PROPOSED COURSE STRUCTURE AND SYLLABI (NEP 2020)

M.TECH (TWO YEARS COURSE)

DEPARMENT OF ELECTRICAL ENGINEERING (EE),

INDIAN INSTITUTE OF ENGINEERING SCIENCE AND TECHNOLOGY (IIEST), SHIBPUR, HOWRAH

MAY 2025

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M.Tech in Control and Industrial Automation (CIA)
Course Structure

		First Semester							
Sl. No.	**Type**	**Course Name**	**Course code**	**Class Load/Week**			**Credit**	**Class load/ week**	**Marks**
				L	**T**	**P**			
1	PC	Applied Linear and Nonlinear Control	EE5101N	3	0	0	3	3	100
2	PC	Industrial Automation	EE5102N	3	0	0	3	3	100
3	PC	Industrial Instrumentation and Process Control	EE5103N	3	0	0	3	3	100
4	PSE (any one)	1. Optimization and Optimal Control 2. Theory of Discrete and Digital Control Systems 3. High Voltage Systems 4. Power system Reliability and Load Forecasting 5. Advanced Microcontroller Technology 6. Power Quality	EE5121 N EE5122 N EE5123 N EE5124 N EE5125 N EE5126 N	3	0	0	3	3	100
5	OE	High-Performance Computation (HPC) Using CPU and GPU for AI Applications	EE5161 N	3	0	0	3	3	100
		Theory Sub-total		**15**	**0**	**0**	**15**	**15**	**500**
6	PC	Lab/Mini Project on Applied Linear and Nonlinear Control	EE5171 N	0	0	3	2	3	50
7	PC	Lab/Mini Project on Industrial Automation	EE5172 N	0	0	3	2	3	50
8	PC	Lab/Mini Project on Industrial Instrumentation and Process Control	EE5173 N	0	0	3	2	3	50
		Practical Sub-total		**0**	**0**	**9**	**6**	**9**	**150**
		First Semester Total		**15**	**0**	**9**	**21**	**24**	**650**

	-	***Second Semester***							
Sl. No.	**Type**	**Course Name**	**Course code**	**Class Load/Week**			**Credit**	**Class load/ week**	**Marks**
				L	**T**	**P**			
1	PC	Identification and Data Driven Control	EE5201 N	3	0	0	3	3	100
2	PC	Intelligent Control Systems	EE5202 N	3	0	0	3	3	100
3	PC	Optimal Filtering & Stochastic Processes	EE5203 N	3	0	0	3	3	100
4	PSE (any one)	1. Elements of Cyber Physical Systems 2. Networked & Distributed Control 3. Restructured Power Systems 4. Smart Grid Technologies and Energy Informatics 5. Special Electrical Machines 6. Power Electronic Converters for Bulk Power Conditioning	EE5221 N EE5222 N EE5223 N EE5224 N EE5225 N EE5226 N	3	0	0	3	3	100
5	OE	Power Supplies for Electrical Equipment	EE5262 N	3	0	0	3	3	100
		Theory Sub-total		**15**	**0**	**0**	**15**	**15**	**500**
6	P	M.Tech. project/Term-paper	EE5291 N	0	0	3	2	3	50
7	O	Seminar/Viva Voce	EE5292 N	0	0	3	2	3	50
		Practical Sub-total		**0**	**0**	**6**	**4**	**6**	**100**
		Second Semester Total		**15**	**0**	**6**	**19**	**21**	**600**

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		Third Semester							
Sl. No.	**Type**	**Course Name**	**Course code**	**Class Load/Week**			**Credit**	**Class load/ week**	**Marks**
				L	**T**	**P**			
1	**VAC**	Energy Audit	EE 6101	3	0	0	3	3	100
2	P	M. Tech. Thesis	EE6191 N				12	24	300
3	O	Progress Seminar and Viva-voce	EE6192 N				6		100
4	I	Summer internship (6-8 weeks) evaluation	EE6193 N				2		50
		Third Semester Total					**23**		**550**

		Fourth Semester							
Sl. No.	**Type**	**Course Name**	**Course code**	**Class Load/Week**			**Credit**	**Class load/ week**	**Marks**
				L	**T**	**P**			
1	P	M. Tech. final thesis	EE6291 N				22	30	400
2	O	Thesis Seminar and Viva-voce	EE6292 N				8		200
		Fourth Semester Total					**30**		**600**

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1st Semester
M.Tech in Control and Industrial Automation (CIA)

Course Code	**EE 5101 N**	Course Name	**Applied Linear and Nonlinear Control**	Course Category	**PC**	L	T	P
						3	0	0

Pre-requisite Courses	**Under graduate Control Systems**	Co-requisite Courses	*Nil*	Progressive Courses	*Adaptive Control, Robust Control, Geometric Control*
Course Offering Department		***Electrical Engineering***		Data Book / Codes/Standards	*Nil*

Course Objectives	1. To develop a strong foundation in applying linear and nonlinear control techniques for physical systems. 2. To develop mathematical models of dynamical systems, study their responses, and analyze system-theoretic properties. 3. To enable students to design various types of controllers for physical systems. 4. To introduce the distinctive features of nonlinear systems, and develop tools for analyzing them. 5. To introduce advanced control strategies for nonlinear systems.

Module	**Syllabus**	**Duration (class-hours)**	**Module Outcomes**
I.	**Recapitulation of Linear System:** State Variable modelling and Transfer Function	**3**	Understand modelling of physical systems using transfer functions and state-space approach.
II.	**Time response of systems:** Homogeneous and non-homogeneous case	**3**	Determine time response of homogeneous and non-homogeneous systems.
III.	**Analysis of linear systems:** Stability, Controllability and observability	**3**	Analyze and check system properties like stability, controllability, and observability.
IV.	**Synthesis:** Linear State Variable Feedback Control, State observers	**4**	Design state-feedback controllers. Design state observers.
V.	**Design of classical controllers, LQR control**	**5**	Design lead, lag, lead-lag, PID controllers. Design LQR controllers.
VI.	**Case Studies** – Controller design of Physical Systems	**4**	Perform modelling, analysis and controller design for physical systems.

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VII.	**Mathematical background for nonlinear systems.**	3	Understand mathematical preliminaries required for nonlinear systems.
VIII.	**Examples** of physical nonlinear systems. Notion of equilibrium points, Essential nonlinear phenomenon like finite escape time, multiple isolated equilibria, chaos, limit cycles, etc., Linearization.	3	Understand models of physical nonlinear systems and their nonlinearities. Perform Jacobian linearization.
IX.	**Analysis of nonlinear systems:** Second-order systems, phase-plane portrait, invariant sets. Classification of equilibrium points.	4	Perform analysis of second order nonlinear systems.
X.	**Stability Analysis:** Asymptotic, global asymptotic, exponential, input-to-state (ISS) and instability. Lyapunov's direct and indirect method, invariance principle. Construction of Lyapunov functions.	5	Perform stability analysis of nonlinear systems using Lyapunov theory.
XI.	**Introduction to nonlinear design methods:** feedback linearization, sliding mode control. **Case studies.**	5	Perform design of advanced controllers for nonlinear systems.
	TOTAL	**42**	

Course Outcomes	The students *shall* be able to, 1.Develop linear and nonlinear dynamic models for physical systems. 2.Apply tools from linear systems theory to determine (i) time response of systems, (ii) stability of systems, and (iii) controllability and observability of systems. 3.Design classical and advanced controllers for physical systems. 4.Perform analysis of nonlinear systems using Lyapunov methods. 5.Design advanced controllers for nonlinear systems.

Learning Resources	1. I. J. Nagrath and M. Gopal, Control Systems Engineering, New Age International Publishers, 8th ed. 2024 2. K. Ogata, Modern Control Engineering, Pearson, 5th ed. 2015 3. C.T. Chen, Linear Systems Theory and Design, Oxford University Press, 3rd ed. 1999 4. H. K. Khalil, Nonlinear Systems, Pearson, 3rd ed. 2014 5. H. J. Marquez, Nonlinear Control Systems, Wiley, 2003 6. C. Edwards and S. K. Spurgeon, Sliding Mode Control: Theory and Application, CRC Press, 1998

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Course Code	**EE5102 N**	Course Name	**Industrial Automation**	Course Category	**PC**	L	T	P
						3	0	0

Pre-requisite Courses	**Undergraduate Control Systems, Instrumentation, Digital Logic and Microprocessors, Programming Basics (C, Ladder Logic, etc.)**	Co-requisite Courses	**Industrial Instrumentation, Industrial Communication Networks**	Progressive Courses	**Robotics and Automation,Process Control and Instrumentation, Safety Instrumented Systems, and Industrial Safety**
Course Offering Department		***Electrical Engineering***		Data Book / Codes/Standards	***IEC 61131-3, IEC 61158,ISA 101.01,IEC 61508, ISO 10218***

Course Objectives	
	1. To introduce the concept, types, levels, and components of industrial automation. 2. To impart knowledge on the architecture, programming, and application of Programmable Logic Controllers (PLCs). 3. To familiarize students with SCADA and DCS systems, their communication protocols, architecture, and applications. 4. To develop understanding of industrial communication networks, safety standards, and cyber-security measures. 5. To enable students to understand the structure, kinematics, dynamics, and motion analysis of industrial robots. 6. To explain different types of end effectors, sensors, actuators, and mobile robots used in industrial automation. 7. To formulate the SLAM algorithm in mobile robots for industrial automation.

Module	**Syllabus**	**Duration (class-hours)**	**Module Outcomes**
I.	**Introduction to Industrial Automation:** Concept and Need for Automation, Types of Automation, Levels of Industrial Automation, Components of Industrial Automation.	**3**	Understand the fundamental concepts of industrial automation. Differentiate between various types and levels of automation. Identify key components of automation systems.
II.	**Programmable Logic Controllers (PLCs):** Basics of PLC, PLC Programming, Interfacing PLCs with Sensors & Actuators, Case Studies.	**8**	Explain the basics of PLCs. Develop simple PLC programs. Interface PLCs with sensors and actuators. Analyze real-world applications through case studies.
III.	**Supervisory Control and Data Acquisition (SCADA) & Distributed Control System (DCS):** SCADA: Components, Architecture, and	**5**	Describe the components, architecture, and operation of SCADA and DCS systems. Understand relevant

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	Operation, Communication Protocols, SCADA Applications in Industrial Monitoring & Control, DCS: Structure, Functionality, Case Studies.		communication protocols, and evaluate their applications in industrial monitoring and control through case studies.
IV.	**Industrial Communication & Networking:** Industrial Communication Protocols.	3	Understand and explain key industrial communication protocols and their role in facilitating reliable data exchange within industrial automation systems.
V.	**Safety Engineering and Cyber-security in Industrial Automation:** Safety Standards and Regulations, Cyber-security Frameworks and Standards, Cyber-security Measures.	3	Apply safety standards and regulations. Recognize cyber-security frameworks. Implement essential cyber-security measures in industrial automation systems.
VI.	**Arm-Type Industrial Robots:** Robot Motion Analysis: Mathematical representation of Robots, Homogeneous transformation, Robot Dynamics, Kinematics. **Robot End Effectors:** Types of end effectors, types of gripper mechanism, considerations in gripper selection and design.	7	Understand the mathematical modelling of Arm-Type Industrial Robots as well as types of end-effectors and their gripping mechanism.
VII.	**Robot sensors and actuators:** Sensors: position and velocity sensors, resolvers, encoders, tactile sensors- touch sensors, force sensors etc. Actuators: Pneumatic and hydraulic actuators, stepper motors, servomotors etc. Power transmissions systems: Gears.	6	Know about the sensors and actuators used in Industrial automation and their proper application.
VIII.	**Mobile Robots for Industrial automation:** Descriptions of different types, Localization and Mapping, Navigation.	8	Implement autonomous navigated robots for industrial purposes.
	TOTAL	**42**	

Course Outcomes	The students *shall* be able to, 1. Explain the fundamentals, types, levels, and components of industrial automation. 2. Develop and implement basic PLC programs and interface PLCs with industrial sensors and actuators. 3. Analyze SCADA and DCS systems for industrial monitoring and control, including communication protocols. 4. Evaluate industrial communication protocols and apply safety engineering and cyber security practices in automation systems.

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	5. Perform mathematical modeling and kinematic/dynamic analysis of arm-type industrial robots. 6. Select appropriate end effectors, sensors, actuators, and design basic systems for mobile and fixed industrial robots and to handle sensor and actuator data in real time. 7. Application of mobile robot in Industrial Automation.

Learning Resources	1. Nicholas Odrey, Mitchell Weiss, Mikell Groover, Roger Nagel, Ashish Dutta, “Industrial Robotics -Technology, Programming and Applications”. 2. Peter Corke, “Robotics, Vision and Control: Fundamental Algorithms in MATLAB®”. 3. Hugh Jack, “Automating Manufacturing Systems with PLCs”. 4. Jon Stenerson, "Industrial Automation and Process Control". 5. B.R. Mehta & Y.J. Reddy, "Industrial Process Automation Systems". 6. Gerasimos G. Rigatos, “Modelling and Control for Intelligent Industrial Systems: Adaptive Algorithms in Robotics and Industrial Engineering. 7. Bolton W. 2015,“Mechatronics: Electronic Control Systems in Mechanical and Electrical Engineering”, Pearson. 8. Krishna Kant, 2017,“Computer-Based Industrial Control”, PHI Learning.

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Course Code	**EE 5103 N**	Course Name	**Industrial Instrumentation and Process Control**	Course Category	**PC**	L	T	P
						3	0	0

Pre-requisite Courses	**Fundamentals of Instrumentation and Control System**	Co-requisite Courses	**Sensors & Transducers**	Progressive Courses	**Advanced Microcontrollers**
Course Offering Department		*Electrical Engineering*		Data Book / Codes/ Standards	*Nil*

Course Objectives	
	1.To introduce the methods of measurement of different industrial parameters with sensors. 2.To discuss on different electronic transmitters and pneumatic systems. 3.To familiarize with the different components and functions of Data Acquisition Systems(DAS). 4.To explore the design and development of embedded hardware with IoT/Microcontrollers. 5.To realize control actions by applying pneumatic, hydraulic and electronic principles. 6.To describe and represent the various complex control techniques applied on industrial processes. 7.To study the role of actuators and control valves in computer aided process control. 8.To have a brief overview on Industrial control of Thermal power plants and related sectors.

Module	Syllabus	Duration (class-hours)	Module Outcomes
I.	**Measurement with Sensors:** Measurement of Flow, temperature, liquid level, Pressure, Strain, Force, Torque, Load cells, Linear and Angular displacement/speed, Position and Motion sensors, etc., and Sensors in Robotics	**6**	Apply measurement methods of industrial parameters with different sensors and sensors in Robotics
II.	**Electronic transmitters and Pneumatic systems:** Capacitive, piezo-resistive, and resonator type. Flapper-nozzle assembly, air filter regulators.	**4**	Deliver the knowledge on the configurations of electronic transmitters and Pneumatic Systems
III.	**Data Acquisition Systems:** Objective of a DAS, single channel DAS, Multi-channel DAS, Components used in DAS–Converter Characteristics-Resolution-Non-linearity, settling time, Monotonicity, Data loggers.	**4**	Describe the objectives of DAS, its components and its application as a Data Logger

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IV.	**Embedded Systems/IoT/Advanced Microcontrollers**: Embedded Hardware; Intel 8051 Microcontroller; PIC Microcontroller; Programmable Peripheral devices and I/O Interfacing with Sensors, ARM & ADSP Microcontrollers.	**7**	Interface sensors with Microcontrollers and its programmable peripheral devices
V.	**Realization of control actions** by applying pneumatic, hydraulic and electronic principles and related process parameters.	**4**	Apply pneumatic and hydraulic control actions using the electronic principles
VI.	**Complex Control Techniques:** Ratio Control, Cascade Control, Feed forward Control, Control Inverse Derivative Control, Variable Structure control, Split range control.	**5**	Represent the various complex control techniques applied on industrial processes
VII.	**Actuator and Control valves:** Operation and types of Actuator, Types of control valves and their working principles, Valve Characteristics, Range-ability and Turn down, Selection of valve for different process variables; Computer aided process control: Distributed Control System (DCS)	**6**	Operate actuators and control valves for different process variables in DCS
VIII.	**Industrial Control of Thermal Power plant and other related utilities:** Instrumentation and Control	**6**	Disseminate a brief overview on Industrial control of Thermal power plants and related utilities
	TOTAL	**42**	

Course Outcomes	The students *shall* be able, 1.To apply the measurement of industrial parameters with different sensors and sensors in Robotics. 2.To deliver the knowledge on the configurations of electronic transmitters and Pneumatic Systems. 3.To describe the objectives of DAS, its components and its application as a Data Logger. 4.To interface sensors with Microcontrollers and its programmable peripheral devices. 5.To apply pneumatic and hydraulic control actions using the electronic principles. 6.To represent the various complex control techniques applied on industrial processes. 7.To operate actuators and control valves for different process variables in DCS. 8.To disseminate a brief overview on Industrial control of Thermal power plants and related utilities.

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Learning Resources	1. A.D. Helfrick and William David Cooper, Modern electronic instrumentation and measurement techniques, Prentice Hall 2. B. G. Liptak - Instrumentation Engineers Handbook (Measurement); Chilton Book Co., 1994 3. John-G. Webster (ed.), The Measurement, Instrumentation, and Sensors: Handbook, Springer 4. Curtis D. Johnson, Process control instrumentation technology, Prentice Hall. 5. D. E. Seborg, T. F. Edgar & D. A. Mellichamp - Process Dynamics & Control; John Wiley & Sons, 2nd Edition, 2003 6. D. P. Eckman - Automatic Process Control; John Wiley, New York, 7th Edition, 1990.

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Course Code	**EE 5121 N**	Course Name	**Optimization and Optimal Control**	Course Category	**PSE**	L	T	P
						3	0	0

Pre-requisite Courses	**Undergraduate Control System Linear Algebra**	Co-requisite Courses	*Nil*	Progressive Courses	*Nonconvex Optimization, Advanced MPC, Stochastic Optimal Control*
Course Offering Department		***Electrical Engineering***		Data Book / Codes/Standards	*Nil*

Course Objectives	1. To develop a foundation in optimization and optimal control. 2. To enable students to formulate and solve optimization problems using convex optimization. 3. To introduce calculus of variations for solving optimal control problems. 4. To develop tools for solving the linear quadratic regulator problem. 5. To introduce model predictive control.

Module	**Syllabus**	**Duration (class-hours)**	**Module Outcomes**
I.	**Introduction to static optimization:** linear and nonlinear problems, constrained and unconstrained optimization, Karush-Kuhn-Tucker (KKT) conditions.	**4**	Differentiate between linear and nonlinear optimization problems. Solve constrained and unconstrained optimization problems.
II.	**Convex Optimization:** Mathematical preliminaries: convex sets, convex functions. Convex optimization problems: standard form, equivalent formulation, optimality criteria. Semi-definite programming, Linear Matrix Inequalities. Formulation of standard optimization problems as LMIs; Numerical examples.	**8**	Understand convex sets and convex functions. Solve convex optimization problems. Formulate control problems using LMIs and solve them.
III.	**Introduction to Calculus of Variations:** Euler's equation, Legendre's condition, conditional extremum problems, examples. **Advanced topics:** Transversality Conditions, sufficient conditions for an extremum.	**10**	Provide the foundation of optimal control by formulating the optimization problem, derive condition for optimality and understand the structure of solutions.
IV.	**Quadratic forms:** Solution to Lyapunov Equation, stability of unforced linear state equations.	**4**	Solve Lyapunov equations. Perform stability analysis of unforced linear systems.

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V.	**Linear Optimal Control:** linear quadratic regulator problem, state feedback solution, LTI infinite horizon problem, Algebraic Riccati Equation (ARE), Hamiltonian Matrix, Numerical design examples.	7	Formulate and solve the linear quadratic regulator problem.
VI.	**Introduction to linear model predictive control (MPC).**	4	Provide a foundational understanding of how MPC works, its mathematical formulation and implementation aspects.
VII.	**Case studies:** study of standard benchmark problems; design examples.	5	Perform optimization and optimal control on physical systems.
	TOTAL	**42**	

Course Outcomes	The students *shall* be able to, 1. Apply optimization techniques to solve engineering problems. 2. Formulate and solve convex optimization problems. 3. Apply calculus of variations to solve optimal control problems. 4. Solve linear optimal control problems. 5. Design model predictive controllers.

Learning Resources	1. I. Petrov, Variational Methods in Optimum Control Theory – I, 2012 2. B. D. O. Anderson and J. B. Moore; Optimal Control: Linear Quadratic Methods, PHI, New Delhi, 2007. 3. S.S. Rao, Engineering Optimization – Theory and Practice, 3rd ed. Wiley, 1996 4. S. Boyd and L. Vandenberghe, Convex Optimization, Cambridge University Press, 2004 (https://web.stanford.edu/~boyd/cvxbook/bv_cvxbook.pdf) 5. S. Boyd, L. El Ghaoui, E. Feron, V. Balakrishnan, Linear Matrix Inequalities in Systems and Control Theory, SIAM, 1994 (https://web.stanford.edu/~boyd/lmibook/lmibook.pdf) 6. C. Scherer and S. Weiland, Linear Matrix Inequalities in Control, DISC Lecture notes, 2015 (https://www.imng.uni-stuttgart.de/mst/files/LectureNotes.pdf.) 7. J. M. Maciejowski, Predictive Control with Constraints, Pearson Education, 2001

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Course Code	**EE 5122 N**	Course Name	**Theory of Discrete and Digital Control Systems**	Course Category	**PSE**	L	T	P
						3	0	0

Pre-requisite Courses	**Signals and Systems**	Co-requisite Courses	**Control Systems**	Progressive Courses	**Discrete-Time Systems**
Course Offering Department	***Electrical Engineering***	Data Book / Codes/Standards	*Nil*		

Course Objectives	1.To introduce and represent different discrete-time input signals applied on analog systems, 2.To discuss and derive the mathematical background of sampling and signal reconstruction, 3.To apply the z-transform theory and its inverse z-transform for the time domain analysis of sampled data control system, 4.To perform the stability analysis and obtain the frequency response of sampled data control system, 5.To induce a brief theory on calculation of error constants and hence design of digital controllers, 6. To study state-space approach of designing of discrete-time systems, 7. To obtain the transfer function of complex systems with mixed sampling rates, 8. To realize discrete time systems through standard and ladder programming.

Module	Syllabus	Duration (class-hours)	Module Outcomes
I.	**Recapitulation of Discrete-time and Sample Data System:** Discrete-time signals and their classifications, Time-invariant system response, Representation of discrete-time signals as sequences, Recursive solution; Discrete convolution; Digital simulation of analog system.	**4**	Classifying the different discrete-time input signals and perform digital simulation of analog systems
II.	**Sampling & Reconstruction of Signals:** Sampling Process; Sampling Theorem; Impulse Sampling; Zero-order and first-order holds, Aliasing, Sampling of Continuous-time signals, Signal reconstruction.	**3**	Perform the sampling and reconstructing the continuous-time signals
III.	**Z-Transform and its applications:** Difference equations, z-transform theory, Obtaining z-transform by convolution integral, z-transfer functions (pulse transfer functions using convolution sums), inverse z-transform and response of linear discrete systems, signal flow graph, Mapping between s-plane to z-plane, z-transform analysis of sampled data control systems, System with	**6**	Obtain z-transform and inverse z-transform to find response of linear discrete systems. Mapping among various frequency plane.

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	dead time/transportation lag; Modified z-transform; Frequency pre-warping.		
IV.	**Stability analysis in z-plane:** Jury's stability criteria, Root Locus Analysis, Routh's Stability Criteria (Bilinear Transformation), Frequency Response of Sample data system, Bode diagram in w-plane.	**6**	Use of various stability analysis technique for the discrete-time systems
V.	**Design of Digital Controllers:** Time-domain specifications; Error constants for different discrete control configurations; Digital PID controller; Relationship with analog and digital controller parameters: Frequency responses; Realization of position and velocity form of discrete-time PID controller.	**6**	Computation of the time domain specifications of discrete time controllers, finding error constants and realization of controllers
VI.	**State Space Representation of Discrete-time Systems:** State model state models for linear discrete time systems, conversion of state variables models to transfer functions in z-domain, solutions of state equations, state transition matrix, state transition flow graphs, eigen values, eigenvectors; canonical state variable models, controllability and observability.	**6**	Analysis and design of controllers for discrete time systems using state-space method.
VII.	**Multirate and Skip sampling:** Skip sampled components; Transfer function of complex system with mixed sampling rates.	**5**	Considering multi-rate sampling for different loops in a discrete time system.
VIII.	**Realization of discrete time systems:** Direct and Standard programming; Series, Parallel and ladder programming; errors in realization.	**6**	To realize discrete-time systems using standard and ladder programming
	TOTAL	**42**	

Course Outcomes	The students *shall* be able to, 1.Classify the different discrete-time input signals and perform digital simulation of analog systems, 2.Perform the sampling and reconstruction of continuous-time signals, 3. Obtain the z-transform and inverse z-transform to find response of linear discrete time systems. Mapping among various frequency plane, 4. Use of various stability analysis techniques for the discrete-time systems, 5. Compute the time domain specifications of discrete time controllers, finding error constants and realization of controllers, 6. Apply state-space method of analysis of discrete time systems and controller design 7. Analyze the discrete time systems with multi-rate sampling and skip sampling. 8. Realize discrete-time systems using standard and ladder programming methods

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Learning Resources	1. Discrete Time Control Systems,K. Ogata-, Prentice Hall Inc., 2e, ©2001. 2. Modern Control System Theory,M. Gopal -, TMH, 2e, ©2005. 3. Digital control systems,B. C. Kuo -, Oxford, 2e, © 2012. 4. Digital Control Systems - Design, Identification and Implementation, Landau, IoanDoré, Zito, Gianluca-, Springer, ©2006. 5. Digital Control Of Dynamic Systems, G.Franklin, J.Powell, M.L. Workman.

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Laboratory /Mini Project

on

Applied Linear and Nonlinear Control

(EE5171 N)

Laboratory /Mini Project

on

Industrial Automation

(EE5172 N)

Laboratory /Mini Project

on

Industrial Instrumentation and Process Control

(EE 5173 N)

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17.

2nd Semester
M.Tech in Control and Industrial Automation (CIA)

Course Code	**EE 5201 N**	Course Name	**Identification and Data Driven Control**	Course Category	**PC**	L	T	P
						3	0	0

Pre-requisite Courses	**Control Systems, Signals and Systems, Linear Algebra, Probability and Statistics**	Co-requisite Courses	**Optimal Filtering & Stochastic Processes**	Progressive Courses	**Nonlinear System Identification and Control, Adaptive Control, Reinforcement Learning for Control**
Course Offering Department		***Electrical Engineering***		Data Book / Codes/Standards	*Nil*

Course Objectives	
	1. To introduce the fundamental concepts of system identification and the role of data-driven control systems. 2. To develop skills in data collection, pre-processing, and application of excitation signals for system modeling. 3. To familiarize students with parameter estimation techniques including LS, RLS, MLE, and subspace methods. 4. To provide understanding of classical and modern system identification approaches, including open-loop and closed-loop methods. 5. To introduce wavelet-based identification and control strategies, and their applications in instrumentation. 6. To explore the application of machine learning techniques in control, including predictive control frameworks. 7. To enable application of learned techniques in real-world industrial systems using MATLAB/Python tools.

Module	**Syllabus**	**Duration (class-hours)**	**Module Outcomes**
I.	**Introduction to System Identification and Data-Driven Control:** Role of data in control systems, Model-based vs. model-free control, Overview of system identification	**3**	Explain the role of data in control systems. Distinguish between model-based and model-free control. Understand the basics of system identification.
II.	**Data Collection and Preprocessing:** Excitation signals (PRBS, white noise), Data preprocessing	**3**	Generate suitable excitation signals and apply pre-processing techniques to prepare data for system identification.
III.	**Parameter Estimation Techniques:** Least Squares (LS), Recursive LS (RLS), Maximum Likelihood Estimation (MLE), Subspace Identification, Gaussian Process	**7**	Apply various parameter estimation methods such as LS, RLS, MLE, Subspace Identification, and Gaussian Process

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	Regression		Regression in control systems.
IV.	**Classical System Identification Methods:** Discrete-time Systems, Persistent Excitation in Input Signal, Model Structures	**5**	Model discrete-time systems using classical identification methods. Understand the role of input signal excitation and model structures.
V.	**Open-loop and Closed-loop Subspace Identification Methods**	**5**	Differentiate and implement open-loop and closed-loop subspace identification techniques.
VI.	**Wavelet Control and its Application in Instrumentation:** Wavelet-Based System Identification, Wavelet Control Strategies, Case Studies	**5**	Utilize wavelet-based methods for system identification and control. Analyze their application through case studies.
VII.	**Machine Learning Control (MLC):** Methods of Machine Learning and Linear Control Theory, System Identification and Model Reduction Techniques in ML, Concept of Predictive Control	**9**	Integrate machine learning techniques with linear control theory. Apply model reduction techniques. Understand predictive control concepts.
VIII.	**Applications in Real-World Systems:** Industrial case studies: robotics, energy systems, AI-powered control in autonomous vehicles and smart grids, MATLAB/Python implementation	**5**	Apply system identification and control techniques in real-world industrial systems using tools like MATLAB or Python.
	TOTAL	**42**	

Course Outcomes	The students *shall* be able to, 1. Explain the principles of system identification and data-driven control, and differentiate between model-based and model-free control strategies. 2. Design data collection experiments, apply pre-processing techniques, and utilize excitation signals effectively for system modeling. 3. Apply and analyze parameter estimation methods such as Least Squares, Recursive Least Squares, Maximum Likelihood Estimation, subspace identification, and Gaussian Process Regression. 4. Implement wavelet-based system identification and control strategies, and integrate machine learning techniques for predictive and data-driven control applications. 5. Develop and evaluate system identification and control models for real-world applications, using tools like MATLAB/Python in areas such as robotics, energy systems, and autonomous systems.

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Learning Resources	1.Ljung L. 1999. System Identification: Theory for the User. Prentice Hall. 2.Söderström T., Stoica P. 1989. System Identification. 3.Duriez T., Brunton, et al. 2017. Machine Learning Control – Taming Nonlinear Dynamics and Turbulence. 4.Steven L. Brunton, J. Nathan Kutz. 2022. Data-Driven Science and Engineering Machine Learning, Dynamical Systems, and Control 2nd Edition. Kindle Edition-Cambridge University Press. 5.Astrom K., Wittenmark B. 2013. Adaptive Control. Dover.

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Course Code	**EE 5202 N**	Course Name	**Intelligent Control Systems**	Course Category	**PC**	L	T	P
						3	0	0

Pre-requisite Courses	**Undergraduate Control Systems**	Co-requisite Courses	**Optimal Control Systems**	Progressive Courses	*Nil*
Course Offering Department		***Electrical Engineering***		Data Book / Codes/Standards	*Nil*

Course Objectives	1. To learn about ANN from basics. 2. To learn modelling and control using ANN. 3. To gain knowledge about fuzzy sets, logics and reasoning. 4. To learn fuzzy logic based controller design. 5. To get acquainted with RL and its basic applications. 6. To know basic optimization algorithms.

Module	**Syllabus**	**Duration (class-hours)**	**Module Outcomes**
I.	**Introduction:** Artificial Neural Networks (ANNs): Basic architecture of Neurons, Feed-forward networks, Gradient Descent Algorithm, Training of ANNs.	**5**	Basic understanding of ANN.
II.	**Neural Networks Based Control:** ANN based control: Introduction: Representation and identification, modeling the plant, Radial Basis Function, control structures – supervised control.	**8**	Able to design controllers based on ANN.
III.	**Introduction to Fuzzy sets:** Fuzzy sets, properties of Fuzzy set, operations on fuzzy set.	**4**	Understanding about the fuzzy sets and its different mathematical operations.
IV.	**Fuzzy logic and reasoning:** Representation of a fuzzy rule, Fuzzy reasoning- Inference of a fuzzy rule, Fuzzy Membership functions, Fuzzification of inputs, Defuzzification of output, Fuzzy control rules- Mamdani fuzzy rules, Sugeno fuzzy rules, Type-2 Fuzzy Systems, Differences and similarities.	**5**	Knowledge about different types of fuzzy rules, membership functions, their differences and similarities.
V.	**Fuzzy Logic Based Control:** Fuzzy Controllers: Preliminaries – Fuzzy sets in commercial products – basic construction of fuzzy controller, Fuzzy supervised	**6**	Able to design different types of fuzzy logic based controller.

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	PID-control, Adaptive fuzzy controller, Applications in different practical systems.		
VI.	**Introduction to Reinforcement Learning (RL):** MDP, Bellman's Optimality, Value based iterations, Policy based iterations, Case Studies, RL-LQR control.	8	Will get acquainted with basic RL and implement existing algorithms
VII.	**Introduction to Optimization algorithms:** Optimized Controller design, Applications to different engineering systems.	6	Understand the optimization techniques. Apply different optimization techniques in engineering systems.
	TOTAL	**42**	

Course Outcomes	The students *shall* be able to, 1. Able to model and design control algorithms for physical systems using ANN. 2. Able to apply fuzzy logic to solve practical problems. 3. Apply fuzzy logic based control algorithms on real time systems. 4. Able to perform basic RL control. 5. Tune controllers using optimization based design for practical systems.

Learning Resources	1. "Machine Learning: A Comprehensive Introduction" by Michael Nielsen. 2. "Artificial neural networks" by Yegnanarayana. 3. "Fuzzy Logic with Engineering Applications" by Timothy J. Ross. 4. "Fuzzy Logic: Intelligence, Control, and Information" by John Yen and Reza Langari. 5. "Reinforcement Learning: An Introduction" by Richard S. Sutton and Andrew G. Barto, 2014, The MIT Press Cambridge. 6. "Artificial Intelligence and Machine Learning" by Hamidreza Moradi. 7. "Introduction to Fuzzy Logic using MATLAB" by S.N. Sivanandam, S. Sumathi, and S. N. Deepa. 8. "Fuzzy Logic: A Practical Approach" by F. Martin McNeill and Ellen Thro. 9. "Hands-on Reinforcement Learning with Python" by Sudharsan Ravichandiran.

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Course Code	EE 5203 N	Course Name	**Optimal Filtering and Stochastic Processes**	Course Category	**PC**	L	T	P
						3	0	0

Pre-requisite Courses	**Statistics**	Co-requisite Courses	**Optimal Control Systems**	Progressive Courses	**Discrete Time Systems**
Course Offering Department	***Electrical Engineering***	Data Book / Codes/Standards		*Nil*	

Course Objectives	
	1. To introduce and represent different sources of uncertainties in the systems. 2. To study the statistical properties of signals and systems. 3. To understand phenomena and noumena. 4. To study mathematical background of optimal filtering concept and different approaches with practical implementation problems. 5. To be acquainted with the differences between deterministic and stochastic control. 6. To induce LQ theory and application in stochastic control for continuous and discrete time systems. 7. To study disturbance modeling and augmentation of system with application to some practical stochastic processes.

Module	**Syllabus**	**Duration (class-hours)**	**Module Outcomes**
I.	**Probability and Random Variables (RV):** Basics of Stochastic Processes – Langevian Equation. Discrete and Continuous Random Variables. Probability Distribution and Densities; Interactive Random Variables; Expectancy & Moment; Function of RV; Mean, Correlation, Covariance, Standard Deviation.	**7**	Defining and classifying various random variables and their interactions, finding their functions, properties and applications in stochastic processes.
II.	**Random Processes and Sequences:** Stationary, Ergodic, Markov and Gaussian processes and sequences; Orthogonality principle	**5**	Learning various random processes and sequences, and their properties.
III.	**Kalman Filter:** Computational Origin, Description of Noise processes; Discrete-time Kalman Filter algorithms; Filter equations and their significances; Alternative form of Discrete Kalman algorithm; Deterministic Least Square Estimation and Kalman Filtering; Stability considerations with Kalman Filter; Kalman-Bucy Filter.	**7**	Learning of mathematical basis of optimal filtering and building blocks of Kalman filter, solving optimal filter equations for estimating linear systems, and finding stability conditions with optimal filters in control loop.
IV.	**Non-linear Application of Kalman Filter:** Linearized and Extended	**6**	Applying optimal filter to non-linear systems and

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	Kalman Filter Algorithms; Unscented Kalman Filter.		extensions thereof.
V.	**Practical Implementation Considerations**: Predicted and unpredicted non-convergence problems and remedies; Bad-data problem. Round-off error etc.	3	Learning causes of non-convergence issues in optimal filtering methods and remedy thereof.
VI.	**Filtering, Prediction and Smoothing**: Fixed point, fixed lag and fixed interval smoothing: Maximum Likelihood Estimator, Particle Filter.	3	Knowledge of various Filtering, Prediction and Smoothing techniques.
VII.	**Control of Stochastic Processes**: LQ Theory, LQR Problem, LQG Problem, LQ estimator and LQ optimization of controller, Separation Principle, Discrete time LQG problem, LQG controller design for a regulator problem. Disturbance Modelling – Augmented model of the systems. Robustness of LQG controllers and Loop Transfer Recovery. General Optimal Filtering, FIR and IIR case.	8	Applying LQ theory for optimizing estimation and control problems in stochastic environments in continuous and discrete time, augmenting systems by disturbance modelling and robustness analysis of LQG process.
VIII.	**Examples of Stochastic Processes:** Physiological System, Room temperature control, Inventory Control, market economic process etc.	3	Design of LQG controller and finding physical parameters for some real-life stochastic processes.
	TOTAL	**42**	

Course Outcomes	The students *shall* be able to, 1. Define and classify various random variables and their interactions, finding their properties and applications in stochastic processes. 2. Learn various random processes and sequences, and their properties, 3. Learn mathematical basis of optimal filtering and building blocks of Kalman filter, and to solve optimal filter equations for linear systems and find stability conditions with optimal filters in the control loop, 4. Write sequences of optimal filter equations for estimating nonlinear processes, 5. Overcome practical non-convergence issues in various optimal filtering methods, 6. Study various Filtering, Prediction and Smoothing techniques, 7. Apply LQ theory for design of optimal estimation and optimal control problems in stochastic environments, and augment the systems using disturbance model and analyse robustness and stability of stochastic control systems 8. Design LQG controllers and find physical parameters for some real-life stochastic processes.

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Learning Resources	1. Signals and Systems, Alan V. Oppenheim, A. S. Willsky and S. H. Nawab, 2nd edition, Pearson India, 2015. 2. Circuits and Systems, K. M. Soni, S. K. Kataria & Sons, New Delhi, 2010. 3. Fundamentals of Signals and Systems,M. J. Roberts and G. Sharma, ,2nd edition, Mc Graw-Hill Education, 2017. 4. Networks and Systems, D. Roy Choudhury, 2nd edition, New Age International (P) Ltd., 2014. 5. Circuit Theory: Analysis and Synthesis, A. Chakrabarti, 7th revised edition, Dhanpat Rai & Co, 2018. 6. Network Analysis and Synthesis, C. L. Wadhwa, 3rd edition, New Age International(p)Ltd., 2014.

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Course Code	EE 5221 N	Course Name	**Elements of Cyber Physical Systems**	Course Category	**PSE**	L	T	P
						3	0	0

Pre-requisite Courses	**Control System, Instrumentation, Microprocessors and Microcontrollers, Signals and Systems**	Co-requisite Courses	*Nil*	Progressive Courses	**Advanced Cyber Physical Systems, Networked & Distributed Control, Machine Learning for Cyber Physical Systems**
Course Offering Department		***Electrical Engineering***		Data Book / Codes/Standards	***IEEE Standards (IEEE 1451, IEEE 802.15.4) ISA-95 and ISA/IEC 62443 Standards***

Course Objectives	
	1. Introduce the fundamentals, architecture, and characteristics of Cyber-Physical Systems (CPS). 2. Develop mathematical modeling and analysis skills for hybrid systems and stability in CPS. 3. Impart knowledge of control strategies suitable for CPS. 4. Familiarize students with communication protocols, networking, and real-time aspects of CPS. 5. Address the challenges of security, privacy, and resilience in CPS. 6. Expose students to diverse applications, emerging technologies, and future trends in CPS.

Module	Syllabus	Duration (class-hours)	Module Outcomes
I.	**Introduction to Cyber-Physical Systems (CPS):** Definition and Characteristics of CPS, Architecture of CPS, Practical examples.	**3**	Define CPS. Describe its architecture and characteristics
II.	**Mathematical Modelling and Analysis of CPS:** Hybrid Systems and concept of Stability Analysis of CPS	**8**	Model CPS using hybrid systems. Perform basic stability analysis.
III.	**Control Strategies in CPS**	**9**	Design various control techniques for CPS environments.
IV.	**Communication and Networking in CPS:** CPS Communication Protocols	**3**	Identify and explain CPS-specific communication protocols and their role in system integration.
V.	**Security and Privacy in CPS:** Cyber-attacks, Data Integrity, and Resilience, Secure Control Systems	**4**	Assess cyber-security risks. Understand secure control system design. Implement measures for ensuring data integrity and system resilience.

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VI.	**Real-Time Systems in CPS:** Introduction to Real-Time Systems: Concepts, definitions, events and determinism, Real-Time Task Scheduling: Classifications of real-time tasks and their characteristics, concepts of different scheduling algorithms, Real-time Operating Systems	9	Explain real-time system concepts. Classify real-time tasks. Understand scheduling algorithms and real-time operating systems in CPS.
VII.	**Applications of CPS and Future Trends:** Biomedical Applications, Realizing Anomalies, Digital Twins and Edge Computing in CPS, Future Research Directions	6	Explore CPS applications in areas like healthcare and smart systems. Understand concepts like digital twins and edge computing. Identify future research directions.
	TOTAL	**42**	

Course Outcomes	The students *shall* be able to, 1. Describe the architecture, characteristics, and practical examples of Cyber-Physical Systems. 2. Develop mathematical models for hybrid CPS and analyze their stability. 3. Apply suitable control strategies in the design and operation of CPS. 4. Analyze communication protocols and networking requirements for CPS. 5. Identify security threats, ensure data integrity, and design resilient CPS. 6. Explain real-time system concepts, task scheduling, and the role of real-time operating systems in CPS. 7. Explore applications like biomedical systems, digital twins, edge computing, and identify future research directions in CPS.

Learning Resources	1.Raj Raj kumar, Dionisio De Niz & Mark Klein - Cyber-Physical Systems, 2016. 2.Edward Lee & Sanjit Seshia - Introduction to Embedded Systems: A Cyber-Physical Systems Approach, 2020. 3.Alberto Bemporad, Moritz Diehl & Manfred Morari - Model Predictive Control: Theory and Design, 2017. 4.Karl J. Åström & Richard M. Murray - Feedback Systems: An Introduction for Scientists and Engineers, 2010. 5.Mathias Pahl & Wim Van der Aalst - Security and Privacy in Cyber-Physical Systems, 2021. 6.Jiawei Han, Micheline Kambers & Jian Pei - Data Mining - Concepts and Techniques, 3rd edition, Morgan Kaufman Publications, 2012. 7.Ethem Alpaydin - Introduction to Machine Learning, 3rd edition, MIT Press, Prentice Hall of India, 2014. 8.Allen Burns & Andy Wellings - Real Time Systems and Programming Languages, Pearson Education, 2003. 9.R.J.ABuhr & D.L Bailey - An Introduction to Real-Time Systems, Prentice Hall International, 1999.

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Course Code	EE 5222 N	Course Name	**Networked and Distributed Control**	Course Category	**PSE**	L	T	P
						3	0	0

Pre-requisite Courses	**Linear Algebra**	Co-requisite Courses	*Nil*	Progressive Courses	*Event-triggered control, Stochastic Networked Control Systems,*
Course Offering Department		*Electrical Engineering*		Data Book / Codes/Standards	*Nil*

Course Objectives	
	1. To develop a foundation in networked and distributed control. 2. To formulate problems involving dynamical systems using graph-theoretic tools. 3. To introduce the consensus problem over directed and undirected networks. 4. To introduce the formation control problem in multi-agent networks. 5. To introduce the fundamentals of cooperative robotics. 6. To introduce the distributed estimation problem. 7. To analyze networked systems.

Module	Syllabus	Duration (class-hours)	Module Outcomes
I.	**Mathematical Preliminaries:** Matrix theory, graph theory, algebraic graph theory, graphs and dynamic systems	**6**	Employ algebraic graph theory techniques to extract information about network structure and properties from matrix representations.
II.	**The Consensus problem:** over undirected networks, over directed networks, using Lyapunov functions, switching digraphs	**10**	Define and explain the consensus problem. Analyze the conditions for achieving consensus. Apply Lyapunov stability theory to prove the convergence of consensus algorithms. Design and implement consensus algorithms.
III.	**Formation Control in multi-agent networks:** shape-based control, relative state-based control, dynamic formation selection. **Cases studies**	**8**	Understand the principles of formation control. Differentiate and apply various approaches to formation control. Design control laws to achieve desired formations. Analyze the stability and robustness of formation control algorithms.
IV.	**Mobile robots:** cooperative robotics, weighted graph-based	**6**	Understand the fundamentals of cooperative robotics.

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	feedback, dynamic graphs, the coverage problem		Apply weighted graph theory to design feedback control strategies. Formulate and solve the coverage problem.
V.	**Distributed Estimation:** Distributed linear least squares, distributed Kalman filtering	6	Understand the concept and necessity of distributed estimation. Formulate and solve distributed linear least squares problems. Derive and implement distributed Kalman filters.
VI.	**Analysis of networked systems:** Structural Controllability, network feedback, network formation	6	Assess structural controllability of complex networked systems. Analyze the impact of network topology on system performance and control effectiveness.
	TOTAL	**42**	

Course Outcomes	The students *shall* be able to, 1. Develop the connection between dynamical systems and graph theory. 2. Analyze and solve the consensus problem over directed and undirected networks. 3. Solve the formation control problem in multi-agent networks. 4. Solve problems in cooperative robotics. 5. Solve the distributed estimation problem. 6. Analyze the properties of networked systems.

Learning Resources	1. D.D. Siljak, Decentralized Control of Complex Systems, Academic Press, 1991 2. F. Bullo, Lectures on Network Systems (http:motion.me.ucsb.edu/book-lns) 3. M. Mesbahi and M.Egerstedt, Graph Theoretic Methods in Multiagent Networks, Princeton University Press, 2010

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M.Tech in Power and Energy Systems (PES)
Course Structure

		First Semester							
Sl. No.	**Type**	**Course Name**	**Course code**	**Class Load/Week**			**Credit**	**Class load/ week**	**Marks**
				L	**T**	**P**			
1	PC	Computer Aided Power System Analysis	EE5104 N	3	0	0	3	3	100
2	PC	Power System Operation and Control	EE5105 N	3	0	0	3	3	100
3	PC	Power Transmission and Power Quality	EE5106 N	3	0	0	3	3	100
4	PSE (any one)	1. Optimization and Optimal Control 2. Theory of Discrete and Digital Control Systems 3. High Voltage Systems 4. Power system Reliability and Load Forecasting 5. Advanced Microcontroller Technology 6. Power Quality	EE5121 N EE5122 N EE5123 N EE5124 N EE5125 N EE5126 N	3	0	0	3	3	100
5	OE	High-Performance Computation (HPC) Using CPU and GPU for AI Applications	EE5161 N	3	0	0	3	3	100
		Theory Sub-total		**15**	**0**	**0**	**15**	**15**	**500**
6	PC	Lab/Mini Project on Computer Aided Power System Analysis	EE5174 N	0	0	3	2	3	50
7	PC	Lab/Mini Project on Power System Operation and Control	EE5175 N	0	0	3	2	3	50
8	PC	Lab/Mini Project on Power Transmission and Power Quality	EE5176 N	0	0	3	2	3	50
		Practical Sub-total		**0**	**0**	**9**	**6**	**9**	**150**
		First Semester Total		**15**	**0**	**9**	**21**	**24**	**650**

		Second Semester							
Sl. No.	**Type**	**Course Name**	**Course code**	**Class Load/Week**			**Credit**	**Class load/ week**	**Marks**
				L	**T**	**P**			
1	PC	Advanced Power System Protection	EE5204 N	3	0	0	3	3	100
2	PC	Artificial Intelligence and Optimization in Power Systems	EE5205 N	3	0	0	3	3	100
3	PC	Grid Integration of Renewable Energy	EE5206 N	3	0	0	3	3	100
4	PSE (any one)	1. Elements of Cyber Physical Systems 2. Networks & Distributed Control Systems 3. Restructured Power Systems 4. Smart Grid Technologies and Energy Informatics 5.Special Electrical Machines 6. Power Electronic Converters for Bulk Power Conditioning	EE5221 N EE5222 N EE5223 N EE5224 N EE5225 N EE5226 N	3	0	0	3	3	100
5	OE	Power Supplies for Electrical Equipment	EE5262 N	3	0	0	3	3	100
		Theory Sub-total		**15**	**0**	**0**	**15**	**15**	**500**
6	P	M.Tech. project/Term-paper	EE5291 N	0	0	3	2	3	50
7	O	Seminar/Viva Voce	EE5292 N	0	0	3	2	3	50
		Practical Sub-total		**0**	**0**	**6**	**4**	**6**	**100**
		Second Semester Total		**15**	**0**	**6**	**19**	**21**	**600**

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		Third Semester							
Sl. No.	**Type**	**Course Name**	**Course code**	**Class Load/Week**			**Credit**	**Class load/ week**	**Marks**
				L	**T**	**P**			
1	**VAC**	Energy Audit	EE6101N	3	0	0	3	3	100
2	P	M. Tech. Thesis	EE6191 N				12	24	300
3	O	Progress Seminar and Viva-voce	EE6192 N				6		100
4	I	Summer internship (6-8 weeks) evaluation	EE6193 N				2		50
		Third Semester Total					**23**		**550**

		Fourth Semester							
Sl. No.	**Type**	**Course Name**	**Course code**	**Class Load/Week**			**Credit**	**Class load/ week**	**Marks**
				L	**T**	**P**			
1	P	M. Tech. final thesis	EE6291 N				22	30	400
2	O	Thesis Seminar and Viva-voce	EE6292 N				8		200
		Fourth Semester Total					**30**		**600**

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1st Semester
M.Tech in Power and Energy Systems (PES)

Course Code	**EE 5104 N**	**Course Name**	Computer Aided Power System Analysis	**Course Category**	PC	L	T	P
						3	0	0

Pre-requisite Courses	*Power Systems*	**Co-requisite Courses**	*Nil*	**Progressive Courses**	*Nil*
Course Offering Department		***Electrical Engineering***		**Data Book / Codes/Standards**	*Relevant IS, IEC, IEEE & CIGRE standards*

Course Objectives	
	1. To provide a solid foundation in computer-aided techniques for power system analysis. 2. To enable students to formulate and solve power system problems using matrix methods and computational algorithms. 3. To apply numerical methods for fault analysis, load flow studies, and contingency analysis. 4. To develop skills in state estimation, load forecasting, and small signal stability analysis. 5. To introduce modern topics such as power system vulnerability, market economics, and congestion management.

Module	**Syllabus**	**Duration (class-hours)**	**Module Outcomes**
I.	**Matrix Methods:** Formation of Y-bus matrix with and without transformer; Addition and deletion of branch. Z-bus matrix and its modifications. Step by step method of building Z-bus; Algorithm for formation of Z-bus matrix and its modification; Concept of Sparse Matrix Application of computer methods (Gaussian elimination, Kron's method, Triangular factorization)	**6**	After completing this module, the learner will be able to formulate and manipulate the admittance and impedance matrices of power systems using various algorithms. The learner will gain a strong understanding of Y-bus and Z-bus formation techniques and be able to apply sparse matrix methods and computational algorithms such as Gaussian elimination, Kron reduction, and triangular factorization for system modeling.
II.	**Application of Computer methods in Fault Analysis:** Analysis of three phase balanced fault, single phase to ground fault, line to line fault and double line to ground fault using Z-bus. Sequence currents in the interconnecting line between faulted buses. Effect of neutral grounding reactance, Open	**8**	After completing this module, the learner will be capable of performing detailed fault analysis using Z-bus methods for different types of symmetrical and unsymmetrical faults. The learner will also understand the impact of grounding and open conductor conditions and be able to compute sequence currents and their

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Module	Syllabus	Duration (class-hours)	Module Outcomes
	conductor fault.		effects on interconnected systems.
III.	**Load Flow Studies:** Review of N-R method, FDLF method and DC load flow method. Application of voltage controlled busses for NR and FDLF methods. Inclusion of regulating devices and associated limits. Large scale systems. Basic concepts of optimal power flow (OPF), Distribution Load Flow.	**7**	After completing this module, the learner will be proficient in applying numerical techniques such as Newton-Raphson (N-R), Fast Decoupled Load Flow (FDLF), and DC Load Flow methods for power flow analysis. The learner will also understand the role of voltage-controlled buses, regulating devices, and their operational limits in large-scale system analysis, including preliminary concepts of optimal power flow and distribution-level studies.
IV.	**Contingency Analysis:** Relationship between Thevenin's theorem and bus impedance matrix (Z_{Bus}). Addition and remove of line. Current distribution factor and line outage factor. Single line contingency. Contingency analysis of interconnector. Contingency analysis using DC power flow model. Reduction of complex network to 2-bus network.	**6**	After completing this module, the learner will be able to assess system reliability by performing contingency analysis using both Z-bus and DC load flow models. The learner will understand line outage factors, current distribution factors, and the process of simplifying complex networks using Thevenin's equivalents and 2-bus reductions to evaluate the impact of line outages and interconnector faults.
V.	**State Estimation:** Fundamental concept, Basic methods of State Estimation, weighted least square state estimation, use of phasor measurement units (PMU's), Bad data detection and suppression, Observability.	**5**	After completing this module, the learner will be able to implement basic state estimation techniques in power systems, detect and suppress bad data, and analyze system observability.
VI.	**Small Signal Stability Analysis:** Nature of oscillations and modes. Concept of Small Signal Stability. Eigen properties of system matrix, small signal stability model of a SMIB system. State space model. Role of excitation systems. Application of Power System Stabilizer.	**6**	After completing this module, the learner will understand the nature and modes of system oscillations and the role of small signal stability in power systems. The learner will be able to analyze the eigen-properties of the system matrix, construct SMIB models, and apply state-space techniques, including the use of excitation systems and power system stabilizers to enhance system stability.

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Module	Syllabus	Duration (class-hours)	Module Outcomes
VII.	**Power System Vulnerability Analysis:** Power System Network Vulnerability, Concept about grid collapse and cascading failure, Power System Resiliency and Survivability	2	After completing this module, the learner will be able to evaluate the vulnerability of power systems in the context of cascading failures and grid collapses. The learner will gain insights into resiliency and survivability metrics, enabling them to propose preventive and corrective strategies for enhanced grid security.
VIII.	**Power Market Economics and Grid Congestion Management:** Deregulation, Market Economy, Open access, Restructuring of Power Systems, and Congestion Management	2	After completing this module, the learner will understand the foundational principles of deregulated electricity markets, market economy models, and open access systems. The learner will be able to analyze restructuring processes in power systems and apply congestion management strategies to ensure economic and reliable system operation.
	TOTAL	**42**	

Course Outcomes	1. Apply matrix methods and computer techniques for power system modeling, fault analysis, and load flow studies. 2. Perform contingency analysis, state estimation, and load forecasting using computational tools. 3. Analyze system stability and assess power system vulnerability, resiliency, and survivability. 4. Understand deregulated power markets and apply techniques for grid congestion management.

Learning Resources	1. Grainger J.J. and Stevenson W.D., Power System Analysis, McGraw Hill Education. 2. Kothari D.P. and Nagrath I.J., Modern Power System Analysis, McGraw Hill Education. 3. Singh L.P., Advanced Power System Analysis, Wiley Eastern, India.

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Course Code	EE 5105 N	Course Name	Power System Operation and Control	Course Category	PC	L	T	P
						3	0	0

Pre-requisite Courses	Power Systems (UG level)	Co-requisite Courses	*Nil*	Progressive Courses	*Nil*
Course Offering Department		*Electrical Engineering*		Data Book / Codes/Standards	Relevant IS / IEC / IEEE standards

Course Objectives	The course typically aims to teach optimal system operation through optimal generation dispatch, unit commitment, hydro -thermal scheduling and pumped storage plant scheduling and their implementation through various classical methods, automatic generation control in single area and interconnected systems, reactive power compensation techniques, power system deregulation.

Module	Syllabus	Duration (class-hours)	Module Outcomes
I.	**Introduction**: Structure and Representation of a Power System, Necessity of Control and Control Methods, Types of Control, Common Operating Problems, Operating States, Use of Computer Control and Modern Methods in Power System Operation and Control, SCADA system	3	Upon completing this module, students will be able to understand the structure and representation of a power system, recognize the necessity and types of control in power system operation, identify common operating problems and states, and explain the role of computer-based control methods, including SCADA systems, in modern power system management.
II.	**Economic dispatch of thermal units**: Input/Output characteristics of unit, incremental cost curves, constraints in economic operation, lambda iteration method, analytical approach to determine economic operation criterion with and without network losses for thermal plants, transmission loss coefficient, thermal plant scheduling, transmission loss allocation and penalty factor.	5	At the end of this module, students will be able to analyze and apply economic dispatch methods for thermal power plants by interpreting input/output characteristics, incremental cost curves, and system constraints. They will also be able to implement the lambda iteration and analytical techniques to determine optimal generation scheduling with and without transmission losses, incorporating loss coefficients and penalty factors.
III.	**Hydrothermal Coordination**: Hydrothermal scheduling (long range and short range with and without network losses), scheduling of hydraulically	5	By the end of this module, students will be able to understand and apply methods for hydrothermal scheduling, including long-range and short-range coordination with and without network losses, as well

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	coupled unit, scheduling of pumped storage plants.		as the scheduling of hydraulically coupled units and pumped storage plants for optimal power system operation.
IV.	**Unit Commitment**: Constraints in unit commitment, spinning reserve, must run units, unit commitment solution methods - priority-list method, dynamic programming method, Forward DP approach.	**5**	By the end of this module, students will be able to understand the various constraints involved in unit commitment, including spinning reserve and must-run units, and apply solution methods such as the priority-list method and dynamic programming, including the Forward DP approach, for optimal scheduling of generating units.
V.	**Automatic Generation Control**: Generator, prime mover, governor and load modelling, Automatic Load Frequency Control (ALFC), Primary ALFC loop and secondary ALFC loop model, Static and dynamic performance of ALFC loop, optimal control concept in ALFC two area control, automatic generation control in single-area and multi-area systems, Optimal Line Regulator (OLR) design.	**6**	This module will enable the students to model and analyze the components of Automatic Generation Control (AGC) including generator, governor, and load dynamics, and evaluate the static and dynamic performance of ALFC in single-area and multi-area systems. They will also understand the design of primary and secondary ALFC loops and apply optimal control strategies such as Optimal Line Regulator (OLR) in two-area AGC systems.
VI.	**Automatic voltage regulators**: Excitation systems, types of exciters, AVR loop and its static and dynamic performance, power system stabilizers. Methods of voltage control: Excitation control, tap changing transformers, synchronous condensers	**6**	By the end of this module, students will be able to understand the structure and function of automatic voltage regulators (AVRs), various excitation systems and exciters, and evaluate the static and dynamic performance of AVR loops including the role of power system stabilizers. They will also learn different methods of voltage control such as excitation control, tap-changing transformers, and synchronous condensers.
VII.	**Sub Synchronous Resonance (SSR)**: Introduction to SSR, torsional interaction, eigen value analysis.	**3**	Upon completing this topic, students will be able to explain the phenomenon of Sub Synchronous Resonance (SSR), analyze torsional interactions between electrical and mechanical systems, and evaluate system stability using eigen value analysis.
VIII.	**Power System Compensation**: Overview of operation of transmission line during no-load and heavy loading condition, uncompensated and compensated transmission lines, static var compensators,thyristor-controlled	**6**	On studying this module, students will understand the behavior of transmission lines under various loading conditions and the principles and applications of compensation devices like static var compensators, TCSR, and TCSC for enhancing system performance.

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	series reactors (TCSR), thyristor-controlled series capacitors (TCSC).		
IX.	**Power System Economics**: Tariffs, concept of deregulation, power pool and service operator, network restructuring, congestion management and electricity pricing.	**3**	The module will help the students in understanding the fundamentals of power system economics, including tariff structures, the impact of deregulation, the roles of power pools and service operators, and key concepts in network restructuring, congestion management, and electricity pricing.
	TOTAL	**42**	

Course Outcomes	The students undergoing this course are expected learn and understand: 1. The concept of Optimal Power System Operation under various operating constraints. 2. To solve unit commitment and economic dispatch problems. 3. Hydro-thermal scheduling problem and scheduling of pumped storage plants 4. Various reactive power compensation methods in transmission lines 5. The frequency control and AGC in single area and interconnected systems 6. The function of SCADA and EMS 7. Power system deregulation, network restructuring, congestion management

Learning Resources	1.Wood A.J., Wollenberg, Power Generation Operation and Control, John Wiley and Sons Inc, USA. 2.Chakrabarti A. and Haldar S., Power System Analysis, Operation and Control, PHI India 3.Kothari D.P. and J.S. Dhillon, Power System Optimization, PHI, New Delhi 4.Mahalanabis A.K., Kothari D.P. and Ahson S.I., Computer Aided Power System Analysis and Control, McGraw Hill, India 5.Chakrabarti A. and Haldar S., Power System Analysis, Operation and Control, PHI India. 6.Pai M. A., Computer Techniques in Power System Analysis, McGraw Hill, Education 7.N.G. Hingorani & Laszlo Gyugyi, Understanding FACTS - Concepts and Technology of Flexible AC Transmission Systems, Wiley-IEEE Press.

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Course Code	EE 5106 N	Course Name	Power Transmission and Power Quality	Course Category	PC	L	T	P
						3	0	0

Pre-requisite Courses	Power Systems and Power Electronics (UG level)	Co-requisite Courses	*Nil*	Progressive Courses	*Nil*
Course Offering Department		*Electrical Engineering*		Data Book / Codes/Standards	Relevant IS / IEC / IEEE standards

Course Objectives	
	1. To provide students with extensive understanding of voltage stability and reactive power compensation in transmission system. 2. To enable students to understand basic philosophy of EHV AC and HVDC transmission. 3. To familiarize the students various power quality issues, it causes and effects, to understand effects of harmonics due to non-linear load and to learn mitigation methods for harmonics.

Module	Syllabus	Duration (class-hours)	Module Outcomes
I.	**Voltage Stability and Reactive Power Compensation in Transmission Systems:** Reactive Power sensitivity, concept of voltage stability and security, Receiving end bus voltage and power angle at critical voltage, Fast voltage stability index, Line quality factor, Line voltage stability index, Direct indicator, Modal analysis, Global voltage stability indicator, Role of source reactance, Critical transmission limits. Different types of passive compensation in transmission lines.	5	By the end of this module, students will be able to analyze voltage stability issues in transmission systems using various voltage stability indices and indicators, and understand the impact of reactive power sensitivity and source reactance on system security. They will also gain knowledge of different types of passive compensation methods used to enhance voltage stability and critical transmission limits.
II.	**Transient Stability:** Swing equation and different techniques of its solution. Critical clearing angle. Transient stability study in multi-machine system. Development of computer algorithm. Power system security.	4	After completing this module, students will be able to analyze transient stability in power systems using the swing equation and various solution techniques. They will also understand critical clearing angle concepts, perform transient stability studies in multi-machine systems, and develop computer algorithms.

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III.	**EHVAC Transmission:** Review of Basic Concepts, Surge Impedance loading of EHV Lines and its implication, operation of EHV Line during no-load and heavy loading condition, Maximum Power Transfer, Line Load ability, Implication of Voltage Regulation, Stability aspects and line length limitation, Line Congestion. Protection Sub- systems (ATP).	6	Upon completion of this module, students will be able to analyze the performance and operational challenges of Extra High Voltage AC (EHVAC) transmission systems, including surge impedance loading, voltage regulation, line loadability, and stability aspects. They will also understand line congestion issues and the role of protection sub-systems.
IV.	**Power Electronic Converters:** Review of Concept of Controlled Rectification, 3- Phase Controlled Rectifiers, Thyristor Protection Devices, Poly-phase Converter Expressions, 6-Pulse and 12-Pulse Configurations, Effect of Source Inductance, Rectifier Transformer Rating, Principle of Inversion, Necessity of Filters, IGBT Converters	4	Upon completion of this module, students will be able to analyze and design various power electronic converters including single and three-phase controlled rectifiers, understand thyristor protection, poly-phase converter configurations, and evaluate the impact of source inductance and transformer ratings. They will also understand the principles of inversion, need for filters, and the operation of IGBT-based converters.
V.	**HVDC Transmission:** Advantages and Disadvantages of HVDC Transmission, HVDC System Configuration, HVDC Control (Basic requirements, control characteristics, selection of controls), HVDC line and line reactors, HVDC Terminal Equipment, HVDC System Protection, Modelling of HVDC systems, MTDC System, Current Topics	4	This module will help the students in understanding the principles, configurations, and control strategies of HVDC transmission systems, including terminal equipment, line components, and system protection. They will also be able to model HVDC and MTDC systems and evaluate their advantages, limitations, and developments in the field.
VI.	**FACTS Devices:** FACTs devices (Series and shunt FACTs devices), UPFC.	3	Upon completion of this module, students will be able to understand the operating principles, characteristics, and applications of FACTS devices, including series and shunt compensation techniques. They will also gain insight into the structure and control of Unified Power Flow Controller (UPFC) for enhanced power system performance.
VII.	**Power Quality concepts and analysis:** Concept of Quality of Power in utility industries, Role of harmonics in Power Quality, Representation and Characteristics of Harmonics in Power Systems,	8	The module will help the students to understand the concept of power quality and analyze the impact of harmonics in power systems. They will also be able to identify sources of harmonics, compute harmonic

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	Computation of Harmonic Distortion, Sources of Harmonics in Transformers, Rotating Machines, Power Systems, harmonics from distributed generations like solar and wind, Role of Power Electronic Converters in generation of harmonics.		distortion, and assess the role of distributed generation and power electronic converters in power quality issues.
VIII.	**Power quality problems and mitigation techniques:** Classification of power quality problems and its mitigation techniques, Implication of harmonic distortion on thermal losses, core losses, and dielectric losses, effect of harmonics on power system equipment, Power Quality Measurement, Power system harmonics mitigation, passive power filters, its classification, operation and design.	**8**	The module will enable the students to classify various power quality problems, understand their effects on power system equipment and losses, and evaluate appropriate mitigation techniques. They will also gain the ability to measure power quality and design passive power filters for harmonic mitigation.
	TOTAL	**42**	

Course Outcomes	1. The students shall be able to use the concepts of EHVAC and HVDC transmission and power electronic converters concepts in their studies and research. 2. The students are expected to learn different power quality issues and standards. 3. The students are expected to apply the mitigation techniques to reduce the adverse effects of power quality on system and equipment.

Learning Resources	1. Gonen T., Electric Power Transmission System Engineering, John Wiley 2. Adamson and Hingorani, High Voltage Direct Current Power Transmission, Garraway, London 3. Chakrabarti A., Power System Dynamics and Simulation, PHI 4. Arrillaga J., HVDC Transmission, Peter Peregrinus, London 5. Grainger J. J., Stevenson W. B., Power System Analysis, McGraw Hill 6. Heydt. G.T., Electric Power Quality, Circle Publications 7. Ghosh A and G. Ledwich, Power Quality Enhancement Using Custom Power Devices, Kluwer Academics

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Course Code	EE 5123 N	Course Name	High Voltage Systems	Course Category	PSE	L	T	P
						3	0	0

Pre-requisite Courses	Power Systems (UG Level)	Co-requisite Courses	*Nil*	Progressive Courses	*Nil*
Course Offering Department		*Electrical Engineering*		**Data Book / Codes/Standards**	Relevant IS, IEC, IEEE & CIGRE standards

Course Objectives	1. To provide students with a comprehensive understanding of high voltage phenomena, generation, measurement, testing, and insulation coordination in electrical power systems. 2. To equip students with the knowledge and skills necessary to design, analyze, and troubleshoot high voltage equipment and systems, including understanding breakdown phenomena in various dielectrics 3. To familiarize the students with the methods for diagnosing faults and assessing the condition of high voltage equipment

Module	Syllabus	Duration (class-hours)	Module Outcomes
I.	**Over-voltages in Electrical Power Systems:** Temporary and Transient Over-voltages, Lightning and Switching Surges, Oscillatory Transient Over-voltages and their impact on Power System Equipment, Equipment Protection against Over-voltages.	3	In-depth understanding of different overvoltage phenomena in power system
II.	**Insulation Coordination in High Voltage Systems:** Protection Level provided Surge Arresters, Concept of BIL, Volt-Time Curves of equipment insulation, Insulation Coordination in Extra High Voltage Power Systems.	4	Thorough understanding of the principles of insulation coordination in high voltage power system
III.	**Surge Phenomena in Transformers and Rotating Machines:** Surge voltage distribution in windings of transformer and rotating machines, Wagner's theory - initial voltage distribution, free oscillations and pseudo-final voltage distribution. Effect of winding capacitances on surge voltage distribution. Introduction to Interleaved and Intershield windings. Resonant overvoltage in windings, dielectric failures and remedial measures.	8	Ability to analyze and assess the impacts of surges on transformer and rotating electrical machines.
IV.	**Applications of Solid, Liquid and Gaseous Insulations in High Voltage Systems:** Solids as insulating medium in High Voltage Systems: Advantages and limitations of solid insulating materials, surface leakage, surface flashover, and partial discharge in solid insulators and remedial measures. Liquids as insulating medium in High Voltage Systems: Natural and	7	Understanding the behavior and characteristics of different insulating medium for use in high voltage power equipment

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	Synthetic liquid dielectrics and their usage, insulating liquids like Mineral oil, Natural Ester, Synthetic Ester and Silicon oil. Gases as insulating medium in High Voltage Systems: Essential property of the gases for usage as dielectric, electronegative gases and their usage, vacuum as insulating medium.		
V.	**Gas Insulated Systems:** Gas Insulated Substation: unique features, components, advantages and limitations, gas insulated switch-gears and lines, high frequency switching transients in GIS, maintenance of GIS.	**5**	Understanding of GIS and its components and ability to comprehend the relative advantages of GIS over AIS.
VI.	**Generation of High Voltages for Dielectric Testing** Generation of High AC Voltage: High Voltage Testing Transformer – constructional features, voltage regulation, Cascaded High Voltage Transformers – Voltage Regulation and KVA Utilization, Resonant Transformers – Harmonics Elimination and Self-Protective features. Generation of Impulse Voltage: Standard Impulse Wave-shapes, Chopped Impulse Wave, Wave-shape Control, Single and Multi-stage Impulse Generators, Commercial Impulse Generator (Marx Generator) – Triggering and Control mechanisms. Recording of Impulse Voltage using Oscilloscope, Delay Cable.	**8**	Thorough understanding of the methods of dielectric testing of power equipment. Comprehend the methods of high AC and impulse voltage generation for dielectric testing.
VII.	**Quality Control of High Voltage Equipment and Non-Destructive Testing:** High Voltage withstand Tests on Equipment Insulation, assessment of Insulation Health and Quality, International and Indian standards for Dielectric Testing, Impulse Voltage Tests on High Voltage Transformers – diagnosis of Faults by Neutral Current Signature Analysis and Frequency Response Analysis methods. Use of Advanced Signal Processing techniques in Fault Diagnosis.	**7**	Thorough understanding of non-destructive test methods and techniques for quality control of high voltage power equipment.
	TOTAL	**42**	

Course Outcomes	1. Ability to independently carry out research /investigation and development work to solve practical problems in the domain of high voltage engineering and high voltage systems 2. Ability to apply enhanced knowledge and skills in high voltage systems to excel in various sectors in modern power industry/utility and/ or teaching and/or higher education and / or research. 3. Ability to engage in the design of novel products and strategic solutions to real life problems in the areas of high voltage engineering that are technically sound, economically feasible and socially acceptable.

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Learning Resources	1. E. Kuffel and W. S. Zaengl and J. Kuffel, "High Voltage Engineering Fundamentals", Newnes Publication, 2nd Edition, 2005, ISBN 0750636343. 2. Dieter Kind and Kurt Feser, "High Voltage Test Techniques", SBA Publication - Electrical Engineering Series, New Delhi, 1999. 3. Haddad and D. Warne, "Advances in High Voltage Engineering" IET Power and Energy Series 40, ISBN: 9781849190381 4. Mazen Abdel-Salam, "High-Voltage Engineering: Theory and Practice", Second Edition, CRC Press, 2019, ISBN 9780367398194. 5. M. S. Naidu and V. Kamaraju, "High Voltage Engineering", 5th Edition, Tata McGraw-Hill Publishing Co. Ltd., New Delhi, 2015, ISBN: 9781259062896.

43. Aparajita Sengupta 25.6.25

Course Code	EE 5124 N	Course Name	Power System Reliability and Load Forecasting	Course Category	PSE	L	T	P
						3	0	0

Pre-requisite Courses	*Fundamentals of statistics & Probability, Power systems (UG level)*	Co-requisite Courses	*Nil*	Progressive Courses	*Nil*
Course Offering Department		***Electrical Engineering***		**Data Book / Codes/Standards**	*Nil*

Course Objectives	
Course Objectives	1. The students are expected to learn various methods of power system load forecasting and applying them for solving numerical problems through calculations and software programming techniques. 2. To acquaint the students with reliability and its concepts and to introduce the students to methods of estimating the system reliability of simple and complex systems and reliability for generation, transmission, and distribution system.

Module	Syllabus	Duration (class-hours)	Module Outcomes
I.	**Introduction to Load Forecasting:** Objectives of power system load forecasting, key issues and challenges, Data selection, analysis and preprocessing, load forecasting categories	3	On completion of this module, students will understand the objectives, key issues, and challenges in power system load forecasting. They will also be able to categorize different types of load forecasting and apply data selection, analysis, and preprocessing techniques essential for accurate forecasting.
II.	**Statistical load forecasting:** Overview of regression, time series techniques AR, MA, ARMA, ARIMA, Evaluation and monitoring forecasting model performance, exponential smoothing methods, trend estimation, additive and multiplicative decomposition. Artificial Intelligent Technology for Electric Load Forecasting-Neural Network, Support Vector Machine	5 3	This module will help the students to apply statistical techniques such as regression, time series models (AR, MA, ARMA, ARIMA), and exponential smoothing for electric load forecasting, along with performance evaluation methods. They will also gain knowledge of artificial intelligence approaches including neural networks and support vector machines for advanced load forecasting applications.
III.	**Reliability analysis:** Review of basic probability theory, Probability distributions, Probability distribution in reliability evaluation, reliability definition and indices, outage classification	5	On studying this module, students will understand fundamental probability theory and probability distributions as applied to reliability evaluation, including key reliability indices and outage classification. They will also be able to

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	Reliability functions: Survivor function, cumulative failure distribution function, hazard rate, their relationships – exponential distribution – expected value and standard deviation of exponential distribution – Bath tub curve – reliability analysis of series parallel networks using exponential distribution – reliability measures MTTF, MTTR, MTBF.		analyze reliability functions, apply exponential distribution and bath tub curve concepts, and evaluate reliability measures such as MTTF, MTTR, and MTBF for series-parallel systems.
IV.	**Markov modelling:** Continuous Markov processes, evaluation of time dependent and limiting state probabilities for one component repairable system. **Network modelling and reliability analysis:** Analysis of Series, Parallel, Series-Parallel networks– decomposition method, reliability indices- SAIFI, SAIDI, CAIFI, and CAIDI.	**6**	The module will help the students to model and analyze repairable systems using continuous Markov processes to evaluate time-dependent and steady-state probabilities. They will also gain skills in reliability analysis of network configurations and understand key reliability indices such as SAIFI, SAIDI, CAIFI, and CAIDI.
V.	**Frequency and duration techniques:** Frequency and duration concept – evaluation of frequency of encountering state, mean cycle time, for one, two component repairable models. Approximate system reliability evaluation for two component repairable series and parallel system.	**5**	This module will enable the students to understand frequency and duration concepts for repairable systems. They will also be able to approximate reliability for two-component repairable series and parallel systems.
VI.	**Generating system reliability analysis:** Generation system model – capacity outage probability tables – Recursive relation for capacity model building – sequential addition method – unit removal – Evaluation of loss of load and energy indices.	**5**	Upon completion of this module, students will be able to analyze generating system reliability using capacity outage probability tables and recursive methods. They will also develop knowledge in evaluating loss of load and energy indices to assess system performance.
VII.	**Distribution system reliability analysis:** State space diagram, network reduction method of evaluating load point reliability index. Inclusion of bus bar and breaker failures, scheduled maintenance, temporary and transient failures, inclusion of weather.	**6**	This module will help the students to perform distribution system reliability analysis using state space diagrams and network reduction methods to evaluate load point reliability indices. They will also understand how to incorporate factors such as bus bar and breaker failures, scheduled maintenance, transient faults, and weather conditions into reliability assessments.
VIII.	**Reliability assessment of interconnected systems:**	**4**	Upon completion of this module, students will be able to assess the reliability of

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	Probability array method, effect of tie line capacity and number of tie lines.		interconnected power systems using the probability array method, and analyze the impact of tie line capacity and the number of tie lines on system reliability.
	TOTAL	**42**	

Course Outcomes	1. The students are able to apply various load forecasting techniques in power system to solve problems through calculations and using software simulation. 2. The students are able to apply the fundamentals of reliability to generation, transmission and distribution system, and are expected to exercise the reliability concepts/methods for various power system problems.

Learning Resources	1.Douglas Montgomery, C.L. Jennings and M. Kulahci , Introduction to Time series Analysis and Forecasting, John Wiley & Sons Ltd (2nd ed.) 2.Rafal Weron, Modelling and Forecasting Electricity Loads and Prices: A statistical approach, John Wiley & Sons Ltd, 2006. 3.Special issue on Short-Term Load Forecasting by Artificial Intelligent Technologies, Energies, MDPI, 2018 4.IEEE Press Series on Power Engineering: Advances in Electric Power and Energy Systems Load and Price Forecasting, 2017 5.RoyBillinton and Ronald N. Allan, Reliability Evaluation of Power Systems, Springer (2nd ed.) 6.D. Elmakias, New Computational Methods in Power system Reliability, Springer 2008.

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Laboratory /Mini Project

on

Computer Aided Power System Analysis

(EE 5174 N)

Laboratory /Mini Project

on

Power System Operation and Control

(EE 5175 N)

Laboratory /Mini Project

on

Power Transmission & Power Quality

(EE 5176 N)

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2^{nd} Semester
M.Tech in Power and Energy Systems (PES)

Course Code	EE 5204 N	Course Name	Advanced Power System Protection	Course Category	PC	L	T	P
						3	0	0

Pre-requisite Courses	Power System Protection	Co-requisite Courses	*Nil*	Progressive Courses	*Nil*
Course Offering Department		*Electrical Engineering*		**Data Book / Codes/Standards**	Relevant IS, IEC, IEEE & CIGRE standards

Course Objectives	1. To revisit the fundamentals of power system protection, various protection schemes for power system equipment and components and advanced topics on switchgear. 2. To explicate the function of static and numerical relays, aadaptive relaying and intelligent electronic devices. 3. To elucidate the concepts of microprocessor based smart protective relays and digital relaying algorithms.

Module	Syllabus	Duration (class-hours)	Module Outcomes
I.	**Review of Differential Protection:** Percentage Differential Relay, Differential Protection of Transmission Lines - Pilot Relaying, Circulating Current and Opposed Voltage schemes, Carrier Current and Microwave Pilot protection for Transmission Lines, Microprocessor based line differential relays using optical fiber as the communication media.	3	Recapitulate the fundamentals of differential relaying principles and revise the concepts of various differential protection schemes
II.	**Transmission Line Protection:** Distance Relays - Impedance Relay, Reactance Relay, Admittance Relay - characteristics and uses, Modified Distance Relays – Offset Mho Relay, Quadrilateral and Elliptical Relay characteristics, Effects of In-feed & Out-feed effect on distance protection scheme.	6	Thorough understanding of the principles of distance protection for transmission lines
III.	**Alternator Protection:** Stator Earth Fault and Phase Fault Protection, Restricted Earth Fault Relay, Transverse Differential Relay, Inter-turn fault protection based on Zero-Sequence Current, Rotor Earth Fault Protection, Protection against Loss of Excitation and Prime Mover Failure, Stator-overheating Protection, Protection against Negative Sequence Current in Stator Winding.	5	Thorough understanding of the different protection schemes for alternator
IV.	**Transformer Protection:** Transformer Differential Relay, Harmonic Restraint feature in Transformer Differential Relay, Protection against Incipient Faults, Protection against sustained Overloading and Overheating, Over-fluxing protection, Restricted earth fault, Tank-earth protection, Neutral displacement protection.	5	Thorough understanding of the different protection schemes for transformer

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V.	**Motor Protection**: Differential Protection for Large Motors, Short Circuit and Overload Protection, Under Voltage Protection, Earth Fault Protection, Locked Rotor Protection, Protection of DC Motors	4	Thorough understanding of the different protection schemes for different electrical motors
VI.	**Bus Bar, Capacitor Bank and Reactor Protection:** Short Circuit, Over Current, Differential and Earth Fault Protection.	2	Thorough understanding of the different protection schemes for bas bar, capacitor bank and reactor
VII.	**System Protection:** Annunciation and Indication, Tripping and Control Circuit, Interlocking, Co-ordination of Protection Devices, Signal Derivation, Transient Characteristics, System Behavior and Protection during Power Swing, Under Frequency and Islanding.	4	Comprehend the concepts of system protection and its sub-modules
VIII.	**Static and Numerical Relaying:** Basic Operations of Static Relays; Types of Comparators, Two and Multi-input Comparators, Numerical Relays- The functionality and Realization of various Protection Algorithms; Concept and application of Adaptive Relaying of various Electrical Apparatus, Evolution of Intelligent Electronic Devices (IED),Signal Processing Techniques used in IEDs	5	Understand the principles of static and numerical relays and ability to implement various relaying algorithms. Comprehend Intelligent Electronic Devices (IED) and Signal Processing Techniques used in IEDs
IX.	**Smart Protection Systems:** Substation Automation using IEC 61850 protocol, Synchro-Phasor Measurements and its Role in Wide Area Monitoring and Protection, Use of Phasor Measurement Unit (PMU) and Disturbance Recorder (DR) as a system disturbance analytical tool.	4	Comprehend smart protection principles and applications of devices like PMU and DR.
X.	**Advanced Topics on Circuit Breaker:** Advanced methods of Arc Quenching, Re-striking voltage and Recovery voltage, Current Chopping, Capacitive Current Breaking, Resistance Switching, Rating and Selection of Circuit Breakers, HVDC Circuit Breakers.	4	Thorough understanding of the arc quenching mechanisms and various transient phenomena in circuit breakers
	TOTAL	**42**	

Course Outcomes	1. Ability to independently carry out research /investigation and development work to solve real-life problems in the domain of power system protection. 2. Ability to apply enhanced knowledge and skills in power system protection to excel in modern power industry/utility and/ or teaching and/or higher education and / or research. 3. Ability to participate and contribute in the design of novel products/ algorithms and deliver strategic solutions the problems in the domain of power system protection.

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Learning Resources	1. Synchronized Phasor Measurements and Their Applications, A. Phadke, J Thorp, Springer Publication, ISBN: 9781441945631, 1441945636 2. Digital Protection for Power Systems A. T. Johns, S. K. Salman, IET Publication, , 1997 ISBN- 13:9780863413032 3. Digital Signal Processing in Power System Protection and Control, Waldemar Rebizant Janusz Szafran, Andrzej Wiszniewski, Springer-Verlag, 2011.

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Course Code	EE 5205 N	Course Name	Artificial Intelligence and Optimization in Power Systems	Course Category	PC	L	T	P
						3	0	0

Pre-requisite Courses	Engineering Mathematics, Power System	Co-requisite Courses	*Nil*	Progressive Courses	*Nil*
Course Offering Department		*Electrical Engineering*		Data Book / Codes/Standards	Relevant IS, IEC, IEEE & CIGRE standards

Course Objectives	1. To provide students with a comprehensive understanding of AI principles, techniques, and potential applications in the domain of Electrical Power System. 2. To elucidate AI algorithms, machine learning techniques, fuzzy logic and data-driven decision-making approaches, enabling students to integrate these principles into power system research and development. 3. To familiarize students with different optimization techniques and to enable them to apply optimization tools to solve practical problems in power system.

Module	Syllabus	Duration (class-hours)	Module Outcomes
I.	**Introduction to Artificial Intelligence and Machine Learning:** Computational intelligence, Machine Learning and Computer Vision, Biological Inspiration, Learning through Examples.	3	Acquaintance with AI &Machine Learning
II.	**Artificial Neural Network (ANN):** Neuro-Computing (NC), Biological and Artificial Neural Networks, Types and Variants of ANN, Supervised, Unsupervised and Reinforcement Learning Algorithms.	5	ANN Supervised Learning Unsupervised Learning
III.	**Applications of ANN in Power System:** Typical Applications of Supervised Learning ANN in Power System - Power Network Restructuring and Optimization, Load forecasting etc. Typical Applications of Unsupervised Learning ANN in Power System – Stability and Security Analysis, Intelligent and Adaptive Protection, Fault Detection and Diagnosis, Condition Monitoring of Electrical Equipment, etc.	6	Applications of ANN in Power System
IV.	**Decision Trees and its Applications in Power System:** Classification and Regression Tree, Structure of a Decision Tree - Root, Internal and Leaf Nodes, Splitting Criteria - Information Gain, Entropy and Gini Impurity, building a Decision Tree - Feature Selection, Splitting, Pruning, Over-fitting and Mitigation, Ensemble Decision Trees – Bagging, Boosting and	6	Decision Tree Ensemble classifiers Applications of Decision Tree in Power System

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	Random Forest Algorithms, Typical Applications of Decision Tree in Power System.		
V.	**Recent Trend in Machine Learning: Principles and Applications:** Recurring Neural Networks (RNN), Long Short Term Memory (LSTM), Time series prediction in forecasting issues of Modern Power systems. Deep Learning, Convolutional Neural Networks (CNN). Big data Analysis for smart grid and stochastic power systems with renewable energy integration. Deep Reinforcement Learning (DRL) based intelligent controller for load frequency control.	**5** **5**	RNN &LSTM Time series Prediction Deep-learning, CNN Big-data Analysis DRL based Intelligent Controller in Power System
VI.	**Fuzzy Logic and Applications:** Basic concepts of Fuzzy logic approaches, linguistic variables, membership functions, basic operation, Fuzzy relations, different de-Fuzzification techniques, Fuzzy rule-based model, type-2 Fuzzy system. Typical Applications and case studies of fuzzy logic controllers, neuro-fuzzy model for modern Power Systems.	**6**	Fuzzy logic Controllers Neuro-Fuzzy model
VII.	**Genetic Algorithms (GA) and Applications:** Introduction to search optimization method, evolutionary algorithms (EA), biological inspiration behind GA, working principles, encoding, crossover and mutation, basic GA algorithm. Typical Applications of Genetic Algorithm in Optimal sizing and placement of Capacitor bank in power network, Economic load dispatch and optimal resource allocation, Optimization of distribution network for economic operation, optimal placement of PMUs.	**6**	GA based evolutionary algorithms Applications of GA & other evolutionary algorithms in modern Power Systems
	TOTAL	**42**	

Course Outcomes	1. Ability to independently carry out research /investigation and development work to solve real-life problems in the power system using machine learning techniques and optimization tools. 2. Ability to apply the acquired knowledge and skills in AI/ML and optimization to excel in modern power industry and utility and/ or teaching, higher education and research. 3. Ability to develop novel products and algorithms leading to unique AI/ML solutions to problems in the domain of power system

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Learning Resources	1. Neural Networks, Fuzzy Logic and Genetic Algorithm: Synthesis & Applications - S. Rajasekaran and G. A. VijayalakshmiPai, PHI Learning Ltd, 2003. 2. TerezijaMatijašević, TomislavAntić, Tomislav Capuder, A systematic review of machine learning applications in the operation of smart distribution systems, Energy Reports, Volume 8, 2022, Pages 12379-12407, ISSN 2352-4847, https://doi.org/10.1016/ j.egyr.2022.09.068. 3. IEEE Workshop on Machine Learning for Power Systems, 17^{th} November, 2021. 4. Tutorial on Fuzzy Logic Applications in Power System, IEEE—PES winter meeting, Singapore, January, 2000. 5. Genetic Algorithm in Applications, Edited by Dr. Rustem Popa, March 2012.

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Course Code	EE 5206 N	Course Name	Grid Integration of Renewable Energy	Course Category	PC	L	T	P
						3	0	0

Pre-requisite Courses	Fundamentals of Power Systems and Power Electronics	Co-requisite Courses	*Nil*	Progressive Courses	*Nil*
Course Offering Department		*Electrical Engineering*		**Data Book / Codes /Standards**	*Relevant IS, IEC, IEEE & CIGRE standards*

Course Objectives	The course focuses on 1. Equipping students with a strong understanding of power systems, their operation, and control, particularly in relation to integrating distributed renewable generation into the grid. 2. The impact of Power Electronic Converters on Grid Stability operation and Power quality, the technical knowledge, standards and protocols required for such type of integration.

Module	Syllabus	Duration (class-hours)	Module Outcomes
I.	**Introduction:** Various techniques of utilizing power from renewable energy sources, concept of nano/micro/mini grid. Need of integrating large renewable energy sources, issues related to integration of large renewable energy sources, rooftop plants. Concept of VPP	4	Understand techniques for utilizing renewable power, comprehend nano/micro/mini grids, and evaluate challenges in integrating large renewables.
II.	**Grid operation and stabilization:** Scheduling and dispatch, Forecasting, reactive power and voltage control, frequency control, operating reserve, storage systems, electric vehicles. Ancillary services in Indian Electricity Market (regulatory aspect),CERC and CEA orders (technical and safety standards)	6	Understanding methodologies and developing models for optimal power dispatch, balancing generation, storage, and demand efficiently.

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III.	**Power system equipments for grid integration: Synchronous generator:** Synchronization/integration to existing grid, load sharing during parallel operation, stability (swing equation and solution)	**5**	Understanding conditions for synchronization, investigating active and reactive power sharing mechanisms, and its impact on system stability.
IV.	**Induction Generator:** Working principle, classification, stability due to variable speed and counter measures	**5**	Analysis of Induction Generators in Wind Power
V.	**Power Electronics:** Need of power electronic equipments in grid integration, converter, inverter, chopper, ac regulator and cyclo-converters for AC/DC conversion	**5**	Explain the necessity of power electronic equipment in modern grid integration.
VI.	**Power quality and management:** THD, voltage sag, voltage swell, frequency change and its effects, network voltage management, frequency management, system protection, grid codes	**6**	Assess the impact of power electronic systems on power quality. Evaluate System Protection & Grid Codes- Investigate frequency management techniques and their role in grid stability.
VII.	**Integration of alternate sources of energy:** Introduction, principles of power injection: converting technologies, power flow; instantaneous active and reactive power control approach; integrating multiple renewable energy sources; DC link integration; AC link integration; HFAC link integration; islanding and interconnection	**6**	Explain the role of power injection in grid stability and energy balance, identify various converting technologies used for controlled power transfer, Explore HFAC link integration, emphasizing high-frequency power conversion in modern grids.
VIII.	**Case studies:** Based on synchronous/induction generator for peak demand reduction, grid connected PV system	**5**	By the end of this case study, learners will be able to: - Assess Load Management Strategies, Apply Demand Response Techniques – Explore real-world applications of peak shaving and load shifting using generator-based systems.
	TOTAL	**42**	

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Course Outcomes	1. Learners will understand the role of converters, inverters, and other electronic components in managing power flow. 2. Students will learn about AC/DC link integration, islanding, and interconnection of multiple renewable sources. 3. Regulatory and Market Aspects: Participants will study grid codes, ancillary services, and forecasting techniques for efficient renewable energy integration.

Learning Resources	1.Integration of Alternative sources of Energy, Felix A. Farret and M. Godoy Simoes, IEEE Press –Wiley-Interscience publication, 2006. 2. Grid integration of solar photovoltaic systems, Majid Jamil, M. Rizwan, D.P.Kothari, CRC Press (Taylor & Francis group), 2017. 3. Renewable Energy Grid Integration, Marco H. Balderas, Nova Science Publishers, New York, 2009. 4. Wind Power Integration connection and system operational aspects, B. Fox, D. Flynn L. Bryans,N. Jenkins, M. O' Malley, R. Watson and D. Milborrow, IET Power and Energy Series 50 (IET digital library), 2007. 5. Power Generation, Operation, and Control, Allen J. Wood, Bruce F. Wollenberg, Gerald B.Sheblé, John Wiley & Sons, New York, 2013 (3rd edition). 6. Power Electronics: Circuits, Devices, and Applications. M.H.Rashid, Pearson Education India, 2013. 7. Advanced power system analysis and dynamics, L.P.Singh, New age international publishers, 2017. 8. Renewable Energy Engineering and Technology – A Knowledge Compendium, V.V.N. Kishore, TERI Press, 2008.

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Course Code	EE 5223 N	Course Name	Restructured Power Systems	Course Category	PSE	L	T	P
						3	0	0

Pre-requisite Courses	*Power Systems*	Co-requisite Courses	*Nil*	Progressive Courses	*Nil*
Course Offering Department		***Electrical Engineering***		Data Book / Codes/Standards	*Relevant IS, IEC, IEEE Standards*

Course Objectives	
	1. To understand the evolution of power systems and the underlying reasons for restructuring. 2. To analyze the phenomenon of transmission congestion and develop the ability to estimate and allocate power system losses. 3. To evaluate the economic principles and challenges in a restructured power system environment. 4. To examine and determine the essential functions of ancillary services and demand response in maintaining the stability of restructured power systems. 5. To investigate and compare different power system restructuring models adopted globally through the study of relevant case studies.

Module	Syllabus	Duration (class-hours)	Module Outcomes
I.	**Restructuring of Power Industry and Fundamentals of Economics** – Introduction, Reasons for Restructuring / Deregulation of Power Industry, Fundamentals of Deregulation, Motivation of Restructuring the Power Industry, Restructuring Process – Unbundling & Privatization, Components of Restructured Systems, Fundamentals of Economics	8	Upon completion of this module, students will understand the motivations and processes of power industry restructuring and deregulation, including unbundling and privatization, identify key components of restructured power systems, and apply fundamental economic principles to the energy sector.
II.	**Power Market Reforms** – Reforms in Indian Power Sector, Independent System Operator (ISO): Functions and Responsibilities, Smart Grid Trading arrangements (Pool, Bilateral & Multilateral), Open Access Transmission Systems, and Open Access Same Time Information System (OASIS)	5	Upon completion, students will analyze Indian power sector reforms, understand ISO functions, differentiate smart grid trading arrangements (pool, bilateral, multilateral), and explain Open Access Transmission Systems and OASIS.
III.	**Transmission Pricing & Congestion Management** – Cost Components, Postage Stamp Method, Megawatt Mile Method, Contract Path Method. Classification of Congestion	6	Upon completion, students will evaluate transmission pricing methodologies (Postage Stamp, Megawatt Mile, Contract Path), classify and apply congestion

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	Management Methods, Calculation of ATC-TTC-CBM, Non-market methods, Market based methods, Nodal pricing, Inter-zonal Intra-zonal congestion management, Price Area Congestion Management, Locational Marginal Prices		management techniques, calculate ATC, TTC, and CBM, and understand Nodal Pricing, inter/intra-zonal congestion management, and LMPs.
IV.	**Economic Operation in Restructured Environment** – Economic Dispatch Problem and Solutions, Optimal Power Flow (OPF), General OPF Formulation, Security Constrained OPF, Solution Techniques, OPF Application in Electricity Markets	**5**	Upon completion, students will solve economic dispatch problems, formulate and apply OPF and SCOPF using various solution techniques, and understand OPF's application in electricity markets.
V.	**Risk Management in Restructured Environment** – Energy and Reserve Markets, Market Power, Forward and Future market, Smart Grid Optimization with risk constraints - General Risk Measures, Portfolio Selection Problem, Financial Transmission Rights	**6**	Upon completion, students will analyze energy and reserve markets, mitigate market power, understand forward and future markets, apply smart grid optimization with risk constraints and portfolio selection, and grasp the role of FTRs in risk management.
VI.	**Ancillary Services Management and Demand Response in Restructured Environment** – Reactive Power as an Ancillary Service, Energy Storage System, Power Quality, Reliability Analysis, Demand Response, Potential benefits of Demand Response in Smart Grid, Smart Technologies for Demand Response, Demand Response for Electric Vehicles	**6**	Upon completion, students will explain reactive power as an ancillary service and the function of energy storage systems, analyze power quality and reliability, define demand response (DR) and its smart grid benefits, identify smart DR technologies, and understand DR application for electric vehicles.
VII.	**Different Models of Deregulation** – UK Model, California model, Australian and New Zealand models, Deregulation in Asia including India, Bidding Strategies, Forward and Future market	**6**	Upon completion, students will compare diverse deregulation models (e.g., UK, California, Australian, New Zealand, Asian including India), develop and evaluate electricity market bidding strategies, and understand forward and future market functions in a deregulated environment.
	TOTAL	**42**	

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Course Outcomes	1. Students will be able to explain the evolution of power systems and analyze the motivations for restructuring. 2. Students will be able to assess transmission congestion and apply methods to estimate power system losses. 3. Students will be able to evaluate the economic principles and challenges within restructured power systems. 4. Students will be able to determine the functions of ancillary services and demand response in maintaining the stability of the restructured power systems. 5. Students will be able to compare and contrast different global models of power system restructuring through case study analysis.

Learning Resources	1. M. Shahidehpour, M. Alomoush, Restructured Electrical Power Systems – Operation, Trading and Volatility, Marcel Dekker, Inc., 2001. 2. L. L. Lai, Power System Restructuring and Deregulation, John Wiley & Sons Ltd., 2012. 3. K. Bhattacharya, J. E. Daadler, and Math H.J Bollen, Operation of restructured power systems, Kluwer Academic Pub., 2012.

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Course Code	EE 5224 N	Course Name	Smart Grid Technologies and Energy Informatics	Course Category	PSE	L	T	P
						3	0	0

Pre-requisite Courses	UG level Power System	Co-requisite Courses	*Nil*	Progressive Courses	*Nil*
Course Offering Department		*Electrical Engineering*		Data Book / Codes/Standards	*Nil*

Course Objectives	Basic understanding of Smart Grid environment along with information processing techniques of energy related data.

Module	Syllabus	Duration (class-hours)	Module Outcomes
I.	**Introduction to Smart Grids:** Definition, justification for smart grids, smart grid conceptual model, smart grid architectures, Interoperability, communication technologies, role of smart grids standards, intelligent grid initiative, national smart grid missions by Govt. of India	5	Acquaintance with Smart Grid
II.	**Smart Transmission Technologies:** Substation automation, Supervisory control and data acquisition (SCADA), energy management system (EMS), phasor measurement units (PMU), Wide area measurement systems (WAMS), role of Communication and Information Technology (ICT)	6	SCADA PMU WAMS
III.	**Smart Distribution Technologies:** Distribution automation, outage management systems, automated meter reading (AMR), automated metering infrastructure (AMI), fault location isolation and service restoration, Outage Management Systems, Energy Storage, Renewable Integration	6	AMR AMI Renewable Integration Energy Storage
IV.	**Distributed Generation and Smart Consumption:** Distributed energy resources, smart appliances, low voltage DC distribution in homes / buildings, home energy management system, Smart Metering, Building to Grid B2G, Vehicle to Grid V2G, Solar to Grid, Micro grid	6	Micro grid B2G, G2B V2G, G2B
V.	**Regulations and Market Models for Smart Grid:** Demand Response, Demand side Management, Tariff Design, Time of the day pricing, Critical Peak Pricing, Time of use pricing, Consumer privacy and data protection, consumer engagement.	5	Demand side Management Dynamic Pricing
VI.	**Introduction to Energy Informatics:** Energy, sustainability and climate change, Green IT: policy and standards, Green IS, Energy efficiency design principles,	6	Acquaintance with Energy Informatics Energy Efficiency

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	Energy efficient logistics, farming, transportation, buildings, Energy system modelling		
VII.	**Data Driven Energy Management System:** Processing energy data streams: Big Data-driven smart Energy Management Systems, Data analytics for energy-cost efficient system operation, cloud computing for smart grid applications. Multi source data integration and storage, data compressing, data privacy and security.	**8**	Big data driven energy management Cloud Computing Data privacy and security
	TOTAL	**42**	

Course Outcomes	Students would acquaint with fundamentals of smart grid and particularly the impact of renewable energy on power system. They would also learn the communication technology, tools and techniques used for smart grid.

Learning Resources	1. Stuart Borlase. "Smart Grid: Infrastructure Technology Solutions" CRC Press, **2017.** 2. Ali Keyhani, "Design of smart power grid renewable energy systems", Wiley IEEE,**2011**. 3. Clark W. Gellings,"The Smart Grid: Enabling Energy Efficiency and Demand Response", CRC Press, **2009**. 4. Janaka Ekanayake, Nick Jenkins, Kithsiri Liyanage, "Smart Grid: Technology and Applications", Wiley **2012**. 5. A.G.Phadke , "Synchronized Phasor Measurement and their Applications", Springer, **2017** 6. James Momoh, "Smart Grid: Fundamentals of Design and Analysis" – Wiley, IEEE Press, **2012**. 7. H. Lee Willis, Walter G. Scott, "Distributed Power Generation – Planning and Evaluation", Marcel Dekker Press, **2000** 8. India Smart Grid Knowledge Portal 9.Information Systems and Environmentally Sustainable Development: Energy Informatics and New Directions for the IS community, by R. T. Watson et al., MIS Quarterly, **2010** 10. Advances and New Trends in Environmental and Energy Informatics, by J. M. Gomez et. al., Springer, **2014** 11.Energy Informatics: Fundamentals and Standardizations, by B. Huang et al., ICT Express (Elsevier), **2017** 12.Chunming Tu, Xi He, ZhikangShuai, Fei Jiang, Big data issues in smart grid – A review, Renewable and Sustainable Energy Reviews, Volume 79,**2017**, Pages 1099-1107, ISSN 1364-0321, https://doi.org/10.1016/j.rser.2017.05.134.

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M.Tech in Power Electronics, Machines and Drives (PEMD)
Course Structure

First Semester

Sl. No.	Type	Course Name	Course code	Class Load/Week L	T	P	Credit	Class load/ week	Marks
1	PC	Advanced Power Electronics	EE5107 N	3	0	0	3	3	100
2	PC	Generalized Theory of Electrical Machines	EE5108 N	3	0	0	3	3	100
3	PC	Applied Linear and Nonlinear Control	EE5101 N	3	0	0	3	3	100
4	PSE (any one)	1. Optimization and Optimal Control 2. Theory of Discrete and Digital Control Systems 3. High Voltage Systems 4. Power system Reliability and Load Forecasting 5. Advanced Microcontroller Technology 6. Power Quality	EE5121 N EE5122 N EE5123 N EE5124 N EE5125 N EE5126 N	3	0	0	3	3	100
5	OE	High-Performance Computation (HPC) Using CPU and GPU for AI Applications	EE5161 N	3	0	0	3	3	100
		Theory Sub-total		**15**	**0**	**0**	**15**	**15**	**500**
6	PC	Lab on Advanced Power Electronics	EE5177 N	0	0	3	2	3	50
7	PC	Mini Project on Generalized Theory of Electrical Machines	EE5178 N	0	0	3	2	3	50
8	PC	Lab/Mini Project on Applied Linear and Nonlinear Control	EE5171 N	0	0	3	2	3	50
		Practical Sub-total		**0**	**0**	**9**	**6**	**9**	**150**
		First Semester Total		**15**	**0**	**9**	**21**	**24**	**650**

Second Semester

Sl. No.	Type	Course Name	Course code	Class Load/Week L	T	P	Credit	Class load/ week	Marks
1	PC	Advanced Electrical Drives	EE5207 N	3	0	0	3	3	100
2	PC	Selected Topics in Power Electronics	EE5208 N	3	0	0	3	3	100
3	PC	Selected Machines for Electric Vehicle and Wind Power Applications	EE5209 N	3	0	0	3	3	100
4	PSE (any one)	1. Elements of Cyber Physical Systems 2. Networked & Distributed Control 3. Restructured Power Systems 4. Smart Grid Technologies and Energy Informatics 5. Special Electrical Machines 6. Power Electronic Converters for Bulk Power Conditioning	EE5221 N EE5222 N EE5223 N EE5224 N EE5225 N EE5226 N	3	0	0	3	3	100
5	OE	Power Supplies for Electrical Equipment	EE5262 N	3	0	0	3	3	100
		Theory Sub-total		**15**	**0**	**0**	**15**	**15**	**500**
6	P	M.Tech. project/Term-paper	EE5291 N	0	0	3	2	3	50
7	O	Seminar/Viva Voce	EE5292 N	0	0	3	2	3	50
		Practical Sub-total		**0**	**0**	**6**	**4**	**6**	**100**
		Second Semester Total		**15**	**0**	**6**	**19**	**21**	**600**

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		Third Semester							
Sl. No.	**Type**	**Course Name**	**Course code**	**Class Load/Week**			**Credit**	**Class load/ week**	**Marks**
				L	**T**	**P**			
1	**VAC**	Energy Audit	EE6101N	3	0	0	3	3	100
2	P	M. Tech. Thesis	EE6191 N				12	24	300
3	O	Progress Seminar and Viva-voce	EE6192 N				6		100
4	I	Summer internship (6-8 weeks) evaluation	EE6193 N				2		50
		Third Semester Total					**23**		**550**

		Fourth Semester							
Sl. No.	**Type**	**Course Name**	**Course code**	**Class Load/Week**			**Credit**	**Class load/ week**	**Marks**
				L	**T**	**P**			
1	P	M. Tech. final thesis	EE6291 N				22	30	400
2	O	Thesis Seminar and Viva-voce	EE6292 N				8		200
		Fourth Semester Total					**30**		**600**

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1st Semester
M.Tech in Power Electronics, Machines and Drives (PEMD)

<table>
<tr><td rowspan="2">Course Code</td><td rowspan="2">EE 5107 N</td><td rowspan="2">Course Name</td><td rowspan="2">Advanced Power Electronics</td><td rowspan="2">Course Category</td><td rowspan="2">PC</td><td>L</td><td>T</td><td>P</td></tr>
<tr><td>3</td><td>0</td><td>0</td></tr>
</table>

<table>
<tr><td>Pre-requisite Courses</td><td>One course on basic power electronics at UG level</td><td>Co-requisite Courses</td><td>Nil</td><td>Progressive Courses</td><td>1. Special Topics in Power Electronics (EE 5208)
2. Advanced Electric Drives (EE 5207)
3. Selected Machines for Electric Vehicle and Wind Power Applications (EE 5209)</td></tr>
<tr><td colspan="2">Course Offering Department</td><td colspan="2">Electrical Engineering</td><td>Data Book / Codes/ Standards</td><td>Nil</td></tr>
</table>

Course Objectives	This course will enable students to: 1. Learn the operation and characteristics of the common and state-of-the-art solid state power electronic devices, design of their driver stages along with their components 2. Understand the operation of different types of main types of DC-DC converters including the ones without galvanic isolation and those with galvanic isolation 3. Understand the operation of different types of main types of AC-DC converters (rectifiers) 4. Understand the operation of different types of main types of DC-AC converters (inverters) 5. Understand the operation of different types of main types of AC-AC converters (cyclo-converters and matrix converters) 6. Understand the operation of different types of main types of DC-AC converters (inverters). 7. Learn to analyse and synthesise all the above PE Converters through a generalised/ unified approach of switch matrices and source-load dynamics 8. Learn the operation and design of magnetic components (inductors and pulse transformers) and the operating characteristics of different types of capacitors for power electronic applications 9. Learn about switching trajectories, switching and device losses and heat dissipation mechanism of power electronic devices and design of heat dissipation systems 10. Learn the need for use and design of switching aid networks (AANs) / snubbers.

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Module	Syllabus	Duration (class-hours)	Module Outcomes
I.	**Introduction:** Review of existing solid state power devices. Quadrant operation of devices. Modern solid state devices (GaN and SiC), special driver circuits, SOA and switching trajectory, losses in power electronic devices, pulse transformer.	8	Students will be able to select a proper device for a particular power electronic converter of proper rating, design and analyze driver stages, switching aid network/snubbers, pulse transformers and understand, analyze the power losses that occur in power electronic devices.
II.	**DC-DC converters:** Discontinuous conduction, 2-quadrant and 4-quadrant DC-DC converters. Forward, fly-back, push-pull, half-bridge and full-bridge topologies and their open-loop control. Dynamic modeling of DC-DC converters and closed loop control, efficiency issues of DC-DC converters.	9	Students will be able to design and analyze different topologies of DC-DC converters considering power flow capabilities. They will be able to analyze such converters in continuous conduction mode, discontinuous conduction mode, in steady state as well as in dynamic condition.
III.	**AC-DC converters:** Review of diode and thyristor-based rectifiers, discontinuous conduction, effect of source inductance, effects on AC side, efficiency of rectifiers.	5	Students will be able to analyze operation of diode and thyristor-based AC-DC converters in steady state neglecting as well as considering the presence of source inductance for forward as well as reverse power flow.
IV.	**DC-AC conversion:** Single phase and three phase inverters, concept of space vectors, analysis of 2-level inverters with Sine-PWM and Space vector pulse width modulation. Concept of current source inverters, efficiency issues of inverters.	8	Students will be able to design and analyze steady state operation of single phase and three phase two level full bridge voltage source inverters, controlled through sinusoidal and space vector based pulse width modulation techniques. They will learn to analyze the operation of current source inverters also.
V.	**AC-AC conversion:** Review of cyclo-converters, matrix converters.	7	Students will learn to analyze steady state operation of AC-AC converters like thyristor-based cycloconverters and self-commutable device based matrix converters.
VI.	**Passive components:** Magnetics and capacitors for PE applications, design of heat sink for dissipation of losses.	5	Students will be able to learn the operation and characteristics of magnetics and capacitors for pulsed waveforms experienced in power electronics, design magnetic components for such cases and be able to select proper capacitors for such cases. Students will be able to design and/or select heat sink for

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			power electronic devices for a particular converter application.
	TOTAL	**42**	

Course Outcomes	After studying this course, students gain sufficient knowledge to: 1. Select power devices and associated components for designing power electronic converters for any given application 2. Design driver stages for a power electronic device 3. Mathematically analyze steady state and dynamic operation of different types of DC-DC converters 4. Mathematically analyze steady state operation of different types of AC-DC converters, DC-AC converters and AC-AC converters in a generalised/ unified approach. 5. Design heat sink required for heat dissipation of power electronic devices being used in a power converter application 6. Design closed loop controllers for a DC-DC converter for a particular application 7. Design DC chokes for DC-DC converters and select capacitors for power electronic applications 8. Design switching aid networks. 9. Understand and calculate switching trajectories and device related losses.

Learning Resources	1. N. Mohan, T. M. Undeland and, W. P. Robbins — Power Electronics: Converters, Applications and Design, John Wiley & Sons, 2007. 2. C. W. Lander— Power Electronics, McGraw Hill BookCo, 1987. 3. R. W. Erickson and D. Maksimovic— Fundamentals of Power Electronics, 2nd Edition, Kluwer Academic Publishers, New York, 2001. 4. M. H. Rashid — Power Electronics - Circuits, Devices and Applications, Prentice Hall, Pearson Education, 2014. 5. G. K. Dubey, S. R. Doradla, A. W. Joshi, R. M. K. Sinha —Thyristorised Power Controllers, Wiley, 1986. 6. A. I. Pressman, K. Billings, T. Morey— Switching Power Supply Design, 3rd Edition, McGraw-Hill, 2009. 7. Modern research literature, papers and URLs as available in the net.

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Course Code	EE 5108 N	Course Name	Generalized Theory of Electrical Machines	Course Category	PC	L	T	P
						3	0	0

Pre-requisite Courses	Courses on electrical machines and basic power electronics	**Co-requisite Courses**	*Nil*	**Progressive Courses**	Advanced Electrical Drives
Course Offering Department		*Electrical Engineering*		**Data Book / Codes/Standards**	*Nil*

Course Objectives	
	1. This course describes the generalized machine theory basic concepts, Park's transformation, Clarke's transformation. 2. This course familiarizes the different types of d-q transformation, synchronously rotating and arbitrarily rotating reference frames. 3. This course described the transient and steady state modelling and analysis of 3-phase induction machines and synchronous machines. 4. This course described the transient and steady state modelling and analysis of D.C. machines and cross-field machines.

Module	Syllabus	Duration (class-hours)	Module Outcomes
I.	**Introduction:** Review of coupled circuits, electro-mechanical energy conversion basics, energy and co-energy, concept of virtual work and electromagnetic torque production, origin of reluctance torque.	4	To learn the details electro-mechanical energy conversion, torque production
II.	**Generalized machine theory and reference frame theory:** Assumptions behind the theory, Park's transformation, Clarke's transformation.	4	To learn about the Park's transformation
III.	**Transformations:** Different types of d-q transformation used in modern research literatures, stationary, rotor, synchronously rotating and arbitrarily rotating reference frame, mathematical relationships existing between above reference frames, torque and motional impedance matrices.	6	To learn d-q transformation, reference frame with mathematical relations
IV.	**Application of the theory on induction machines:** Transient and steady state modeling and analysis of 3-phase induction machine in terms of above reference frames, case studies showing applications, equivalent circuits.	6	To learn the transient and steady state modelling of 3 phase Induction machines
V.	**Application of the theory on synchronous machines:** Transient and steady state modeling and analysis of 3-phase wound-field	7	To learn the transient and steady state modelling of

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	synchronous machine in terms of above reference frames, case studies showing applications, equivalent circuits, steady state and transient/sub-transient operations of synchronous machines		synchronous machines
VI.	**Generalized theory applied to D.C. and cross field machines:** **a) Introduction:** Adaptability of the theory, transformations, equation for small changes, short circuit studies on D.C. separately excited generator, rotator, shunt generator, block diagrams. **b) Analysis with emphasis on saturation:** Expressions of voltage build up, effect of saturation, Froelich & Rudenburg graphical analysis, measurement of parameters. **c) Control applications of D.C. machines**: Ward Leonard method, cross field machines, rotating amplifiers.	**5** **5** **5**	To learn the transient and steady state modeling of D.C. machines and cross field machines.
	TOTAL	**42**	

Course Outcomes	1. To learn the details electro-mechanical energy conversion, torque production 2. To learn about the Park's transformation 3. To learn d-q transformation, reference frame with mathematical relations 4. To learn the transient and steady state modelling of 3 phase Induction machines 5. To learn the transient and steady state modelling of synchronous machines 6. To learn the transient and steady state modelling of D.C. machines and cross field machines.

Learning Resources	1. Denis O'Kelley, S. Simmons, —Introduction to generalized electrical machine theory‖, McGraw-Hill, 1968. 2. Paul Krause, Oleg Wasynczuk, Scott D. Sudhoff, Steven Pekarek, —Analysis of Electric Machinery and Drive Systems‖, 3rd Edition, IEEE Press, 2013. 3. B. Adkins and R. G. Harley, —The General Theory of Alternating Current Machines: Applications to Practical Problems‖, Springer Science and Business Media, B. V, 1978. 4. Modern research literatures

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Course Code	EE 5125 N	Course Name	Advanced Micro-controller Technology	Course Category	PSE	L	T	P
						3	0	0

Pre-requisite Courses	A preliminary course on microprocessors and microcontrollers	Co-requisite Courses	*Nil*	Progressive Courses	*Nil*
Course Offering Department		*Electrical Engineering*		**Data Book / Codes/Standards**	*Nil*

Course Objectives	
	1. Introduces students to the architecture of 8-bit, 16-bit and 32-bit microcontrollers 2. Makes them familiar with hardware and software concepts necessary to design, implement, and troubleshoot embedded systems utilizing microcontrollers like Intel 8051 or PIC or ARM. 3. Students are exposed to assembly language programming for efficient loop time management. 4. Enables students to create solutions for real-world problems in various applications, from basic control systems to complex drive systems.

Module	Syllabus	Duration (class-hours)	Module Outcomes
I.	**Introductory concepts**: Programmers model of processor, processor architecture; Microcontroller architecture, Types of Memory & memory interfacing, Instruction set, modular assembly programming using subroutines, macros etc. , Concept of interrupts: hardware & software interrupts, Interrupt handling techniques, Interrupt controllers. Programmable Peripheral devices and I/O Interfacing, DMA controller and its interfacing.	7	Students learn fundamental concepts of microcontrollers, their basic architecture Gain foundational knowledge in microcontroller programming and interfacing techniques.
II.	**Introduction to Intel 8051 Microcontroller**: Basic architecture, addressing modes, Port structures, Timers, Interrupts, Serial Interface, Instruction Set and programming	8	Students are exposed to an 8-bit microcontroller and its hardware / software components Learn to use the 8051 and utilize its hardware features through Assembly Language Programming
III.	**Introduction to PIC Microcontroller**: Basic architecture, I/O ports, Timers, CCP Module, ADC Module, Synchronous Serial Port, Instruction Set and programming	8	Students are exposed to a 16-bit microcontroller and its hardware / software components Students gain foundational and practical expertise in

			PIC microcontrollers, their architecture, and programming techniques – there by learning to use PIC as a controller for various control applications
IV.	**Introduction to ARM Microcontroller**: Basic architecture and pipeline structure, Programming modes and instruction set, ARM Coprocessor interface, Cache and Memory management, Timer, ADC/DAC, Interrupts, I^2C, SPI, PWM Interfaces.	**7**	Students are exposed to a 32-bit microcontroller and its hardware / software components Learn to use ARM as a controller / communication module.
V.	**Introduction to ADSP Microcontroller:** Basic architecture, Instruction Set and programming methodology.	**7**	Students are exposed to a DSP and its features (modified Harvard architecture) Learn about the three computational units and dual data address generators for optimized performance Learn the suitability of the architecture for Digital Signal Processing
VI.	**Typical applications of microcontrollers**: Typical examples of applications in drives, power grid control, electric utility or any other suitable examples, highlighting development of system hardware/software (in assembly language/high level language), Debugging and troubleshooting.	**5**	Students gain practical expertise in microcontroller-based system design and ways and means to debug applications Students are ready to design embedded systems for various research / industrial applications.
	TOTAL	**42**	

Course Outcomes	By the end of this course, students will be able to: 1. Understand microcontroller architectures 2. Develop programs in high level / assembly level language to solve a given problem 3. Interface memory and other peripherals with the microcontroller 4. Develop and manage serial communication interfaces between same/different microcontrollers. 5. Develop digital controller hardware / software using microcontrollers to solve any given electrical engineering problem.

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Learning Resources	**Primary Textbooks:** 1. 'PIC Microcontroller and Embedded Systems (using assembly and C for PIC 18 (2e)' by Mazidi, Causey and McKinlay; Pearson Education, 2021 2. DSP Microcontroller - ADSP-2100_ User's Manual, 1993 3. The 8051 Microcontroller (3rd ed.) by Kenneth J. Ayala, Delmar Cengage Learning, 2005 4. ARM Assembly Language Programming & Architecture' (2nd ed.) by Mazidi & Naimi et al., 2016 **Supplementary References:** 5. 'Design with PIC Microcontrollers', by John B. Peatman, Pearson Education 6. 'Digital Signal Processing Applications Using the ADSP 2100 Family' (Vol I & II) – Inc. Analog Devices, 1995 7. 'The 8051 Microcontroller and Embedded Systems', Mazidi & Mazidi, Prentice Hall Inc., 2015 8. 'ARM Microcontrollers: Programming and Circuit Building'(Vol.1), Patrick Hood-Daniel, Newbiehack.

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Course Code	EE 5126 N	Course Name	Power Quality	Course Category	PSE	L	T	P
						3	0	0

Pre-requisite Courses	Network theory, analog and digital electronics, Fourier analysis, electrical machine, power system and power electronics.	Co-requisite Courses	*Advanced Power Electronics*	Progressive Courses	*Selected Topics in Power Electronics*
Course Offering Department		*Electrical Engineering*		Data Book / Codes/Standards	ANSI /IEEE and IEC standards.

Course Objectives	A comprehensive understanding of (1) issues of electrical power quality, (2) the various causes of deterioration of power quality, (3) various remedial measures taken for improving the power quality and (4) various computational tools used to estimate and monitor the power quality (5) familiarization of the existing power quality monitoring and measuring instruments

Module	Syllabus	Duration (class-hours)	Module Outcomes
I.	**Power Quality terms and standards:** Power quality definition, different type of poor power quality events: voltage sag, voltage swell, impulsive transient, oscillatory transient, interruption, harmonic/inter-harmonic distortion, notching and voltage fluctuation (flicker), familiarization with different standards.	7	Enabling the learner to confidently identify power quality issues in the electrical system
II.	**Power and its component: Definition of various power components for non-sinusoidal voltage and current, single phase and three phase balanced and unbalanced circuits.**	6	Enabling the learner to quantify electrical power for non-sinusoidal balanced/unbalanced voltage and currents arising out of non-linear load.
III.	**Harmonic/inter-harmonic distortion:** Voltage and current distortion, harmonic indices, power factor with harmonics/inter-harmonics, displacement factor, harmonic sources from commercial and industrial loads, locating harmonic sources; power system response characteristics, resonance, harmonic distortion evaluation, devices for	9	Enabling the learner to identify harmonics/ inter harmonics and their sources and locations in the electrical power distribution network. Knowing the different standards, the learner can specify the exact standards for quantifying

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	controlling harmonic distortion, passive filters, active filters, power factor correction equipment, IEEE and IEC standards.		power quality.
IV.	**Load voltage regulation: Causes of sags and interruptions, mitigation of voltage sags: active series compensators, static transfer switches and fast transfer switches. Sources of transient over voltages (swells): capacitor switching, lightning, ferro-resonance; mitigation of voltage swells: Introduction to custom power devices (DSTATCOM, DVR) and their applications in power system.**	**10**	Enabling the learner to identify the appropriate remedial measures to address the different power quality issues. The learner with sufficient exposure in analysis and simulation can perform the analysis of the system for necessary improvement according to the requirements of the utility
V.	**Noises: Common mode noises, EMIs, mitigation, cable shielding, isolation.**	**2**	Enabling the learner to locate the source of noises and to know the various methods to attenuate the noises in power electronics converter control circuits.
VI.	**Wiring and grounding: Familiarization with ANSI/IEEE Standard 1100-1992, IEEE Standard 518, reasons for grounding, wiring and grounding problems, solutions, grounding techniques for signal reference, grounding for sensitive equipment.**	**3**	Enabling the learner to take appropriate grounding for critical instruments. The learner will be familiar with different standards and recommendations in wiring and grounding for good power quality.
VII.	**Power quality measurement equipment:** Power analyzer, harmonic / spectrum analyzer, flicker meters, disturbance analyzer, analysis tools.	**3**	Enabling learners to gain sufficient expertise to identify the equipment necessary for a particular power quality issue.
VIII.	**PQ Audit and Benchmarking:** Preparation of report, the different components of the report, comparison with acceptable PQ indices	**2**	Enabling learners to know the power quality audit report preparation needed for utility as well as user.
	TOTAL	**42**	

Course Outcomes	(1) Enabling the learner to confidently identify power quality issues in the electrical system and suggest remedial measures to overcome the malfunctioning of the system.(2) Knowing the different standards, the learner can specify the exact standards for quantifying power quality. (3) The learner with sufficient exposure in analysis and simulation can perform the analysis of the system for necessary improvement according to the requirements of the utility. (4) Enabling learners to gain sufficient expertise to identify the equipment necessary for a particular power quality issue.

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Learning Resources	***Suggested Readings:*** 1. Roger C. Dugan, Mark F. McGranaghan, Surya Santoso, and H. Wayne Beaty, "Electrical Power Systems Quality", McGraw Hill, 2012. 2. C. Sankaran , "Power Quality", CRC press, 2017. 3. Alexander Kusko and Mark T. Thompson, "Power quality in Electrical Systems", McGraw Hill, 2007. 4. Ewald F. Fuchs and Mohammad A. S. Masoum, "Power Quality in Power Systems and Electrical Machines", Academic Press (Elsevier), 2008. 5. Jos Arrilaga, "Power System Harmonic Analysis", John Wiley and Sons Limited, 1997.

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Laboratory

on

Advanced Power Electronics

(EE5177 N)

Mini Project

on

Generalized Theory of Electrical Machines

(EE5178 N)

Laboratory /Mini Project

on

Applied Linear and Nonlinear Control

(EE5171 N)

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2nd Semester
M.Tech in Power Electronics, Machines and Drives (PEMD)

Course Code	**EE 5207 N**	**Course Name**	Advanced Electrical Drives	**Course Category**	PC	L	T	P
						3	0	1

Pre-requisite Courses	Advanced Power Electronics (EE 5107 N), Generalized Machine Theory (EE 5108 N), a basic course on electric drives at undergraduate level	**Co-requisite Courses**	*Nil*	**Progressive Courses**	*Nil*
Course Offering Department		*Electrical Engineering*		**Data Book / Codes/Standards**	*Nil*

Course Objectives	The objective of this course is to impart analytical knowledge about advanced aspects pertaining to various types of significant electrical machine drive applications, namely, induction machines, wound field synchronous machines and switched reluctance machines. The course also focuses on controller design related studies and analysis in electric drives applications with special emphasis on the state-of-the-art field oriented control and direct torque control of AC machines. It also concentrates on discussions and studies with respect to industrial perspective of modern AC drives, the challenges faced, with their probable mitigation strategies. The course also covers discussions and studies related to use of sensors and transducers in electrical drives.

Module	**Syllabus**	**Duration (class-hours)**	**Module Outcomes**
I.	**Introduction:** Review of two-loop control of adjustable speed DC drives, speed and current loop design, multi-quadrant control of DC drives	**6**	Knowledge on accurate measurement of speed and current for effective control. Understanding of converter controlled forward and reverse operation of motors.
II.	**Induction motor (IM) drives:** Review of solid state scalar V/f control of 3-phase induction motors (IM based VFD's). CSI-fed cage IM drives, comparison with VSI-fed drives, details of field-oriented control and direct torque control. Detailed analysis of wound rotor IM drives – chopper based control of rotor, Scherbius drives.	**15**	Understanding speed control techniques of IM drives. Designing and implementing the necessary control circuits for speed and torque control of IM. Selecting right type of motor and drive system for a specific application.
III.	**Wound-field Synchronous motor drives:** Synchronous motor as a variable speed motor – true-synchronous mode and self-synchronous	**9**	Evaluating the suitability of WFSMs for different applications.

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	modes of operation, soft-starting of large synchronous motor drives from weak grids, LCI-fed synchronous motor drive, its performance comparison with VFD-fed synchronous motor drive, vector control of synchronous motors. *		Learning control strategies for WFSMs, such as field weakening and vector control. Analyzing performance of VFD fed WFSM drives.
IV.	**Switched reluctance motor drives:** Introduction, power converter circuits, control methodologies, analysis.	**5**	Understanding different power converter topologies and control techniques for SRM drives. Knowledge about role of switching in controlling the motor
V.	**Sensor-less AC motor drives:** Role of sensors in motor drives, sensor-less operation of AC drives and techniques.	**3**	Implementing control strategies for AC motor drives without the use of position sensors
VI.	**Special Industrial perspective of AC drives:** Energy efficiency of AC drives, effects of PWM switching on motors – issues related to dv/dt stress, effects of partial discharge and corona on machine insulation, effects of bearing currents, effects of vibration and noise, possible remedial measures	**4**	Understanding various issues and effects on AC drives for industrial applications.
	TOTAL	**42**	

*PMSM machines and drives are discussed in the other core course, 'Selected Machines on Electric Vehicle and Wind Power Applications'.)

Course Outcomes	After studying this course, the students will be able to: 1. Design torque, speed and position controllers for DC machines, induction machines, and synchronous machines 2. Analyze and design different scalar and vector control techniques of induction machines and wound field synchronous machines 3. Analyze and design LCI fed wound field synchronous motor drives 4. Analyze and design switched reluctance motor drives 5. Know current, voltage, position and speed sensors for electric drive applications 6. Understand industrial challenges faced by modern electrical drives and their probable mitigation strategies 7. Differentiate between traditional and sensor-less AC drives

Learning Resources	1. G. K. Dubey—Fundamentals of Electric Drives, Narosa Publishing House, 2003. 2. G.K. Dubey—Power Semiconductor Controlled Drives, Prentice Hall, 1989. 3. B.K. Bose—Power Electronics and AC Drives, Prentice Hall, 1986. 4. J. Murphy and F.G. Turnbull—Power Electronic Control of AC Motors, Pergamon Press, 1988. 5. Krishnan Ramu—Switched Reluctance Motor Drive, CRC Press, 2001. 6. T. J. E Miller—Switched Reluctance Motors and their control, Magna Physics Publishing, Oxford Science Publications, 1993. 7. Modern research literatures

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Course Code	EE 5208 N	Course Name	Selected Topics in Power Electronics	Course Category	PC	L	T	P
						3	0	0

Pre-requisite Courses	Advanced Power Electronics (EE 5107 N) and Generalized Theory of Electrical Machines (EE 5108 N).	Co-requisite Courses	Advanced Electrical Drives EE 5207 N	Progressive Courses	*Nil*
Course Offering Department		*Electrical Engineering*		**Data Book / Codes/Standards**	*.Nil*

Course Objectives	A comprehensive knowledge of (1) Hardware realization of controller and switching pulse generations in digital signal processing platform, (2) ways of improving the efficiency of converters by soft switching, (3) application of different converter topology for induction heating and weldings and (4) various converters to improve the quality of electrical power transmission (5) various converters used to extract electrical energy from non-conventional power sources like wind, hydel and solar.

Module	Syllabus	Duration (class-hours)	Module Outcomes
I.	**Digital signal based control of Power Electronic Installations**: For electrical machine drives and for applications – interfacing, generation and sequencing of trigger pulses, sensing issues, applications to different types of solid state power converters, monitoring and signaling, DSP and FPGA applications.	13	Enabling the learner to implement control and switching logics in digital signal processing platforms like DSP, Microcontrollers and FPGAs
II.	**Soft-switched Converters:** Resonant converters, synchronous link converters, hybrid resonant link converters, quasi-resonant link inverters.	8	Enabling the learner to know the methods to reduce the losses in various switching converters
III.	**Special topics:** Multilevel inverters, Active filters, power electronic converters for induction heating and welding applications	8	Enabling the learner to design various converters for induction heating and welding applications
IV.	**Converters for electrical power systems:** STATCOM and UPQC	7	Enabling the learner to design power quality equipment like STATCOM, UPQC and Active filters
V.	**Converters for distributed generation:** Power Electronics-related issues in Wind energy applications, micro-hydel and PV-based power conditioning and grid	6	Enabling the learner to design various converters required to harness electrical energy from

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	integration.		various non-conventional energy sources.
	TOTAL	**42**	

Course Outcomes	Enabling the learner (1) to implement control and switching logics in digital signal processing platforms like DSP, Microcontrollers and FPGAs (2) to reduce the losses in various switching converters (3) to design various converters for induction heating and welding applications (4) to design power quality equipment like STATCOM, UPQC and Active filters, (5) to design various converters required to harness electrical energy from various non-conventional energy sources.

Learning Resources	***Suggested Readings:*** 1. Hamid Toliyat and S. G. Campbell, "DSP-based Electromechanical Motion Control", CRC Press, 2003. 2. N. Mohan. T. M. Undeland and W. P. Robbins, "Power Electronics – Converters, Applications and Design", 2nd Edition, John Wiley & Sons, 1995. 3. N. G. Hingorani, L. Gyugyi, "Understanding FACTS: Concepts and Technology of Flexible AC Transmission Systems" IEEE Press, 2013. 4. Gilbert M. Masters, "Renewable and Efficient Electric Power Systems", 2nd Edition, John Wiley & Sons, 2013. 5. Bin Wu, Mehdi Narimani, "High-Power Converters and AC Drives", John Wiley & Sons, 2016. 6. S. Zinn & S. L. Semiatin, "Elements of Induction Heating: Design, Control, and Applications", ASM International &EPRI, 1988.

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Course Code	EE 5209 N	Course Name	Selected Machines for Electric Vehicle and Wind Power Applications	Course Category	PC	L	T	P
						3	0	0

Pre-requisite Courses	Generalized Theory of Electrical Machines (EE 5108 N)	Co-requisite Courses	*Nil*	Progressive Courses	*Nil*
Course Offering Department		*Electrical Engineering*		Data Book / Codes/Standards	*Nil*

Course Objectives	This course will enable students to: 1. Learn the operation, construction and detailed mathematical modelling and steady state and transient analysis of a PMSM 2. Understand the operation, construction and detailed mathematical modelling and steady state and transient analysis of a BLDC machine 3. Learn the operation, construction and detailed mathematical modelling and steady state and transient analysis of a Wind energy fed grid tied DFIM system 4. Understand state of the art field oriented control and direct torque control mechanisms. 5. Learn 'Green' issues associated with above machine based solutions

Module	Syllabus	Duration (class-hours)	Module Outcomes
I.	**A. Permanent Magnet Synchronous Machines for Electric Vehicle(EV) applications:**		Knowing basics and fundamentals of PMSM and BLDC machines
a.	Introduction, principle of operation, outline of Permanent Magnet (PM) materials	**2**	
b.	Steady state and dynamic model and equivalent circuit of PMSMs, magnetic circuit.	**3**	
c.	Construction, classification and types, comparison between PMSM and BLDC machines	**3**	
d.	Special requirements of EV power-train components, review of DC series motors with their advantages and disadvantages, PMSM and BLDC motors and drives for EV applications, their similarities and differences, converters topologies.	**4**	Learning various converters and drives for PMSM based EV power train.
e.	Drive Control strategies viz., vector control (VC), maximum torque per ampere (MTPA) control and direct torque control (DTC).	**11**	Understanding control methodologies for EV drives and impacts on battery performance
f.	Effects of these motor drives on the EV battery, battery power and energy density issues.	**2**	
II.	**B. Doubly-fed induction machines (DFIM) for wind power applications:**		

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a.	Steady state operation – equivalent circuit in a-b-c frame, operating modes with respect to speed and power flows, active and reactive power exchanges, steady state characteristics, design requirements for the DFIM in wind energy generation applications.	**4**	Analyzing operating modes, modeling of DFIM
b.	Dynamic modelling in α-β and d-q reference frames.	**3**	
c.	Introduction to a wind energy generating system – Wind energy and wind turbine fundamentals, fixed speed wind energy conversion systems, variable speed wind energy conversion systems, Variable Speed Wind Energy Generation System based on DFIM, Maximum power point tracking for grid-connected DFIG.	**5**	Learning DFIM based WECS and its relevant control strategies.
d.	Drives for grid-connected DFIM, vector control of DFIM from rotor side, startup of the DFIM for grid-connected applications	**5**	
	TOTAL	**42**	

Course Outcomes	After Studying this course, students gain sufficient knowledge to: 1. Mathematically analyze PMSM based electrical drive systems 2. Mathematically analyze BLDC based drive system 3. Design closed loop torque and speed controllers for above machine based drive systems based on field oriented and direct torque control based strategies 4. Mathematically analyse wind energy based grid-tied DFIM systems 5. Design closed loop power and torque controllers for above machine based drive systems based on field oriented and control based strategies

Learning Resources	1. P. C. Krause, O. Wasynczuk and S. D. Sudhoff, —Analysis of Electric Machinery and Drive Systems, 2nd Edition, Wiley, paperback, 2010. 2. K. Venkataratnam—Special Electrical Machines, University Press (India) Pvt. Ltd., Hyderabad, India, 2009. 3. J. R. Hendershot Jr. and T. J. E. Miller — Design of Brushless Permanent-Magnet Motors, Magna Physics Publishing and Clarendon Press, Oxford, 1994. 4. R. Krishnan — Permanent Magnet Synchronous and Brushless DC Motor Drives, CRC Press, Taylor and Francis Group, Boca Raton, USA,2010. 5. Gonzalo Abad, Jesus Lopez, Miguel Rodriguez, Luis Marroyo, G. Iwanski—Doubly Fed Induction Machine: Modeling and Control for Wind Energy Generation, WILEY-IEEE Press, USA, 2011. 6. Modern research literatures

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Course Code	EE 5225 N	Course Name	Special Electrical Machines	Course Category	PSE	L	T	P
						3	0	0

Pre-requisite Courses	Basic courses on DC and AC machines, Generalized Machine Theory (EE 5108 N)	**Co-requisite Courses**	Knowledge on magnetic circuits, reluctance, radial, axial flux, space vector basics	**Progressive Courses**	*Nil*
Course Offering Department		*Electrical Engineering*		**Data Book / Codes/Standards**	*IEEE Std 112; IEC 60034 Series; IEEE Std 1812*

Course Objectives	
	1. To introduce students to advanced concepts in special electrical machines beyond conventional DC and AC machines. 2. To develop an understanding of space vector theory and its application to machine modeling and control. 3. To explore the principles, design aspects, and applications of linear motors, switched reluctance motors, and permanent magnet machines. 4. To provide insights into the construction, modeling, and analysis of axial flux machines. 5. To prepare students for research and industrial applications involving modern and emerging motor technologies.

Module	Syllabus	Duration (Class-hours)	Module Outcomes
I.	**Space vector theory of Electrical Machines**: Its application in modeling of electrical machines in steady state and dynamics, control of machines using space vector concepts.	7	Students should be able to apply the space vector concept for modeling electrical machines in steady-state and dynamic conditions, and understand its use in modern control strategies.
II.	**Linear Motors**: Basic principle of operation and types, end effects & transverse edge effects, depth of penetration and its effects, field analysis & propulsion force, mathematical modeling, equivalent circuit. Linear Induction Motors (LIM), Linear Permanent Magnet Synchronous Machine (LPMSM), LSRM etc., TLIM, their applications, design challenges, modeling and analysis. Difficulties in constructing TLPM machines or TLSRM.	9	Students should be able to analyze the principles, modeling, and challenges in the design and application of various types of linear motors, including LIMs, LPMSMs, TLIMs and LSRMs.

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III.	**Switched Reluctance Motors (SRM):** Construction (radial flux), Basic principle of operation, importance of stator & rotor arc angles, design aspects and profile of the SRM, position sensor & indirect rotor position sensing, torque expression, steady state and dynamic performance.	8	Students should be able to understand the construction, operating principles, design aspects, torque characteristics, steady state and dynamic performance of SRMs, and explore sensor-based and sensorless control techniques, study drives applications etc.
IV.	**Special Permanent Magnet (PM) Machines**: Outer rotor varieties, details of issues related to PM materials and design, use of Halbach array configuration in PM machines Non-overlapping winding PM machines and their applications: Concepts, design changes with regard to distributed winding machines, effects on performance, applications of both inner and outer rotor varieties.	7	Students should be able to understand the design issues related to PM machines, apply Halbach arrays, and acquire ideas on non-overlapping winding configurations. Students should also gain ideas on the design changes with regard to distributed winding machines and applications of both inner and outer rotor machines.
V.	**Axial Flux Machines :**Axial flux varieties of SRM, BLDC and PMSM, applications, their design challenges, modeling, and analysis	7	Students should be able to comprehend the design, modeling, and operational challenges of axial flux variants of SRMs, BLDC, and PMSM machines, along with their application areas.
VI.	**Synchronous Reluctance Machines**	4	Students should know the basic operation, performance analysis of this machine which is widely used in some varieties of EVs as these are PM-less machines
	TOTAL	**42**	

Course Outcomes	1. To understand and apply space vector theory for modeling and controlling various electrical machines. 2. Analyze the operation and design aspects of linear motors, including LIMs, LPMSMs, TLIMs, and LSRMs. 3. Acquire ideas on the construction, working principles, and torque characteristics of switched reluctance motors (SRMs). 4. Understand design issues of special permanent magnet machines, including Halbach array configurations and non-overlapping windings. 5. Model, analyze and understand the performance of axial flux machines (SRM, BLDC, PMSM) and their industrial applications. 6. Address design challenges associated with special machine topologies.

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Learning Resources	1. K. Venkataratnam, Special Electrical Machines, Universities Press (India) Pvt. Ltd., 2008. 2. T. J. E. Miller, Brushless Permanent-Magnet and Reluctance Motor Drives, Clarendon Press, Oxford, 1989. 3. T. Kenjo and S. Nagamori, Permanent Magnet and Brushless DC Motors, Clarendon Press, London, 1988. 4. R. Krishnan, Switched Reluctance Motor Drives: Modeling, Simulation, Analysis, Design and Applications, CRC Press, 2001. 5. E. R. Laithwaite, Induction Machines for Special Purposes, George Newnes, London, 1966. 6. S. A. Nasar & I. Boldea, Linear Motion Electric Machines, Wiley, 1976.

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Course Code	**EE 5226 N**	**Course Name**	Power Electronic Converters for Bulk Power Conditioning	**Course Category**	PSE	L	T	P
						3	0	0

Pre-requisite Courses	*UG Courses on Power Electronics & Electric Power System*	**Co-requisite Courses**	*Nil*	**Progressive Courses**	*Nil*
Course Offering Department		*Electrical Engineering*		**Data Book / Codes/Standards**	*IEEE Std. 519-2014; Datasheet of Power Semiconductor Devices*

Course Objectives	
	1. Understanding the basic concepts regarding the working and characteristics of phase shifting transformers and derivation of related phasor diagrams and voltage ratios. 2. Understanding the working of multi-pulse rectifiers and understanding their principal advantages over 6-pulse rectifiers, operating area, output voltage equation etc. 3. Understanding the principles of shunt and series compensation, working of such compensators, their open and closed loop operation, operating area, principal waveforms and design methodologies

Module	**Syllabus**	**Duration (class-hours)**	**Module Outcomes**
I.	**Phase Shifting Transformers:** Principle of operation, phasor diagram and calculation of turns ratio etc., some examples and applications	4	Students should be able to analyze and predict the phase shift and magnitude of output voltage for various types of phase shifting transformers. Students should be able to draw phasor diagrams for different types of phase shifting transformers.
II.	**HVDC Converters:** Major problems of conventional 6-pulse rectifiers; 12, 18 and 24-pulse rectifiers – basic operating characteristics and waveforms – advantages over 6-pulse rectifiers; symmetrical and sequential modes of control; operating area; Harmonic cancellation techniques using SHEPWM, multi-level and multi-pulse inverters; synthesis of receiving end HVDC inverters; general structures of HVDC systems	7	Students should be able to understand & analyze the operation of multi-pulse rectifiers, multi-pulse inverters, multi-level inverters & draw waveforms. Students should be able to solve numerical problems on such converters & design such converters.

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III.	**Static Converters for Shunt VAR Compensation:** Necessity and general methods of VAR compensation – SVG& SVC; TCR, TSC, FC-TCR&TSC-TCR – principle of operation and operating area, harmonic reduction, closed loop control schemes etc. for each; STATCOM – operating principle, direct and indirect methods of closed loop control; Hybrid VAR generators and control schemes etc.; basic design equations	**13**	Students should be capable of analyzing and designing shunt VAR compensator circuits. Students should be able to draw steady state waveforms, predict operating areas, and solve numerical problems related to such compensators.
IV.	**Static Converters for Series Compensation:** Basic essence and advantages; GCSC, TSSC, TCSC and SSSC – Principles, control-modes, closed-loop control schemes and operating area, compensation of harmonics generated, ratings etc.; Hybrid compensation using SSSC and FC; basic design equations	**18**	Students should be capable of analyzing and designing series VAR compensator circuits. Students should be able to draw steady state waveforms, predict operating areas, and solve numerical problems related to such compensators.
	TOTAL	**42**	

Course Outcomes	1. Students should be able to analyze the operation and draw relevant diagrams/waveforms of Phase Shifting Transformers and Power Electronic Converters, applied for power conversion / conditioning for electric grid. 2. Students should be able to design power conversion circuits for bulk power conversion / conditioning in electrical grids. 3. Students should be capable of selecting a power converter topology and its control-strategy for such bulk power-conversion applications.

Learning Resources	***Suggested Readings:*** 1. G. K. Dubey, S. R. Doradla, A. Joshi and R. M. K. Sinha – Thyristorised Power Controllers, Wiley Eastern Limited, 1986 2. Bin Wu – High Power Converters and AC Drives, IEEE Press, Wiley-Inderscience, 2006. 3. N. G. Hingorani and L. Gyugyi – Understanding FACTS: Concepts and Technology of Flexible AC Transmission Systems, IEEE Press, 2000.

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Open Elective (Semester 1)

Course Code	EE 5161 N	Course Name	High-Performance Computation (HPC) Using CPU and GPU for AI Applications	Course Category	OE	L	T	P
						3	0	0

Pre-requisite Courses	A preliminary course on (i) Basic programming knowledge in C, C++, or Python (ii) Familiarity with Linux commands is recommended (iii) Prior exposure to AI frameworks (Tensor Flow/PyTorch) is beneficial but not required	Co-requisite Courses	*Nil*	Progressive Courses	*Nil*
Course Offering Department		***Electrical Engineering***		**Data Book / Codes/Standards**	*Nil*

Course Objectives	This course introduces students to high-performance computing (HPC) architectures, parallel programming models, and system administration with a strong focus on CPU and GPU optimization for AI applications. Students will gain practical experience in OpenMP, MPI, CUDA, and AI-specific frameworks like TensorFlow and PyTorch, while also understanding HPC applications in deep learning, numerical computation, engineering simulations, and scientific research.

Module	Syllabus	Duration (class-hours)	Module Outcomes
I.	**Introduction to High-Performance Computing:** • HPC Overview: Importance, real-world applications in AI and scientific computing. • Parallel Computing Architectures: Flynn's Taxonomy (SISD, SIMD, MIMD, MISD). • CPU vs GPU for AI: Key differences, compute capabilities, and optimization. • Shared vs Distributed Memory Architectures in AI workloads. • Performance Metrics: Speedup, Efficiency, Scalability, Amdahl's Law, Gustafson's Law.	5	Understand HPC architectures, shared vs distributed memory architectures and different performance metrics
II.	**OpenMP Programming (Shared Memory Parallelism):** • Basics of OpenMP Programming: Threads, Parallel Regions, Work Sharing. • Synchronization & Data Handling: Mutex, Reduction, Atomic Operations. • Performance Optimization: Load Balancing, Thread Affinity. • AI Workloads with OpenMP: Accelerating AI inferencing with	6	Apply Parallel computing models for AI applications, synchronization and data handling, performance optimization and AI Workloads

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	OpenMP.		
III.	**MPI and Distributed Memory Programming** • Introduction to MPI & Distributed Memory Programming. • MPI Communication Primitives: Point-to-Point, Collective Operations. • Parallel Training of Deep Neural Networks Using MPI. • Hybrid Programming (MPI + OpenMP) for Large-Scale AI Models.	**7**	Distributed Memory Programming, communication primitives, training of deep neural networks and Hybrid programming
IV.	**GPGPU and CUDA Programming** • Introduction to GPU Programming & General-Purpose GPUs (GPGPU). • CUDA Basics: Thread Execution Model, Memory Hierarchy. • CUDA Performance Optimization: Coalescing, Shared Memory, Occupancy. • AI-Specific CUDA Applications: Accelerating Neural Networks. • Introduction to OpenACC for GPU Acceleration. • Multi-GPU & Exascale Computing Trends in AI Training.	**6**	GPU Programming, CUDA Basics and Performance Optimizations, applications and computing trends in AI training
V.	**HPC Applications in AI and Numerical Computation** • AI Model Training Optimization: GPU Acceleration in Deep Learning. • Scientific Simulations: Maxwell's Equations & HPC-Based Solvers. • FFT and Spectral Methods in AI Signal Processing. • Krylov Subspace Methods for Sparse Systems in AI Research. • Finite Difference (FDM) & Finite Element Methods (FEM) for AI-Powered Simulations.	**6**	Implement HPC techniques to optimize deep learning workloads
VI.	**HPC Systems and AI Model Deployment** • HPC Hardware & Software Stack for AI Workloads. • Cluster Networking:InfiniBand, RDMA, High-Speed Interconnects. • Performance Benchmarking (LINPACK, STREAM, IOR) for AI systems. • Energy Efficiency & Green HPC in AI Research.	**5**	Configure and manage HPC clusters, job schedulers, and Linux-based HPC environments
VII.	**UNIX and LINUX Commands for HPC Systems** • Linux System Administration for HPC AI Clusters. • Remote Access & Job Scheduling (SSH, SLURM, PBS, Torque). • Virtualization & Containerization	**7**	Explore AI-driven HPC career opportunities in research, cloud computing, and data centers

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	(Docker, Singularity) for AI. • Storage & File Systems in HPC (Lustre, BeeGFS, GPFS).		
	TOTAL	**42**	

Course Outcomes	By the end of this course, students will be able to: 1. Understand HPC architectures and parallel computing models for AI applications. 2. Develop parallel programs using OpenMP, MPI, and CUDA for scientific computing and AI. 3. Implement HPC techniques to optimize deep learning workloads. 4. Configure and manage HPC clusters, job schedulers, and Linux-based HPC environments. 5. Explore AI-driven HPC career opportunities in research, cloud computing, and data centers.

Learning Resources	**Primary Textbooks:** 1. **Grama, A., Gupta, A., Karypis, G., & Kumar, V.** – *Introduction to Parallel Computing*, Addison Wesley, 2003. o Covers parallel architectures, algorithms, and programming models. 2. **Gropp, W., Lusk, E., &Skjellum, A.** – *Using MPI: Portable Parallel Programming with the Message-Passing Interface*, MIT Press, 1999. o Best introduction to MPI-based parallel programming. 3. **Cook, S.** – *CUDA Programming: A Developer's Guide to Parallel Computing with GPUs*, MK Publishers, 2012. o Practical book for learning CUDA and GPU programming. 4. **Kirk, D. &Hwu, W.** – *Programming Massively Parallel Processors: A Hands-on Approach*, Morgan Kaufmann, 2016. o Great for CUDA programming, optimization, and AI applications. 5. **Goodfellow, I., Bengio, Y., Courville, A.** – *Deep Learning*, MIT Press, 2016. o Covers AI fundamentals and computational techniques. **Supplementary References:** 6. **NVIDIA** – *CUDA C Programming Guide (Official Documentation).* o Essential reference for CUDA development and AI best practices. 7. **Das, Sumitabha** – *UNIX: Concepts and Applications*, McGraw Hill. o Useful for Linux system administration and scripting. 8. **Sloan, Joseph D.** – *High-Performance Linux Clusters with OSCAR, Rocks, OpenMosix& MPI*, O'Reilly, 2004. o Covers HPC cluster setup and administration. 9. **Sterling, T. et al.** – *Beowulf Cluster Computing with Linux*, MIT Press, 2003. o Classic book on Linux-based HPC cluster management. 10. **Chapman, B., Jost, G., & van der Pas, R.** – *Using OpenMP: Portable Shared Memory Parallel Programming*, MIT Press, 2007. o Essential for OpenMP programming techniques.

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Open Elective (Semester 2)

Course Code	EE 5262 N	Course Name	Power Supplies for Electrical Equipment	Course Category	OE	L	T	P
						3	0	0

Pre-requisite Courses	A course on basic electrical engineering and basic electronics at undergraduate level	Co-requisite Courses	*Nil*	Progressive Courses	*Nil*
Course Offering Department		***Electrical Engineering***		Data Book / Codes/Standards	*Nil*

Course Objectives	
	1. This course describes the general concept of electrical distribution system, electrical isolation and desired general specification of power supplies. 2. This course familiarizes the different types power electronics device as switches 3. This course described the different types of DC power supplies and AC power supplies. 4. This course also described the different types of SMPS and UPS systems. 5. This course gives an idea about the different batteries and battery chargers.

Module	Syllabus	Duration (class-hours)	Module Outcomes
I.	**Introduction:** Electrical utility distribution systems, DC and AC electrical power supplies – basic requirements and desired general specifications, issue of regulation, electrical isolation, output ripple, efficiency etc.	3	To learn the basic concept of electrical distribution systems and electrical isolation.
II.	**Power Electronic devices used as switches:** Power diodes, power MOSFETs, IGBT‘s and thyristors, quadrant operation of power electronic devices, power losses in power devices, dissipation and idea of heat sinks, driver stages of power devices.	8	To learn about different power electronics devices as switches.
III.	**DC power supplies:** Linear power supplies – advantages and disadvantages, relevance of switched mode power conversion, DC-DC converters – non-isolated and isolated DC-DC converters, role of high frequency transformers.	6	To learn the basic concepts of DC power supply, isolated and non-isolated converters.
IV.	**DC switched mode power supplies (SMPS):** Basic block diagram of a switched mode power supply, power supplies with bidirectional power flow capabilities.	3	To learn the DC SMPS in detail.
V.	**AC power supplies:** Voltage source inverters – Single phase and three phase inverters, pulse width modulation (PWM), harmonics, AC power supplies based on inverters, AC power supplies with bidirectional power flow capabilities.	8	To learn the basic concepts of AC power supply, pulse width modulation

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VI.	**Front end of AC/DC power supplies fed from electrical utilities:** Rectifiers - Single phase diode rectifiers with R-paralleled-C loads, thyristorized rectifiers, effects on utility, power quality aspects, PWM rectifier as a solution.	**5**	To learn the front end of AC/DC power supplies fed from electrical utilities
VII.	**Batteries and Battery chargers:** Different types of batteries used at present, their types, basic characteristics, basic terminologies of a battery. Types of battery charging battery Charger block diagrams employing discussed power converters, control.	**4**	To learn about different types of batteries and battery chargers
VIII.	**Uninterruptible Power Supplies (UPS):** Classification, block-diagram based explanations	**3**	To learn about the different types of UPS
IX.	**Passive components in power electronic applications**: Inductors and capacitors	**2**	To learn the concept of inductors and capacitors in power electronics applications
	TOTAL	**42**	

Course Outcomes	1. To learn the basic concept of electrical distribution system and electrical isolation 2. To learn about different power electronics devices as switches 3. To learn basic concept of DC power supply, isolated and non-isolated converter 4. To learn the DC SMPS in details 5. To learn basic concept of AC power supply, pulse width modulation 6. To learn front end of AC/DC power supplies fed from electrical utilities 7. To learn different types of batteries and battery chargers 8. To learn about the different types UPS 9. To learn the concept of inductor and capacitor in power electronics applications

Learning Resources	1. M. H. Rashid, —Power Electronics - Circuits, Devices and Applications‖, Prentice Hall, Pearson Education, 2014. 2. N. Mohan, T. M. Undeland and W.P. Robbins, —Power Electronics: Converters, Applications and Design‖, John Wiley & Sons, 2007. 3. C. W. Lander, —Power Electronics‖, McGraw Hill Book Co, 1987. 4. G. K. Dubey, S. R. Doradla, A. W. Joshi, R. M. K. Sinha, —Thyristorised Power Controllers‖, Wiley, 1986. 5. R. M. Dell and D. A. J. Rand, —Understanding Batteries‖, The Royal Society of Chemistry, Cambridge, UK, 2001.

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Course Code	EE6101N	Course Name	Energy Audit	Course Category	VAC	L	T	P
						3	0	0

Pre-requisite Courses	*Nil*	Co-requisite Courses	*Nil*	Progressive Courses	*Nil*
Course Offering Department		Electrical Engineering		**Data Book / Codes/Standards**	IEEE 739 – 1995 (Bronze Book)

Course Objectives	
	1. To make students aware about global energy crisis and the requirement of energy efficiency **2.** To impart to students, knowledge and skills to calculate energy usage and effectively manage it to achieve energy saving thereby saving cost **3.** To equip students with the knowledge of basic hardware and software tools to evaluate energy consumption, identify areas of improvement by means of data analysis and produce an energy auditor's report.

Module	Syllabus	Duration (class-hours)	Module Outcomes
I.	**Energy Scenarios and Basics:** Introduction to global and regional energy situation, including energy resources and consumption patterns. Various forms of energy, energy pricing, and the role of the environment. Importance of energy conservation.	**5**	Understand global and regional energy trends, resources, and pricing. Recognize the importance of energy conservation and its environmental impact.
II.	**Energy Management Principles:** Objectives of energy management, benefits of energy audits, and the role of energy managers, Benchmarking, energy performance.	**5**	Understand the objectives of energy management and the role of energy audits. Learn benchmarking and evaluate energy performance for efficiency improvement.
III.	**Energy Conservation Measures:** Identification and implementation of energy-saving opportunities in various sectors - domestic, commercial, industrial sectors, and transportations. Energy performance contracts, fuel substitution, and the use of energy-efficient equipment. International agreements on climate change.	**6**	Identify and implement energy-saving measures across domestic, commercial, industrial, and transportation sectors.Understand energy-efficient technologies, fuel substitution, and international climate change agreements.
IV.	**Energy Auditing, Monitoring and Targeting Methodologies:** Different types of energy audits (preliminary, targeted, detailed), instruments used for auditing, steps	**8**	Understand types and steps of energy audits with relevant instruments. Learn energy monitoring, target setting, and basic mathematical and

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	involved in conducting a comprehensive energy audit. Importance of monitoring energy consumption and setting targets for improvement, Mathematical and Statistical Modeling and Analysis.		statistical analysis for performance improvement.
V.	**Regulations, Standards and Energy Auditors:** Introduces to relevant regulations and standards related to energy conservation, such as the Energy Conservation Act, Electricity Act 2003.BEE Schemes Standards and labeling programs. Certified Energy Auditors (CEA) or Energy Managers, Government (BEE) and Energy service companies (ESCOs)	**7**	Understand key energy conservation regulations, standards, and labeling programs. Recognize the roles of BEE, CEAs, Energy Managers, and ESCOs in promoting energy efficiency.
VI.	**Financial Analysis and Project Management:** Financial aspects of energy audits, including cost-benefit analysis, Payback period calculations, Project management techniques.	**6**	Learn financial analysis of energy projects, including cost-benefit and payback period calculations. Understand basic project management techniques for implementing energy efficiency measures.
VII.	**Case Studies:** Case studies of successful energy audits Energy audit and conservation applied to an IIEST laboratory / classroom / seminar hall / office.	**5**	Analyze real-world case studies of successful energy audits and conservation. Apply energy audit techniques to IIEST facilities like labs, classrooms, or offices.
	TOTAL	**42**	

Course Outcomes	1. Students should be able to understand energy management principles 2. Students should be capable of conducting energy audits, analyze energy data, and recommend solutions for enhanced energy efficiency. 3. Students should be able to produce an energy auditors' report.

Learning Resources	**Text Book:** 1. LC Witte, PS Schmidt and DR Brown: **Industrial Energy Management and Utilization** (Hemisphere Publishing Corporation, Washington, 1998). **Reference Books:** 1. Albert Thumann, William J. Younger, **Handbook of Energy Audits**, CRC Press, 2003. 2. Charles M. Gottschalk, **Industrial energy conservation**, John Wiley &

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	Sons, 1996 3. YP Abbi and Shashank Jain: **Handbook on Energy Audit and Environment Management**, (TERI Press, 2006) 4. WC Turner: **Energy Management Handbook**, Seventh Edition, (Fairmont Press Inc., 2007) 5. G.G. Rajan, Optimizing energy efficiencies in industry --, Tata McGraw Hill, Pub. Co., 2001 **Websites**: National Productivity Council (http://www.npcindia.gov.in/) Bureau of Energy Efficiency (https://www.beeindia.gov.in/) EA/EM Guide Books (http://www.em-ea.org/)

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