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. 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 of CO	PO	PSO1	PSO2
CO1	Attain knowledge on the basic concepts of Wind energy conversion system.	PO1 (3) PO2 (3) PO3(2)	3	2
CO2	Analyze the electrical characteristics of various wind-driven electrical generators	PO1 (3) PO2 (3) PO3 (2)	3	3
CO3	Identify and design suitable power electronic converters for wind energy conversion system	PO1 (2) PO2 (3) PO3 (2)	3	2
CO4	Study about the need of Variable speed system and its modelling.	PO1 (3) PO3(3)	3	3
CO5	Learn about Grid integration issues and current practices of wind interconnections with power system.	PO1 (3) PO2 (3) PO3 (3)	3	3

PX25001	EMBEDDED SYSTEMS FOR POWER ELECTRONIC APPLICATIONS	L	T	P	C
		3	0	0	3
<p>Course Objective:</p> <p>To enable the learner to understand the concepts of embedded controllers with its application to power electronics</p>					
<p>Introduction:</p> <p>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.</p>					
<p>Data Acquisition:</p> <p>Sensor and Actuator, I/O – ADC, DAC, timers, DMA, Servos, Relays, stepper motors, H-Bridge, CODECs, FPGA, ASIC, diagnostic port.</p>					
<p>Real-time Operating systems:</p> <p>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.</p>					
<p>Embedded Networks:</p> <p>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.</p>					
<p>Real-time control applications:</p> <p>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.</p>					
Weightage:	Continuous Assessment: 40%	End Semester Theory Examination: 60%			
	(i). Activities: 10% (ii). Internal Theory Examinations: 30%				
<p>Mandated Activities with marks:</p> <p>Assignments (30), Quiz (10), Virtual demonstration (25), Flipped Classroom (10),</p>					

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, 2nd Edition, 2011.
4. Nazzareno Rossetti, "Managing Power Electronics: VLSI and DSP-driven Computing systems:", Wiley Interscience Publications, 2006.

CO	Description of CO	PO	PSO1	PSO2
CO1	Understand the basics of embedded systems.	PO1(2) PO2(1)	2	2
CO2	Identify suitable peripherals for a particular application.	PO1(2) PO3(2) PO5(1)	2	2
CO3	Understand the requirements of real-time OS and embedded networks.	PO1(2) PO2(2) PO4(1)	2	2
CO4	Apply the concepts of embedded control for power applications.	PO1(3) PO2(2) PO3(2) PO5(2)	3	3

PX25002	EMI and EMC in POWER CONVERTERS	L	T	P	C
		3	0	0	3
Course Objectives:					
<ul style="list-style-type: none"> ➤ 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					
<p>Definitions of EMI/EMC -Sources of EMI- Inter systems and Intra system- Conducted and radiated interference- Characteristics - Designing for electromagnetic compatibility (EMC)- EMC regulation typical noise path- EMI predictions and modelling, Methods of eliminating interferences and noise mitigation</p>					
GROUNDING AND CABLING					
<p>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.</p>					
BALANCING, FILTERING AND SHIELDING					
<p>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.</p>					
EMI TESTING METHODOLOGY					
<p>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.</p>					
ELECTROSTATIC DISCHARGE, STANDARDS AND TESTING TECHNIQUES					
<p>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.</p>					
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:		
<ol style="list-style-type: none"> 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 of CO	PO	PSO1	PSO2
CO1	Ability to understand the types and sources of EMI.	PO1(2) PO2(2)	2	2
CO2	Ability to understand the needs of grounding and cabling.	PO1(2) PO2(2) PO5(1)	2	2
CO3	Ability to understand the design concept of filtering and shielding.	PO1(3) PO3(2) PO5(2)	3	3
CO4	Ability to study the effect of EMI in elements and circuits.	PO1(3) PO2(2) PO4(1)	3	3
CO5	Ability to know about the effects of electrostatic discharge and testing techniques.	PO1(2) PO2(2) PO4(1) PO5(1)	2	2

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, Hierarchical 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.					
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 of CO	PO	PSO1	PSO2
CO1	Understand the basics of the FPGA.	PO1(2) PO2(1)	2	2
CO2	Appraise the use of Verilog HDL for logic circuit design.	PO1(2) PO3(2) PO5(1)	2	2
CO3	Understand the requirements of the peripherals in FPGA boards.	PO1(2) PO2(2) PO5(1)	2	2
CO4	Apply the concepts of FPGA control for power applications.	PO1(3) PO2(2) PO3(2) PO5(2)	3	3

PX25004	POWER ELECTRONICS FOR RENEWABLE ENERGY SYSTEMS	L	T	P	C
		3	0	0	3
<p>Course Objectives:</p> <ul style="list-style-type: none"> • 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. 					
<p>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.</p> <p>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.</p> <p>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.</p> <p>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.</p> <p>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.</p>					

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:		
<ol style="list-style-type: none"> 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 		

CO	Description of CO	PO	PSO1	PSO2
CO1	Analyze the environmental impacts of renewable energy technologies and demonstrate their application in harnessing electrical power	PO1(2) PO2(2) PO4(2)	3	2
CO2	Select suitable electrical machines for Wind Energy Conversion Systems	PO1(3) PO2(3) PO3(2)	3	3
CO3	Design power converters such as AC–DC, DC–DC, and AC–AC converters for wind energy systems	PO1(3) PO3(3) PO5(3)	3	3
CO4	Design power converters such as DC–DC and DC–AC converters for solar energy and fuel cell systems	PO1(3) PO3(3) PO5(3)	3	3
CO5	Interpret stand-alone, grid-connected, and hybrid renewable energy systems with Maximum Power Point Tracking (MPPT)	PO1(3) PO2(3) PO3(2) PO5(2)	3	3

PS25C01	Distributed Generation and Micro-Grids	L	T	P	C
		3	0	0	3

Course Objectives:
This course aims to

- Understand the planning and operational issues related to Distributed Generation
- Understand various configurations of Micro-grids
- Analyse the various operating conditions of Micro-grids with and without DGs
- Evaluate the technical, economic, and regulatory challenges of DG and microgrids.
- Foster skills for planning and designing microgrids in urban and remote settings.

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.
Activity: Analysis of interconnection issues such as voltage rise and harmonics in distribution systems.

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.
Activity: Analysis of interconnection issues such as voltage rise and harmonics in 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.
Activity: Case study: economic analysis and feasibility of a microgrid for a remote village.

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.
Activity: Hands-on lab: Interfacing DG units with grid using dSPACE or similar platform (if available).

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.
Activity: Group project: Proposal for a smart microgrid implementation in a real-world scenario (e.g., hospital, university, EV charging hub).

Assessment 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		
References:		
<ol style="list-style-type: none"> 1. H. Lee Willis, Walter G. Scott, 'Distributed Power Generation – Planning and Evaluation', Marcel Decker Press, 2000. 2. M. Godoy Simoes, 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	PO Mapping	PSO1	PSO2
CO1	Understand the current scenario and need for the implementation of DGs.	PO1 (2) PO2 (2) PO3 (3)	3	3
CO2	Investigate the types of interfaces and control schemes for the grid integration of DGs	PO1 (3) PO2 (1) PO3 (3)	3	3
CO3	Evaluate the technical and economic impacts of DGs	PO1 (3) PO2 (2) PO3 (3)	3	3
CO4	Understand different configurations of micro-grid and its modelling.	PO1 (3) PO2 (2) PO3 (3)	3	3
CO5	Evaluate the economic viability and regulatory implications of DG and microgrids.	PO1 (2) PO2 (2) PO3 (3)	3	3

PS25C02	FACTS		L	T	P	C
			3	0	0	3
<p>Course Objectives:</p> <ul style="list-style-type: none"> ➤ 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. 						
<p>Introduction to FACTS and Power Flow Control Overview of power system stability and control needs- Basic types of FACTS controllers: series, shunt, and combined- Benefits and challenges in implementing FACTS devices- Power flow control and voltage regulation using FACTS Activity: Modeling of SVC and STATCOM in MATLAB/Simulink for reactive power control. Static VAR Compensator (SVC) and STATCOM SVC: Configuration, operating principles, and characteristics- STATCOM: V-I characteristics, control strategies, dynamic performance- Comparison between SVC and STATCOM- Reactive power compensation and voltage support. Activity: Simulation of power flow enhancement using TCSC and UPFC in PSCAD. Series Compensation using TCSC and SSSC Thyristor Controlled Series Capacitor (TCSC): operation and control- Sub-Synchronous Resonance (SSR) and mitigation using TCSC- Static Synchronous Series Compensator (SSSC): features and advantages- Power flow control and damping of oscillations using series controllers. Activity: Comparative analysis of series vs shunt compensation using case study data. Unified Power Flow Controller (UPFC) and IPFC Basic operation and control of UPFC- Power flow control using UPFC: modeling and simulation- Interline Power Flow Controller (IPFC): structure and advantages- Control interactions and coordination with other devices. Activity: Case study analysis of grid stability improvement using FACTS in Indian or global power networks. Modeling, Simulation, and Application of FACTS Mathematical modeling and steady-state analysis of FACTS- Dynamic modeling and simulation using MATLAB/Simulink, PSCAD- Integration of FACTS in transmission networks- Case studies and future trends in FACTS deployment Activity: Integrated control scheme using multiple FACTS devices for power system enhancement.</p>						
Weightage:	Continuous Assessment: 40%		End Semester Theory Examination: 60%			
	I. Activities: 10%					
		II. Internal Theory Examinations: 30%				
<p>Mandated Activities with marks: Assignments (30), Quiz (10), Virtual demonstration (25), Flipped Classroom (10), Review of GATE & IES questions (25).</p>						
<p>Internal Examinations: TWO tests</p>						
<p>References:</p> <ol style="list-style-type: none"> 1. Narain G. Hingorani and Laszlo Gyugyi, 'Understanding FACTS: Concepts and Technology of Flexible AC Transmission Systems', IEEE Press, 2000. - Foundational book on theory and practice of FACTS. 						

2. R. Mohan Mathur and Rajiv K. Varma, 'Thyristor-Based FACTS Controllers for Electrical Transmission Systems', Wiley-IEEE Press, 2002. - Practical insight into thyristor-controlled devices.
3. K. R. Padiyar, 'FACTS Controllers in Power Transmission and Distribution', New Age International, 2nd Edition, 2017. - Indian perspective with emphasis on control and system integration.
4. Song, Yong-Hua, and Allan T. Johns, 'Flexible AC Transmission Systems (FACTS)', IET Power and Energy Series, 1999. - Covers research-based insights and advanced control schemes.
5. IEEE/PES Special Publications and Technical Papers on FACTS applications and developments.

	CO Description	PO Mapping	PSO1	PSO2
CO1	Explain the necessity and functioning of FACTS controllers in modern power systems.	-	-	-
CO2	Differentiate between various FACTS devices and analyze their operational characteristics.	PO1 (3) PO2 (1) PO3 (3)	3	3
CO3	Design and model FACTS devices for power flow control and stability enhancement.	PO1 (3) PO2 (2) PO3 (3)	3	3
CO4	Simulate FACTS devices using tools like MATLAB/Simulink or PSCAD.	PO1 (3) PO2 (2) PO3 (3)	3	3
CO5	Apply FACTS technologies to solve real-world power system problems with improved reliability and efficiency.	PO1 (2) PO2 (2) PO3 (3)	3	3

PX25005	NON-LINEAR CONTROL OF POWER ELECTRONIC CIRCUITS		L	T	P	C
			3	0	0	3
Course Objectives:						
<ul style="list-style-type: none"> ➤ 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 of CO	PO	PSO1	PSO2
CO1	Ability to understand, model, and analyse nonlinear systems.	PO1(2) PO2(2) PO4(1)	3	2
CO2	Ability to understand, model, and simulate sliding mode controllers for power converters.	PO1(2) PO2(2) PO3(2) PO5(2)	3	3
CO3	Ability to understand, model, and simulate model predictive controllers for power converters.	PO1(2) PO2(2) PO3(2) PO5(2)	3	3
CO4	Ability to understand, model, and simulate adaptive controllers for power converters.	PO1(2) PO2(2) PO3(2) PO5(2)	3	3

PX25006	NON-LINEAR DYNAMICS IN POWER ELECTRONIC CIRCUITS		L	T	P	C
			3	0	0	3
<p>Course Objectives:</p> <ul style="list-style-type: none"> ➤ 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. 						
<p>BASICS OF NONLINEAR DYNAMICS</p> <p>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.</p>						
<p>TECHNIQUES FOR INVESTIGATION OF NONLINEAR PHENOMENA</p> <p>Techniques for experimental investigation, Techniques for numerical investigation, Computation of averages under chaos, Computations of spectral peaks, Computation of the bifurcation and analyzing stability.</p>						
<p>NONLINEAR PHENOMENA IN DC-DC CONVERTERS</p> <p>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.</p>						
<p>NONLINEAR PHENOMENA IN DRIVES</p> <p>Nonlinear Phenomenon in Current controlled and voltage-controlled DC Drives, Nonlinear Phenomenon in PMSM Drives.</p>						
<p>CONTROL OF CHAOS</p> <p>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.</p>						
Weightage:	Continuous Assessment: 40%		End Semester Theory Examination: 60%			
	(iii).Activities: 10%					
	(iv). Internal Theory Examinations: 30%					

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 of CO	PO	PSO1	PSO2
CO1	Ability to understand, model, and simulate chaotic behavior in power electronic systems.	PO1(2) PO2(2) PO4(1)	3	2
CO2	Ability to investigate the various techniques of nonlinear phenomena.	PO1(2) PO2(2) PO4(1)	3	2
CO3	Ability to analyse the nonlinear phenomena in DC–DC converters.	PO1(2) PO2(2) PO3(2)	3	3
CO4	Ability to analyse the nonlinear phenomena in electrical drives.	PO1(2) PO2(2) PO3(2)	3	3
CO5	Ability to mitigate chaotic behavior noticed in power systems.	PO1(2) PO2(2) PO3(2) PO5(2)	3	3

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	End Semester Theory Examination: 60
	I. Activity :10 II. Internal Assessment: 30	

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 of CO	PO	PSO1	PSO2
CO1	Understand the components, architecture, and operation of smart grids and microgrids.	PO1(2) PO2(2)	3	2
CO2	Understanding of Smart Grid Policies, Standards, and Future Trends.	PO1(2) PO6(1) PO7(1)	2	2
CO3	Illustrate the communication technologies, protocols, and cybersecurity measures used in smart grid systems.	PO1(2) PO3(2) PO5(2)	2	3
CO4	Apply demand side management and advanced metering infrastructure techniques for efficient energy usage.	PO1(2) PO2(2) PO3(2) PO5(2)	3	3
CO5	Demonstrate the working of EV integration, smart charging infrastructure, and analyze future trends and standards.	PO1(2) PO2(2) PO3(2) PO5(2)	3	3

PX25008	Modern Rectifiers and Resonant Converters	L	T	P	C
		3	0	0	3
<p>Course Objectives:</p> <ul style="list-style-type: none"> 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. 					
<p>PWM Rectifiers</p> <p>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.</p> <p>Source Current Shaping of Rectifiers</p> <p>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.</p> <p>Quasi Resonant DC-DC Converters</p> <p>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.</p> <p>Class-D Resonant Converters</p> <p>Introduction – Basic operation of Class-D series resonant converter- parallel resonant converter – series-parallel resonant converter – CLL resonant converter – LLC resonant converter.</p> <p>Dynamic Analysis of Switching Converters</p> <p>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.</p>					
Weightage:	Continuous Assessment: 40%		End Semester Theory Examination: 60%		
	(i). Activities: 10%				
	(ii). Internal Theory Examinations: 30%				
<p>Mandated Activities with marks:</p> <p>Assignments (30), Quiz (10), Virtual demonstration (25), Flipped Classroom (10),</p>					

Internal Examinations: TWO tests**Text Books:**

- ❖ Robert W. Erickson and Dragomir 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 of CO	PO	PSO1	PSO2
CO1	Illustrate the concept of pulse-width modulated rectifier and its characteristics.	PO1(2) PO2(1)	2	2
CO2	Analyse the various source current shaping methods for AC–DC PFC rectifiers.	PO1(2) PO2(2) PO4(1)	3	3
CO3	Demonstrate the concept of quasi-resonant DC–DC converters.	PO1(2) PO3(2) PO5(2)	3	3
CO4	Explain the concept of Class-D resonant power converters.	PO1(2) PO2(2) PO3(2)	3	3
CO5	Analyse the state-space average modelling of DC–DC converters and control methods.	PO1(3) PO2(2) PO3(2) PO5(2)	3	3

PX25009	Soft Computing Techniques	L	T	P	C
		3	0	0	3
Course Objective:					
<p>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.</p>					
Introduction to Soft Computing					
<p>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</p>					
Fuzzy Logic Systems					
<p>Fuzzy Sets and operations, Membership Functions, Linguistic Variables, Fuzzy Rule Base, Inference Mechanisms, Fuzzification and Defuzzification techniques, Fuzzy Controllers in Engineering Systems</p>					
Artificial Neural Networks (ANN)					
<p>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</p>					
Genetic Algorithms (GA) and Evolutionary Techniques					
<p>GA Terminology, Population, Fitness Function, Selection, Crossover, Mutation Techniques, Convergence and elitism, Applications in Optimization and Scheduling, Other Evolutionary Algorithms: DE, PSO basics</p>					
Hybrid Soft Computing Systems and Case Studies					
<p>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</p>					
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. Pratihari (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 of CO	PO	PSO1	PSO2
CO1	Understand and explain the fundamental concepts of soft computing and its components.	-	-	-
CO2	Design and implement fuzzy logic systems for intelligent control and decision-making.	PO1(2) PO3(2) PO5(1)	3	3
CO3	Develop neural network models for solving real-world problems.	PO1(2) PO3(2) PO5(2)	3	3
CO4	Apply genetic algorithms and other evolutionary approaches for optimization in engineering problems.	PO1(2) PO3(2) PO5(2)	3	3
CO5	Understand how different soft computing techniques can work together and simulate basic models using MATLAB/Simulink.	PO1(2) PO3(2) PO5(2)	3	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%	End Semester Theory Examination: 40%
	i. Activities: 15% ii. Internal Theory Examinations: 30% iii. Internal Laboratory Examinations: 15%	
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 of CO	PO	PSO1	PSO2
CO1	Analyze and compare the performance characteristics of conventional two-level and multilevel inverter topologies.	PO1(2) PO2(2)	3	3
CO2	Employ appropriate modulation technique(s) for a given multilevel inverter.	PO1(2) PO3(2) PO5(2)	3	3
CO3	Evaluate application-specific merits and limitations of various topologies of multilevel power inverters.	PO1(2) PO2(2) PO3(2)	3	3
CO4	Investigate recent advancements/patents/industry applications in MLI technology and effectively communicate the findings through technical reports and/or presentations.	PO1(2) PO2(2) PO4(2) PO10(2)	2	3

PX25011	GRID INTEGRATION OF RENEWABLE ENERGY SOURCES		L	T	P	C
			3	0	0	3
Course Objectives:						
<ul style="list-style-type: none"> ➤ 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 						
INTRODUCTION						
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 inverter-based 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 of CO	PO	PSO1	PSO2
CO1	Know about the integration of various renewable energy sources into the grid.	PO1(2) PO2(2)	3	2
CO2	Able to analyze various grid issues due to renewable energy sources.	PO1(2) PO2(2) PO4(1)	3	3
CO3	Able to analyze the dynamics of network due to wind farm.	PO1(2) PO2(2) PO4(1)	3	3
CO4	Know about power system stabilizers.	PO1(2) PO2(2) PO3(1)	2	3
CO5	Able to design the grid-connected and standalone PV system.	PO1(2) PO2(2) PO3(2) PO5(2)	3	3

PX25C03	POWER QUALITY	L	T	P	C
		3	0	0	3
Course Objective:					
<ul style="list-style-type: none"> 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 Examination: 60%	Theory	
	(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 of CO	PO	PSO1	PSO2
CO1	Understand different types of power quality problems with their sources of generation.	PO1(2) PO2(2)	3	2
CO2	Interpret and analyse the results of power quality monitoring equipment.	PO1(2) PO2(2) PO4(1)	3	3
CO3	Develop different methodologies for detection and classification of power quality problems.	PO1(2) PO3(2) PO5(2)	3	3
CO4	Interpret and analyse the results of power quality monitoring equipment.	PO1(2) PO2(2) PO4(1)	3	3

PX25012	LINEAR SYSTEM THEORY	L	T	P	C
		3	0	0	3
<p>Course Objectives:</p> <p>To understand the concept of state space and to obtain the state space model.</p> <p>To obtain the solution of state equations in both continuous and discrete domains.</p> <p>To test controllability and observability of systems</p> <p>To design state controller and observer using pole-placement technique.</p> <p>To analyze stability of a systems using Lyapunov criterion</p>					
<p>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.</p> <p>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.</p> <p>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.</p> <p>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.</p> <p>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.</p>					
Weightage:	Continuous Assessment: 40%		End Semester Theory Examination: 60%		
	i. Activities: 10% ii. Internal Theory Examinations: 30%				

<p>Mandated Activities with marks:</p> <p>Assignments (30), Quiz (10), Virtual demonstration (25), Flipped Classroom (10),</p>
<p>Internal Examinations: TWO tests</p>
<p>References:</p> <ol style="list-style-type: none"> 1. Katsuhiko Ogata, 'Modern Control Engineering', Fifth Edition, Prentice-Hall of India, 2015. 2. Nagarath and M. Gopal, 'Control System Engineering', Eighth Edition, New Age International, 2024. 3. Benjamin C. Kuo and Farid Golnaraghi, 'Automatic Control Systems', Eighth Edition, John Wiley & Sons, 2017. 4. Chen CT, "Linear System Theory and Design", Fourth Edition, Oxford University Press, 2014.
<p>E-resources:</p> <ol style="list-style-type: none"> 1. https://archive.nptel.ac.in/courses/107/106/107106081/ 2. https://archive.nptel.ac.in/courses/108/106/108106098

CO	Description of CO	PO	PSO1	PSO2
CO1	Understand the concept of state space and obtain the state space model.	PO1(2) PO2(2)	3	2
CO2	Solve the state equations in both continuous and discrete domains.	PO1(2) PO2(2) PO5(1)	3	3
CO3	Understand and test controllability and observability of systems.	PO1(2) PO2(2) PO3(1)	3	3
CO4	Design state controller and observer using pole-placement technique.	PO1(2) PO2(2) PO3(2) PO5(2)	3	3
CO5	Analyze stability of a system using Lyapunov criterion.	PO1(2) PO2(2) PO4(1)	3	3

PX25013	Special Electrical Machines	L	T	P	C
		3	0	0	3
Course Objective:					
<p>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.</p>					
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					
Weightage:	Continuous Assessment: 60%		End Semester Examination: 40%	Theory	
	I. Activities: 15%	II. Internal Theory Examinations: 30%			
	III. Internal Laboratory Examinations: 15%				

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 of CO	PO	PSO1	PSO2
CO1	Articulate construction, operating principles, and electromagnetic behaviour of electrical machines	PO1(3) PO2(2)	3	2
CO2	Develop and solve dynamic machine models	PO1(3) PO2(3) PO3(2)	3	3
CO3	Apply control strategies to enhance the precision and efficiency of drive systems	PO1(3) PO2(2) PO3(3) PO5(3)	3	3
CO4	Specify and size power-electronic converters	PO1(3) PO3(3) PO5(3)	3	3
CO5	Develop research capability to innovate for next-generation drive systems	PO1(3) PO3(3) PO4(2) PO5(2)	3	3

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%	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. 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 of CO	PO	PSO1	PSO2
CO1	Understand the working of voltage lift converters.	PO1(2) PO2(1)	2	2
CO2	Understand the operation of super lift and ultra-lift Luo converters.	PO1(2) PO2(2)	3	2
CO3	Design the bidirectional dual active bridge DC–DC converters.	PO1(2) PO2(2) PO3(2) PO5(2)	3	3
CO4	Design the voltage-fed and current-fed impedance source converters.	PO1(2) PO2(2) PO3(2)	3	3

		PO5(2)		
CO5	Describe the working of multilevel inverters and understand various modulation techniques.	PO1(2) PO2(2) PO3(2)	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.

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. 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, Elsevier, 2015.
4. D. Linden and T. B. Reddy – Handbook of Batteries, McGraw-Hill, 2002.

E-Resources:

❖ <https://standards.ieee.org>

CO	Description of CO	PO	PSO1	PSO2
CO1	Understand the battery principles, electrochemistry, and evaluate chemistries for applications.	PO1(2) PO2(1)	3	2
CO2	Understand the modelling of batteries considering electrical, thermal, and aging behavior.	PO1(2) PO2(2) PO5(1)	3	3
CO3	Design BMS with appropriate architecture and protection mechanisms.	PO1(2) PO2(2) PO3(2) PO5(2)	3	3
CO4	Apply estimation and cell balancing techniques in BMS systems.	PO1(2) PO2(2) PO3(2) PO5(2)	3	3
CO5	Demonstrate integration of BMS in EVs and apply relevant standards.	PO1(2) PO2(2) PO3(2) PO5(2)	3	3

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

Activities:

Quiz on BEV, HEV, PHEV, FCEV features

Team design activity: Design its architecture (battery, motor, converter, controller layout)

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

Activities:

Group Discussion/Debate: Types of electric motors used in EVs (Pros/cons in EVs ,Torque-speed curve sketch ,strengths/limitations and real-world use of each motor.)

Simulation:Run and observe simulations for **Field-Oriented Control (FOC) vs. Direct Torque Control (DTC)**

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

Activities:

Technical seminar: Compare Li-ion, NiMH, and Lead-acid batteries based on key parameters

Modelling: Estimate required battery size, discharge rate, and range for an EV

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

Activities:

Simulation: Simulation or flowchart design during drive and regenerative braking (e.g., motor ↔ battery ↔ grid)

Group Discussion/Debate:Compare AC charging vs DC fast charging (e.g., speed, efficiency, cost, grid impact)

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

Activities:

Case Study:Analyze and optimize power flow between battery, motor, regenerative braking, and auxiliary systems during different drive conditions

Team design activity: Propose an EV charging solution using solar/wind, including storage and grid backup.

Assessment Weightage: Internal Assessment 1 – 15%; Internal Assessment 2 – 15%; Digital Assignments/Simulations (minimum 2) – 10%; Final Assessment – 60%

References:

1. “Advanced Electric Drive Vehicles”, Authors: Ali Emadi, MehrdadEhsani, 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. SaberFallah, AvestaGoodarzi, Publisher:Wiley, Published Year:2014

CO	Description of CO	PO	PSO1	PSO2
CO1	Understand the architecture of EV powertrains and identify the role of various subsystems in power and energy flow management.	PO1 (2) PO2 (2) PO3 (3)	3	3
CO2	Analyze battery systems, charging infrastructure, and battery management techniques to ensure safety, efficiency, and longevity of EVs.	PO1 (3) PO2 (1) PO3 (3)	3	3
CO3	Apply power electronics converters and control strategies for energy conversion, bidirectional charging, and regenerative braking in electric vehicles.	PO1 (3) PO2 (2) PO3 (3)	3	2
CO4	Evaluate real-time power management strategies under different driving conditions using performance metrics such as efficiency, thermal stability, and cost-effectiveness.	PO1 (3) PO2 (2) PO3 (3)	3	3
CO5	Design intelligent energy management systems using rule-based, fuzzy logic, and optimization-based algorithms for hybrid and battery electric vehicles.	PO1 (2) PO2 (2) PO3 (3)	3	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 of CO	PO	PSO1	PSO2
CO1	Ability to understand the basic PCB design and CAD tool.	PO1(2) PO2(1)	2	2
CO2	Ability to understand the product architecture and layout development.	PO1(2) PO2(2)	3	2
CO3	Ability to understand the safety concerns and high voltage design suitability for industrial applications.	PO1(2) PO2(2) PO6(1)	3	2
CO4	Ability to design for manufacturing and product development with EMI & EMC filters.	PO1(2) PO2(2) PO3(2) PO5(2)	3	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. - <i>Power Electronics: Circuits, Devices & Applications, Princeton Publications,2021</i>					

❖ **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 Publications, 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 of CO	PO	PSO1	PSO2
CO1	A review of industrial applications of power electronics.	PO1(2) PO2(1)	3	2
CO2	Demonstrate the implementation of AI techniques in power electronics applications.	PO1(2) PO3(2) PO5(2)	3	3
CO3	Demonstrate AI-based condition monitoring of power electronics systems.	PO1(2) PO2(2) PO3(2) PO5(2)	3	3
CO4	Understand AI-based renewable integration and smart grids.	PO1(2) PO2(2) PO3(1) PO5(2)	3	3

ET25C03	PYTHON PROGRAMMING FOR MACHINE LEARNING	L	T	P	C
		3	0	0	3
<p>Course objectives:</p> <ul style="list-style-type: none"> To understand and apply fundamental Python programming concepts including control structures, functions, recursion, and basic data structures. To develop skills in handling data using lists, dictionaries, files, and images, and in implementing programs using Python. To introduce machine learning concepts and enable students to formulate and implement basic machine learning solutions using Python through practice and exercises. 					
<p>Introduction to Machine Learning and Python: Introduction to Machine Learning: Significance, Advantage and Applications – Categories of Machine Learning – Basic Steps in Machine Learning: Raw Data Collection, Pre-processing, Training a Model, Evaluation of Model, Performance Improvement</p> <p>Introduction to Python and its significance – Difference between C, C++ and Python Languages; Compiler and Interpreters – Python3 Installation & Running – Basics of Python Programming Syntax: Variable Types, Basic Operators, Reading Input from User – Arrays/List, Dictionary and Set – Conditional Statements – Control Flow and loop control statements</p> <p>Activities: Write a simple Python program and map the steps of a machine learning workflow using a real-world example.</p>					
<p>Python Functions and Packages: File Handling: Reading and Writing Data – Errors and Exceptions Handling – Functions & Modules – Package Handling in Python – Pip Installation & Exploring Functions in python package – Installing the Numpy Library and exploring various operations on Arrays: Indexing, Slicing, Multi-Dimensional Arrays, Joining Numpy Arrays, Array intersection and Difference, Saving and Loading Numpy Arrays – Introduction to SciPy Package & its functions - Introduction to Object Oriented Programming with Python</p> <p>Activities: Perform file handling and array operations using NumPy and SciPy on a sample dataset.</p>					
<p>Implementation of Machine Learning using Python: Description of Standard Datasets: Coco, ImageNet, MNIST (Handwritten Digits) Dataset, Boston Housing Dataset – Introducing the concepts of Regression – Linear, Polynomial & Logistic Regression with analytical understanding - Introduction to SciPy Package & its functions – Python Application of Linear Regression and Polynomial Regression using SciPy – Interpolation, Overfitting and Underfitting concepts & examples using SciPy.</p> <p>Activities: Implement and compare linear and polynomial regression models using a standard dataset.</p>					
<p>Classification and Clustering Concepts: Introduction to ML Concepts of Clustering and Classification – Types of Classification Algorithms – Support Vector Machines (SVM) - Decision Tree - Random Forest – Introduction to ML using scikit-learn – Using scikit-learn, loading a sample dataset, Learning & prediction, interpolation & fitting, Multiclass fitting - Implementation of SVM using Blood Cancer Dataset, Decision Tree using data from csv.</p>					

Types of Clustering Algorithms & Techniques – K-means Algorithm, Mean Shift Algorithm & Hierarchical Clustering Algorithm – Introduction to Python Visualization using Matplotlib: Plotting 2- dimensional, 3-dimensional graphs; formatting axis values; plotting multiple rows of data in same graph – Implementation of K-means Algorithm and Mean Shift Algorithm using Python.

Activities: Train a classification model and perform clustering on a dataset, then visualize the results using Matplotlib.

Introduction to Neural Networks and Embedded Machine Learning: Introduction to Neural Networks & Significance – Neural Network Architecture – Single Layer Perceptron & Multi-Layer Perceptron (MLP) – Commonly Used Activation Functions - Forward Propagation, Back Propagation, and Epochs – Gradient Descent – Introduction to Tensorflow and Keras ML Python packages – Implementation of MLP Neural Network on Iris Dataset – Introduction to Convolution Neural Networks – Implementation of Digit Classification using MNIST Dataset

ML for Embedded Systems: Comparison with conventional ML – Challenges & Methods for Overcoming – TinyML and Tensorflow Lite for Microcontrollers – on-Board AI – ML Edge Devices: Arduino Nano BLE Sense, Google Edge TPU and Intel Movidius.

Activities: Build a simple neural network for digit classification and discuss its deployment on an edge device.

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

Assessment Methodology: Quiz (10%), Assignments (40%), Internal Examinations (50%)

References:

1. Mark Lutz, "Learning Python, Powerful OOPs,O'reilly,2011
2. Zelle, John "M. Python Programming: An Introduction to Computer Science.", Franklin Beedle& Associates, 2003
3. Andreas C. Müller, Sarah Guido, "Introduction to Machine Learning with Python", O'Reilly,2016
4. Sebastian Raschka , VahidMirjalili, "Python Machine Learning - Third Edition", Packt, December 2019.

	Description of CO	PO	PSO
CO1	Explain basic machine learning concepts, workflows, and implement fundamental Python programs.	-	-
CO2	Use Python functions, packages, and numerical libraries to process and analyze data.	PO1(3) PO2(2) PO3(2)	PSO1(3) PSO2(2)
CO3	Implement regression models and analyze overfitting and underfitting using standard datasets.	PO1(3) PO2(3) PO3(3)	PSO1(3) PSO2(2)
CO4	Apply classification and clustering algorithms using scikit-learn and visualize results.	PO1(3) PO2(3) PO3(3) PO5(3)	PSO1(2) PSO2(3)
CO5	Develop basic neural network models and understand embedded machine learning and TinyML concepts.	PO1(2) PO2(2) PO3(3) PO4(2)	PSO1(3) PSO2(3)

ET25C02	MACHINE LEARNING AND DEEP LEARNING	L	T	P	C
		3	0	0	3
<p>Course objectives:</p> <ul style="list-style-type: none"> • Familiarizing students with the fundamental concepts of machine learning and neural networks. • Enabling students to acquire knowledge about pattern recognition. • Motivating the students to apply deep learning algorithms for solving real life problems. 					
<p>Foundations of Machine Learning in Embedded System: Various paradigms of learning problems, Forms of Learning: Supervised, Semi-supervised, and Unsupervised algorithms, Reinforcement Learning, Machine Learning Terminologies and Model Evaluation: Confusion Matrix, Accuracy, Precision, Recall, F1-Score, the curse of dimensionality, training, testing, validation, cross-validation, overfitting, underfitting, early stopping, regularization, bias and variance, Introduction to TinyML and Edge AI, Challenges in real-time ML deployment: latency, memory, and power.</p> <p>Activities: Students analyze a small dataset and compute accuracy, precision, recall, and F1-score using a confusion matrix, then discuss overfitting vs underfitting.</p>					
<p>Advanced Machine Learning Techniques: Feature Engineering, Dimensionality Reduction, Classifiers: K-Nearest Neighbour (KNN), Support Vector Machine (SVM), Decision Trees, Naïve Bayes, Binary Classification, Multi-class Classification, Clustering, Ensemble learning, Meta Learning, Foundation to Quantum Machine Learning, Low-power classification methods for Embedded controllers.</p> <p>Activities: Implement and compare KNN and SVM classifiers on a low-dimensional dataset to observe accuracy vs memory trade-offs for embedded systems.</p>					
<p>Neural Networks and Model Training: Differences between Biological and Artificial Neural Networks - General Architecture, Multi-layer neural network, Linear Separability, Hebb Net, Perceptron, Adaline, Standard Back propagation, Training Algorithms for Pattern Association - Hebb rule and Delta rule, Hetero associative, Auto associative, Kohonen Self Organising Maps, Learning Vector Quantization, Gradient descent, Boltzmann Machine Learning, Model training vs inference on embedded systems, Lightweight Neural Network deployment strategies -quantization and pruning</p> <p>Activities: Train a simple perceptron or small neural network and apply quantization to compare model size and inference accuracy.</p>					
<p>Deep Learning Architectures: Convolutional Neural Networks: Convolution layers, Pooling layers, Fully connected layers, Advanced CNN models: Alexnet, VGGnet, ResNet, Google net, Handling overfitting in CNN: drop out, transfer learning, data augmentation, Recurrent Neural Networks and Autoencoders, State, Structure of RNN Cell, LSTM and GRU, Time Distributed Layers, Autoencoders: Convolutional Autoencoders, Denoising</p>					

Autoencoders, Variational Autoencoders, Lightweight DL architectures for embedded systems: SqueezeNet, MobileNetV3, and Tiny-YOLO.

Activities: Fine-tune a lightweight CNN (MobileNet or SqueezeNet) on a small image dataset and evaluate inference speed and accuracy.

Generative Models, Deployment and Real-World Applications: Generative Adversarial Networks (GANs): The Discriminator, Generator, Deep Convolutional GANs (DCGANs), Introduction to BERT Transformer, Real-world applications in NLP, Computer Vision, Healthcare, and Finance, Fundamentals of Federated Learning, Federated Learning in IoT-based embedded networks, Deployment frameworks: TensorFlow Lite, PyTorch Mobile.

Activities: Deploy a pre-trained TensorFlow Lite or PyTorch Mobile model on an edge device or emulator and measure latency and memory usage.

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

Assessment Methodology: Quiz (10%), Assignments (40%), Internal Examinations (50%)

References:

1. ShaiShalev-Shwartz and Shai Ben-David, "Understanding Machine Learning", 1st Edition, Cambridge University Press, 2017.
2. Ian Good fellow, Yoshua Bengio and Aaron Courville, "Deep Learning", MIT Press,2016.
3. J. S. R. Jang, C. T. Sun, E. Mizutani, "Neuro Fuzzy and Soft Computing - A Computational Approach to Learning and Machine Intelligence",1st Edition, PHI learning, 2012.
4. Trevor Hastie, Robert Tibshirani and Jerome Friedman, "The Elements of Statistical Learning",2nd Edition, Springer Series, 2009.
5. P. Warden and D. Situnayake , "TinyML: Machine Learning with TensorFlow Lite on Arduino and Ultra-Low-Power Microcontrollers", O'Reilly Media Publishers, 2020.
6. Christopher M. Bishop and Hugh Bishop, Deep Learning: Foundations and Concepts, Springer Nature, 2023
7. Christopher M. Bishop, Pattern Recognition and Machine Learning, Springer,2016.

	Description of CO	PO	PSO
CO1	Evaluate different paradigms of machine learning to determine their suitability for embedded systems.	PO1(3) PO2(3) PO3(2) PO5(2)	PSO1(2) PSO2(1)
CO2	Interpret the architecture and training mechanisms of neural network models suitable for embedded deployment.	PO1(3) PO2(2) PO3(2) PO4(2)	PSO1(2) PSO2(2)
CO3	Apply feature selection, dimensionality reduction, and classification techniques for efficient pattern recognition.	PO1(3) PO2(3) PO3(3)	PSO1(3) PSO2(2)
CO4	Analyze the design and performance of deep learning models including CNNs, RNNs, and autoencoders in embedded systems.	PO1(3) PO2(3) PO3(3) PO5(2)	PSO1(3) PSO2(3)
CO5	Demonstrate the use of generative models and deployment frameworks in real-world embedded machine learning applications.	PO1(2) PO2(3) PO3(3)	PSO1(2) PSO2(3)

ET25C01	IoT For Smart Systems	L	T	P	C
		3	0	0	3
Course objectives: <ul style="list-style-type: none"> Understand IoT technologies, architectures, and communication methods. Learn about embedded processors, sensors, and IoT platforms. Explore IoT applications, data analytics, and security aspects. 					
Introduction to Internet of Things: Definition, elements, and characteristics of IoT. Architectural stack, enabling technologies, challenges, and hardware platforms like Arduino, Raspberry Pi, and ESP boards. Activities: Students explore the definition, elements, architecture, and hardware platforms of IoT by designing a small-scale IoT prototype using embedded boards.					
IoT Architecture: Reference models and architectures, node structure (sensing, processing, communication, power). Networking topologies, IoT standards, cloud and fog computing, and Bluetooth-based solutions. Activities: Case study to construct a IoT reference architectures and node structure					
Protocols And Wireless Technologies for IoT : Overview of protocols: NFC, SCADA, RFID, Zigbee, MIPI family, GSM/CDMA, LTE, and 5G small cells. Wireless standards for IoT including WiFi, Bluetooth, ZigBee, UWB, LoRa, 6LoWPAN, Thread vs. Matter, and proprietary systems. Activities: Group activity to perform the selection of protocols for a typical use case.					
IoT Subsystems: IoT services and attributes: analytics, dependability, interoperability, security, and maintainability. Platforms for data analytics, visualization, virtualization, and IoT application development with emphasis on privacy and security. Activities: Compare the performance of various data analytics & visualization tools.					
Case Studies: Applications of IoT in industrial systems, smart homes, cities, grids, vehicles, EV charging, agriculture, environment, productivity, and defense. Activities: Each student group can prepare a short report/presentation on different use cases.					
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: <ol style="list-style-type: none"> Bahga, A., & Madiseti, V. (2015). <i>Internet of things: A hands-on approach</i>. Universities Press. Greengard, S. (2015). <i>The internet of things</i>. The MIT Press. Raj, P., & Raman, A. C. (2017). <i>The internet of things: Enabling technologies, platforms, and use cases</i>. CRC Press. Cirani, S., Ferrari, G., Picone, M., & Veltri, L. (2018). <i>Internet of things: Architectures, protocols and standards</i>. Wiley. Madiseti, V., & Bahga, A. (2014). <i>Internet of things: A hands-on approach</i>. 					

	Description of CO	PO	PSO
CO1	Explain IoT fundamentals, ecosystem, and technologies.	PO1(1) PO2(2) PO3(1)	PSO1(3) PSO2(1)
CO2	Analyze IoT architectures, nodes, and standards.	PO1(2) PO2(1) PO3(1)	PSO1(3) PSO2(1)
CO3	Evaluate IoT protocols, wireless tech, and trends.	PO1(3) PO2(1) PO3(2)	PSO1(2) PSO2(3)
CO4	Integrate IoT subsystems in application development.	PO1(2) PO2(1) PO3(2)	PSO1(3) PSO2(2)
CO5	Examine IoT case studies for innovative solutions.	PO1(3) PO2(3) PO3(2)	PSO1(1) PSO2(3)