Curriculum Structure & Detailed Syllabus

Master of Technology
in
Power Engineering & Energy Systems

(Two-Year Post-Graduate Program)

Silicon University, Odisha

Silicon Hills, Patia, Bhubaneswar - 751024

https://silicon.ac.in

Effective From Academic Year 2024-25

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Approval History

ACM#	Date	Resolutions
SU-1	27/04/2024	The curriculum structure of M.Tech.(PE & ES) was approved in principle by the Academic Council.
SU-2	17/08/2024	The curriculum structure and detailed syllabus of M.Tech(PE & ES) was approved by the Academic Council.

Program Outcomes

Program Outcomes (POs) form a set of individually assessable outcomes that are the components indicative of the post-graduate's potential to acquire competence to practice at the appropriate level.

PO1. Apply the knowledge of science and mathematics in designing, analyzing and using power converters for various industrial and domestic applications.

PO2. Design the modern electric machines, drives, power converters, and control circuits for specific applications.

PO3. Use modern tools, professional software platforms, embedded systems for the diversified applications.

PO4. Solve the problems which need critical and independent thinking to show reflective learning.

PO5. Explore ideas for inculcating research skills and undertake independent research in cutting edge technologies.

PO6. Visualize the larger picture and correlate the domain knowledge with the global industrial problems.

PO7. Understand the impact of power electronics devices in an economic, social and environment context.

PO8. Understand intellectual property rights and overall professional & ethical responsibility.

PO9. Communicate effectively in a technically sound manner with a wide range of audience.

PO10. Continue to learn independently and engage in life-long learning.

Program Specific Outcomes (PSOs)

PSO1. **Engineering Knowledge and Analysis**: Apply engineering fundamental knowledge to identify, formulate, design and investigate complex engineering problems of electric circuits, power electronics, electrical machines and power systems and to succeed in competitive exams.

PSO2. **System Design & Professionalism**: Apply appropriate techniques and modern engineering hardware and software tools in power systems and power electronics to meet desired needs within realistic constraints such as economical, environmental, social, political, ethical, health and safety, manufacturability and sustainability.

PSO3. **Leadership & Lifelong Learning**: Function effectively as an individual or a leader in a team to manage different projects in multidisciplinary environment and appreciate the need for, and an ability to engage in life-long learning.

Program Educational Objectives (PEOs)

PEO1. **Fundamental Knowledge**: To provide students with a foundation in mathematics, physics and core electrical and electronic areas required to formulate, solve and analyze engineering problems.

PEO2. **Professional Skill & Society**: To analyze real life problems; apply the knowledge gained from modern design methodologies to address issues in a manner i.e., technically sound, economically feasible and socially acceptable.

PEO3. **Ethics & Lifelong Learning**: To inculcate ethical attitude, effective communication skills, teamwork in their profession and adapt to current trends by engaging in lifelong learning needed for a successful professional career.

Course Categories & Definitions

L	Lecture
T	Tutorial
P	Practical / Laboratory / Sessional
WCH	Weekly Contact Hours
UCR	University Core Course
UMC	University Mandatory Course (0-Credit)
PCR	Program Core Course
PEL	Program Elective Course
OEL	Open Elective Course
HNS	Honours (Choice-based) Course
MNR	Minor (Choice-based) Course
OOC	Open Online Course (on NPTEL / Swayam / Other)
INT	Summer Internship
PSI	Practice School / Industry Internship
PRJ	Project Work
SEC	Skill Enhancement Course
VAC	Value Addition Course

Contents

Part I

Curriculum Structure

Curriculum Structure

Semester I								
Category	**Code**	**Course Title**	**WCH** L-T-P			**Credits** L-T-P		
THEORY								
PCR	MT5007	Computational Methods	3	1	0	3	1	0
PCR	EE5001	Smart Energy Systems	3	0	0	3	0	0
PCR	EE5002	Power System Analysis	3	1	0	3	1	0
PCR	EE5003	Machine Analysis	3	0	0	3	0	0
PCR	EE5004	Solar & Wind Power Technologies	3	0	0	3	0	0
UCR	RS7001	Research Methodology & IPR	2	0	0	2	0	0
PRACTICAL								
PCR	EE5005	Smart Energy Systems Lab	0	0	2	0	0	1
PCR	EE5006	Power System Analysis Lab	0	0	4	0	0	2
PCR	EE5007	Modelling & Simulation Lab	0	0	2	0	0	1
		SUB-TOTAL	**17**	**2**	**8**	**17**	**2**	**4**
		TOTAL	**27**			**23**		

Semester II								
Category	**Code**	**Course Title**	**WCH** L-T-P			**Credits** L-T-P		
THEORY								
PCR	EE5008	Power Converters & Drives	3	1	0	3	1	0
PCR	EE5009	Power System Optimization	3	0	0	3	0	0
PCR	EE5010	Systems & Control Theory	3	1	0	3	1	0
PEL		Program Elective - I	3	0	0	3	0	0
PEL		Program Elective - II	3	0	0	3	0	0
UCR	HS5004	English for Research Paper Writing	2	0	0	2	0	0
PRACTICAL								
PCR	EE5011	Power Converters & Drives Lab	0	0	4	0	0	2
PCR	EE5012	Power Systems Optimization Lab	0	0	4	0	0	2
UCR	RS7002	Pre-Thesis Literature Survey	0	0	2	0	0	1
		SUB-TOTAL	**17**	**2**	**10**	**17**	**2**	**5**
		TOTAL	**29**			**24**		

P.T.O

Semester III								
Category	**Code**	**Course Title**	**WCH** L-T-P			**Credits** L-T-P		
THEORY								
PEL		Program Elective-IV	3	0	0	3	0	0
PEL		Program Elective-V	3	0	0	3	0	0
PEL		Program Elective-V	3	0	0	3	0	0
OOC	EE6011	MOOC	3	0	0	3	0	0
PRACTICAL								
PCR	RS7003	Thesis (Part - I) & Seminar	0	0	12	0	0	6
INT	IP4001	Summer Internship	0	0	0	0	0	1
		SUB-TOTAL	**9**	**0**	**12**	**12**	**0**	**7**
		TOTAL	**21**			**19**		

Semester IV								
Category	**Code**	**Course Title**	**WCH** L-T-P			**Credits** L-T-P		
PRACTICAL								
PCR	RS7004	Thesis (Part - II) & Seminar	0	0	28	0	0	14
VAC	VA0001	Yoga / NCC / NSS	0	0	2	0	0	0
		SUB-TOTAL	**0**	**0**	**30**	**0**	**0**	**14**
		TOTAL	**30**			**14**		

		GRAND TOTAL (4 SEMESTERS)	**107**	**80**

Note:

1. Courses offered under each elective are given in “List of Electives” on Page 4.
2. MOOC - Massive Open Online Course (on NPTEL / Swayam / Other).
3. Approved list of courses for MOOC (self study) shall be published by the department. Students are advised to complete the same before the end of 3rd semester.
4. The Value Addition Course (Yoga / NSS / NCC) may be assigned in a different semester depending on available capacity.

List of Electives

Code	Elective # and Subjects
	Program Elective - I
EE5013	Embedded Systems
EE5014	Electric & Hybrid Vehicle Technology
EC5010	Machine Learning & Applications
EE5016	PWM Power Converters
	Program Elective - II
EE5017	Advanced Power System Protection
EE5018	Restructured Power Systems
EE5019	Power System Dynamics
	Program Elective - III
EE6001	Distributed Generation & Microgrids
EE6002	Power Quality
EE6003	Non-Linear & Robust Control Systems
	Program Elective - IV
EE6004	Power Systems Planning & Reliability
EE6005	Data Acquisition & Signal Conditioning
EE6006	Cyber Physical Systems
EE6007	Advanced Machine Drives
	Program Elective-V
EE6008	Power Distribution Systems
EE6009	Energy Management & Audit
EE6010	Power System Transients

Part II

Detailed Syllabus

Category	Code	Computational Methods	L-T-P	Credits	Marks
PCR	MT5007		3-1-0	4	100

Objectives	The objective of this course is to introduce the students to the concepts of mathematics, optimization and soft computing methods, optimization techniques for linear and nonlinear programming and their application to different electrical and power engineering problems.
Pre-Requisites	Knowledge of engineering mathematics and power systems is required.
Teaching Scheme	Regular classroom lectures with use of ICT as and when required, sessions are planned to be interactive with focus on problem solving activities.

Evaluation Scheme

Attendance	Teacher's Assessment	Mid-Term	End-Term	Total
10	20	20	50	100

Detailed Syllabus

Module-#	Topics	Hours
Module-1	Linear Programming: Graphical Method, Simplex Method, Methods of Artificial Variables, Alternate optima, redundancy & degeneracy, Integer Linear Programming: Gomory's cutting Plane Method for All Integer & Mixed Integer Programming, Branch & Bound Method.	**10 Hours**
Module-2	Optimality Conditions, Lagrangian & Lagrange Multipliers, KKT Necessary/sufficient optimality conditions, Duality in non-linear programming; Unconstrained optimization – Line search methods for uni-modal functions, The steepest descent method, Newton's method, Modified Newton's Method, The Conjugate Gradient Method.	**11 Hours**
Module-3	Constrained Optimization: Frank Wolfe's Method, Rosen's Gradient Projection Method, Penalty function method, Barrier function method, Karmakar's algorithm for Linear Programming, Centering transformation, Projection matrix and the complete algorithm.	**9 Hours**
Module-4	Fuzzy Logic: Basic concepts of Fuzzy logic, Fuzzy vs. Crisp set, Linguistic variables, Membership functions, Operation of fuzzy sets, Fuzzy if-then rules, Variable inference techniques, De-fuzzification, Basic fuzzy inference algorithm, Fuzzy system design, FKBC and PID control, Control of electrical drive using fuzzy controller and other industrial applications.	**14 Hours**
Module-5	Neural Networks: Artificial neural network and introduction, Learning rules, Knowledge representation and acquisition, Different methods of learning, Algorithm of neural network: Feed forward back propagation, Hopfield model, Kohonen's feature map, K-means clustering, ART networks, RBFN, Application of neural networks to electrical problems.	**12 Hours**
	Total	**56 Hours**

Text Books:

T1. S. Chandra, Jayadeva, and A. Mehera, ***Numerical Optimization with Applications***, 1st *Ed.*, Narosa Publishing, 2013.
T2. J. S. R. Jang, C. T. Sun, and E. Mizutani, ***Neuro-Fuzzy and Soft-Computing***, Prentice-Hall India, 2008.

Reference Books:

R1. S. S. Rao, ***Engineering Optimization***, 3rd *Ed.*, New Age Publishers, 2013.
R2. K. Dev, ***Optimization for Engineering Design***, 2nd *Ed.*, Prentice-Hall India, 2004.
R3. S. Haykins, ***Neural Networks: A Comprehensive Foundation***, 3rd *Ed.*, Pearson Education India, 2011.
R4. V. Kecman, ***Learning and Soft Computing: Support Vector Machines, Neural Networks, and Fuzzy Logic Models***, Pearson Education India, 2006.

Course Outcomes: *At the end of this course, the students will be able to:*

CO1	Apply linear programming methods to engineering problems.
CO2	Understand and apply methods of solutions for unconstrained optimization problems.
CO3	Understand and apply methods of solutions for constrained optimization problems.
CO4	Study and design fuzzy logic controllers for different electrical applications.
CO5	Learn different neural networks and its application to solve different electrical problems.

Program Outcomes Relevant to the Course:

PO1	Apply the knowledge of science and mathematics in designing, analyzing and using power converters for various industrial and domestic applications.
PO2	Design the modern electric machines, drives, power converters, and control circuits for specific applications.
PO3	Use modern tools, professional software platforms, embedded systems for the diversified applications.
PO4	Solve the problems which need critical and independent thinking to show reflective learning.
PO5	Explore ideas for inculcating research skills and undertake independent research in cutting edge technologies.
PO10	Continue to learn independently and engage in life-long learning.

Mapping of COs to POs and PSOs (1: Low, 2: Medium, 3: High)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PSO1	PSO2	PSO3
CO1	3	2	1	2	2						3	1	
CO2	3	3	2	3	2						3	2	1
CO3	3	3	2	3	2						3	2	1
CO4	3	3	3	2	2					1	3	3	1
CO5	3	3	3	2	2					1	3	3	2

Category	Code	Smart Energy Systems	L-T-P	Credits	Marks
PCR	EE5001		3-0-0	3	100

Objectives	The objective of this course is to introduce the concepts of smart and emerging technologies of renewable energy sources and its impact on grid, study the architecture & standards in smart grid, concepts of microgrids, green buildings, and energy storage systems.
Pre-Requisites	Knowledge of Power Electronics and Power System is required.
Teaching Scheme	Regular classroom lectures with use of ICT as and when required, sessions are planned to be interactive with focus on renewable energy systems and smart grids.

Evaluation Scheme

Attendance	Teacher's Assessment	Mid-Term	End-Term	Total
10	20	20	50	100

Detailed Syllabus

Module-#	Topics	Hours
Module-1	**Grid Connectivity of RE Systems**: Smart grid and emerging technologies, Operating principles and models of grid components, Key technologies for generation, Networks, Loads and their control capabilities; Decision-making tools; Introduction and Concept of demand side management (DSM): The concepts and methods of DSM, Load control, Energy efficiency, Load management; Wide Area Measurement System (WAMS) and its application in Smart Grids.	**8 Hours**
Module-2	**Architecture & Standards in Smart Grid**: Smart metering, Advanced Metering Infrastructure (AMI), Distribution Automation (DA), SCADA System, Outage Management System (OMS), Plug-in Hybrid Electric Vehicle (PHEV), Vehicle-to-Grid (V2G), IEC61850 Protocol.	**8 Hours**
Module-3	**Microgrid**: Introduction, Definitions, Types of Micro grids, Modes of operation, Introduction to Microgrid control & protection, Structure of AC and DC Microgrid, Challenges in Microgrid, Peak load management by microgrids and demand response.	**9 Hours**
Module-4	**Energy Conservative Buildings**: Energy conservation in building: Air conditioning, HVAC equipments, Computer packages for thermal design of buildings and performance prediction; Monitoring and instrumentation of passive buildings: Control systems for energy efficient buildings, Illustrative passive buildings; Integration of emerging technologies; Intelligent building design principles.	**10 Hours**
Module-5	**Energy Storage for RE Sources**: Battery sizing, Battery Management System (BMS) and stand-alone Applications; Large scale applications/ Stationary (Grid applications): Power and energy applications; Small scale applications: Portable storage systems/medical devices; Mobile storage applications: Electric vehicles: Introduction and types of EV's Batteries and fuel cells, and future technologies; Hybrid systems for energy storage.	**7 Hours**
	Total	**42 Hours**

P.T.O

Text Books:

T1. M. H. J. Bollen and F. Hassan, ***Integration of Distributed Generation in the Power System***, IEEE Press Series on Power Engineering, Wiley, 2011.
T2. S. Borlase, ***Smart Grid: Infrastructure, Technology and Solutions***, 1^{st} *Ed.*, CRC Press, 2012.
T3. J. K. Nayak and J. A. Prajapati, ***Handbook on Energy Conscious Buildings***, Solar Energy Control MNES, 2006.
T4. H. H. Alhelou and A. Y. Abdelaziz, ***Wide Area Power Systems: Stability, Protection, and Security***, Springer, 2021.

Reference Books:

R1. A. G. Phadke, ***Synchronized Phasor Measurement and their Applications***, 2^{nd} *Ed.*, Springer, 2008.
R2. G. Boyle, ***Renewable Energy - Power for a Sustainable Future***, 3^{rd} *Ed.*, Oxford University Press, 2012.
R3. S. K. Salman, ***Introduction to the Smart Grid: Concepts, Technologies and Evolution***, Institution of Engineering and Technology (IET), 2017.
R4. J. Jensen and B. Sorenson, ***Fundamentals of Energy Storage***, 1^{st} *Ed.*, Wiley-Interscience, 1984.
R5. C. W. Gellings, ***The Smart Grid: Enabling Energy Efficiency and Demand Response***, 1^{st} *Ed.*, CRC Press, 2009.
R6. J. B. Ekanayake, N. Jenkins, K. Liyanage, and others, ***Smart Grid: Technology and Applications***, 1^{st} *Ed.*, Wiley, 2012.
R7. A. F. Zobaa (Ed.), ***Energy Storage - Technologies and Applications***, InTech, 2013.

Online Resources:

1. https://nptel.ac.in/courses/108/107/108107143/: by Prof. A. Bhattacharya, IIT Roorkee
2. https://ieeexplore.ieee.org/document/9388040
3. https://cdn.intechopen.com/pdfs/31086/intech-wide_area_measurement_systems.pdf

Course Outcomes: *At the end of this course, the students will be able to:*

CO1	Explain the emerging technologies of renewable energy systems and grid connectivity.
CO2	Analyze the different components of smart grid architecture.
CO3	Learn the working of microgrid and grid connectivity issues.
CO4	Understand the concepts of energy conservative buildings and design of intelligent buildings.
CO5	Interpret the working of different energy storage systems for renewable energy sources and its application.

Program Outcomes Relevant to the Course:

PO1	Apply the knowledge of science and mathematics in designing, analyzing and using power converters for various industrial and domestic applications.
PO2	Design the modern electric machines, drives, power converters, and control circuits for specific applications.
PO3	Use modern tools, professional software platforms, embedded systems for the diversified applications.
PO4	Solve the problems which need critical and independent thinking to show reflective learning.
PO5	Explore ideas for inculcating research skills and undertake independent research in cutting edge technologies.
PO6	Visualize the larger picture and correlate the domain knowledge with the global industrial problems.
PO7	Understand the impact of power electronics devices in an economic, social and environment context.

P.T.O

Mapping of COs to POs and PSOs (1: Low, 2: Medium, 3: High)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PSO1	PSO2	PSO3
CO1	3	3	2	2	1	3	1				1	3	
CO2	3	3	2	1	2	3	1				1	3	
CO3	3	3	2	2	1	3	2				1	3	
CO4	3	3	3	2	3	2	1				1	3	
CO5	3	3	2	2	2	2	1				1	3	

Category	Code	Power System Analysis	L-T-P	Credits	Marks
PCR	EE5002		3-1-0	4	100

Objectives	The objective of this course is to study various methods of load flow and their implications, analysis of faults in power systems, power system security and rank the contingencies, state estimation & algorithms for state estimation, and voltage instability phenomenon in power systems.
Pre-Requisites	Knowledge of Mathematics such as calculus, ordinary differential equations, matrices, solving circuit problem using nodal and mesh current method, and synchronous machines are required.
Teaching Scheme	Regular classroom lectures with use of ICT as and when required, sessions are planned to be interactive with focus on problem solving activities.

Evaluation Scheme

Attendance	Teacher's Assessment	Mid-Term	End-Term	Total
10	20	20	50	100

Detailed Syllabus

Module-#	Topics	Hours
Module-1	**Network Modeling and Power Flow**: Introduction to PU system, Single-line diagram, Impedance Diagram, Y-bus formation, Formulation of Power flow problem, Solution through Gauss-Seidel, Newton Raphson and Fast Decoupled method, Modeling of FACTs devices and Renewable Energy Sources.	**12 Hours**
Module-2	**Symmetrical Faults**: Transient in RL series circuit, Short-Circuit Currents and Reactances of Synchronous Machine, Short-Circuit Analysis of Large systems, Formation of Z-bus matrix, Algorithm for building Z-bus matrix.	**10 Hours**
Module-3	**Unsymmetrical Faults**: Symmetrical components of an unbalanced three-phase systems, Power invariance, Sequence impedances of Transmission line, Synchronous Machine and Transformer, Sequence Network of Loaded Synchronous Machine, Analysis of LG, LL, LLG faults and Open Conductor faults.	**10 Hours**
Module-4	**Power System Security**: Introduction, Factors affecting Security, State Transition Diagram, Contingency Analysis - Adding and Removing Multiple lines, Piece-wise solution of interconnected systems, Analysis through Network Sensitivity method and AC/DC Power Flow method. Voltage Stability - Introduction, P-V Curve, Q-V Curve, Mechanism of Voltage Collapse.	**10 Hours**
Module-5	**State Estimation**: Introduction, Method of Least Squares, Statistics, Errors, Estimates, Static State Estimation of Power Systems, Tracking State Estimation, Computational considerations, Observability and Pseudo Measurement.	**10 Hours**
	Total	**52 Hours**

Text Books:

T1. J. J. Grainger & W. D. Stevenson, ***Power System Analysis***, 1st *Ed.*, McGraw-Hill, 2017.
T2. D. P. Kothari and I. J. Nagrath, ***Modern Power System Analysis***, 4th *Ed.*, Tata McGraw-Hill, 2011.
T3. A. J. Wood and B. F. Wollenberg, ***Power Generation, Operation and Control***, 2nd *Ed.*, John Wiley & Sons, 2006.

Reference Books:
R1. L. P. Singh, ***Advanced Power System Analysis and Dynamics***, 6^{th} *Ed.*, New Age International, 2012.
R2. G. L. Kusic, ***Computer Aided Power System Analysis***, 2^{nd} *Ed.*, Prentice Hall India, 2008.
R3. P. M. Anderson, ***Faulted Power System Analysis***, IEEE Press, 1995.
R4. D. Das, ***Electrical Power Systems***, New Age international, 2006.
R5. G. W. Stagg, A. H. Ei-Abiad, ***Computer Methods in Power System Analysis***, MedTech Publisher, 2019.

Online Resources:
1. http://nptel.ac.in/courses/108102047/: by Prof. D. P. Kothari, IIT Delhi
2. https://courses.engr.illinois.edu/ece476/fa2016/Lecture%20Notes/
3. https://onlinecourses.nptel.ac.in/noc18ee16/preview

Course Outcomes: *At the end of this course, the students will be able to:*

CO1	Apply various methods of load flow to calculate voltage phasor at all buses with given data.
CO2	Calculate fault currents in each phase for symmetrical faults in power systems network.
CO3	Analyze different unsymmetrical faults and apply the concept for calculation of fault currents.
CO4	Rank various contingencies according to their severity in terms of bus voltage and line loading.
CO5	Understand the state estimation application in various power system networks.

Program Outcomes Relevant to the Course:

PO1	Apply the knowledge of science and mathematics in designing, analyzing and using power converters for various industrial and domestic applications.
PO3	Use modern tools, professional software platforms, embedded systems for the diversified applications.
PO4	Solve the problems which need critical and independent thinking to show reflective learning.
PO5	Explore ideas for inculcating research skills and undertake independent research in cutting edge technologies.
PO6	Visualize the larger picture and correlate the domain knowledge with the global industrial problems.
PO10	Continue to learn independently and engage in life-long learning.

Mapping of COs to POs and PSOs (1: Low, 2: Medium, 3: High)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PSO1	PSO2	PSO3
CO1	3		3	2	1	1				1	3	1	1
CO2	3		2	1	1	1				1	3	1	1
CO3	2		1	2	1	1				1	3	1	1
CO4	3		2	2	1	1				1	3	1	1
CO5	3		2	2	1	1				1	3	1	1

Category	Code	Machine Analysis	L-T-P	Credits	Marks
PCR	EE5003		3-0-0	3	100

Objectives	The objective of this course is to study the modelling of electrical machines to obtain its dynamic performances and understand the application of reference frame theory to obtain simplified model of electrical machines.
Pre-Requisites	Knowledge of electrical machines and electromagnetic circuits is required.
Teaching Scheme	Regular classroom lectures with use of ICT as and when required, sessions are planned to be interactive with focus on problem solving activities.

Evaluation Scheme

Attendance	Teacher's Assessment	Mid-Term	End-Term	Total
10	20	20	50	100

Detailed Syllabus

Module-#	Topics	Hours
Module-1	Basic Principles of Electric Machine Analysis: Air-Gap MMF, Winding Inductance and Voltage Equations in AC Machines, Reference Frame Theory: Park's Transformation and Kron's Primitive Machine, Commonly used Reference Frames and Transformations between Reference Frames, Transformations in Machines: Power invariance, 3-phase to 2-phase transformation, Balanced Steady-State Phasor Relationships.	**12 Hours**
Module-2	Symmetrical Induction Machines: D-Q model, Voltage and Torque Equations in Machine Variables and in Arbitrary Reference-Frame Variables, Analysis of Steady State from different frames of references.	**8 Hours**
Module-3	Polyphase Synchronous Machines: D-Q model and equivalent circuit: Voltage and Torque Equations in Machine Variables and in Arbitrary Reference-Frame Variables, Analysis of Steady State.	**8 Hours**
Module-4	Permanent Magnet Machines (DFIG, BLDC Machines): Voltage and Torque Equations in Machine Variables and in Arbitrary Reference-Frame Variables, Steady State analysis with PWM techniques, Introduction to BLDC drives.	**8 Hours**
Module-5	DC Machines: Voltage and torque equations, transfer function of DC Machines, Steady State and Dynamic Performance	**6 Hours**
	Total	**42 Hours**

Text Books:

T1. P. C. Krause, O. Wasynczuk, and S. D. Sudhoff, ***Analysis of Electric Machinery and Drive Systems***, John Wiley, 2004.
T2. D. O'Kelly and S. Simmons, ***Introduction to Generalized Electrical Machine Theory***, McGraw-Hill Education, 1968.

Reference Books:

R1. P. S. Bhimbra, ***Generalized Theory of Electrical Machines***, Khanna Publishers, 2021.
R2. A. E. Fitzgerald, C. Kingsley Jr., and S. D. Umans, ***Electric Machinery***, 6^{th} *Ed.*, McGraw-Hill Education, 2017.
R3. C. M. Ong, ***Dynamic Simulations of Electric Machinery: Using Matlab/Simulink***, Prentice-Hall, 1998.
R4. N. N. Hancock, ***Matrix Analysis of Electric Machinery***, 2^{nd} *Revised Ed.*, Pergamon Press, 1975.

R5. N. Biranchi, ***Electrical Machines Analysis using Finite Elements***, CRC Press, 2005.
R6. M. G. Simoes, F. A. Farret, ***Modelling and Analysis with Induction Generators***, CRC Press, 2015.
R7. A. K. Mukhopadhyay, ***Matrix Analysis of Electrical Machines***, New Age International, 1996.

Online Resources:
1. https://nptel.ac.in/courses/108/106/108106023/: by Prof. K. Vasudevan, IIT Madras
2. https://library.oapen.org/bitstream/handle/20.500.12657/43857/external_content.pdf?sequence=1&isAllowed=y

Course Outcomes: *At the end of this course, the students will be able to:*

CO1	Obtain a simplified dynamic model for electric machines by applying principles of reference frame theory to electrical machines.
CO2	Acquire the necessary knowledge about the induction machine modelling and its steady-state and dynamic analysis.
CO3	Understand and analyze synchronous machine modelling and its steady-state and dynamic performances.
CO4	Learn the concept of permanent magnet machines design and its performance analysis.
CO5	Apply the principles of reference frame approach to DC machines modeling and its analysis.

Program Outcomes Relevant to the Course:

PO1	Apply the knowledge of science and mathematics in designing, analyzing and using power converters for various industrial and domestic applications.
PO2	Design the modern electric machines, drives, power converters, and control circuits for specific applications.
PO3	Use modern tools, professional software platforms, embedded systems for the diversified applications.
PO4	Solve the problems which need critical and independent thinking to show reflective learning.
PO5	Explore ideas for inculcating research skills and undertake independent research in cutting edge technologies.
PO6	Visualize the larger picture and correlate the domain knowledge with the global industrial problems.
PO7	Understand the impact of power electronics devices in an economic, social and environment context.

Mapping of COs to POs and PSOs (1: Low, 2: Medium, 3: High)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PSO1	PSO2	PSO3
CO1	3	3	1	1	3	2	1				3	1	1
CO2	3	3	1	1	3	2	1				3	1	1
CO3	2	3	1	1	3	2	1				3	1	1
CO4	2	3	1	1	3	2	1				3	1	1
CO5	2	3	1	1	3	2	1				3	1	1

Category	Code	Solar & Wind Power Technologies	L-T-P	Credits	Marks
PCR	EE5004		3-0-0	3	100

Objectives	The objective of this course is to study about the renewable, Solar and Wind Energy Sources, the technologies for generation, storage, grid integration, and efficient utilization of renewable energy.
Pre-Requisites	Knowledge of semiconductor physics, fluid dynamics, electrical machines and power electronics is required.
Teaching Scheme	Regular classroom lectures with use of ICT as and when required, sessions are planned to be interactive with focus on problem solving activities.

Evaluation Scheme

Attendance	Teacher's Assessment	Mid-Term	End-Term	Total
10	20	20	50	100

Detailed Syllabus

Module-#	Topics	Hours
Module-1	Sources of Energy: Renewable energy sources and features, Introduction to wind and solar energy; Wind Energy: General theories of wind machines: Basic laws and concept of aerodynamics, Efficiency limit for wind energy conversion; Description and performances of horizontal and vertical axis wind turbine: Design of the blades and determination of forces acting on the wind power plant, Power vs speed and torque vs speed characteristics of wind turbines, Wind turbine control systems.	**10 Hours**
Module-2	Wind Energy Conversion System: Induction and synchronous generators, Grid connected and self-excited induction generator operation, Generation schemes with variable speed turbines, Constant voltage and constant frequency generation with power electronic control, Optimized control of induction generators and synchronous generators.	**10 Hours**
Module-3	Solar Energy: Introduction to solar cells, Solar cell technologies, Solar Photovoltaic systems: Operating principle, Solar PV module, standard PV module parameters, Solar PV arrays, Solar PV system Design and Integration, MPPT techniques.	**10 Hours**
Module-4	Power Converters for Photovoltaic Systems: Converters for stand-alone PV systems, Multi-level inverter based PV systems, Control of grid connected PV systems; Applications: Concentrating Solar Thermal Power.	**7 Hours**
Module-5	Storage Systems: Types and parameters of batteries for PV and Wind systems, connections and performance characteristics; Hybrid Energy Systems: Need for hybrid systems, types and issues with hybrid systems.	**5 Hours**
	Total	**42 Hours**

Text Books:

T1. S. N. Bhadra, D. Kastha, and S. Banerjee, ***Wind Electrical Systems***, 7th *Ed.*, Oxford Univ. Press, 2005.
T2. C. S. Solanki, ***Solar Photovoltaic Technology and Systems***, 1st *Ed.*, PHI Learning, 2013.

Reference Books:

R1. M. G. Simoes and F. A. Farret, ***Renewable Energy Systems Design and Analysis with Induction Generator***, CRC Press, 2004.
R2. B. H. Khan, ***Non-Conventional Energy Resources***, 3rd *Ed.*, McGraw-Hill Education, 2017.

R3. S. Peake, ***Renewable Energy: Power for a Sustainable Future***, 4th *Ed.*, Oxford University Press, 2018.
R4. G. Boyel, ***Renewable Energy - Power for a Sustainable Future***, 3rd *Ed.*, Oxford University Press, 2012.

Online Resources:

1. https://nptel.ac.in/courses/103/107/103107157/: by Prof. B. Mondal, IIT Roorkee
2. https://nptel.ac.in/courses/108/105/108105058/: by Prof. S. Banerjee, IIT Kharagpur
3. https://nptel.ac.in/courses/121/106/121106014/: by Dr. P. Haridoss, IIT Madras

Course Outcomes: *At the end of this course, the students will be able to:*

CO1	Infer various wind energy conversion systems and analyze their operational characteristics.
CO2	Analyze the application of electrical machines for wind energy control systems.
CO3	Develop an understanding of the design of a solar photovoltaic system and the ability of integrating power electronics device with renewable energy sources.
CO4	Design of control strategies for stand alone and grid connected PV systems.
CO5	Identify the need of storage systems for renewable source with their performance characteristics and classify the configuration of different hybrid energy systems.

Program Outcomes Relevant to the Course:

PO1	Apply the knowledge of science and mathematics in designing, analyzing and using power converters for various industrial and domestic applications.
PO2	Design the modern electric machines, drives, power converters, and control circuits for specific applications.
PO3	Use modern tools, professional software platforms, embedded systems for the diversified applications.
PO4	Solve the problems which need critical and independent thinking to show reflective learning.
PO5	Explore ideas for inculcating research skills and undertake independent research in cutting edge technologies.
PO6	Visualize the larger picture and correlate the domain knowledge with the global industrial problems.
PO7	Understand the impact of power electronics devices in an economic, social and environment context.
PO10	Continue to learn independently and engage in life-long learning.

Mapping of COs to POs and PSOs (1: Low, 2: Medium, 3: High)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PSO1	PSO2	PSO3
CO1	3	2			3	2				3	1	1	1
CO2	3	2		1	3	3	2			3	2	3	3
CO3	3	3	2	2	3	3	3			3	3	3	3
CO4	3	3	2	2	3	2	2				3	2	1
CO5	3				1	2	1			1	1	1	1

Category	Code	Research Methodology & IPR	L-T-P	Credits	Marks
UCR	RS7001		2-0-0	2	100

Objectives	The objective of this course is to introduce the principles and practices involved in conducting scientific research. The course is designed to cover three broad areas - The Scientific Method and Hypothesis Testing, Review of Literature and writing Technical Reports, and the elements of Intellectual Property Rights (IPR).
Pre-Requisites	Basic knowledge of probability & statistics will be helpful.
Teaching Scheme	Regular classroom lectures with use of ICT as and when required, sessions are planned to be interactive with focus on problem solving & examples.

Evaluation Scheme

Attendance	Teacher's Assessment	Mid-Term	End-Term	Total
10	20	20	50	100

Detailed Syllabus

Module-#	Topics	Hours
Module-1	Introduction to research, its significance and meaning; Types of research - fundamental, pure, theoretical, applied and experimental; Identification of the research problem and formulation of hypothesis; Research design and errors in research, error analysis; The Scientific Method as the established way of doing research; Data collection, measurement and scaling techniques.	**8 Hours**
Module-2	Meaning and need for hypothesis, Types of hypothesis, Functions and characteristics of a good hypothesis; Statistical testing of hypothesis – T-test, Chi-squared test; Sampling methods, Types of sampling, Probability and non-probability sampling; One-sample and two-sample tests, Correlation and regression analysis.	**8 Hours**
Module-3	Literature - types and review; Literature survey using the web, Search engines; Journal, report and thesis writing; Types of reports, Structure of the research report and presentation of results.	**7 Hours**
Module-4	Code of ethics in research - Intellectual Property Rights; Details of patents, Copyrights, Trademarks and Trade Secrets.	**5 Hours**
	Total	**28 Hours**

Text Books:

T1. C. R. Kothari & G. Garg, ***Research Methodology: Methods and Techniques***, 2nd *Ed.*, New Age International Publishers, 2004.
T2. D. Chawla & N.Sodhi, ***Research Methodology: Concepts and Cases***, 2nd *Ed.*, Vikas Publishing, 2016.

Reference Books:

R1. E. L. Lehman & J. P. Romano, ***Testing Statistical Hypothesis***, 3rd *Ed.*, Springer, 2008.
R2. R. Panneerselvam, ***Research Methodology***, 2nd *Ed.*, Prentice Hall India, 2013.

Online Resources:

1. https://nptel.ac.in/courses/127106227: by Prof. S. Banerjee, IIT Madras
2. https://nptel.ac.in/courses/109105115: by Prof. A. Malik, IIT Kharagpur
3. https://nptel.ac.in/courses/109105112: by Prof. T. K. Bandyopadhyay, IIT Kharagpur
4. https://ocw.mit.edu/courses/sloan-school-of-management/15-347-doctoral-seminar-in-research-methods-i-fall-2004/readings/: MIT Open Courseware (MIT-OCW).

Course Outcomes: *At the end of this course, the students will be able to:*

CO1	Disseminate the scientific method as a structured way of conducing scientific research.
CO2	Apply statistical principles for conducting hypothesis testing.
CO3	Conduct effective review of literature and write technical reports.
CO4	Acquire knowledge of the various intellectual property rights.

Program Outcomes Relevant to the Course:

PO1	Apply the knowledge of science and mathematics in designing, analyzing and using power converters for various industrial and domestic applications.
PO2	Design the modern electric machines, drives, power converters, and control circuits for specific applications.
PO3	Use modern tools, professional software platforms, embedded systems for the diversified applications.
PO4	Solve the problems which need critical and independent thinking to show reflective learning.
PO5	Explore ideas for inculcating research skills and undertake independent research in cutting edge technologies.
PO8	Understand intellectual property rights and overall professional & ethical responsibility.
PO9	Communicate effectively in a technically sound manner with a wide range of audience.
PO10	Continue to learn independently and engage in life-long learning.

Mapping of COs to POs and PSOs (1: Low, 2: Medium, 3: High)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PSO1	PSO2	PSO3
CO1	2	2	1	1	1					1	1	1	2
CO2	2	2	1	1	1					1		1	1
CO3					3				2	1		1	2
CO4								3		1		1	2

Category	Code	Smart Energy Systems Lab	L-T-P	Credits	Marks
PCR	EE5005		0-0-2	1	100

Objectives	The objective of this laboratory course is to provide practical exposure on real time working of smart energy systems and understand grid integration of distributed energy resources.
Pre-Requisites	Knowledge of UG level mathematics, physics, control systems, electrical machines, and power electronics is required.
Teaching Scheme	Regular laboratory experiments executed by the students under supervision of the teacher. Demonstration shall be given for each experiment.

Evaluation Scheme

Attendance	Daily Performance	Lab Record	Lab Test / Project	Viva-voce	Total
10	30	15	30	15	100

Detailed Syllabus

Experiment-#	Assignment/Experiment
1	Study of single PV module, I-V and P-V characteristics with radiation and temperature changing effect.
2	Study of I-V and P-V characteristics with series and parallel combination of modules.
3	Effect of shading and tilt angle on I-V and P-V characteristics of solar module.
4	Find MPP by varying the resistive load by varying the duty cycle of DC-DC converter.
5-6	Determine the efficiency of Wind Energy System.
7-8	Study of fuel cells and their performance analysis.
9	Study of hybrid energy system and its performance analysis.
10-11	Study of micro grid integrated with distributed energy resources and its performance analysis.
12	Determine the efficiency of mini hydro plant.
13-14	Study of battery management system and its performance analysis.

Text Books:

T1. M. G. Simões & F. A. Farret, ***Renewable Energy Systems - Design and Analysis with Induction Generators***, CRC Press, 2004.

T2. H. L. Willis & W. G. Scott, ***Distributed Power Generation - Planning and Evaluation***, 2nd *Ed.*, CRC Press, 2004.

T3. E. Amir, ***Microgrids: Operation, Control, and Protection***, Lambert Academic Publishing, 2014.

Reference Books:

R1. S. Borlase, ***Smart Grid: Infrastructure Technology Solutions***, 1st *Ed.*, CRC Press, 2017.

Online Resources:

1. https://nptel.ac.in/courses/108107143/: by Prof. A. Bhattacharya, IIT Roorkee

P.T.O

Course Outcomes: *At the end of this course, the students will be able to:*

CO1	Understand operating characteristics and analyze the factors affecting the performance of Solar PV systems.
CO2	Understand operating characteristics and analyze the factors affecting the performance of Solar PV systems.
CO3	Model and study the operating characteristics and analyse the factors affecting the performance of wind energy systems.
CO4	Perform the performance analysis of fuel cells.
CO5	Understand various smart devices and their interfacing for smart energy system.

Program Outcomes Relevant to the Course:

PO1	Apply the knowledge of science and mathematics in designing, analyzing and using power converters for various industrial and domestic applications.
PO2	Design the modern electric machines, drives, power converters, and control circuits for specific applications.
PO3	Use modern tools, professional software platforms, embedded systems for the diversified applications.
PO4	Solve the problems which need critical and independent thinking to show reflective learning.
PO5	Explore ideas for inculcating research skills and undertake independent research in cutting edge technologies.
PO6	Visualize the larger picture and correlate the domain knowledge with the global industrial problems.
PO7	Understand the impact of power electronics devices in an economic, social and environment context.

Mapping of COs to POs and PSOs (1: Low, 2: Medium, 3: High)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PSO1	PSO2	PSO3
CO1	3	1	3	1	1	2	3		1		3	2	
CO2	3	1	3	2	2	3	3		1		3	2	
CO3	3	2	3	2	3	3	3		1		3	3	
CO4	3	3	3	3	3	3	3		1		3	3	
CO5	2	2	3	3	3	2	3		1		3	3	

Category	Code	Power Systems Analysis Lab	L-T-P	Credits	Marks
PCR	EE5006		0-0-4	2	100

Objectives	The objective of this laboratory course is to introduce the advanced concepts of power systems. The course will train the students for performance analysis & their improvement to power systems through software & modern tools.
Pre-Requisites	Knowledge of Network Theory, Power Systems Analysis, and Engineering Mathematics is required.
Teaching Scheme	Regular laboratory experiments executed by the students under supervision of the teacher. Demonstration shall be given for each experiment.

Evaluation Scheme

Attendance	Daily Performance	Lab Record	Lab Test / Project	Viva-voce	Total
10	30	15	30	15	100

Detailed Syllabus

Experiment-#	Assignment/Experiment
1	Determination of voltage regulation in HV transmission line.
2	Effect of continuous compensation in HV transmission line using FACT devices.
3	Determination of Bus admittance & impedance matrices for a given power system network.
4-7	Load flow study for a given power system using NR & Fast decoupled method.
8-9	Optimal generator scheduling for thermal power plants.
10-14	Optimal power flow solution.
15-18	Unit Commitment of thermal generator.
19	Load-frequency control of a single area power system.
20-21	Transient and Small Signal Stability Analysis: Single-Machine Infinite Bus System.
22-24	Transient and Small Signal Stability Analysis: Multi-Machine Power system.
25	Study and simulation of automatic voltage regulator.
26	Study of automatic generation control with AVR and ALFC.
27	Steady state stability analysis of synchronous machine.
28	Determination of size and location for fixed capacitor compensation.

Text Books:

T1. H. Saadat, ***Power System Analysis***, 2nd *Ed.*, Tata McGraw-Hill, 2002.
T2. J. J. Grainger & W. D. Stevenson, ***Power System Analysis***, 1st *Ed.*, McGraw-Hill, 2017.
T3. A. J. Wood, ***Power Generation, Operation and Control***, 3rd *Ed.*, John Wiley, 2013.
T4. P. Kundur, ***Power System Stability and Control***, 1st *Ed.*, McGraw-Hill, 2006.

Reference Books:

R1. L. P. Singh, ***Advanced Power System Analysis and Dynamics***, 6th *Ed.*, New Age International, 2012.
R2. T. K. Nagsarkar & M. S. Sukhija, ***Power System Analysis***, Oxford University Press, 2007.

Online Resources:

1. http://nptel.ac.in/courses/108102047/: by Prof. D. P. Kothari, IIT Delhi

Course Outcomes: *At the end of this course, the students will be able to:*

CO1	Describe load flow analysis of a given power system.
CO2	Explain the concepts of load frequency control & economic load dispatch.
CO3	Articulate the concepts of generator scheduling.
CO4	Explain and analyze automatic voltage and reactive power control.
CO5	Analyze the steady state stability of a synchronous machine.

Program Outcomes Relevant to the Course:

PO1	Apply the knowledge of science and mathematics in designing, analyzing and using power converters for various industrial and domestic applications.
PO2	Design the modern electric machines, drives, power converters, and control circuits for specific applications.
PO3	Use modern tools, professional software platforms, embedded systems for the diversified applications.
PO4	Solve the problems which need critical and independent thinking to show reflective learning.
PO5	Explore ideas for inculcating research skills and undertake independent research in cutting edge technologies.
PO6	Visualize the larger picture and correlate the domain knowledge with the global industrial problems.
PO10	Continue to learn independently and engage in life-long learning.

Mapping of COs to POs and PSOs (1: Low, 2: Medium, 3: High)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PSO1	PSO2	PSO3
CO1	3	1									3	1	
CO2	3	1	3	3	3						3	1	
CO3	3	2	3	2	1					1	3	2	
CO4	3	1	1								3	2	
CO5	3	3	3	1	1	1				1	2	3	

Category	Code	Modelling & Simulation Lab	L-T-P	Credits	Marks
PCR	EE5007		0-0-2	1	100

Objectives	The objective of this laboratory course is to study concepts of modelling, simulation and design of Electrical Engineering equipment & characteristics. The course will provide exposure on performance analysis & improvement to electrical systems through software & modern tools.
Pre-Requisites	Knowledge of mathematics, physics, control system, power systems, electrical machines, and power electronics is required.
Teaching Scheme	Regular laboratory experiments executed by the students under supervision of the teacher. Demonstration shall be given for each experiment.

Evaluation Scheme

Attendance	Daily Performance	Lab Record	Lab Test / Project	Viva-voce	Total
10	30	15	30	15	100

Detailed Syllabus

Experiment-#	Assignment/Experiment
1	Introduction to MiPower software.
2	Obtain swing curve of a given power system for a fault.
3	Computation of fault level at different buses in a power system for a (i) L-G fault and (ii) 3-phase fault.
4	Calculation of fault clearing time for a (i) L-G fault and (ii) 3-phase fault.
5	Calculation of L-index for determining most sensitive bus in a power system and obtain the PV curve.
6 - 7	Static and dynamic analysis of FACT devices into power systems.
8 - 10	Design of Shunt active power filters.
11 -12	Design and study of Multilevel inverter.

Text Books:

T1. J. J. Grainger & W. D. Stevenson, ***Power System Analysis***, 1st *Ed.*, McGraw-Hill, 2017.
T2. N. G. Hingorani and L. Gyugyi, ***Understanding FACTs***, 1st *Ed.*, IEEE Press, 2001.
T3. M. H. Rashid, ***Power Electronics: Devices, Circuits, and Applications***, 4th *Ed.*, Pearson, 2017.

Reference Books:

R1. R. K. Chauhan and K. Chauhan, ***Distributed Energy Resources in Microgrids***, 1st *Ed.*, Elsevier, 2019.
R2. M. A. Pai, ***Computer Techniques in Power System Analysis***, 3rd *Ed.*, McGraw-Hill, 2017.

Online Resources:

1. https://nptel.ac.in/courses/103103206/: by Prof. V. V. Goud, IIT Guwahati
2. https://nptel.ac.in/courses/108102157/: by Prof. A. Das, IIT Delhi

P.T.O

Course Outcomes: *At the end of this course, the students will be able to:*

CO1	Apply mathematical approaches towards protection of power systems.
CO2	Explain transient & dynamic characteristics of a power system.
CO3	Design and simulate Flexible AC Transmission Systems.
CO4	Design and integrate shunt active power filters.
CO5	Design and simulate power electronics converters.

Program Outcomes Relevant to the Course:

PO1	Apply the knowledge of science and mathematics in designing, analyzing and using power converters for various industrial and domestic applications.
PO2	Design the modern electric machines, drives, power converters, and control circuits for specific applications.
PO3	Use modern tools, professional software platforms, embedded systems for the diversified applications.
PO4	Solve the problems which need critical and independent thinking to show reflective learning.
PO5	Explore ideas for inculcating research skills and undertake independent research in cutting edge technologies.
PO6	Visualize the larger picture and correlate the domain knowledge with the global industrial problems.
PO7	Understand the impact of power electronics devices in an economic, social and environment context.

Mapping of COs to POs and PSOs (1: Low, 2: Medium, 3: High)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PSO1	PSO2	PSO3
CO1	3	1	3	1	1	2	3				3	2	
CO2	3	1	3	2	2	3	3				3	2	
CO3	3	2	3	2	3	3	3				3	3	
CO4	3	3	3	3	3	3	3				3	3	
CO5	2	2	3	3	3	2	3				3	3	

Category	Code	Power Converters & Drives	L-T-P	Credits	Marks
PCR	EE5008		3-1-0	4	100

Objectives	The objectives of this course is to analyze the operation of the different power converters with various loads, study chopper fed dc motor drives, and study inverter fed ac motor drives.
Pre-Requisites	Knowledge of Electrical Machines drives and Power Electronics is required.
Teaching Scheme	Regular classroom lectures with use of ICT as and when required, sessions are planned to be interactive with focus on problem solving activities.

Evaluation Scheme

Attendance	Teacher's Assessment	Mid-Term	End-Term	Total
10	20	20	50	100

Detailed Syllabus

Module-#	Topics	Hours
Module-1	Power Electronic Devices: Diodes, Transistors, Thyristors, MOSFET and IGBT - operating principle; Static, dynamic and thermal characteristics, Data sheet ratings, gate drive circuits; Operation and performance analysis of Single phase half controlled and fully controlled AC/DC bridge converter with R, R-L, R-L-E (motor) loads, effect of input line inductance assuming constant current dc load, Torque-speed characteristics of converter controlled separately excited dc motor.	**16 Hours**
Module-2	Three-phase half controlled and fully controlled AC/DC bridge converter assuming constant dc current load: operation and performance analysis, series and parallel operation of converters, power factor improvement, 12 pulse/18 pulse operation, Dual converters.	**12 Hours**
Module-3	DC-DC choppers: Basic voltage commutated thyristor chopper analysis , Separately excited DC motor drive using DC-DC choppers made of gate controlled devices, four quadrant operation, dynamic and regenerative braking of series DC motor using choppers; Basic DC-DC converters: buck, boost buck-boost and Cuk converter, operation, waveforms and design.	**8 Hours**
Module-4	DC-AC inverters using gate controlled devices: single phase and three phase square wave inverters, operation waveforms and harmonics in pole voltage, load phase voltage and line voltage, output voltage control in single phase square wave inverter using chopper control and phase shift, harmonic analysis, operating principles of single phase and three phase PWM inverters, modulation techniques, SPWM, Selective Harmonic Elimination PWM and delta modulation, harmonic spectrum and comparison among different PWM techniques.	**12 Hours**
Module-5	Variable frequency operation of three phase induction motors: Steady state analysis, Torque-speed, current-speed and slip frequency-speed characteristics and operating limits with constant volts/Hz and constant air gap flux operation, implementation using PWM VSI.	**8 Hours**
	Total	**56 Hours**

Text Books:

T1. M. H. Rashid, ***Power Electronics, Circuits, Devices, and Applications***, 4^{th} *Ed.*, Pearson, 2013.

T2. N. Mohan, T. M. Undeland, and W. P. Robbins, ***Power Electronics: Converter, Applications & Design***, 3rd *Ed.*, John Wiley & Sons, 2003.

Reference Books:

R1. G. K. Dubey, ***Fundamentals of Electrical Drives***, 2nd *Ed.*, Narosa Publishing, 2002.
R2. B. K. Bose, ***Modern Power Electronics and A.C. Drives***, PHI Learning, 2002.

Online Resources:

1. https://nptel.ac.in/courses/108/104/108104140/: by Prof. S. P. Das, IIT Kanpur

Course Outcomes: *At the end of this course, the students will be able to:*

CO1	Develop competency in function of various power electronics devices.
CO2	Explain the techniques of analyzing power electronic devices.
CO3	Select and design important elements of a power converter system.
CO4	Develop competency in designing dynamic model of ac drive system.
CO5	Analyze the performance of variable frequency based three phase induction motors.

Program Outcomes Relevant to the Course:

PO1	Apply the knowledge of science and mathematics in designing, analyzing and using power converters for various industrial and domestic applications.
PO2	Design the modern electric machines, drives, power converters, and control circuits for specific applications.
PO3	Use modern tools, professional software platforms, embedded systems for the diversified applications.
PO4	Solve the problems which need critical and independent thinking to show reflective learning.
PO5	Explore ideas for inculcating research skills and undertake independent research in cutting edge technologies.
PO6	Visualize the larger picture and correlate the domain knowledge with the global industrial problems.
PO7	Understand the impact of power electronics devices in an economic, social and environment context.

Mapping of COs to POs and PSOs (1: Low, 2: Medium, 3: High)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PSO1	PSO2	PSO3
CO1	3	3	1	1	3	2	1				3		1
CO2	3	3	1	1	3	2	1				3		1
CO3	2	3	1	1	3	2	1				3		1
CO4	2	3	1	1	3	2	1				3		1
CO5	2	3	1	1	3	2	1				3		1

Category	Code	Power System Optimization	L-T-P	Credits	Marks
PCR	EE5009		3-0-0	3	100

Objectives	The objective of this course is to learn the basics of knowledge representation and problem solving on power system optimization, role of AI in Electrical Engineering, and to apply computational models for optimization of power systems.
Pre-Requisites	Knowledge of engineering mathematics, Power systems and basics of soft computing techniques is required.
Teaching Scheme	Regular classroom lectures with use of ICT as and when required, sessions are planned to be interactive with focus on problem solving activities.

Evaluation Scheme

Attendance	Teacher's Assessment	Mid-Term	End-Term	Total
10	20	20	50	100

Detailed Syllabus

Module-#	Topics	Hours
Module-1	**Multi-objective Generation Scheduling**: Weighting method, Min-max optimum, Utility function method, Global criterion method; Introduction to Fuzzy logic, Inference mechanism in fuzzy logic, Fuzzy Inference – Fuzzy rule-based system – Defuzzification methods, Multi-objective thermal power dispatch using fuzzy system.	**10 Hours**
Module-2	**Stochastic Multi-objective Generation Scheduling**: Stochastic problem formulation, Models of Neural Network Architectures, Learning process, Error correction learning, Multi–layer perceptron using Back propagation algorithm, Multi-objective thermal power dispatch using ANN, Load forecasting using ANN.	**9 Hours**
Module-3	**Evolutionary Programming for Generation Scheduling**: Introduction, Genetic modelling, Genetic operators, Crossover – Single–site crossover, Two-point crossover, Multi-point crossover, Uniform crossover, Matrix crossover, Crossover Rate, Inversion & Deletion, Economic dispatch using GA.	**8 Hours**
Module-4	**Nature Inspired Computing**: Artificial Neuro Fuzzy Inference System (ANFIS), Simulated Annealing, Particle Swarm Optimization, Ant Colony Algorithm. Multi objective formulation using nature inspired computing.	**6 Hours**
Module-5	**Applications of AI Techniques**:, Load flow studies, Economic load dispatch, Load frequency control, Single area system and two area system, Small Signal Stability (Dynamic stability) Reactive power control, speed control of DC and AC Motors.	**9 Hours**
	Total	**42 Hours**

Text Books:

T1. D. P. Kothari and J. S. Dhillon, ***Power System Optimization***, 2nd *Ed.*, PHI Learning, 2010.

T2. S. J. Russell and P. Norvig, ***Artificial Intelligence - A Modern Approach***, 3rd *Ed.*, Pearson Education, 2016.

T3. S. Rajasekaran and G. A. V. Pai, ***Neural Networks, Fuzzy Systems and Evolutionary Algorithms : Synthesis and Applications***, 2nd *Revised Ed.*, PHI Learning, 2017.

Reference Books:

R1. F. O. Karry and C. DeSilva, ***Soft Computing and Intelligent Systems Design: Theory, Tools and Applications***, 1st *Ed.*, Pearson Education,2009.
R2. S. Haykin, ***Neural Networks : A Comprehensive Foundation***, 2nd *Ed.*, Pearson Education, 1999.
R3. T. J. Ross, ***Fuzzy Logic with Engineering Applications***, 3rd *Ed.*, Wiley, 2011.
R4. D. E. Goldberg, ***Genetic Algorithms In Search, Optimization and Machine Learning***, 1st *Ed.*, Pearson Education, 2002.

Online Resources:

1. https://nptel.ac.in/courses/127105006/: by Prof. D. K. Pratihar, IIT Kharagpur
2. https://archive.nptel.ac.in/courses/112106064/: by C. Balaji, IIT Madras

Course Outcomes: *At the end of this course, the students will be able to:*

CO1	Explain the power system optimization formulation problem.
CO2	Apply various soft computing techniques for multi-objective generation scheduling.
CO3	Apply evolutionary programming for generation scheduling and economic dispatch.
CO4	Explore nature-inspired computing methods for power system optimization problems.
CO5	Apply Artificial Intelligence techniques to solve load, flow, and stability problems.

Program Outcomes Relevant to the Course:

PO1	Apply the knowledge of science and mathematics in designing, analyzing and using power converters for various industrial and domestic applications.
PO2	Design the modern electric machines, drives, power converters, and control circuits for specific applications.
PO3	Use modern tools, professional software platforms, embedded systems for the diversified applications.
PO4	Solve the problems which need critical and independent thinking to show reflective learning.
PO5	Explore ideas for inculcating research skills and undertake independent research in cutting edge technologies.
PO6	Visualize the larger picture and correlate the domain knowledge with the global industrial problems.
PO9	Communicate effectively in a technically sound manner with a wide range of audience.
PO10	Continue to learn independently and engage in life-long learning.

Mapping of COs to POs and PSOs (1: Low, 2: Medium, 3: High)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PSO1	PSO2	PSO3
CO1	3	3		2	2	1					3	3	
CO2	3	2	1	2	2					1	3	2	
CO3	3	2	1	2	2					1	3	2	
CO4	3	2	1	3	3	2			2	1	3	2	
CO5	3	1	2	3	3	2			3	1	3	3	

Category	Code	Systems & Control Theory	L-T-P	Credits	Marks
PCR	EE5010		3-1-0	4	100

Objectives	The objectives of this course is to introduce advanced techniques for solving complex control problems in digital platform. The course presents theory and methodology for analysis and modeling of non-linear systems & signals, and methods for designing and synthesis of feedback controllers.
Pre-Requisites	Knowledge of differential equation, Laplace transforms, Linear Control System, and Digital Signal Processing is required.
Teaching Scheme	Regular classroom lectures with use of ICT as and when required, sessions are planned to be interactive with focus on problem solving activities.

Evaluation Scheme

Attendance	Teacher's Assessment	Mid-Term	End-Term	Total
10	20	20	50	100

Detailed Syllabus

Module-#	Topics	Hours
Module-1	**Digital Control System**: Introduction, Types of control system, Sampling process, Sample and hold, Z-transform of elementary functions, The inverse Z-Transform, Solving of difference equation using Z-transform, Sampling Theorem, Folding & aliasing, Pulse transfer function of open and closed loop systems, Mapping between s-plane and z-plane, Stability analysis using Bilinear Transformation and Routh's stability criterion, Dead beat response.	**15 Hours**
Module-2	**State-Variable Analysis and Design**: Introduction to state and state model, Phase variable and canonical form of state space representation, derivation of transfer function for state model, State-space representation of Digital Systems in Controllable canonical form, Diagonalization. State transition matrix, Solution of State transition matrix using z-transformation and Cayley-Hamilton method. Pole placement by state feedback and state Observer design, Feedback linearization.	**13 Hours**
Module-3	**Optimal Control System**: Introduction, Concept of Lyapunov Function and Stability, Parameter optimization, Performance Index, Optimum of a function and functional, Linear Quadratic Regulator and linear quadratic estimator, Algebric Riccati Equation (ARE) and its solution, Linear Quadratic Tracking System, Introduction to h-infinity control.	**13 Hours**
Module-4	**Non-Linear Control System**: Introduction to common non-linearities in control system, Limit Cycles and Phase trajectories, phase plane analysis, Derivation of describing Function: Dead-zone, saturation, relay with dead zone, Hysteresis and Backlash. Stability analysis by describing function method, Jump Resonance, Lyapunov Functions for Non-linear Systems, Introduction to Sliding mode control. Design of Compensator for different systems using MATLAB.	**15 Hours**
	Total	**56 Hours**

Text Books:

T1. K. Ogata, ***Discrete-Time Control Systems***, 2nd *Ed.*, PHI Learning, 2009.
T2. M. Gopal, ***Digital Control and State Variable Methods***, 4th *Ed.*, Tata McGraw Hill, 2003.

Reference Books:

R1. I. J. Nagrath and M. Gopal, ***Control Systems Engineering***, 5th *Ed.*, New Age International, 2009.
R2. R. C. Dorf and R. H. Bishop, ***Modern Control Systems***, 11th *Ed.*, Pearson Education, 2008.
R3. N. S. Nise, ***Control Systems Engineering***, 4th *Ed.*, Wiley India, 2008.
R4. H. K. Khalil, ***Nonlinear Systems***, 3rd *Ed.*, Pearson Education, 2014.

Online Resources:

1. https://www.nptel.ac.in/courses/108103008: by Prof. I. Kar and Prof. S. Majhi, IIT Guwahati
2. https://web.mit.edu/2.14/www/Handouts/StateSpace.pdf
3. https://www.nptelvideos.in/2012/11/advanced-control-system-design_27.html
4. https://www.electrical4u.com/different-types-non-linearities-in-control%20system/

Course Outcomes: *At the end of this course, the students will be able to:*

CO1	Explain Z-transform and use them for solving difference equation in discrete time control system and check the system stability in Z-plane by various methods.
CO2	Describe the concept of state variables, state space representation in different form and study of the system controllability and observability.
CO3	Articulate finite- and infinite-dimensional optimization and methods for constructing optimal regulators and estimator.
CO4	Understand physical non-linearity and methods of stability analysis for a non-linear system and study of describing function and stability analysis by various methods.

Program Outcomes Relevant to the Course:

PO1	Apply the knowledge of science and mathematics in designing, analyzing and using power converters for various industrial and domestic applications.
PO2	Design the modern electric machines, drives, power converters, and control circuits for specific applications.
PO3	Use modern tools, professional software platforms, embedded systems for the diversified applications.
PO4	Solve the problems which need critical and independent thinking to show reflective learning.
PO5	Explore ideas for inculcating research skills and undertake independent research in cutting edge technologies.
PO6	Visualize the larger picture and correlate the domain knowledge with the global industrial problems.
PO7	Understand the impact of power electronics devices in an economic, social and environment context.
PO10	Continue to learn independently and engage in life-long learning.

Mapping of COs to POs and PSOs (1: Low, 2: Medium, 3: High)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PSO1	PSO2	PSO3
CO1	3	1	1	3	2	2	1			1	2	2	
CO2	3	3	2	3	2	2	1			1	2	2	1
CO3	3	3	3	3	3	2	2			2	3	2	1
CO4	3	3	3	3	3	2	2			2	3	2	1

Category	Code	Embedded Systems	L-T-P	Credits	Marks
PEL	EE5013		3-0-0	3	100

Objectives	The objective of this course is to study ARM Cortex-M3/M4 microcontrollers, develop assembly-level programs, and interface with other external devices as per the requirements of the systems and application.
Pre-Requisites	Basic knowledge of Microprocessors, Microcontrollers, and Digital Electronic Circuits is required.
Teaching Scheme	Regular classroom lectures with use of ICT as and when required; interactive sessions are planned with focus on programming and embedded design activities.

Evaluation Scheme

Attendance	Teacher's Assessment	Mid-Term	End-Term	Total
10	20	20	50	100

Detailed Syllabus

Module-#	Topics	Hours
Module-1	Embedded Systems: Introduction, Application areas, Categories of embedded systems, Overview of embedded system architecture, Specialties of embedded systems, Recent trends in embedded systems, Application software, Communication software, Development and debugging tools.	**8 Hours**
Module-2	Background of ARM Architecture, Processor Naming, Instruction Set Development, Thumb-2 and Instruction Set Architecture; Cortex-M3 Basics: Registers, General Purpose Registers, Stack Pointer, Link Register, Program Counter, Special Registers, Operation Mode, Exceptions and Interrupts, Stack Memory Operations, Reset Sequence; Instruction Sets: Assembly Basics, Instruction List, Instruction Description.	**8 Hours**
Module-3	Cortex-M3 Implementation Overview: Pipeline, Block Diagram, Bus Interfaces on Cortex-M3, I-Code Bus, D-Code Bus, System Bus, External PPB and DAP Bus; Exceptions: Exception Types, Priority, Vector Tables, Interrupt Inputs and Pending Behaviour, Fault Exceptions, Supervisor Call and Service Call; Interrupt Behaviour: Interrupt/Exception Sequences, Exception Exits, Nested Interrupts, Tail-Chaining Interrupts, Late Arrivals and Interrupt Latency.	**8 Hours**
Module-4	Cortex-M3/M4 Programming: Overview, Typical Development Flow, Using C, Using Assembly. Exception Programming: Using Interrupts, Exception/Interrupt Handlers, Software Interrupts, Memory Protection Unit and other Cortex-M3 features: MPU Registers, Setting Up the MPU, Power Management, Multiprocessor Communication.	**9 Hours**
Module-5	STM32L15xxx ARM Cortex M3/M4 Microcontroller: Memory and Bus Architecture, Power Control, Reset and Clock Control; STM32L15xxx Peripherals: GPIOs, System Configuration Controller, ADC, Comparators, GP Timers; Development & Debugging Tools: Software and Hardware tools like Cross Assembler, Compiler, Debugger, Simulator, In-Circuit Emulator (ICE), Logic Analyzer, etc.; Application and Case studies: Location and Time synchronization with GPS module, GPS time stamping, Real time clock time stamping, Data logging.	**9 Hours**
	Total	**42 Hours**

Text Books:

T1. J. Yiu, ***The Definitive Guide to ARM Cortex-M3 and Cortex-M4 Processors***, 3rd *Ed.*, Newnes Publication, 2013.
T2. D. Seal, ***ARM Architecture Reference Manual***, 2nd *Ed.*, Addison Wesley, 2001.
T3. A. N. Sloss, D. Symes, and C. Wright, ***ARM System Developer's Guide - Designing and Optimizing System Software***, 1st *Ed.*, Elsevier, 2006.

Reference Books:

R1. S. Furber, ***ARM System-on-Chip Architecture***, 2nd *Ed.*, Addison-Wesley, 2000.
R2. A. Deshmukh, ***Microcontroller - Theory & Applications***, Tata McGraw Hill, 2017.

Other References:

1. Cortex-M series-ARM Reference Manual
2. Cortex-M3 Technical Reference Manual (TRM)
3. STM32L152xx ARM Cortex M3 Microcontroller Reference Manual
4. ARM Architecture Reference Manual– ARM DDI 0100E
5. ARM v7-M Architecture Reference Manual (ARM v7-M ARM)

Online Resources:

1. https://nptel.ac.in/courses/108105057: by Prof. R. Mall and Prof. A. Patra, IIT Kharagpur

Course Outcomes: *At the end of this course, the students will be able to:*

CO1	Explain the concepts of microcontrollers and microprocessors for embedded systems.
CO2	Describe the architecture, modes of operation, memory organization, interrupts of ARM Cortex-M3 family of microprocessors.
CO3	Describe the programming and interrupts of ARM Cortex-M3 family of microprocessors.
CO4	Design ARM Cortex-M3/M4 microcontroller-based interfacing, interrupt handling for various applications.
CO5	Demonstrate peripheral interfacing with advanced programming of ARM Cortex-M3/M4 microcontrollers for real-time applications.

Program Outcomes Relevant to the Course:

PO3	Use modern tools, professional software platforms, embedded systems for the diversified applications.
PO4	Solve the problems which need critical and independent thinking to show reflective learning.
PO5	Explore ideas for inculcating research skills and undertake independent research in cutting edge technologies.
PO6	Visualize the larger picture and correlate the domain knowledge with the global industrial problems.
PO10	Continue to learn independently and engage in life-long learning.

Mapping of COs to POs and PSOs (1: Low, 2: Medium, 3: High)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PSO1	PSO2	PSO3
CO1			3	1	1					1	3	1	1
CO2			3	2	1	2				1	3	1	1
CO3			3	2	1	2				1	3	2	1
CO4			3	2	1	2				1	3	3	1
CO5			3	2	1	2				2	3	3	1

Category	Code	Electric & Hybrid Vehicle Technology	L-T-P	Credits	Marks
PEL	EE5014		3-0-0	3	100

Objectives	The objective of this course is to study the concepts of electric and hybrid electric vehicles including their architecture & standards, different motor drives, design aspects, charging & energy storage systems.
Pre-Requisites	Knowledge of power electronics and electric drives is required.
Teaching Scheme	Regular classroom lectures with use of ICT as and when required; interactive sessions are planned with focus on programming and embedded design activities.

Evaluation Scheme

Attendance	Teacher's Assessment	Mid-Term	End-Term	Total
10	20	20	50	100

Detailed Syllabus

Module-#	Topics	Hours
Module-1	Electric and Hybrid Electric Vehicles: Configuration of Electric Vehicles, Performance of Electric Vehicles, Traction motor characteristics, Tractive effort and Transmission requirement, Vehicle performance, Tractive effort in normal driving, Energy consumption Concept of Hybrid Electric Drive, Architecture of Hybrid Electric Drive, Series Hybrid Electric Drive, Parallel hybrid electric drive; Standards of Electric Vehicle.	**5 Hours**
Module-2	Energy storage for EV and HEV: Energy storage requirements, Battery parameters, Types of Batteries, modeling of Battery, Fuel Cell basic principle and operation, Types of Fuel Cells, PEMFC and its operation, modeling of PEMFC, super-capacitors.	**10 Hours**
Module-3	Electric Propulsion: EV consideration, DC motor drives and speed control, Induction motor drives, Permanent magnet motor drives, Switch reluctance motor drive for electric vehicles configuration and control of drives.	**10 Hours**
Module-4	Design of Electric and Hybrid Electric Vehicles: Series Hybrid Electric Drive Design, Operating patterns, Control strategies, Sizing of major components, Power rating of traction motor, Power rating of engine/generator, Design of PPS; Parallel Hybrid Electric Drive Design: Control strategies of parallel hybrid drive train, Design of engine power capacity, Design of electric motor drive capacity, Transmission design, Energy storage design.	**10 Hours**
Module-5	Power Electronic Converter for Battery Charging: Charging methods for battery, Termination methods, Charging from grid, The Z-converter, Isolated bidirectional DC-DC converter, Design of Z converter for battery charging, High-frequency transformer based isolated charger topology, Transformer-less topology; Concept of charging stations and their types.	**7 Hours**
	Total	**42 Hours**

Text Books:

T1. M. Ehsani, Y. Gao, S. Gay, and A. Emadi, ***Modern Electric, Hybrid Electric, and Fuel Cell Vehicles: Fundamentals, Theory, and Design***, CRC Press, 2005.
T2. I. Husain, ***Electric and Hybrid Vehicles: Design Fundamentals***, CRC Press, 2003.
T3. C. Mi, M. A. Masrur, and D. W. Gao, ***Hybrid Electric Vehicles: Principles and Applications with Practical Perspectives***, Wiley Publication, 2011.

Reference Books:

R1. S. S. Williamson, ***Energy Management Strategies for Electric and Plug-in Hybrid Electric Vehicles***, Springer 2013.
R2. C. C. Chan and K. T. Chau, ***Modern Electric Vehicle Technology***, Oxford University Press, 2001.

Online Resources:

1. https://nptel.ac.in/courses/108102121: by Prof. A. Jain, IIT Delhi
2. https://nptel.ac.in/courses/108106182: by Prof. A. Jhunjhunwala, Prof. P. Kaur, Prof. K. K. Jha, and Prof. L. Kannan, IIT Madras
3. https://nptel.ac.in/courses/108103009: by Prof. S. Majhi and Dr. P. Kumar, IIT Guwahati

Course Outcomes: *At the end of this course, the students will be able to:*

CO1	Illustrate the concept of emerging technologies and the working of electric vehicles.
CO2	Analyze the different components of Electric and Hybrid Electric Vehicle architecture and standards.
CO3	Learn the working and Develop the electric propulsion unit and its control for application of electric vehicles.
CO4	Develop understanding of the concepts and methods of battery charging and charging stations.
CO5	Interpret the working of different power electronics converters for electric and hybrid electric vehicles.

Program Outcomes Relevant to the Course:

PO1	Apply the knowledge of science and mathematics in designing, analyzing and using power converters for various industrial and domestic applications.
PO2	Design the modern electric machines, drives, power converters, and control circuits for specific applications.
PO3	Use modern tools, professional software platforms, embedded systems for the diversified applications.
PO4	Solve the problems which need critical and independent thinking to show reflective learning.
PO5	Explore ideas for inculcating research skills and undertake independent research in cutting edge technologies.
PO6	Visualize the larger picture and correlate the domain knowledge with the global industrial problems.
PO7	Understand the impact of power electronics devices in an economic, social and environment context.

Mapping of COs to POs and PSOs (1: Low, 2: Medium, 3: High)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PSO1	PSO2	PSO3
CO1	3	3	2	2	1	3	1				1	3	
CO2	3	3	2	1	2	3	1				1	3	
CO3	3	3	2	2	1	3	2				1	3	
CO4	3	3	3	2	3	2	1				1	3	
CO5	3	3	2	2	2	2	1				1	3	

Category	Code	Machine Learning & Applications	L-T-P	Credits	Marks
ERR	EC5010		3-0-0	3	100

Objectives	The objective of this course is to learn patterns and concepts from data using various machine learning techniques focusing on recent advances. Students will explore supervised & unsupervised learning paradigms, deep learning technique and various feature extraction strategies.
Pre-Requisites	Knowledge of algorithms, optimization, and matrix theory is required.
Teaching Scheme	Regular classroom lectures with use of ICT as and when required, sessions are planned to be interactive with focus on problem solving and real-life examples.

Evaluation Scheme

Attendance	Teacher's Assessment	Mid-Term	End-Term	Total
10	20	20	50	100

Detailed Syllabus

Module-#	Topics	Hours
Module-1	**Linear Regression & Classification**: Overview of supervised learning, Linear regression models and least squares, Multiple linear and polynomial regression, Ridge regression, Least angle regression and Lasso, Elastic Net.	**9 Hours**
Module-2	**Dimensionality Reduction**: Principal Components, Kernel Principal Component Analysis (PCA), Linear Discriminant Analysis, Independent Component Analysis, Locally Linear Embedding (LLE), Feature Selection.	**8 Hours**
Module-3	**Model Assessment & Selection**: Bias, Variance, and model complexity, Bias-variance trade-off, Cross-validation, Bootstrap methods, Regression and classification trees, Boosting methods, AdaBoost and Random forest.	**8 Hours**
Module-4	**Support Vector Machines**: Generative model for discrete data (Bayesian concept learning, Naive Bayes classifier), Support Vector Machine (SVM) for classification, Reproducing Kernels, SVM for Regression.	**9 Hours**
Module-5	**Neural Networks**: Model of a neuron, Least Mean Squares (LMS), Perceptron and its learning algorithm, Multi-Layer Perceptron (MLP) and Back Propagation algorithm (BPA), Heuristics for improving performance of BPA, Higher order convergence methods for BPA (Newton method, Conjugate gradient method); Radial Basis Function Networks, Self-Organizing Maps.	**8 Hours**
	Total	**42 Hours**

Text Books:

T1. T. Hastie, R. Tibshirani, and J. Friedman, ***The Elements of Statistical Learning: Data Mining, Inference and Prediction***, 2nd *Ed.*, Springer Verlag, 2009.
T2. S. Haykin, ***Neural Networks: A Comprehensive Foundation***, 2nd *Ed.*, Pearson Education, 1999.

Reference Books:

R1. C. Bishop, ***Pattern Recognition and Machine Learning***, 1st *Ed.*, Springer, 2007.
R2. T. Mitchel, ***Machine Learning***, 1st *Ed.*, McGraw-Hill Education, 1997.
R3. G. James, D. Witten, T. Hastie, and R. Tibshirani, ***An Introduction to Statistical Learning with Applications in R***, 7th *Ed.*, Springer, 2013.
R4. K. P. Murphy, ***Machine Learning: A Probabilistic Perspective***, 4th *Ed.*, MIT Press, 2012.

Online Resources:

1. https://nptel.ac.in/courses/106/106/106106202/: by Prof. C. G. Jansson, IIT Madras
2. https://nptel.ac.in/courses/106/105/106105152/: by Prof. S. Sarkar, IIT Kharagpur
3. https://github.com/josephmisiti/awesome-machine-learning: An exhaustive index of machine learning concepts and programming materials.
4. http://mlss.cc/: Machine Learning Summer School Study Material

Course Outcomes: *At the end of this course, the students will be able to:*

CO1	Formulate and solve machine learning problems using linear models of regression and classification.
CO2	Explain unsupervised learning models of dimensionality reduction and factor analysis.
CO3	Analyze the building blocks of probabilistic model assessment and selection.
CO4	Classify data sets using regression, SVM and decision tree based models.
CO5	Apply the concepts of neural networks for solving real-world problems.

Program Outcomes Relevant to the Course:

PO1	Apply the knowledge of science and mathematics in designing, analyzing and using power converters for various industrial and domestic applications.
PO2	Design the modern electric machines, drives, power converters, and control circuits for specific applications.
PO3	Use modern tools, professional software platforms, embedded systems for the diversified applications.
PO5	Explore ideas for inculcating research skills and undertake independent research in cutting edge technologies.
PO6	Visualize the larger picture and correlate the domain knowledge with the global industrial problems.
PO9	Communicate effectively in a technically sound manner with a wide range of audience.
PO10	Continue to learn independently and engage in life-long learning.

Mapping of COs to POs and PSOs (1: Low, 2: Medium, 3: High)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PSO1	PSO2	PSO3
CO1	3	2	3		1	2			1	1	3	3	2
CO2	3	3	2		1	2			1	1	3	3	2
CO3	3	3	2		1	2			1	1	3	3	2
CO4	3	3	2		2	2			1	1	3	3	2
CO5	3	3	2		2	2			1	1	3	3	2

Category	Code	PWM Power Converters	L-T-P	Credits	Marks
PEL	EE5016		3-0-0	3	100

Objectives	The objective of this course is to introduce the concept of different modulation techniques applied to power electronics converters and implementation of various PWM controllers.
Pre-Requisites	Knowledge of Power Electronics Converters is required.
Teaching Scheme	Regular classroom lectures with use of ICT as and when required, sessions are planned to be interactive with focus on analysis of different PWM techniques.

Evaluation Scheme

Attendance	Teacher's Assessment	Mid-Term	End-Term	Total
10	20	20	50	100

Detailed Syllabus

Module-#	Topics	Hours
Module-1	Introduction to Power Electronics Converters: DC-DC and DC-AC converter, Multilevel inverter (MLI); Modulation techniques of single phase converter, Concept of sinusoidal pulse width modulation (PWM) technique; Voltage source inverter and its analysis.	**8 Hours**
Module-2	PWM Techniques: Single PWM, Multiple PWM, Phase displacement control, Sinusoidal PWM (Bipolar, Unipolar) and its spectrum analysis, Hysteresis (Delta) PWM, Selective harmonic elimination and optimized PWM, Harmonic injection PWM, Bus-clamping PWM (BCPWM) or discontinuous PWM.	**10 Hours**
Module-3	Space Vector PWM (SVPWM) Technique: Conventional SVPWM, Space vector based BCPWM and advanced BCPWM, SVPWM for MLI, Analysis of converters with over-modulation technique, Space vector approach to over-modulation.	**9 Hours**
Module-4	Different modulation schemes for multilevel inverters, Implementation of modulation controller, Evaluation of inverter loss, Minimum pulse width and its effect, Necessity of providing dead time.	**9 Hours**
Module-5	Application of PWM for voltage unbalance system, Analysis of line current and DC link current for inverter, Analysis of torque ripple in induction motor drives.	**6 Hours**
	Total	**42 Hours**

Text Books:

T1. D. G. Holmes and T. A. Lipo, ***Pulse Width Modulation of Power Converter: Principles and Practices***, John Wiley & Sons, 2014.
T2. N. Mohan, T. M. Undeland, and W. P. Robbins, ***Power Electronics: Converters, Applications, and Design***, 3rd *Ed.*, John Wiley & Sons, 2002.
T3. B. Vew, ***High Power Converter***, 2nd *Ed.*, Wiley Publication, 2016.

Reference Books:

R1. M. K. Kazimicrczuk, ***Pulse Width Modulated DC-DC Power Converter***, Wiley Publication, 2008.
R2. L. D. Branko and B. Branko, ***Power Electronics: Converters and Regulators***, Springer Publication.
R3. B. K. Bose, ***Modern Power Electronics and AC Drives***, 1st *Ed.*, Pearson Education, 2005.
R4. M. H. Rashid, ***Power Electronics: Circuits, Devices and Applications***, 4th *Ed.*, Pearson Education, 2017.

Online Resources:

1. https://nptel.ac.in/courses/108108035: by Prof. G. Narayanan, IISc Bangalore

Course Outcomes: *At the end of this course, the students will be able to:*

CO1	Illustrate the concept of modulation techniques applied to voltage source inverters.
CO2	Analyze the working of inverters with carrier based and bus-clamped PWM technique.
CO3	Learn about different modulation techniques with space vector modulation concept.
CO4	Develop understanding of the effects of over modulation, losses of inverter, and minimum pulse width and dead time effect in PWM.
CO5	Interpret the application of PWM, analyze the line current and DC link current for an inverter, and torque ripple for an inverter fed induction motor drives.

Program Outcomes Relevant to the Course:

PO1	Apply the knowledge of science and mathematics in designing, analyzing and using power converters for various industrial and domestic applications.
PO2	Design the modern electric machines, drives, power converters, and control circuits for specific applications.
PO3	Use modern tools, professional software platforms, embedded systems for the diversified applications.
PO4	Solve the problems which need critical and independent thinking to show reflective learning.
PO5	Explore ideas for inculcating research skills and undertake independent research in cutting edge technologies.
PO6	Visualize the larger picture and correlate the domain knowledge with the global industrial problems.
PO7	Understand the impact of power electronics devices in an economic, social and environment context.
PO10	Continue to learn independently and engage in life-long learning.

Mapping of COs to POs and PSOs (1: Low, 2: Medium, 3: High)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PSO1	PSO2	PSO3
CO1	3	1	3	1	1	2	3			1	3	2	1
CO2	3	1	3	2	2	3	3			1	3	2	1
CO3	3	2	3	2	3	3	3			1	3	3	1
CO4	3	3	3	3	3	3	3			1	3	3	1
CO5	2	2	3	3	3	2	3			1	3	3	1

Category	Code	Advanced Power System Protection	L-T-P	Credits	Marks
PEL	EE5017		3-0-0	3	100

Objectives	The objectives of this course is to upgrade the knowledge and skills of practicing engineers involved in the protection of modern power systems and utilize the concepts of advanced digital power system protection.
Pre-Requisites	Knowledge of power electronics, electronic circuits, STLD and basics of relays and protection is required.
Teaching Scheme	Regular classroom lectures with use of ICT as and when required, sessions are planned to be interactive with focus on problem solving activities.

Evaluation Scheme

Attendance	Teacher's Assessment	Mid-Term	End-Term	Total
10	20	20	50	100

Detailed Syllabus

Module-#	Topics	Hours
Module-1	**Advanced Relaying**: Evolution of advanced relays from electro-mechanical relays, Performance and operational characteristics of advanced protection; Basic elements in advanced protection: Signal conditioning, Transducers, Surge protection, Analog filtering & analog multiplexers; Conversion subsystem: the sampling theorem, signal aliasing error, sample & hold circuits, multiplexer, A/D conversion, Digital filtering concepts; The digital relay as a unit consisting of hardware & software.	**10 Hours**
Module-2	**Computer Applications to Protective Relaying**: Simulation of power system disturbances-simulation of current and voltage transformers-simulation of distance relays during transient conditions, Offline application of computers, Online application of computers, Relay co-ordination programs.	**8 Hours**
Module-3	**Interconnected System Protection**: Protection of an interconnected systems, Link net structure, Flow chart of primary and backup relay pairs, Examples based on existing power system networks.	**6 Hours**
Module-4	**Microprocessor based Protective Relays**: Multistage frequency relay-measurement of power system signals through phase locked loop interface, protection of alternators against loss of excitation, Microprocessor based over current relays, impedance relays, directional relay, reactance relay, distance relay, measurement of R and X-mho relay, quadrilateral relay, generalized interface for distance relays.	**10 Hours**
Module-5	**Recent Trends in Protection**: Recent advances in digital protection, Digital differential protection of transformer, Digital protection of transmission line; Problems and solution for protection of a series compensated lines; Application of embedded system in protection systems.	**8 Hours**
	Total	**42 Hours**

Text Books:

T1. A. G. Phadke and J. S. Thorp, ***Computer Relaying for Power Systems***, 2^{nd} *Ed.*, Wiley India, 2012.
T2. S. R. Bhide, ***Digital Power System Protection***, 1^{st} *Ed.*, PHI Learning, 2014.

P.T.O

Reference Books:

R1. A. T. Johns and S. K. Salman, ***Digital Protection of Power Systems***, IEEE Press,1999.
R2. G. Zeigler, ***Numerical Distance Protection: Principles and Applications***, 4th *Ed.*, Siemens Publicis, 2011.
R3. P. M. Anderson, ***Power System Protection***, IEEE Press Power Engineering Series, 1998.

Online Resources:

1. https://onlinecourses.nptel.ac.in/noc22_ee46/preview: by Prof. B. R. Bhalija, IIT Roorkee

Course Outcomes: *At the end of this course, the students will be able to:*

CO1	Explain the construction of static relays.
CO2	Describe the operation of amplitude & phase comparators and static over current relays.
CO3	Comprehend the concepts of static differential and static distance relays.
CO4	Understand multi-input comparators and concept of power swings on the distance relays.
CO5	Describe the operation of microprocessor based protective relays.

Program Outcomes Relevant to the Course:

PO1	Apply the knowledge of science and mathematics in designing, analyzing and using power converters for various industrial and domestic applications.
PO2	Design the modern electric machines, drives, power converters, and control circuits for specific applications.
PO3	Use modern tools, professional software platforms, embedded systems for the diversified applications.
PO4	Solve the problems which need critical and independent thinking to show reflective learning.
PO5	Explore ideas for inculcating research skills and undertake independent research in cutting edge technologies.
PO6	Visualize the larger picture and correlate the domain knowledge with the global industrial problems.
PO7	Understand the impact of power electronics devices in an economic, social and environment context.

Mapping of COs to POs and PSOs (1: Low, 2: Medium, 3: High)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PSO1	PSO2	PSO3
CO1	2	3	2		2	2	2				3	2	
CO2		1		1	2	2	1				3	2	
CO3		1		1	2	2	1				3	2	
CO4		1		1	2	2	1				3	2	
CO5		1	2	1	2	2	1				2	1	

Category	Code	Restructured Power Systems	L-T-P	Credits	Marks
PEL	EE5018		3-0-0	3	100

Objectives	The objective of this course is to study restructuring of the electricity market, the need behind deregulation of the electricity market, and the basics of money, power & information flow in a deregulated power system.
Pre-Requisites	Knowledge of power systems and economics is required.
Teaching Scheme	Regular classroom lectures with use of ICT as and when required, sessions are planned to be interactive with focus on problem solving activities.

Evaluation Scheme

Attendance	Teacher's Assessment	Mid-Term	End-Term	Total
10	20	20	50	100

Detailed Syllabus

Module-#	Topics	Hours
Module-1	Fundamentals of restructured system, Inefficiency due to vertical integrated market, Irrational pricing, Inefficient workforce, Market architecture of restructured electricity market, Entities in deregulated market, Types of load, Behavior of load, Load volatility, Load elasticity, Load risk analysis, Benefits from a competitive electricity market, Efficient capacity expansion planning, Cheaper market price, Introducing Innovation, Social welfare maximization, Customer vs consumer, Customer driven market strategy.	**8 Hours**
Module-2	Generation Scheduling, Economic Load Dispatch, Karush-Kuhn-Tucker (KKT) conditions, Economic load dispatch with network loss, Network loss calculation, B-matrix calculation, Unit commitment, Constraints in unit commitment, Issues in unit commitment, The basic optimal power flow formulation, Different objective optimization, Control variables for OPF, Role in vertically integrated systems and in restructured markets, Congestion management, Economic instrument for congestion.	**8 Hours**
Module-3	Central auction, Bidding, Market clearing pricing, Sequential and simultaneous markets, Optimal bidding, Risk assessment, Difficulty in price and reliability management, Manage joint price, Intraday load curve, Hedging, Joint price risk, Transmission pricing, Rolled-in pricing methods, Marginal/incremental pricing method, Embedded cost recovery, Transmission pricing method with examples, Transmission loss compensation, System control, Dispatch, Tracing of power.	**8 Hours**
Module-4	Primary and secondary control in ancillary services, Reliability and power quality control using ancillary services, Voltage and reactive power control as ancillary services, Maintenance of generation and transmission reserves, Ancillary service management in different market, Renewable integration as ancillary services.	**8 Hours**
Module-5	Developments in India: Reforms initiative during 1990-1995, Availability based tariff in India, The electricity act 2003, Open access issues and power exchange in Indian scenario, IT applications in restructured markets, Working of restructured power systems, Case studies on different markets, Comparison in power market, Recent trends in restructured power market.	**10 Hours**
	Total	**42 Hours**

Text Books:

T1. L. Philipson and H. L. Willis, ***Understanding Electric Utilities and De-regulation***, 2^{nd} *Ed.*, Marcel Dekker Pub., 2005.

T2. S. Stoft, ***Power System Economics: Designing Markets for Electricity***, Wiley-IEEE Press, 2002.

Reference Books:

R1. K. Bhattacharya, J. E. Daadler, and M. H. J. Boolen, ***Operation of Restructured Power Systems***, 1^{st} *Ed.*, Kluwer Academic Pub.,2001.

R2. Md. Shahidehpour and M. Alomoush, ***Restructured Electrical Power Systems: Operation, Trading and Volatility***, 1^{st} *Ed.*, Marcel Dekker Pub., 2001.

Online Resources:

1. http://nptel.ac.in/courses/108101005/: by Prof. S. A. Khaparde and Dr. A. R. Abhyankar, IIT Delhi
2. https://ieeexplore.ieee.org/stamp/sta/mp.jsp?arnumber=993762
3. https://www.slideshare.net/sarapluto999/restructuring-of-power-grid

Course Outcomes: *At the end of this course, the students will be able to:*

CO1	Describe the Technical and Non-technical issues in Deregulated Power Industry.
CO2	Understand OPF technique in regulated and restructured systems and its application to congestion management.
CO3	Classify different pricing mechanisms in deregulated environment.
CO4	Identify the importance of ancillary services in restructured power systems.
CO5	Develop IT infrastructure for restructured power systems with emphasis to development in India and discuss the recent trends in restructuring of power systems and their operation.

Program Outcomes Relevant to the Course:

PO1	Apply the knowledge of science and mathematics in designing, analyzing and using power converters for various industrial and domestic applications.
PO3	Use modern tools, professional software platforms, embedded systems for the diversified applications.
PO4	Solve the problems which need critical and independent thinking to show reflective learning.
PO5	Explore ideas for inculcating research skills and undertake independent research in cutting edge technologies.
PO6	Visualize the larger picture and correlate the domain knowledge with the global industrial problems.
PO7	Understand the impact of power electronics devices in an economic, social and environment context.

Mapping of COs to POs and PSOs (1: Low, 2: Medium, 3: High)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PSO1	PSO2	PSO3
CO1			1		2	2						1	
CO2	2		2	1		2						1	
CO3	3		3	1			1				2	2	
CO4			1	1	2	2	1				1	1	
CO5			3			1	3				1	2	1

Category	Code	Power System Dynamics	L-T-P	Credits	Marks
PEL	EE5019		3-0-0	3	100

Objectives	The objective of this course is to study the dynamic characteristics of power system equipment, recognize the dynamic performance of power systems, and illustrate the system stability and controls.
Pre-Requisites	Knowledge of power systems, power quality, and control systems is required.
Teaching Scheme	Regular classroom lectures with use of ICT as required, interactive sessions are planned to focus on dynamic performance and stability of power systems.

Evaluation Scheme

Attendance	Teacher's Assessment	Mid-Term	End-Term	Total
10	20	20	50	100

Detailed Syllabus

Module-#	Topics	Hours
Module-1	Power System Stability Problems: Basic concepts and definitions, Rotor angle stability, Synchronous machine characteristics, Power versus angle relationship, Stability phenomena, Voltage stability and voltage collapse, Mid-term and long-term stability, Classification of stability.	**8 Hours**
Module-2	Small Signal Stability: State space concepts, Basic linearization technique, Participation factors, Eigen properties of state matrix, Small signal stability of a single machine infinite bus system, Studies of parametric effect: effect of loading, Effect of KA, Effect of type of load, Hopf bifurcation, Electromechanical oscillating modes, Stability improvement by power system stabilizers, Design of power system stabilizers.	**8 Hours**
Module-3	Large Perturbation Stability: Transient stability, Swing equation, Time domain simulations and direct stability analysis techniques (extended equal area criterion) Energy function methods: Physical and mathematical aspects of the problem, Lyapunov's method, Modeling issues, Energy function formulation, Potential Energy Boundary Surface (PEBS): Energy function of a single machine infinite bus system, Equal area criterion and the energy function, Multimachine PEBS.	**10 Hours**
Module-4	Sub Synchronous Oscillations: Turbine generator torsional characteristics, Shaft system model, Torsional natural frequencies and mode shapes, Torsional interaction with power system controls: interaction with generator excitation controls, speed governors, and nearby DC converters; Sub Synchronous Resonance (SSR): characteristics of series capacitor - compensated transmission systems, self–excitation due to induction generator effect, torsional interaction resulting in SSR, Analytical methods, Counter measures to SSR problems; Voltage stability, System oscillations.	**10 Hours**
Module-5	Application of Power System Stabilizers: Concepts of applying PSS - Control signals - Structure & tuning of PSS - Washout circuit - Dynamic compensator analysis of single machine infinite bus system with & without PSS.	**6 Hours**
	Total	**42 Hours**

Text Books:

T1. P. Kundur, ***Power System Stability and Control***, 1st *Ed.*, McGraw-Hill, 2006.

T2. P. W. Sauer and M. Pai, ***Power System Dynamics and Stability***, Prentice Hall, 1998.

Reference Books:

R1. K. R. Padiyar, ***Power System Dynamics, Stability and Control***, Interline Publishing, 1999.
R2. C. VanCustem and T. Vournas, ***Voltage Stability of Electric Power Systems***, Riever Academic Press, 1999.
R3. R. Ramanujan, ***Power Systems Dynamics: Analysis & Simulation***, PHI Learning, 2009.
R4. P. M. Anderson and A. A. Fouad, ***Power System Control and Stability***, IEEE Press.

Online Resources:

1. https://nptel.ac.in/courses/108/102/108102080/: by Prof. M. L. Kothari, IIT Delhi
2. https://nptel.ac.in/courses/108/101/108101004/: by Prof. A. M. Kulkarni, IIT Bombay
3. https://nptel.ac.in/courses/108/105/108105133/: by Prof. D. Das, IIT Kharagpur

Course Outcomes: *At the end of this course, the students will be able to:*

CO1	Understand the concept of power system stability.
CO2	Comprehend small signal stability in power systems.
CO3	Explain large disturbance stability and its effect on power system.
CO4	Determine sub synchronous oscillations and various methods to mitigate.
CO5	Apply the knowledge of power system stability in PSS.

Program Outcomes Relevant to the Course:

PO1	Apply the knowledge of science and mathematics in designing, analyzing and using power converters for various industrial and domestic applications.
PO2	Design the modern electric machines, drives, power converters, and control circuits for specific applications.
PO3	Use modern tools, professional software platforms, embedded systems for the diversified applications.
PO4	Solve the problems which need critical and independent thinking to show reflective learning.
PO5	Explore ideas for inculcating research skills and undertake independent research in cutting edge technologies.
PO6	Visualize the larger picture and correlate the domain knowledge with the global industrial problems.
PO7	Understand the impact of power electronics devices in an economic, social and environment context.

Mapping of COs to POs and PSOs (1: Low, 2: Medium, 3: High)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PSO1	PSO2	PSO3
CO1		1	2	3	1	3					2		
CO2	2		1	1	2	1					2		
CO3	2		1	1	2	1					2		
CO4	1			2	1	2					2	1	
CO5	3		1	1	1	1	1				3	2	

Category	Code	English for Research Paper Writing	L-T-P	Credits	Marks
UCR	HS5004		2-0-0	2	100

Objectives	The objective of this course is to give learners an exposure to different aspects of research related technical writing and to help them write such matter effectively through practice.
Pre-Requisites	Basic knowledge of English grammar and the ability to read and write using the English language.
Teaching Scheme	Regular classroom lectures with use of ICT as and when required, sessions are planned to be interactive with focus on technical writing activities.

Evaluation Scheme

Attendance	Teacher's Assessment	Mid-Term	End-Term	Total
10	20	20	50	100

Detailed Syllabus

Module-#	Topics	Hours
Module-1	Technical Communication: Differentiating between general and technical writing, purpose of writing, plain English, mechanics of writing, elements of style. Essentials of English Grammar: basic word order, tense forms, reported speech, use of passives, conditionals, concord, clauses, common errors.	**9 Hours**
Module-2	Elements of Writing: Process writing, developing an effective paragraph, qualities of a paragraph, structuring a paragraph, types of essays, writing reports.	**5 Hours**
Module-3	Key Reading Skills: sub-skills of reading, local and global comprehension, types of technical texts, critical analysis of technical texts, note-making, the purpose and importance of literature review, evaluating literature.	**5 Hours**
Module-4	Developing Writing Skills: writing abstracts, technical letters, project reports, elements of proposal writing.	**6 Hours**
Module-5	Research and Writing: The research paper as a form of communication, Writing a review of Literature, developing a hypothesis, formulating a thesis statement, plagiarism issues.	**3 Hours**
	Total	**28 Hours**

Text Books:

T1. C. Ellison, ***McGraw-Hill's Concise Guide to Writing Research Papers***, McGraw-Hill, 2010.
T2. A. Wallwork, ***English for Writing Research Papers***, Springer, 2011.
T3. R. A. Day, ***How to Write and Publish a Scientific Paper***, 7th *Ed.*, Greenwood, 2011.

Reference Books:

R1. R. Goldbort, ***Writing for Science***, Yale University Press, 2006.
R2. N. J. Higham, ***Handbook of Writing for the Mathematical Sciences***, 2nd *Ed.*, SIAN, 1998.
R3. C. R. Kothari & G. Garg, ***Research Methodology: Methods and Techniques***, 2nd *Ed.*, New Age International Publishers, 2014.

Online Resources:

1. https://msu.edu/course/be/485/bewritingguideV2.0.pdf: Michigan State University Press, USA, Technical Writing Guide, 2007.

2. http://web.mit.edu/me-ugoffice/communication/technical-writing.pdf: Sentence Structure of Technical Writing, Nicole Kelley, MIT, USA, 2006.
3. http://www.inf.ed.ac.uk/teaching/courses/pi/2017_2018/slides/Technical-Writing-Basics.pdf: Notes from Pocketbook of Technical Writing for Engineers and Scientists by Leo Finkelstein, NY, 2007.
4. https://www.shs-conferences.org/articles/shsconf/pdf/2016/04/shsconf_erpa2016_01090.pdf: A need analysis of technical writing skill of engineering students in India, JCK Evangeline & K. Ganesh, DOI: 10.1051/ shsconf/20162601090, 2016

Course Outcomes: *At the end of this course, the students will be able to:*

CO1	Understand the importance and application of technical communication and apply essentials of English grammar to make research writing effective.
CO2	Apply the elements of technical writing to produce effective research papers.
CO3	Develop critical reading and analysis skills of technical research papers and texts.
CO4	Develop the ability to write technical articles and effectively present the ideas.
CO5	Develop research acumen by understanding the key skills of research.

Program Outcomes Relevant to the Course:

PO6	Visualize the larger picture and correlate the domain knowledge with the global industrial problems.
PO7	Understand the impact of power electronics devices in an economic, social and environment context.
PO8	Understand intellectual property rights and overall professional & ethical responsibility.
PO9	Communicate effectively in a technically sound manner with a wide range of audience.
PO10	Continue to learn independently and engage in life-long learning.

Mapping of COs to POs and PSOs (1: Low, 2: Medium, 3: High)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PSO1	PSO2	PSO3
CO1						3	1	1	3	3	1	2	3
CO2						3			3	3	1	2	3
CO3						3	1	1	3	3	2	2	3
CO4						2		1	3	3	2	2	3
CO5						2	1	3	3	3	2	2	3

Category	Code	Power Converters & Drives Lab	L-T-P	Credits	Marks
PCR	EE5011		0-0-4	2	100

Objectives	The objective of this laboratory course is to provide hands-on exposure on power electronics converters & their applications, and perform simulated analysis of different aspects of power electronics converters like drives, FACTs controller, power quality problems, etc.
Pre-Requisites	Knowledge and concepts of converter topology, analysis of PWM switching schemes, control theories and knowledge of MATLAB are required.
Teaching Scheme	Regular laboratory experiments executed by the students under supervision of the teacher. Demonstration shall be given for each experiment.

Evaluation Scheme

Attendance	Daily Performance	Lab Record	Lab Test / Project	Viva-voce	Total
10	30	15	30	15	100

Detailed Syllabus

Experiment-#	Assignment/Experiment
1	Triggering of IGBT, MOSFET and Power Transistor.
2	Study of single-phase AC voltage regulator with resistive and inductive loads.
3	Study the operation of Cyclo-converter.
4	The operation of the chopper fed DC motor drive.
5	The PWM inverter fed 3-phase Induction motor drive control.
6	Study the operation of Flyback and Forward Converter.
7-8	Study the operation of ZCS and ZVS resonant converter.
9	Study the single-phase series-resonant inverter
10	The V/f scalar control operation of three phase induction motor drive.
11	Speed control of DC motor using single phase dual converter.
12	Speed control of DC motor using Three phase Fully Controlled Rectifier.
13-15	Control and Implementation of electric drives using DSP.
16-17	Study of speed control of induction motor drive by using Kramer drive method.
18	PLC based AC/DC motor drive control operation.
19	Study the operation of DC-DC Sepic Converter.
20-22	Study the operation of Closed Loop Control of Boost Converter.

Text Books:

T1. N. Mohan, T. M. Undeland, and W. P. Robbins, ***Power Electronics: Converters, Applications, and Design***, 3rd *Ed.*, John Wiley & Sons, 2003.

T2. M. H. Rashid, ***Power Electronics: Circuits, Devices and Applications***, 4th *Ed.*, Pearson Education, 2017.

Reference Books:

R1. B. K. Bose, ***Modern Power Electronics and AC Drives***, 1st *Ed.*, Pearson Education, 2005.

R2. K. R. Padiyar, ***FACTS Controllers in Power Transmission and Distribution***, 2nd *Ed.*, New Age International Publishers, 2016.

Online Resources:

1. https://nptel.ac.in/courses/108/104/108104140/: by Prof. S. P. Das, IIT Kanpur

Course Outcomes: *At the end of this course, the students will be able to:*

CO1	Design various PE converters, voltage controllers, triggering circuit of different semiconductor switches and resonant inverters.
CO2	Analyze the control of various drives and its performance analysis.
CO3	Analyze the speed controller induction motor by Kremer's Drive method.
CO4	Design and implement PLC based drive controls.
CO5	Develop and implement closed loop control operation for boost converters.

Program Outcomes Relevant to the Course:

PO1	Apply the knowledge of science and mathematics in designing, analyzing and using power converters for various industrial and domestic applications.
PO2	Design the modern electric machines, drives, power converters, and control circuits for specific applications.
PO3	Use modern tools, professional software platforms, embedded systems for the diversified applications.
PO4	Solve the problems which need critical and independent thinking to show reflective learning.
PO5	Explore ideas for inculcating research skills and undertake independent research in cutting edge technologies.
PO6	Visualize the larger picture and correlate the domain knowledge with the global industrial problems.
PO10	Continue to learn independently and engage in life-long learning.

Mapping of COs to POs and PSOs (1: Low, 2: Medium, 3: High)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PSO1	PSO2	PSO3
CO1	3	2	2	1	1	1				1	3	2	2
CO2	2	3	2	1	1	2				2	2	2	2
CO3	2		2	2	1	1				2	3	2	2
CO4	3		2	2	1	1				1	3	2	2
CO5	3		2	1	1	1				1	3	2	2

Category	Code	Power Systems Optimization Lab	L-T-P	Credits	Marks
PCR	EE5012		0-0-4	2	100

Objectives	The objective of this laboratory course is to study concepts of modeling, and optimization of Electrical power systems. The course will provide exposure on performance analysis & improvement to electrical systems.
Pre-Requisites	Knowledge of mathematics, physics, power system, algorithms is required.
Teaching Scheme	Regular laboratory experiments executed by the students under supervision of the teacher. Demonstration shall be given for each experiment.

Evaluation Scheme

Attendance	Daily Performance	Lab Record	Lab Test / Project	Viva-voce	Total
10	30	15	30	15	100

Detailed Syllabus

Experiment-#	Assignment/Experiment
1-2	Evaluation of transmission loss coefficients (B-Coefficients).
3-4	Optimal power flow based on Gradient method.
5-7	Optimal distribution system power flow using PSO.
8-9	Long range generation scheduling for hydro-thermal system.
10-12	Fuzzy based multi optimal thermal scheduling.
13-15	Multi-objective thermal power dispatch using ANN.
16-19	Evolutionary programming for generation scheduling based on GA or PSO.
20-23	Risk index and sensitivity trade-offs implementation in generator scheduling.

Text Books:

T1. D. P. Kothari and J. S. Dhillon, ***Power System Optimization***, 2nd *Ed.*, PHI Learning, 2010.

Reference Books:

R1. J. J. Grainger and W. D. Stevenson, ***Power System Analysis***, 1st *Ed.*, McGraw-Hill, 2017.
R2. M. A. Pai, ***Computer Techniques in Power System Analysis***, 3rd *Ed.*, McGraw-Hill, 2017.

Online Resources:

1. https://archive.nptel.ac.in/courses/112/106/112106064/: by C. Balaji, IIT Madras

Course Outcomes: *At the end of this course, the students will be able to:*

CO1	Analyze load flow studies of a given power system.
CO2	Apply modern techniques and concepts for power generation scheduling.
CO3	Explain the concepts of multi-objective optimization techniques in power systems.
CO4	Implement evolutionary computing techniques to solve power system optimization problems.
CO5	Analyze risk and sensitivity trade-offs in power systems for generator scheduling.

P.T.O

Program Outcomes Relevant to the Course:

PO1	Apply the knowledge of science and mathematics in designing, analyzing and using power converters for various industrial and domestic applications.
PO2	Design the modern electric machines, drives, power converters, and control circuits for specific applications.
PO3	Use modern tools, professional software platforms, embedded systems for the diversified applications.
PO4	Solve the problems which need critical and independent thinking to show reflective learning.
PO5	Explore ideas for inculcating research skills and undertake independent research in cutting edge technologies.
PO6	Visualize the larger picture and correlate the domain knowledge with the global industrial problems.
PO7	Understand the impact of power electronics devices in an economic, social and environment context.
PO10	Continue to learn independently and engage in life-long learning.

Mapping of COs to POs and PSOs (1: Low, 2: Medium, 3: High)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PSO1	PSO2	PSO3
CO1	3	1	3	1	1	2	3				3	2	
CO2	3	1	3	2	2	3	3				3	2	
CO3	3	2	3	2	3	3	3			1	3	3	
CO4	3	3	3	3	3	3	3				3	3	
CO5	2	2	3	3	3	2	3			1	3	3	

Category	Code	Pre-Thesis Literature Survey	L-T-P	Credits	Marks
UCR	RS7002		0-0-2	1	100

Objectives	The objective of this practical course is to enable the student to choose a particular research problem and effectively conduct literature survey to determine the latest research works done and solutions proposed by in that domain.
Pre-Requisites	Familiarity with internet search tools and a focused reading habit is required.
Teaching Scheme	The research guide of the student shall closely work with the student to determine a research problem and guide the student to read through research papers and their references. The student is expected to finally prepare a comprehensive literature survey report on the assigned research problem.

Evaluation Scheme

Attendance	Daily Performance	Lab Record	Lab Test / Project	Viva-voce	Total
10	30	15	30	15	100

Detailed Syllabus

Experiment-#	Assignment/Experiment
1	Importance of literature survey, reputed publishers, conferences, journals, impact factor of journals, citation count and other metrics.
2	Determine problem statement and obtain relevant publications using different search tools, subscribed Journals and various other sources.
3 - 8	Study research papers with their references, evaluate proposed solutions, and prepare a final list of relevant & quality publications to consider for literature survey.
9 - 12	Write the synopsis of studied research papers and perform systematic analysis of the proposed solutions to determine their pros and cons.
13 - 14	Compile the findings and prepare a comprehensive literature survey report.

Text Books:

T1. A. Booth, A. Sutton, M. Clowes, and M. M-St James, ***Systematic Approaches to a Successful Literature Review***, 3rd *Ed.*, Sage Publications, 2021.

Reference Books:

R1. D. Ridley, ***The Literature Review: A Step-by-Step Guide for Students***, 2nd *Ed.*, Sage Publications, 2012.

R2. D. Harris, ***Literature Review and Research Design: A Guide to Effective Research Practice***, 1st *Ed.*, Routledge Publishers, 2019.

Online Resources:

1. https://nptel.ac.in/courses/121106007/: by Dr. P. Haridoss and Prof. E. Prasad, IIT Madras
2. https://archive.nptel.ac.in/courses/110/105/110105091/: by Prof. A. Malik, IIT Kharagpur

Course Outcomes: *At the end of this course, the students will be able to:*

CO1	Understand literature survey and collect relevant quality publications on problem statement.
CO2	Study research papers and their references in a systematic manner in the research area.
CO3	Perform scientific comparison between the proposed approaches of relevant publications.
CO4	Compile the findings of literature survey and write a comprehensive literature review.

Program Outcomes Relevant to the Course:

PO5	Explore ideas for inculcating research skills and undertake independent research in cutting edge technologies.
PO7	Understand the impact of power electronics devices in an economic, social and environment context.
PO8	Understand intellectual property rights and overall professional & ethical responsibility.
PO9	Communicate effectively in a technically sound manner with a wide range of audience.
PO10	Continue to learn independently and engage in life-long learning.

Mapping of COs to POs and PSOs (1: Low, 2: Medium, 3: High)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PSO1	PSO2	PSO3
CO1					2			2	2	2	1	1	2
CO2					2		1	2	2	3	1	1	2
CO3					2		1	3	3	3	1	1	3
CO4					3		2	3	3	3	2	2	3

Category	Code	Distributed Generation & Microgrids	L-T-P	Credits	Marks
PEL	EE6001		3-0-0	3	100

Objectives	The objective of the course is to study the concepts of distributed generation, analyze the impact on grid integration, concepts of microgrid and its configuration.
Pre-Requisites	Knowledge of non-conventional energy resources, advanced power electronics, and power quality is required.
Teaching Scheme	Regular classroom lectures with use of ICT as and when required, sessions are planned to be interactive with focus on problem solving activities.

Evaluation Scheme

Attendance	Teacher's Assessment	Mid-Term	End-Term	Total
10	20	20	50	100

Detailed Syllabus

Module-#	Topics	Hours
Module-1	Introduction: Conventional power generation, advantages and disadvantages, Energy crises, Non-conventional energy (NCE) resources, review of Solar PV, Wind Energy systems, Fuel Cells, Micro-turbines, Biomass, and Tidal sources.	**8 Hours**
Module-2	Distributed Generations (DG): Concept of distributed generations, Topologies, Selection of sources, Regulatory standards/framework, Standards for interconnecting distributed resources to electric power systems: IEEE 1547, DG installation classes, Security issues in DG implementations; Energy storage elements: Batteries, Ultra-capacitors, Flywheels, Captive power plant; Introduction to automation of distributed generation system.	**9 Hours**
Module-3	Impact of Grid Integration: Requirements for grid interconnection, limits on operational parameters: voltage, frequency, Total Harmonic Distortion, response to grid abnormal operating conditions, islanding issues. Impact of grid integration with NCE sources on existing power system: reliability, stability and power quality issues.	**9 Hours**
Module-4	Basics of Microgrid: Concept and definition of microgrid, microgrid drivers and benefits, Review of sources of microgrids, Typical structure and configuration of a microgrid, AC and DC microgrids, Power Electronics interfaces in DC and AC microgrids.	**8 Hours**
Module-5	Control and Operation of Microgrid: Modes of operation and control, Grid connected and islanded mode, Active and reactive power control, Protection issues, Anti-islanding schemes: Passive, Active and Communication-based techniques, Microgrid communication infrastructure, Power quality issues in microgrids, Regulatory standards, Microgrid economics, Introduction to smart microgrids.	**8 Hours**
	Total	**42 Hours**

Text Books:

T1. N. Hatziargyriou, ***Microgrids: Architectures and Control***, 1st *Ed.*, Wiley-IEEE Press, 2014.
T2. A. Yezdani and Reza Iravani, ***Voltage-Sourced Converters in Power Systems: Modeling, Control, and Applications***, 1st *Ed.*, Wiley-IEEE Press, 2010.

P.T.O

Reference Books:

R1. D. O. Neacsu, ***Power Switching Converters: Medium and High Power***, 1st *Ed.*, CRC Press, 2006.
R2. C. S. Solanki, ***Solar Photovoltaic Technology and Systems: A Manual for Technicians, Trainers and Engineers***, 1st *Ed.*, PHI Learning, 2013.
R3. J. F. Manwell, J. G. McGowan, and A. L. Rogers, ***Wind Energy Explained: Theory, Design and Application***, 2nd *Ed.*Wiley, 2009.
R4. G. W. Stagg and A.H. Ei-Abiad, ***Computer Methods in Power System Analysis***, MedTech Publisher, 2019.
R5. H. Bevrani, B. Francois, and T. Ise, ***Microgrid Dynamics and Control***, 1st *Ed.*, Wiley, 2017.

Online Resources:

1. https://nptel.ac.in/courses/108107143/: by Prof. A. Bhattacharya, IIT Roorkee
2. https://nptel.ac.in/courses/108108034/: by Dr. V. John, IISc Bangalore

Course Outcomes: *At the end of this course, the students will be able to:*

CO1	Review the conventional and non-conventional power generation.
CO2	Analyze the concept of distributed generation and installation.
CO3	Design grid integration systems with conventional and non-conventional energy sources.
CO4	Design DC and AC microgrids with power electronics interfaces.
CO5	Analyze power quality issues and control operation of microgrid.

Program Outcomes Relevant to the Course:

PO1	Apply the knowledge of science and mathematics in designing, analyzing and using power converters for various industrial and domestic applications.
PO2	Design the modern electric machines, drives, power converters, and control circuits for specific applications.
PO3	Use modern tools, professional software platforms, embedded systems for the diversified applications.
PO4	Solve the problems which need critical and independent thinking to show reflective learning.
PO5	Explore ideas for inculcating research skills and undertake independent research in cutting edge technologies.
PO6	Visualize the larger picture and correlate the domain knowledge with the global industrial problems.
PO10	Continue to learn independently and engage in life-long learning.

Mapping of COs to POs and PSOs (1: Low, 2: Medium, 3: High)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PSO1	PSO2	PSO3
CO1	3		1	2	1	1				1	2		
CO2	3	1	2	1	1	2				1	3	2	2
CO3	2	2	2	2	2	1				1	3	1	1
CO4	3	3	2	2	1	2				2	2	2	
CO5	3	2	3	2	2	2				2	2	1	

Category	Code	Power Quality	L-T-P	Credits	Marks
PEL	EE6002		3-0-0	3	100

Objectives	The objective of this course is to introduce the students to the fundamentals of electrical power quality, its effect on cost of electrical power, problems & principles of mitigation, and monitoring & mitigating equipment.
Pre-Requisites	Knowledge of engineering physics, network theory, control systems, electrical machines, and power electronics is required.
Teaching Scheme	Regular classroom lectures with use of ICT as and when required, sessions are planned to be interactive with focus on problem solving activities.

Evaluation Scheme

Attendance	Teacher's Assessment	Mid-Term	End-Term	Total
10	20	20	50	100

Detailed Syllabus

Module-#	Topics	Hours
Module-1	**Introduction**: Power and voltage quality, Overview of power quality phenomena, Classification of power quality problems, Power quality terms, Power acceptability curves - IEEE guides; Power Quality Disturbances: Transients, Short duration voltage variation, Long duration voltage variations, Waveform distortion, Voltage imbalance, Voltage fluctuations and Power frequency variations.	**8 Hours**
Module-2	**Transients**: Origin and classifications, Capacitor switching, Transient-lighting-load switching and its impact on users, Protection and mitigation of transients; Harmonics: Harmonic distortion standards, Power system quantities under non-sinusoidal conditions, Harmonic indices, Harmonic sources, System response characteristics, Effects of harmonic distortion, Principles of controlling harmonics, Devices for controlling harmonics.	**10 Hours**
Module-3	**Voltage Sags & Characterization**: Voltage sag magnitude, Voltage sag duration, load influence on voltage sag; Voltage sags: Equipment behavior: Computer and consumer electronics, Adjustable speed AC drives, Adjustable speed DC drives, other sensitive loads.	**8 Hours**
Module-4	**Power Factor Improvement**: Passive Compensation, Passive Filtering. Harmonic Resonance. Impedance Scan Analysis, Active Power Factor Corrected Single Phase Front End, Control Methods for Single Phase APFC, Three Phase APFC and Control Techniques, PFC based on Bilateral Single Phase and Three Phase Converter; **Power Quality Conditioner**: Shunt and series compensators, Distribution STATCOMS and Dynamic voltage restorers (DVRs), Unified power quality conditioners.	**8 Hours**

Cont'd...

Module-#	Topics	Hours
Module-5	**Power Quality Monitoring**: Need, objectives and requirements, Initial site survey, Power quality instrumentation, Selection power quality monitors, location and period, Selection of transducers, Harmonic monitoring, transient monitoring, Event recording and flicker monitoring; Power quality assessment and mitigation: Power quality assessment, Power quality indices and standards, Voltage and current unbalances, Power quality state estimation, State variable method, Observity analysis, Capabilities of harmonic state estimation.	**8 Hours**
	Total	**42 Hours**

Text Books:

T1. M. H. Bollen, ***Understanding Power Quality Problems***, IEEE Press, 2000.

T2. R. C. Dugan, M. F. McGranaghan, S. Santoso, and H. W. Beaty, ***Electrical Power Systems Quality***, 3rd *Ed.*, TMH Education, 2012.

Reference Books:

R1. J. Arrillaga, N. R. Watson, and S. Chen, ***Power System Quality Assessment***, John Wiley & Sons, 2011.

R2. J. Arrillaga, B. C. Smith, N. R. Watson, and A. R. Wood, ***Power System Harmonic Analysis***, 3rd *Ed.*, John Wiley & Sons, 2013.

Online Resources:

1. https://www.svec.education/wp-content/uploads/2020/01/power-quality-course-material.pdf
2. http://www.sasurieengg.com/e-course-material/EEE/IV-Year%20Sem%208/EE2028%20PQ.pdf
3. https://nptel.ac.in/courses/108106025: by Prof. M. Kumar, IIT Madras

Course Outcomes: *At the end of this course, the students will be able to:*

CO1	Understand importance of power quality with power quality issues & standards.
CO2	Understand transients and harmonics and its sources in power systems.
CO3	Analyze characteristics of voltage sag and its effect on different equipment.
CO4	Identify and apply different methods of power factor improvement techniques and power quality conditioning methods to improve power quality.
CO5	Apply the power monitoring and mitigation technique to reduce the adverse effects of power quality on system equipment.

Program Outcomes Relevant to the Course:

PO1	Apply the knowledge of science and mathematics in designing, analyzing and using power converters for various industrial and domestic applications.
PO2	Design the modern electric machines, drives, power converters, and control circuits for specific applications.
PO3	Use modern tools, professional software platforms, embedded systems for the diversified applications.
PO4	Solve the problems which need critical and independent thinking to show reflective learning.
PO5	Explore ideas for inculcating research skills and undertake independent research in cutting edge technologies.
PO6	Visualize the larger picture and correlate the domain knowledge with the global industrial problems.

Cont'd...

PO7	Understand the impact of power electronics devices in an economic, social and environment context.
PO10	Continue to learn independently and engage in life-long learning.

Mapping of COs to POs and PSOs (1: Low, 2: Medium, 3: High)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PSO1	PSO2	PSO3
CO1	3	2	2	2	1	1	1			1	3	2	1
CO2	3	2	2	2	1	1	1			1	3	2	1
CO3	3	3	3	3	1	1				1	3	3	1
CO4	3	2	3	2	1	1	1			1	3	3	1
CO5	3	3	3	3	1	1				1	3	3	1

Category	Code	Nonlinear & Robust Control Systems	L-T-P	Credits	Marks
PEL	EE6003		3-0-0	3	100

Objectives	The objectives of this course is to study the characteristics and stability theory of non-linear systems, design of non-linear controllers for real world applications, signal norms, system norms and their effectiveness to quantify robustness.
Pre-Requisites	Knowledge of differential equations, Laplace transforms, linear control systems and signals & systems is required.
Teaching Scheme	Regular classroom lectures with use of ICT as and when required, sessions are planned to be interactive with focus on problem solving activities.

Evaluation Scheme

Attendance	Teacher's Assessment	Mid-Term	End-Term	Total
10	20	20	50	100

Detailed Syllabus

Module-#	Topics	Hours
Module-1	Review of Classical Feedback Control: The control problem, Transfer functions, Deriving linear models, Frequency response, Feedback control design by loop shaping method, Closed loop stability, Evaluating closed-loop performance, Introduction to Multivariable Control Transfer functions for MIMO systems, Multivariable frequency response analysis, Control of multivariable plants.	**9 Hours**
Module-2	Elements of Linear System Theory: Internal stability of feedback systems, Stabilizing controllers, System norms, Input-Output Controllability, Perfect control and plant inversion, Constraints on S and T; Sliding mode control.	**7 Hours**
Module-3	Robust Stability and Performance Analysis: Introduction to robustness, Uncertainty and Robustness for SISO Systems, Parametric uncertainty in frequency response Computing H2 and H∞ norms Singular Value plots, Small gain theorem, General control formulation with uncertainty; Linear fractional transformation. H∞ controller with state and output feedback controller synthesis, μ-synthesis and DK-iteration.	**10 Hours**
Module-4	Introduction: State-space representation of dynamical systems, phase-portraits of second order systems, types of equilibrium points: stable/unstable node, stable/unstable focus, saddle; Existence and Uniqueness of Solutions: Lipchitz continuity, limit cycles, Bendixson criterion, Poincare-Bendixson criterion; Linearization: linearization around an equilibrium point, validity of linearization around a solution.	**10 Hours**
Module-5	Stability Analysis: Lyapunov stability of autonomous systems, Lyapunov theorem of stability, Converse theorems of Lyapunov theorem, Construction of Lyapunov functions; Control of Nonlinear Systems: Describing functions method, Passivity theorem, Small gain theorem, Kalman-Yakubovich-Popov lemma, Aizermann conjecture, Circle/Popov criteria.	**6 Hours**
	Total	**42 Hours**

Text Books:

T1. H. K. Khalil, ***Nonlinear Systems***, 3rd *Ed.*, Prentice Hall, 2002.
T2. K. Zhou and J. C. Doyle, ***Essentials of Robust Control***, Prentice Hall, 1996.

Reference Books:

R1. J. J. E. Slotine and W. Li, ***Applied Nonlinear Control***, Prentice Hall, 1991.

R2. J. C. Doyle, B. A. Francis, and A. R. Tannenbaum, ***Feedback Control Theory***, Dover, 2009.

Online Resources:

1. https://nptel.ac.in/courses/108106162/: by Prof. R. Pasumarthy and Prof. A. D. Mahindrakar, IIT Madras
2. https://nptel.ac.in/courses/115108104/: by Prof. G. R. Jayanth, IISc Bangalore

Course Outcomes: *At the end of this course, the students will be able to:*

CO1	Learn basic feedback control design techniques including loop shaping method and would also understand the multivariable system design.
CO2	Analyze stability criteria and the application constraints for non-linear systems.
CO3	Desribe robust stability with parametric uncertainty and design robust controllers.
CO4	Explain the methods for analyzing the structure and behavior of nonlinear feedback systems.
CO5	Design control laws for non-linear systems and analyze stability of dynamic systems using Lyapunov method.

Program Outcomes Relevant to the Course:

PO2	Design the modern electric machines, drives, power converters, and control circuits for specific applications.
PO3	Use modern tools, professional software platforms, embedded systems for the diversified applications.
PO4	Solve the problems which need critical and independent thinking to show reflective learning.
PO5	Explore ideas for inculcating research skills and undertake independent research in cutting edge technologies.
PO6	Visualize the larger picture and correlate the domain knowledge with the global industrial problems.
PO10	Continue to learn independently and engage in life-long learning.

Mapping of COs to POs and PSOs (1: Low, 2: Medium, 3: High)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PSO1	PSO2	PSO3
CO1		2	2	3	3	3				2	1	2	2
CO2		2	2	3	3	2					1	2	
CO3		2	1	2	3	2				2	1	2	2
CO4		1	1	3	3	2				2	1	2	2
CO5		2	2	3	3	1					1	2	

Category	Code	Power System Planning & Reliability	L-T-P	Credits	Marks
PEL	EE6004		3-0-0	3	100

Objectives	The objective of this course is to learn load forecasting, power system planning & power reliability issues in power systems, the concepts of evaluation of generation, transmission & distribution system reliability and their impacts on system planning.
Pre-Requisites	Knowledge of Power System Analysis, Electric Power Generation, Transmission and Distribution is required.
Teaching Scheme	Regular classroom lectures with use of ICT as and when required, sessions are planned to be interactive with focus on problem solving activities.

Evaluation Scheme

Attendance	Teacher's Assessment	Mid-Term	End-Term	Total
10	20	20	50	100

Detailed Syllabus

Module-#	Topics	Hours
Module-1	**Load Forecasting**: Objectives of forecasting, Characteristics of loads, methodology of forecasting, Load growth patterns and their importance in planning, Load Forecasting Based on discounted multiple regression technique, Weather sensitive load forecasting, Energy forecasting, Peak demand forecasting, Total forecasting, Annual and monthly peak demand forecasting, Use of AI in load forecasting.	**10 Hours**
Module-2	**Generation System Reliability Analysis**: Reliability concepts, Exponential distributions, Meantime to failure, Series and parallel system, MARKOV process, Recursive technique, Probabilistic generation and load models, Determination of LOLP and expected value of demand not served, Determination of reliability of isolated and interconnected generation systems.	**9 Hours**
Module-3	**Transmission System Reliability Analysis**: Deterministic contingency analysis, probabilistic load flow, Fuzzy load flow probabilistic transmission system reliability analysis, Determination of reliability indices like LOLP and expected value of demand not serve.	**8 Hours**
Module-4	**Expansion Planning**: Objectives of planning, Long and short term planning, Procedure followed for integrate transmission system planning, current practice in India, Capacitor placer problem in transmission system and radial distributions system.	**8 Hours**
Module-5	**Distribution System Planning**: Introduction, sub transmission lines and distribution substations, Design primary and secondary systems, distribution system protection and coordination of protective devices	**7 Hours**
	Total	**42 Hours**

Text Books:

T1. R. Billinton and R. N. Allan, ***Reliability Evaluation of Power Systems***, 2nd *Ed.*, Springer/BSP Publication, 2008.
T2. R. L. Sullivan, ***Power System Planning***, Tata McGraw Hill.

P.T.O

Reference Books:

R1. X. Wang and J. R. McDonald, ***Modern Power System Planning***, McGraw-Hill.
R2. T. Gönen, ***Electrical Power Distribution Engineering***, McGraw-Hill.
R3. B. R. Gupta, ***Generation of Electrical Energy***, S. Chand Publication.

Online Resources:

1. https://sites.google.com/a/hindustanuniv.ac.in/nmlindsay/resume/power-system-planning-and-reliability
2. https://slideplayer.com/slide/5291948/

Course Outcomes: *At the end of this course, the students will be able to:*

CO1	List the objectives of load forecasting and to apply various AI techniques for load forecasting.
CO2	Understand the Reliability concepts and analyze reliability of interconnected generation systems.
CO3	Analyze the reliability of transmission systems considering various factors.
CO4	Explain the expansion planning and capacitor placement problems.
CO5	Design distribution systems & explain distribution system protective scheme and its coordination.

Program Outcomes Relevant to the Course:

PO3	Use modern tools, professional software platforms, embedded systems for the diversified applications.
PO4	Solve the problems which need critical and independent thinking to show reflective learning.
PO5	Explore ideas for inculcating research skills and undertake independent research in cutting edge technologies.
PO6	Visualize the larger picture and correlate the domain knowledge with the global industrial problems.

Mapping of COs to POs and PSOs (1: Low, 2: Medium, 3: High)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PSO1	PSO2	PSO3
CO1			2	1	1	2					2	1	1
CO2			1	1	2	1					3	1	
CO3			1	1	2	2						1	
CO4			2	1	2	2					1	1	
CO5			2	1	2	2					1	2	

Category	Code	Data Acquisition & Signal Conditioning	L-T-P	Credits	Marks
PEL	EE6005		3-0-0	3	100

Objectives	The objective of this course is to study the concepts of signal and its analysis in frequency domain, design of FIR filters, Wavelet Transform and its application in filter banks, and different data acquisition techniques.
Pre-Requisites	Knowledge of Digital Electronics, DSP and Mathematics is required.
Teaching Scheme	Regular classroom lectures with use of ICT as and when required, sessions are planned to be interactive with focus on problem solving activities.

Evaluation Scheme

Attendance	Teacher's Assessment	Mid-Term	End-Term	Total
10	20	20	50	100

Detailed Syllabus

Module-#	Topics	Hours
Module-1	Signals & Analysis in Frequency Domain: Sequences, Representation of signals on orthogonal basis, Sampling and reconstruction of signals; Discrete Systems: Attributes, Z-Transform, Analysis of LSI systems, Frequency Analysis, Inverse Systems, Discrete Fourier Transform (DFT), Fast Fourier Transform Algorithm, Implementation of Discrete Time Systems.	**8 Hours**
Module-2	Design of FIR Digital Filters: Window method, Park McClellan's method; Design of IIR Digital Filters: Butterworth, Chebyshev and Elliptic Approximations, Low-pass, Band-pass, Band-stop and High-pass filters, Effect of finite register length.	**8 Hours**
Module-3	Multirate Systems: Basic multi-rate operations, Interconnection of building blocks, Poly-phase representation, Multistage implementation, Applications of multi-rate systems, Filter banks.	**8 Hours**
Module-4	Wavelet Transform: Continuous wavelet transform (CWT), Time and frequency resolution of the continuous wavelet transform; Construction of Continuous Wavelets: Spline, Orthonormal, Bi-orthonormal, Inverse continuous wavelet transform; Discrete Wavelet Transform and Filter Banks: Orthogonal and bi-orthogonal two-channel filter banks, Design of two-channel filter banks.	**10 Hours**
Module-5	Data Acquisition Techniques: Analog and digital data acquisition, Sensor/ transducer interfacing, Unipolar and bipolar transducers, Sample and hold circuits, Interference, Grounding and shielding, Single channel and multichannel, Graphical Interface (GUI) Software for DAS, RTUs, PC-Based data acquisition system.	**8 Hours**
	Total	**42 Hours**

Text Books:

T1. A. V. Oppenheim and R. Schafer, ***Discrete Time Signal Processing***, 3rd *Ed.*, Prentice Hall, 2013.

T2. J. G. Proakis and D. G. Manolakis, ***Digital Signal Processing: Principles, Algorithms and Applications***, 4th *Ed.*, Prentice Hall India, 2007.

T3. L. R. Rabiner and B. Gold, ***Theory and Application of Digital Signal Processing***, 2nd *Ed.*, Prentice Hall India, 1992.

T4. J. C. Goswami and A. K. Chan, ***Fundamentals of Wavelets: Theory, Algorithms, and Applications***, 2nd *Ed.*, Wiley, 2011.
T5. M. Misiti, Y. Misiti, G. Oppenheim, and J. M. Poggi, ***Wavelets and their Applications***, 1st *Ed.*, John Wiley & Sons, 2010.
T6. P. P. Vaidyanathan, ***Multirate Systems and Filter Banks***, 1st *Ed.*, Pearson Education, 2004.

Reference Books:
R1. J. R. Johnson, ***Introduction to Digital Signal Processing***, Prentice Hall, 1992.
R2. D. J. DeFatta, J. G. Lucas and W. S. Hodgkiss, ***Digital Signal Processing: A System Design Approach***, Student Edition, John Wiley & Sons, 2009.
R3. H. G. Stark, ***Wavelets and Signal Processing: An Application Based Introduction***, Springer, 2010.
R4. G. Keiser, ***A Friendly Guide to Wavelets***, Springer, 2011.

Online Resources:
1. https://nptel.ac.in/courses/108101174: by Prof. Prof. V. M. Gadre, IIT Bombay
2. https://nptel.ac.in/courses/108101093: by Prof. Prof. V. M. Gadre, IIT Bombay

Course Outcomes: *At the end of this course, the students will be able to:*

CO1	Explain discrete time signals and use of algorithms for efficiently computing the DFT.
CO2	Analyze different components of FIR filters and their design.
CO3	Describe the working of multi-rate signal processing, decimators, and interpolators.
CO4	Explain the methods of Wavelet transforms and their role in DSP.
CO5	Interpret the working of different data acquisition techniques.

Program Outcomes Relevant to the Course:

PO1	Apply the knowledge of science and mathematics in designing, analyzing and using power converters for various industrial and domestic applications.
PO2	Design the modern electric machines, drives, power converters, and control circuits for specific applications.
PO3	Use modern tools, professional software platforms, embedded systems for the diversified applications.
PO4	Solve the problems which need critical and independent thinking to show reflective learning.
PO5	Explore ideas for inculcating research skills and undertake independent research in cutting edge technologies.
PO6	Visualize the larger picture and correlate the domain knowledge with the global industrial problems.
PO7	Understand the impact of power electronics devices in an economic, social and environment context.

Mapping of COs to POs and PSOs (1: Low, 2: Medium, 3: High)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PSO1	PSO2	PSO3
CO1	3	3	2	2	1	3	1				2	3	
CO2	3	3	2	1	2	3	1				2	3	
CO3	3	3	2	2	1	3	2				2	3	
CO4	3	3	3	2	3	2	1				2	3	
CO5	3	3	2	2	2	2	1				2	3	

Category	Code	Cyber Physical Systems	L-T-P	Credits	Marks
PEL	EE6006		3-0-0	3	100

Objectives	The objective of this course is to introduce mathematical framework for modeling of Cyber Physical Systems (CPS) and perform simulation and analysis of the same.
Pre-Requisites	Knowledge of calculus, ordinary differential equations, matrices and basic understanding of microprocessors and IoT is required.
Teaching Scheme	Regular classroom lectures with use of ICT as and when required, sessions are planned to be interactive with focus on problem solving activities.

Evaluation Scheme

Attendance	Teacher's Assessment	Mid-Term	End-Term	Total
10	20	20	50	100

Detailed Syllabus

Module-#	Topics	Hours
Module-1	**Introduction**: Cyber-Physical Systems (CPS) in the real world, Energy, Medical and transportation cyber physical systems, Basic principles of design and validation of CPS, Industry 4.0, AutoSAR, IIoT implications, Building Automation, Medical CPS; **CPS Platform Components**: CPS H/W Platforms - Processors, Sensors, Actuators, CPS Network – Wireless Hart, CAN, Automotive Ethernet, CPS S/W Stack – RTOS, Scheduling Real Time control tasks.	**9 Hours**
Module-2	**CPS Implementation**: Features and software components, Mapping software components to ECUs, CPS Performance Analysis - Effect of scheduling, Bus latency, Sense and actuation faults on control performance, Network congestion, Control, Bus and network scheduling using Truetime.	**8 Hours**
Module-3	**CPS Safety Assurance**: Advanced Automata based Modeling and Analysis - Introduction and examples, Timed and Hybrid Automata, Formal Analysis - Flow pipe construction, Reachability analysis, Analysis of CPS Software, Hybrid Automata Modeling - Flowpipe construction using SpaceX and Phaver tools, CPS S/W Verification: Frama-C, CBMC.	**8 Hours**
Module-4	**Secure Deployment of CPS**: Attack models, Secure Task mapping and Partitioning, State estimation for attack detection, Automotive case study - Vehicle ABS hacking, Power distribution case study - Attacks on SmartGrids.	**8 Hours**
Module-5	**CPS Case Studies**: Automotive - S/W Controllers for ABS, ACC, Lane Departure Warning, Suspension Control, Big data and Internet of Things monitoring, Mobility in smart cities; Health Care - Wireless Sensor Networks for wellness monitoring - Types of sensors & actuators, Wireless protocols, Wireless network implementation, Artificial Pancreas/Infusion, Pump/Pacemaker, Green Buildings - Automated lighting, AC control.	**9 Hours**
	Total	**42 Hours**

Text Books:

T1. E. A. Lee and S. A. Seshia, ***Introduction to Embedded Systems – A Cyber–Physical Systems Approach***, 2nd *Ed.*, MIT Press, 2017.

T2. S. Roy and S. K. Das, ***Principles of Cyber-Physical Systems: An Interdisciplinary Approach***, 1st *Ed.*, Cambridge University Press, 2020.

T3. R. Alur, ***Principles of Cyber-Physical Systems***, 1st *Ed.*, MIT Press, 2015.

Reference Books:

R1. R. Rajkumar, D. de. Niz, and M. Klein, ***Cyber Physical Systems***, 1st *Ed.*, Pearson Education, 2017.
R2. A. Platzer, ***Logical Foundations of Cyber Physical Systems***, 1st *Ed.*, Springer, 2017.
R3. J. Chow, ***Informed Urban Transport Systems: Classic and Emerging Mobility Methods Toward Smart Cities***, 1st *Ed.*, Elsevier Science Publishing, 2018.
R4. F. J. Furrer, ***Safety and Security of Cyber-Physical Systems: Engineering Dependable Software using Principle-based Development***, 1st *Ed.*, Springer Vieweg, 2022.

Online Resources:

1. https://nptel.ac.in/courses/106105241: by Prof. S. Dey, IIT Kharagpur
2. https://nptel.ac.in/courses/106106248: by Prof. Saji K Mathew, IIT Madras
3. https://www.coursera.org/learn/cyber-physical-systems-1

Course Outcomes: *At the end of this course, the students will be able to:*

CO1	Explain Cyber-Physical System (CPS) concepts and their platform components.
CO2	Describe and analyze different CPS implementations.
CO3	Analyze vulnerabilities and implement methods for assuring safety of Cyber-Physical Systems.
CO4	Deploy CPS with considerations towards security and design attack resilient systems.
CO5	Explore CPS case studies in different domains and design improved systems.

Program Outcomes Relevant to the Course:

PO1	Apply the knowledge of science and mathematics in designing, analyzing and using power converters for various industrial and domestic applications.
PO2	Design the modern electric machines, drives, power converters, and control circuits for specific applications.
PO3	Use modern tools, professional software platforms, embedded systems for the diversified applications.
PO5	Explore ideas for inculcating research skills and undertake independent research in cutting edge technologies.
PO6	Visualize the larger picture and correlate the domain knowledge with the global industrial problems.

Mapping of COs to POs and PSOs (1: Low, 2: Medium, 3: High)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PSO1	PSO2	PSO3
CO1	2	2	2		2	3					2	2	
CO2	3	3			2	3					2	2	1
CO3	2	2	2		3	2					1	2	1
CO4	2	2	2		3	3					2	2	1
CO5	3	2	2		2	2					2	3	

Category	Code	Advanced Machine Drives	L-T-P	Credits	Marks
PEL	EE6007		3-0-0	3	100

Objectives	The objectives of this course is to study and apply scalar & vector control techniques on induction motor drives, apply estimation techniques and develop sensorless vector controlled drives, apply direct torque control technique on induction motor drives, develop unity power factor drives and fast response vector controlled synchronous motor drives.
Pre-Requisites	Knowledge of power electronics and fundamentals of machine drives is required.
Teaching Scheme	Regular classroom lectures with use of ICT as and when required, sessions are planned to be interactive with focus on problem solving activities.

Evaluation Scheme

Attendance	Teacher's Assessment	Mid-Term	End-Term	Total
10	20	20	50	100

Detailed Syllabus

Module-#	Topics	Hours
Module-1	Induction Motor Drives: 3-phase induction motor operation from non-sinusoidal supply, Speed Control Methods, Voltage control at constant frequency, AC voltage controller fed 3-phase induction motor, Speed control of wound rotor induction motors, Static rotor resistance control, Static slip power control, Static Scherbius drive and Kramer drive, Variable frequency operation from voltage & current sources, Constant V/f control.	**10 Hours**
Module-2	Vector Control of Induction Machines: Reference frame theory & transformations, Induction motor model in stationary and synchronously rotating d-q reference frames, Principle of vector control, Direct and indirect vector control, Rotor flux and stator flux orientation control, Implementation of direct and indirect vector control schemes, Effects of machine parameter variation on the performance of vector controlled drives, Methods of flux estimation, Current controlled PWM VSI with hysteresis band, Synchronous frame P-I current control, Stator flux orientation control.	**12 Hours**
Module-3	Speed Sensorless Vector Control of IM: Speed estimation through slip calculation, Direct synthesis from state equations, Speed adaptive flux observer, Extended Kalman filter, Model reference adaptive system, Direct Torque Control of induction motor, DTC with space vector PWM, Dwell time calculation.	**6 Hours**
Module-4	Synchronous Motor Drive: Review of cylindrical rotor and salient pole synchronous machine, Constant V/f control, Scalar control with unity power factor, Dynamic d-q axis model; Vector Control of Synchronous Motor: Principles, Phasor diagram and scheme of control; Permanent Magnet Synchronous Motor: Surface permanent magnet machine and interior permanent magnet motors.	**8 Hours**
Module-5	Brushless DC motor, Synchronous reluctance motor, switched reluctance machine, speed control scheme for SRM drive.	**5 Hours**
	Total	**42 Hours**

Text Books:
T1. B. K. Bose, ***Modern Power Electronics and AC Drives***, Pearson Education, 2002.
T2. G. K. Dubey, ***Power Semiconductor Controlled Drives***, Prentice Hall International, 2010.

Reference Books:
R1. R. Krishnan, ***Electric Motor Drives: Modeling, Analysis, and Control***, Pearson Education, 2001.
R2. P. Vas, ***Sensorless Vector and Direct Torque Control***, Oxford University Press, 1999.
R3. W. Leonhard, ***Control of Electrical Drives***, Springer-Verlag, 1985.
R4. P. L. Jansen and R. D. Lorenz, ***A Physical Insightful Approach to the Design and Accuracy Assessment of Flux Observers for Field Oriented Induction Machine Drives***, IEEE Transactions on Industry Applications, Vol. 30, Issue 1, 1994, pp. 101-110.

Online Resources:
1. https://nptel.ac.in/courses/108104011: by Dr. S. P. Das, IIT Kanpur

Course Outcomes: *At the end of this course, the students will be able to:*

CO1	Describe the techniques of low cost, scalar controlled induction motor drives.
CO2	Explain the reference frame theory and develop high performance vector controlled induction motor drives.
CO3	Design sensorless vector controlled and direct torque controlled induction motor drives.
CO4	Develop and analyze vector control of synchronous motor drives.
CO5	Use special types of machines like PMSM, IPMSM, SPMSM, SRM and SRM drives.

Program Outcomes Relevant to the Course:

PO1	Apply the knowledge of science and mathematics in designing, analyzing and using power converters for various industrial and domestic applications.
PO2	Design the modern electric machines, drives, power converters, and control circuits for specific applications.
PO3	Use modern tools, professional software platforms, embedded systems for the diversified applications.
PO5	Explore ideas for inculcating research skills and undertake independent research in cutting edge technologies.
PO6	Visualize the larger picture and correlate the domain knowledge with the global industrial problems.
PO7	Understand the impact of power electronics devices in an economic, social and environment context.
PO10	Continue to learn independently and engage in life-long learning.

Mapping of COs to POs and PSOs (1: Low, 2: Medium, 3: High)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PSO1	PSO2	PSO3
CO1	3	3	2		2	2	2			1	3	2	2
CO2	3	3	2		2	2	2			1	3	2	2
CO3	3	3	2		2	2	2			1	3	2	2
CO4	3	3	2		2	2	2			1	3	2	2
CO5	3	3	2		2	2	2			1	3	2	2

Category	Code	Power Distribution Systems	L-T-P	Credits	Marks
PEL	EE6008		3-0-0	3	100

Objectives	The objective of this course is to familiarize students with rudimentary concepts and design of modern power distribution system, technologies adopted for its automation, maintenance and protection.
Pre-Requisites	Concepts of power flow, power system operation & control are required.
Teaching Scheme	Regular classroom lectures with use of ICT as and when required, sessions are planned to be interactive with focus on problem solving activities.

Evaluation Scheme

Attendance	Teacher's Assessment	Mid-Term	End-Term	Total
10	20	20	50	100

Detailed Syllabus

Module-#	Topics	Hours
Module-1	Distribution of power, management, power loads, Short term and long term load forecasting, Methods of load forecasting, Power system loading, Technological forecasting.	**8 Hours**
Module-2	Advantages of distribution management system (DMS), Distribution automation, Restoration/ Reconfiguration of distribution network, Different methods and constraints, Power factor correction.	**7 Hours**
Module-3	Interconnection of distribution, Control and communication systems, Remote metering, Automatic meter reading and its implementation.	**7 Hours**
Module-4	SCADA: Introduction and block diagram, Application of SCADA in distribution automation, Common functions of SCADA, Advantages of distribution automation through SCADA.	**8 Hours**
Module-5	Calculation of optimum number of switches, capacitors, Optimum switching device placement in radial distribution systems, Sectionalizing switches: Types and benefits, Bellman's optimality principle, Remote terminal units, Energy efficiency in electrical distribution and monitoring.	**6 Hours**
Module-6	Maintenance of automated distribution system, Difficulties in implementing distribution, Automation in actual practice, Urban/rural distribution, Energy management, Artificial Intelligence techniques applied to distribution automation.	**6 Hours**
	Total	**42 Hours**

Text Books:

T1. A.S. Pabla, ***Electric Power Distribution***, 6th Edition, Tata McGraw-Hill, 2017.
T2. J. Momoh, ***Electric Power Distribution, Automation, Protection & Control***, CRC Press, 2008.

Reference Books:

R1. M. K. Khedkar, G. M. Dhole, ***A Text Book of Electrical Power Distribution Automation***, 1st Edition, University Science Press, New Delhi, 2010.
R2. A. J. Panseni, ***Electrical Distribution Engineering***, 6th Edition, CRC Press, 2000.

Online Resources:

1. https://nptel.ac.in/courses/108106022: by Dr. K. S. Swarup, IIT Madras
2. https://nptel.ac.in/courses/108107112: by Prof. G. B. Kumbhar, IIT Roorkee

Course Outcomes: *At the end of this course, the students will be able to:*

CO1	Understand intricacies of distribution of electrical power and methods of load forecasting.
CO2	Acquire knowlege of distribution management system, interconnected power system and power system automation.
CO3	Learn SCADA and its application in real-world power distribution problems.
CO4	Understand various applications of artificial intelligence techniques in distribution automation.
CO5	Determine the optimal placement of switching devices in distribution network to minimize losses and improve the performance.
CO6	Gain knowledge on different aspects of distribution system maintenance and energy management.

Program Outcomes Relevant to the Course:

PO1	Apply the knowledge of science and mathematics in designing, analyzing and using power converters for various industrial and domestic applications.
PO2	Design the modern electric machines, drives, power converters, and control circuits for specific applications.
PO3	Use modern tools, professional software platforms, embedded systems for the diversified applications.
PO5	Explore ideas for inculcating research skills and undertake independent research in cutting edge technologies.
PO6	Visualize the larger picture and correlate the domain knowledge with the global industrial problems.

Mapping of COs to POs and PSOs (1: Low, 2: Medium, 3: High)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PSO1	PSO2	PSO3
CO1	2	2	2		2	3					2	2	
CO2	3	3			2	3					3	1	
CO3	2	2	2		3	2					1	2	1
CO4	2	2	2		3	3					2	2	1
CO5	3	2	2		2	2					3	2	
CO6	2	3	3		2	2					2	2	

Category	Code	Energy Management & Audit	L-T-P	Credits	Marks
PEL	EE6009		3-0-0	3	100

Objectives	The objective of this course is to understand the current energy scenario, importance of energy conservation, improving efficiency, concepts of energy management and audit in modern electrical systems.
Pre-Requisites	Knowledge of power systems, transmission and distribution, electrical machines and renewable energy systems is required.
Teaching Scheme	Regular classroom lectures with use of ICT as and when required, sessions are planned to be interactive with focus on problem solving activities.

Evaluation Scheme

Attendance	Teacher's Assessment	Mid-Term	End-Term	Total
10	20	20	50	100

Detailed Syllabus

Module-#	Topics	Hours
Module-1	Energy Scenario and Environment: Commercial and non-commercial energy, Conventional and non-conventional energy, Primary and secondary energy resources, Commercial energy production, Final energy consumption, Energy needs of growing economy, Long term energy scenario, Energy pricing, Energy sector reforms, Energy security, Energy conservation and its importance, Restructuring of the energy supply sector, Energy strategy for the future, Air pollution, Climate change, Energy and environment, Energy Conservation Act-2001, UN Framework Convention on Climate Change (UNFCC), Sustainable development, Kyoto protocol, Clean Development Mechanism (CDM), Prototype Carbon Fund (PCF).	**8 Hours**
Module-2	Energy Economics: Electricity tariff, Electricity billing, Load management and maximum demand control, Power factor improvement and its benefit, Selection & location of capacitors, Simple Payback Period, Time Value of Money, IRR, NPV, Life Cycle Costing, Cost of Saved Energy, Cost of Energy generated, Examples from energy generation and conservation in Steam engineering.	**10 Hours**
Module-3	Energy Audit: Definition & methodology, Energy audit, Need & types of energy audit, Energy Audit Instruments, Benchmarking for energy performance, Energy Action Planning, Optimizing the input energy requirements, Fuel & energy substitution; Material and Energy Balance: Facility as an energy system, Methods for preparing process flow, Material and energy balance diagrams, Duties and responsibilities of Energy Manager; Energy financial management, Project Management, Energy monitoring and targeting.	**8 Hours**

Cont'd. . .

Module-#	Topics	Hours
Module-4	Energy Efficiency in Industrial Systems: Electric motors – Types, Losses in induction motors, Motor efficiency, Factors affecting motor performance, Energy saving opportunities with energy efficient motors; Compressed Air System: Types of air compressors, Compressor efficiency, Energy consumption & energy saving potentials; Refrigeration & Air Conditioning: Heat load estimation, Energy conservation in cooling towers & spray ponds; Pumps and Pumping System: Types, Performance evaluation, Efficient system operation, Flow control strategies and energy conservation opportunities; Lighting System: Light source, Choice of lighting, Luminance requirements and energy conservation avenues.	**9 Hours**
Module-5	Energy Efficient Technologies in Electrical Systems: Maximum demand controllers, Automatic power factor controllers, Energy efficient motors, Soft starters with energy saver, Variable speed drives, Energy efficient transformers, Electronic ballast, Occupancy sensors, Energy efficient lighting controls, Energy saving potential of each technology; Case studies across industries, Visit to energy generation / consumption facility.	**7 Hours**
	Total	**42 Hours**

Text Books:

T1. W. R. Murphy, ***Energy Management***, Elsevier, 2007.
T2. A. Chakrabarti, ***Energy Engineering and Management***, Prentice Hall India, 2011.
T3. A. K. Tyagi, ***Handbook on Energy Audits and Management***, The Energy and Resources Institute, 2003.

Reference Books:

R1. B. L. Capehart, W. C. Turner, and W. J. Kennedy, ***Guide to Energy Management***, 5th *Ed.*, Fairmont Press, 2006.
R2. S. Desai, ***Handbook of Energy Audit***, McGraw-Hill Education, 2015.
R3. W. C. Turner and S. Doty, ***Energy Management Handbook***, 8th *Ed.*, Fairmont Press, 2012.
R4. IEEE, ***IEEE Recommended Practice for Energy Management in Industrial and Commercial Facilities***, IEEE, 1996.

Online Resources:

1. https://nptel.ac.in/courses/109106161: by Dr. S. Dasgupta , IIT Mandi
2. https://nptel.ac.in/courses/109101171: by R. Banerjee, IIT Mumbai

Course Outcomes: *At the end of this course, the students will be able to:*

CO1	Explain energy sources, technologies and environment related issues associated with energy management.
CO2	Evaluate the cost-benefit analysis of various energy sources for meeting the modern energy system requirements.
CO3	Apply the energy audit methods to identify the opportunities to save on energy expenditure.
CO4	Design energy efficient systems by analyzing & optimizing the energy consumption in an organization.
CO5	Identify and apply advanced energy efficient technologies in electrical systems.

P.T.O

Program Outcomes Relevant to the Course:

PO1	Apply the knowledge of science and mathematics in designing, analyzing and using power converters for various industrial and domestic applications.
PO2	Design the modern electric machines, drives, power converters, and control circuits for specific applications.
PO3	Use modern tools, professional software platforms, embedded systems for the diversified applications.
PO4	Solve the problems which need critical and independent thinking to show reflective learning.
PO6	Visualize the larger picture and correlate the domain knowledge with the global industrial problems.
PO7	Understand the impact of power electronics devices in an economic, social and environment context.
PO8	Understand intellectual property rights and overall professional & ethical responsibility.
PO9	Communicate effectively in a technically sound manner with a wide range of audience.
PO10	Continue to learn independently and engage in life-long learning.

Mapping of COs to POs and PSOs (1: Low, 2: Medium, 3: High)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PSO1	PSO2	PSO3
CO1				2		2	2	2	1	1			
CO2	3		3	2		1				1	3		3
CO3	1			2		2		3	3	1	1		
CO4	3	3	3	3		2		1			3	3	3
CO5	1	1	1			2		1	1	1	1	1	1

Category	Code	Power System Transients	L-T-P	Credits	Marks
PEL	EE6010		3-0-0	3	100

Objectives	The objective of the course is to provide an overview of various causes of transients, their effects on power system operations, apparatus and methods adopted to protect power system from harmful effects of transients.
Pre-Requisites	Knowledge of Laplace and Z-transformation, various components & protective devices, and power system operation & control is required.
Teaching Scheme	Regular classroom lectures with use of ICT as and when required, sessions are planned to be interactive with focus on problem solving activities.

Evaluation Scheme

Attendance	Teacher's Assessment	Mid-Term	End-Term	Total
10	20	20	50	100

Detailed Syllabus

Module-#	Topics	Hours
Module-1	Transients in Power Systems: Fundamental circuit analysis of electrical transients, Laplace transformation for solving simple switching transients, Circuit closing and recovery transients, Arcing grounds, Double frequency transients; Normal switching transients: Circuit breaker making and breaking transients, Resistance switching, Load switching, Capacitance switching, Reactor switching Damping circuit.	**11 Hours**
Module-2	Abnormal Switching Transients: Current chopping, Arc furnace switching, Transformer magnetizing inrush currents, Arcing ground phenomena, Re-striking phenomena and its effects on recovery voltage, Ferro-resonance.	**7 Hours**
Module-3	Transients in Three-phase Circuits: Importance of neutral, Three-phase transformer and capacitance switching, Symmetrical component method for solving three-phase switching transients.	**7 Hours**
Module-4	Traveling Waves: Traveling waves on transmission lines, Reflection and refraction of waves, Typical characteristics of traveling waves at line termination, Attenuation and Distortion, Equivalent circuits for traveling wave studies, Forked line, Multi-conductor systems.	**6 Hours**
Module-5	Lightning: Mechanism, Over voltage due to lightning, Protection of electrical apparatus against lightning strokes, Kilometric fault; Lightning Protection Schemes: Arrestors, Neutral grounding, Lightning over voltage protection and protection of substation equipment, Surge diverters, Surge capacitors and reactors, Overhead ground wire, Insulation co-ordination, Over voltage and their significance, Standard voltage level, Insulation co-ordination of a substation.	**11 Hours**
	Total	**42 Hours**

Text Books:

T1. A. Greenwood, ***Electric Transients in Power System***, 2nd *Ed.*, Willy & Sons, 2010.
T2. B. R. Gupta, ***Power System Analysis and Design***, 1st *Ed.*, S.Chand & Co., 2003.
T3. C. S. Indulkar, D. P. Kothari, and K. Ramalingam, ***Power System Transients - A Statistical Approach***, 2nd *Ed.*, PHI Learning, 2010.

Reference Books:

R1. S. Melipoulus, ***Power System Grounding and Transients***, 1st *Ed.*, CRC Press, 1988.
R2. M. S. Naidu and V. Kamaraju, ***High Voltage Engineering***, 5th *Ed.*, Tata McGraw-Hill, 2013.
R3. R. R. Berg, ***Transient Performance of Electric Power systems***, MIT Press, 1991.
R4. P. Harold, ***Transients in Power Systems***, John Wiley & Sons, 1999.

Online Resources:

1. https://nptel.ac.in/courses/108105104: by Prof. D. Das, IIK Kharagpur
2. https://nptel.ac.in/courses/108104048: by Prof. R. Arora, IIT Kanpur
3. https://nptel.ac.in/courses/108104013: by Prof. S. N. Singh, IIT Kanpur

Course Outcomes: *At the end of this course, the students will be able to:*

CO1	Understand basic concepts and various causes of power system transients such as lightning, switching and their effects by mathematically modelling of the electrical parameters.
CO2	Formulate the mathematical model for detail analysis of power system transients.
CO3	Realize the effect of transients in three-phase power systems and study various case studies.
CO4	Visualize the effect of travelling waves in transmission lines and their characteristics.
CO5	Understand the lightning mechanism and analyze the protection schemes adopted to protect power system against transients.

Program Outcomes Relevant to the Course:

PO1	Apply the knowledge of science and mathematics in designing, analyzing and using power converters for various industrial and domestic applications.
PO3	Use modern tools, professional software platforms, embedded systems for the diversified applications.
PO4	Solve the problems which need critical and independent thinking to show reflective learning.
PO5	Explore ideas for inculcating research skills and undertake independent research in cutting edge technologies.
PO6	Visualize the larger picture and correlate the domain knowledge with the global industrial problems.

Mapping of COs to POs and PSOs (1: Low, 2: Medium, 3: High)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PSO1	PSO2	PSO3
CO1	2		2	1		3					2	1	
CO2	2		2	2		2					3	1	1
CO3	2		1	1	1	3					2	1	
CO4	2		1	1	1	3					2	2	1
CO5	1		1	2	1	3					2	1	

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