PROPOSED DRAFT SYLLABUS 2021

M.TECH - POWER ELECTRONICS AND DRIVES

DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING

Power Electronics plays an important role in processing and controlling the flow of electrical energy by supplying voltages and currents in forms that are optimally suited for the user loads from a few watts to several megawatts. The application areas include wide spectrum such as Heating and Lighting Control, AC and DC Power Supplies, Electric Motor Control, Electric Vehicles, Energy Conservation, Process Control, Factory Automation, Transportation, HVDC, FACTS Devices, Power Quality Improvement, Renewable Energy Integration, Wireless Charging, Smart Grid, etc.

Power Electronics encompasses many fields within Electrical engineering.

The PG program includes courses in Mathematics, Research Methodology, Career Competency, Cultural Education and the core subject areas. In core subject areas, emphasis is given on power processors with recent and emerging power switching devices, electrical machines and their control, measurement and processing of signals, signal processors, control systems and digital system design required to build any power electronic equipment with necessary controllers. The program offers electives for the students to enhance the knowledge of emerging machines, areas of power electronics applications and techniques to optimize the designs.

The Program culminates with a project work in which the students are encouraged to work on specific areas involving design, simulation, fabrication and testing of any power electronics system having research/industrial application values.

Program Educational Objectives (PEOs)

The broad educational objectives of the MTech (Power Electronics and Drives) program are:

PEO1: To prepare graduates to acquire high quality technical competence in Power electronics and its allied application areas so that they are employable in innovative Power Electronic and Drives Industries and/or in research and consultancy.

PEO2: To transform students to be industry ready by providing advanced techniques and experimentations on modelling, design and performance analysis on thrust areas of power electronics and unleash new research directions and discoveries.

PEO3: To prepare graduates to practice professionalism, maintain ethics in all their research and professional accomplishments and provide opportunity to participate in team work and develop effective communication skills.

Program Outcomes (POs):

On completion of the MTech (Power Electronics and Drives) program, the graduate will acquire / able:

PO1: An ability to independently carry out research /investigation and development work to solve practical problems
PO2: An ability to write and present a substantial technical report/document
PO3: Students should be able to demonstrate a degree of mastery over the area as per the specialization of the program. The mastery should be at a level higher than the requirements in the appropriate bachelor program
PO4: To develop models and analyse power electronic systems using modern engineering and computational tools
PO5: To formulate methodology for decision making upon investigations into power electronic and drives research problems
PO6: To develop prudence in project management and communication skills, meeting professional ethics, and standards

CURRICULUM

First Semester

Course Code	Type	Course	L T P	Cr
21PE601	F C	Power Converters I	3 0 2	4
21PE602	FC	Modelling and Analysis of Electrical Machines	3 1 0	4
21PE603	SC	Electric Drive Systems	3 1 0	4
21PE604	FC	Digital Signal Processing Techniques	3 0 2	4
21RM610	SC	Research Methodology	2 0 0	2
21PE681	SC	Power Electronic Systems Simulation Lab	0 0 2	1
21HU601	HU	Amrita Values Program*		P/F
21HU602	HU	Career Competency I*		P/F
			Credits	**19**

* Non-Credit Course

Second Semester

Course Code	Type	Course	L T P	Cr
21PE611	FC	Power Converters II	3 0 2	4
21PE612	SC	Advanced Electric Drives	3 0 2	4
21PE613	SC	Embedded Controllers for Power Electronics	3 0 2	4
21PE614	FC	Advanced Control Theory	4 0 0	4
	E	Elective I		3
21LIV602*	E	Elective II/Live-in-Labs		3
21HU603		Career Competency II	0 0 2	1
*21LIV602 –Code for Live in Lab				
			Credits	**23**

Third Semester

Course Code	Type	Course	L T P	Cr
21PE798	P	Dissertation I		**10**
			Credits	**10**

Fourth Semester

Course Code	Type	Course	L T P	Cr
21PE799	P	Dissertation II		**16**
			Credits	**16**

Total Credits: 68

List of Courses

Foundation Core

Course Code	Course	L T P	Cr
21PE601	Power Converters I	3 0 2	4
21PE611	Power Converters II	3 0 2	4
21PE604	Digital Signal Processing Techniques	3 0 2	4
21PE602	Modelling and Analysis of Electrical Machines	3 1 0	4
21PE614	Advanced Control Theory	4 0 0	4

Subject Core

Course Code	Course	L T P	Cr
21PE603	Electric Drive Systems	3 1 0	4
21PE681	Power Electronic Systems Simulation Lab	0 0 2	1
21PE612	Advanced Electric Drives	3 0 2	4
21PE613	Embedded Controllers for Power Electronics	3 0 2	4
21RM610	Research Methodology	2 0 0	2

Open Electives

Course Code	Course	L T P	Cr
21PE631	Modulation Techniques for Power Electronic systems	2 0 2	3
21PE632	Electric Vehicles and Architectures	3 0 0	3
21PE633	Electrical Machine Analysis Using FEM	3 0 0	3
21PE634	Modelling and Control of Power Converters	3 0 0	3
21PE635	Electric Power Quality Improvement	3 0 0	3
21PE636	FACTS and HVDC	3 0 0	3
21PE637	Special Power Converters	3 0 0	3
21PE638	Advanced Signal Processing	2 0 2	3
21PE639	FPGA Based Power Converter Control	2 0 2	3
21PE640	Microgrids and its Control	3 0 0	3
21PE641	Smart Grid	2 0 2	3
21PE642	Renewable Energy Technologies	3 0 0	3
21PE643	Programmable Logic Controllers	3 0 0	3
21PE644	Digital Control Systems	3 0 0	3
21PE645	Adaptive Control Systems	3 0 0	3
21PE646	Power System Operation, Control and Stability	2 0 2	3
21PE647	Electromagnetic Interference and Compatibility	3 0 0	3
21MA604	Optimization Theory	2 0 2	3
21PE648	Power System Modelling	3 0 0	3
21PE649	Design for Reliability	3 0 0	3
21PE650	Distributed Generation	3 0 0	3
21PE651	Power System Dynamics and Control	3 0 0	3
21PE652	Energy Conservation and Management	3 0 0	3

Course Code	Course	L T P	Cr
21PE798	Dissertation I		**10**
21PE799	Dissertation II		**16**

21PE601 **POWER CONVERTERS I** **3-0-2-4**

Power semiconductor switches: ratings, characteristics, power loss, temperature rise calculations, and control (MOSFETS, IGBT, Thyristors, IPM, IGCT). Introduction to Wide Band Gap devices (SiC and GaN) and their applications. Review of AC voltage controllers, Line commutated, uncontrolled, phase controlled converters, twelve pulse converters: Performance factors, Line notching and distortion.
Voltage source inverters: single phase and three phase inverters. Sinusoidal PWM and Space vector PWM. Introduction to Finite set Model Predictive Control for power converters – Utility connected converters, their control, and applications. UPS. Demonstration designs. Multilevel inverters- neutral point clamped inverters, Flying Capacitor, Cascaded H-Bridge and Modular Multilevel Converters.

TEXT BOOKS/ REFERENCES:

1. Ned Mohan, Tore M. Undeland and William P. Robbins, "*Power Electronics, Converters, Applications and Design*", Third Edition, John Wiley and Sons Inc., 2006.
2. Muhammad H. Rashid, "*Power Electronics, Devices, Circuits and Applications*", Fourth Edition, Pearson, 2017.
3. John G. Kassakian, Martin F. Schlecht and George C. Verghese, "*Principles of Power Electronics*", Pearson, 2010.
4. Araújo, Samuel Vasconcelos, "*On the perspectives of wide-band gap power devices in electronic-based power conversion for renewable systems",* Vol. 3. Kassel university press GmbH, 2013.
5. Barry W Williams, "*Principles and Elements of Power Electronics Devices, Drivers, Applications, and Passive Components*", Barry W Williams, 2006.

CO Code	Course Outcome Statement
21PE***.1	Analyze the static and dynamic characteristics of fundamental power semiconductor devices, power modules and wide band gap devices

21PE***.2	Analyze techniques to design and assess the performance of power converters such as AC-DC Converters, AC-AC converters and DC-AC inverters
21PE***.3	Assess power quality, power factor and harmonic issues of various power electronic converters
21PE***.4	Apply PWM techniques for various converters
21PE***.5	Design, simulate, and test various power conversion circuits in the laboratory and their corresponding PWM techniques

CO Code	PO1	PO2	PO3	PO4	PO5	PO6
21PE***.1	3	1	3			
21PE***.2	3	1	3	2		
21PE***.3	3	1	3	2	2	1
21PE***.4	3	1	3	2	2	1
21PE***.5	3	2	3	3	2	1

21PE602 MODELLING AND ANALYSIS OF ELECTRICAL MACHINES 3-1-0-4

Principles of electromagnetic energy conversion: General expression of stored magnetic energy, co-energy and force/torque, single and doubly excited system; Calculation of air gap mmf and per phase machine inductance, Three phase symmetrical induction machines and salient pole synchronous machines in phase variable form.

Generalized theory of rotating electrical machine and Kron's primitive machine; modelling, steady state and transient analysis of DC machines, Introduction to reference frame theory,
Application of reference frame theory to three phase symmetrical induction and synchronous machines, modelling, steady state and transient analysis of induction machines, Unbalanced operation and fault analysis in three phase induction motors. Steady state and transient analysis of synchronous machines, standard and derived machine time constants, Transient power angle curves. Modelling and Analysis of switched reluctance machine.

TEXT BOOKS/ REFERENCES:

1. P.C. Krause, "*Analysis of Electric Machines and Drive Systems*", Wiley International, 2013.
2. T.A. Lipo, "*Electrical Machine Analysis and Simulation*", John Wiley & Sons, 2009
3. B. Adkins, "*Generalized Machine Theory*", McGraw Hill Book Company, 1964.
4. Bimbhra P S, "*Generalized Theory of Electrical Machines*", Khanna Publishers, 2017.
5. Valeria Hrabovcova, Pavol Rafajdus, Pavol Makys, "*Analysis of Electrical Machines*", IntechOpen Publishers, 2020.

CO Code	Course Outcome Statement
21PE***.1	Review the principles of electro-mechanical energy conversion
21PE***.2	Formulate the mathematical model of DC and AC Machines for transient and steady state conditions
21PE***.3	Apply reference frame theory to AC machines
21PE***.4	Analyze the dynamic behaviour of AC & DC machines using

	Simulation Tools

CO Code	PO 1	PO 2	PO 3	PO 4	PO 5	PO6
21PE***.1	1					
21PE***.2	2		2			
21PE***.3	3	2	3	2	2	
21PE***.4	3	2	3	3	2	2

21PE603 ELECTRIC DRIVE SYSTEMS 3-1-0-4

Introduction to Electric Drives – Need of electric drives, basic parts, present scenario of power electronics and drives (market share, manufacturers and likely projections in the future) - Mechanical Dynamics in an Electric Drive - Speed-torque characteristics of some common motors and loads, multi-quadrant operation, equivalent values of drive parameters, stability of an electric drive, General Block Diagram of a Closed Loop Drive System – Speed, torque and position control, Selection of Motor Power Rating – Thermal model of motor for heating and cooling, classes of motor duty, determination of motor rating.

Closed Loop Control of DC Motor – Operating limits of a separately excited DC motor drive, dynamic model of DC motor, dynamic model of chopper and phase controlled rectifier, design of single loop speed controller, cascaded controller design for chopper fed DC motor using inner current control loop and outer speed control loop, field weakening operation.

Induction Motor Drive – Voltage Source Inverter and Current Source inverter based induction motor drives- Steady state equivalent circuit and phasor diagram with variable frequency supply, v/f control and constant air gap flux control of induction motor drive, field weakening operation of induction motor drive.

Induction Motor Drives: Field oriented control- Direct and indirect field orientation, stator-flux, rotor-flux and airgap-flux orientation. Flux-torque decoupling, Extended speed operation and Field weakening, Vector control of line-side PWM rectifier - Direct torque control of Induction Motor, Flux and speed observers.

TEXT BOOKS/REFERENCES:

1. S.K. Pillai, "*A First course on Electric Drives*", New Age Publishers, 2012
2. G.K Dubey, "*Fundamentals of Electric Drives*", Narosa Publishing House, 2010
3. Krishnan R, "*Electric Motor Drives Modeling, Analysis and Control*", Pearson, 2015.
4. Bimal K. Bose, "*Power Electronics and Variable Frequency Drives*", Wiley IEEE Press, 2010.
5. Jan A. Melkebeek, "*Electrical Machines and Drives: Fundamentals and Advanced Modeling*", Springer, 2018.

CO Code	Course Outcome Statement
21PE*.1**	Review the basic characteristics and selection of electric drives
21PE*.2**	Modelling and control of DC drives
21PE*.3**	Analyze scalar control techniques for Induction Motor Drives
21PE*.4**	Develop vector and flux-torque control strategies for Induction Motor Drives

CO Code	PO1	PO2	PO3	PO4	PO5	PO6
21PE*.1**	1					
21PE*.2**	1	1	2	1		1
21PE*.3**	3	1	2	2	1	1
21PE*.4**	3	1	3	2	3	1

21PE604 DIGITAL SIGNAL PROCESSING TECHNIQUES 3-0-2-4

Review of Sampling and aliasing, Fast Fourier Transform. Review of Digital Filters, IIR Filters, FIR filters with MATLAB. Adaptive Filters (Four basic types), Estimation Theory, Multirate Digital Signal Processing Basic Concepts. Introduction to Wavelet Transforms—Discrete Wavelet Transforms- Discrete Wavelets and Filter banks. Applications.

TEXT BOOKS/ REFERENCES:

1. Mitra S.K., "*Digital Signal Processing, A Computer-Based Approach*", 4th Edition, McGraw Hill, 2013.
2. Ifeachor E. C. and Jervis B. W., "*Digital Signal Processing: A Practical Approach*", 2nd Edition, Pearson Education, 2009.
3. Vaidyanathan P. P, "*Multirate Systems and Filter Banks*", Prentice Hall, 1993.
4. Simon Haykin, "*Adaptive Filter Theory*", 4th Edition Pearson Education, 2008.
5. K.P. Soman, K.I. Ramachandran, N.G. Resmi, "*Insight into Wavelets*", Sixth Edition, PHI,2010

CO Code	Course Outcome Statement
21PE***.1	Illustrate digital processing techniques in discrete time domain
21PE***.2	Understand advanced digital filters like Adaptive Filter and Kalman Filter
21PE***.3	Review the concepts of multirate digital signal processing
21PE***.4	Comprehend discrete wavelets as filter banks in real time electrical networks
21PE***.5	Apply signal processing techniques to solve problems in electrical domain

CO Code	PO1	PO2	PO3	PO4	PO5	PO6
21PE***.1	1	1		1	2	2
21PE***.2	2	2	1	2		2
21PE***.3	2	2	2	1	1	1
21PE***.4	2	2	2	1	2	3
21PE***.5	3	3	3	2	2	2

21RM610 RESEARCH METHODOLOGY 2-0-0-2

Unit I:

Meaning of Research, Types of Research, Research Process, Problem definition, Objectives of Research, Research Questions, Research design, Approaches to Research, Quantitative vs. Qualitative Approach, Understanding Theory, Building and Validating Theoretical Models, Exploratory vs. ConfirmatoryResearch, Experimental vs Theoretical Research, Importance of reasoning in research.

Unit II:

Problem Formulation, Understanding Modelling & Simulation, Conducting Literature Review, Referencing, Information Sources, Information Retrieval, Role of libraries in Information Retrieval, Tools for identifying literatures, Indexing and abstracting services, Citation indexes

Unit III:

Experimental Research: Cause effect relationship, Development of Hypothesis, Measurement SystemsAnalysis, Error Propagation, Validity of experiments, Statistical Design of Experiments, FieldExperiments, Data/Variable Types & Classification, Data collection, Numerical and Graphical DataAnalysis: Sampling, Observation, Surveys, Inferential Statistics, and Interpretation of Results

Unit IV:

Preparation of Dissertation and Research Papers, Tables and illustrations, Guidelines for writing the abstract, introduction, methodology, results and discussion, conclusion sections of a manuscript. References, Citation and listing system of documents

Unit V:

Intellectual property rights (IPR) - Patents-Copyrights-Trademarks-Industrial design geographical indication. Ethics of Research- Scientific Misconduct- Forms of Scientific Misconduct.Plagiarism, Unscientific practices in thesis work, Ethics in science

TEXT BOOKS/ REFERENCES:

1. Bordens, K. S. and Abbott, B. B., "*Research Design and Methods – A Process Approach*", 8thEdition, McGraw-Hill, 2011
2. C. R. Kothari, "*Research Methodology – Methods and Techniques*", 2nd Edition, New Age International Publishers.
3. Davis, M., Davis K., and Dunagan M., "*Scientific Papers and Presentations*", 3rd Edition,
   Elsevier Inc.
4. Michael P. Marder, "*Research Methods for Science*", Cambridge University Press, 2011
5. T. Ramappa, "*Intellectual Property Rights Under WTO*", S. Chand, 2008
6. Robert P. Merges, Peter S. Menell, Mark A. Lemley, "*Intellectual Property in New Technological Age*". Aspen Law & Business; 6 edition July 2012

CO Code	Course outcome statement
21PE***.1	Understand types and methods of research, modelling, referencing, etc.
21PE***.2	Analyze experimental results
21PE***.3	Prepare and present research papers
21PE***.4	Knowledge on IPR and ethics in publication

CO Code	PO1	PO2	PO3	PO4	PO5	PO6
21PE***.1	1	3	1			
21PE***.2	1	3	2			
21PE***.3	2	3	2			
21PE***.4	2	3	1			

21PE681 POWER ELECTRONIC SYSTEMS SIMULATION LAB 0-0-2-1

MATLAB-Programming, Simulink - simscape, simpowersystems, PSpice, LTSpice, PSCAD /EMTDC and EMTP for Power Electronics, Drives and Control applications. Octave, Open Modelica.

CO Code	Course outcome statement
21PE*.1**	Understand the simulation tools for solving Electrical engineering problems related to power electronics
21PE*.2**	Recognize various tool boxes used for power electronic application development
21PE*.3**	Examine the methods for troubleshooting in various simulation tools
21PE*.4**	Implement and verify control strategies in the simulation platform for power electronic converters and electrical drives

CO Code	PO1	PO2	PO3	PO4	PO5	PO6
21PE*.1**	2	2	2	3	2	
21PE*.2**	2	2	2	3	2	2
21PE*.3**	2	2	2	3	2	2
21PE*.4**	2	2	2	3	3	2

21PE611 POWER CONVERTERS II 3-0-2-4

DC-DC converters: buck, boost, buck-boost, SEPIC, Multiport, fly-back, forward, push-pull, half bridge, full bridge converters, soft switched bidirectional DC-DC converters, Resonant/quasi resonant DC-DC converters- Application of zero voltage and zero current switching for DC-DC converters. Switched mode voltage regulator specifications, block diagram, modelling approach, assumptions and approximations. Voltage mode control and current mode control, modelling of the converters, Compensation of the feedback system for DC-DC converters. Design of high frequency transformers and inductors. Drive and protection of switching power devices- Single phase AC to DC converters with high power factor. Typical specifications of power converters, design of power circuit to meet the specifications. EMI and Layout fundamentals for switched mode circuits.

TEXT BOOKS/ REFERENCES:

1. Ned Mohan, Tore M. Undeland and William P.Robbins, "*Power Electronics, Converters, Applications and Design*", Third Edition, John Wiley and Sons Inc., 2006.
2. Robert W Erickson and DraganMaksimovic, "*Fundamentals of Power Electronics*", Springer International, 2001.
3. Daniel W Hart, "*Power Electronics*", Tata McGraw Hill, 2011.
4. John G. Kassakian, Martin F. Schlecht and George C.Verghese, "*Principles of PowerElectronics*", Pearson, 2010.
5. V. Ramanarayanan, "*Course Material on Switched Mode Power Conversion*", Department of Electrical Engineering, Indian Institute of Science, Bangalore.*http://minchu.ee.iisc.ernet.in/new/people/faculty/vr/book.pdf*

CO Code	**Course Outcome Statement**
21PE***.1	Analyse DC-DC power converter circuits with and without isolation
21PE***.2	Analyse and design the operation of DC-DC converters in CCM and DCM modes
21PE***.3	Design of protection and magnetic circuits for power converters
21PE***.4	Develop mathematical models of DC-DC converters and the closed loop controllers
21PE***.5	Design and analysis of power converter circuit for real-world applications
21PE***.6	Design, simulate, and test various DC-DC power conversion circuits in the laboratory and their corresponding PWM techniques

CO Code	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
21PE***.1	3	2	3	3		1
21PE***.2	2	2	3	3		1
21PE***.3	2	2	3	1	1	
21PE***.4	2	2	3	3		1
21PE***.5	3	2	3	3	2	2
21PE***.6	2	2	3	3	1	2

21PE612 **ADVANCED ELECTRIC DRIVES** **3-0-2-4**

Synchronous Motor Drive – Overview of Equivalent circuit, starting and phasor diagram for various power factors, Permanent magnet synchronous motor drive with Variable Voltage Variable Frequency control (Open loop V/Hz, Self-control), Wound - field synchronous motor(WFSM) drive using load commutated thyristor inverter, Scalar Control of WFSM using cyclo converter drive - Vector control of Cycloconverter fed WFSM

Introduction to PM Synchronous Motor, Various rotor configurations of PMSM, Sinusoidal Back-Emf PMSM: Field oriented control, Direct torque control. Interior PM Machine: Maximum torque per ampere control, Field weakening

Induction Motor Drives: Slip Power Recovery Systems, Static Kramer and Scherbius Systems-Induction generators, Doubly Fed Induction Machines (DFIM): Different modes of operation, Equivalent circuit, Active and reactive power control, Vector control of DFIM.

Introduction to Brushless DC Motor, EMF and Torque of BLDC machine, Voltage Source Inverter fed BLDC: Half-wave and Full-wave operation, Speed control, Torque ripple minimization.

Introduction to Switched Reluctance Motor Drive: Principle, Modes of operation, Converter circuits and control

Identification of different Motor Parameters: Linear Model, Nonlinear least square identification, Parameter error indices. Speed sensor less control: Direct Synthesis, Signal injection and model based techniques, zero/low speed operation.

TEXT BOOKS/REFERENCES:

1. De Doncker, Rik, Pulle, Duco W J, Veltman, Andre, "*Advanced Electrical Drives – Analysis, Modeling, Control*", Springer, 2011.
2. Krishnan R, "*Electric Motor Drives Modeling, Analysis and Control*", Pearson, 2015.
3. Bimal K. Bose, "*Power Electronics and Variable Frequency Drives*", Wiley IEEE Press, 2010.
4. Krishnan R, "*Switched Reluctance Motor Drives: Modeling, Simulation, Analysis, Design and Applications*", CRC Press, Taylor & Francis Group, 2001.
5. Theodore Wildi, "*Electrical Machines, Drives and Power Systems*", Pearson Education, Sixth Edition.

CO Code	Course Outcome Statement
21PE*.1**	Understand the operation of modern control strategies used in electric drives
21PE*.2**	Analyze the performance of advanced control strategies used in AC drives
21PE***.3	Discuss the working and control of special electric machines
21PE*.4**	Implement the control techniques for electric drives in simulation environment

CO Code	PO1	PO2	PO3	PO4	PO5	PO6
21PE*.1**	2	1	3			
21PE*.2**	3	2	3	2	2	2

21PE*.3**	3	2	3	1	2	1
21PE*.4**	3	1	3	3	1	1

21PE613 EMBEDDED CONTROLLERS FOR POWER ELECTRONICS 3-0-2-4

Architecture of dsPIC30F4011 DSC, MPLAB, C30 Compiler, Peripherals – Ports – Timers – Input capture – Output compare - ADC – MCPWM – QEI – UART- CAN- I^2C. Architecture of TMS320F28335 Delfino DSP – Simple programs in Code Composer Studio. Introduction to real world application development using dsPIC30F4011, Pulse generation for various power converters - DC to DC converter control- AC to AC converter control- AC to DC converter control – DC to AC converter control- sine PWM, Space vector PWM, Closed loop control of power converters for electric drive applications, Application of dsPIC in power system and Digital signal processing.

TEXT BOOKS/REFERENCES:

1. *dsPIC30F Programmers Reference Manual.*
2. *TMS320F28335 Delfino Technical Reference Manual*.
3. Andy Bateman and Iain Paterson-Stephens, "*The DSP Handbook, Algorithms, Applications and Design Techniques*", Pearson Education,2008
4. B Venkataramani and M Bhaskar, "*Digital Signal Processors: Architecture, Programming and Applications*", 2nd Edition Tata McGraw Hill, 2017.

CO Code	Course Outcome Statement
21PE***.1	Understand the architecture of dsPIC30F4011 and TMS320F28335 Delfino microcontrollers
21PE***.2	Apply the software MPLAB and Code Composer Studio for programming the microcontrollers
21PE***.3	Discuss the working of various peripherals of dsPIC30F4011
21PE***.4	Develop programme for configuring the peripherals of dsPIC30F4011
21PE***.5	Implement real world applications in the area of power electronics and drives using dsPIC30F4011

CO Code	PO1	PO2	PO3	PO4	PO5	PO6
21PE***.1	2		2			
21PE***.2	2		2	2		
21PE***.3	3		2	2		
21PE***.4	3	2	3	2		1
21PE***.5	3	3	3	3	3	2

21PE614 ADVANCED CONTROL THEORY 4-0-0-4

State-space representations of transfer function systems: Observable, diagonal and Jordan canonical forms - diagonalisation- invariance of eigen values - solution to state equations.
Control system design in state space: concept of controllability and observability. Pole placement techniques design using state feedback, design of state observers. Design of regulator systems with observer. Design of control systems with observer. Quadratic optimal regulator systems.

Non-linear systems: Introduction, behavior of non-linear system, common physical non linearity-saturation, friction, backlash, dead zone, relay, multi- variable non-linearity. Phase plane method, singular points, stability of nonlinear system, limit cycles, construction of phase trajectories. Liapunov stability criteria, Liapunov functions, direct method of Liapunov and the linear system, Hurwitz criterion and Liapunov's direct method, construction of Liapunov functions for nonlinear system.
Introduction to Adaptive control techniques: Self tuning regulator (STR)-Model reference adaptive control(MRAS)-Model predictive control (MPC).

TEXT BOOKS/ REFERENCES:

1. Ogata, "*Modern Control Engineering*". Fifth Edition, Prentice Hall, 2015.
2. B. Friedland, "*Control system design : An introduction to state space methods*", Dover Publications, 2005.
3. M.J. Marquez, "*Nonlinear control systems: Analysis and design*", Wiley publications, 2003.
4. J-J E. Slotine and W.Li, "*Applied non linear control*", First edition, Pearson,1990.
5. Karl J Astrom and Bjorn Wittenmark, "*Adaptive Control*", Second Edition, Dover Publications Inc., 2008

CO Code	Course outcome statement
21PE***.1	Review of linear system in state space approach
21PE***.2	Design state feedback controller, observer and optimal controller for linear systems
21PE***.3	Analyse non-linear system characteristics and its stability
21PE***.4	Apply the concept of adaptive control techniques

CO Code	PO1	PO2	PO3	PO4	PO5	PO6
21PE***.1	2	2	3	1		
21PE***.2	2	2	3	2		2
21PE***.3	2	2	3	2		2
21PE***.4	2	2	3	2		2

21PE631 MODULATION TECHNIQUES FOR POWER ELECTRONIC SYSTEMS 2-0-2-3

Overview of applications of voltage source converter. Review of Fourier series, fundamental and harmonic voltages; machine model for harmonic voltages - line current distortion, increased losses, Control of fundamental voltage; mitigation of harmonics. Triangle-comparison based PWM: Average pole voltages, sinusoidal modulation, third harmonic injection, continuous PWM, bus-clamping PWM, Synchronously revolving reference frame - Space vector modulation, Per-phase and space vector approaches to over-modulation. Selective harmonic elimination, THD optimized PWM, off-line PWM- Line current ripple; hybrid PWM for reduced line current ripple. Model Predictive Control- Predictive Current Control. Inverter losses, influence of PWM techniques and switching frequency on switching losses, PWM for low inverter losses. compensation of dead-time effect. PWM for multilevel inverter: Extensions of sine-triangle PWM to multilevel inverters, voltage space vectors, space vector based PWM, analysis of line current ripple and torque ripple. Relation between line-side currents and DC link current - rms current rating of DC capacitors. Harmonic torques and RMS torque ripple, hybrid PWM for reduced torque ripple.

TEXT BOOKS/ REFERENCES:

1. Dr. G. Narayanan, IISc, Bangalore, NPTEL Online Video course on "*Pulse width Modulation for Power Electronic Converters*" 2016.
2. Holmes, D. G., and Lipo, T. A., *Pulse Width Modulation for Power Converters: Principles and Practice* (Vol. 18), John Wiley and Sons, 2014.
3. Rodriguez, Jose, and Patricio Cortes, "Predictive *control of power converters and electrical drives*", Vol. 40. John Wiley & Sons, 2012
4. Ned Mohan, Tore M. Undeland and William P.Robbins, "*Power Electronics, Converters, Applications and Design*", Third Edition, John Wiley and Sons Inc., 2006.
5. Haitham Abu-Rub, Atif Iqbal, Jaroslaw Guzinski , "*High Performance Control of AC Drives with Matlab/Simulink Models",* John Wiley and Sons Inc., 2012.

CO Code	**Course Outcome Statement**
21PE***.1	Review of voltage source converters in inverter and rectifier mode of operation for various applications and Harmonic analysis of these converters
21PE***.2	Analyze various PWM techniques and their harmonic composition in voltage source converters and Multi level inverters
21PE***.3	Implement various PWM techniques for rectifier and motor drive applications
21PE***.4	Analyze Inverter losses with various PWM techniques and their means of control

CO Code	PO1	PO2	PO3	PO4	PO5	PO6
21PE***.1	3	1	2	2		
21PE***.2	3	1	3	3	2	1
21PE***.3	3	1	3	3	2	1
21PE***.4	3		3	3		

21PE632 ELECTRIC VEHICLES AND ARCHITECTURES 3-0-0-3

Introduction to Electric Vehicles: History of hybrid and electric vehicles, social and environmental importance, Drive cycle, Vehicle dynamics, Electric system in Automotives. Classification of HEV, Design of EV Power train.

Introduction to power converter and motor control: Power Electronic converters for electric and hybrid vehicles - Electric Motor Drive systems for EV/ HEVs - Power Electronic Converter for Battery Charging, EV Charging Infrastructure, V2G, V2H, V2B. EV integration in smart grid. Case Studies. Overview of Battery Management System (BMS), On board and Off board Charging and associated standards.

TEXT BOOKS/ REFERENCES:

1. Haitham Abu-Rub, Mariusz Malinowski, Kamal Al-Haddad, "*Power Electronics for*

Renewable Energy Systems, Transportation and Industrial Applications", Wiley Publishers, June 2014.
2. Chris Mi; M. Abul Masrur and David Wenzhong Gao, "*Hybrid Electric Vehicles: Principles and Applications with Practical Perspectives*", Wiley Publishers, 2017
3. Yangsheng Xu, Jingyu Yan, Huiihuan Qian and Tin Lun Lam, "*Hybrid Electric Vehicle Design and Control: Intelligent Omni directional Hybrids*", Mc-Graw Hill Education, 2013.
4. Bruno Scrosati, Garche and Werner Tillmetz, "*Advances in Battery Technologies for Electric Vehicles*", Woodhead Publishing Series in Energy, 2015
5. Ehsani, Mehrdad, Yimin Gao, Stefano Longo, and Kambiz Ebrahimi, "*Modern electric, hybrid electric, and fuel cell vehicles",* CRC press, 2019.

CO Code	Course Outcome Statement
21PE***.1	Understand Electric Vehicle architecture, drive trains, drive cycles, EV Standards
21PE***.2	Apply Power Converters for EV Charging, V2G, V2H
21PE***.3	Illustrate different Energy storage systems for EV and discuss the impact of EV – Grid integration
21PE***.4	Design Electric Vehicle Topologies

CO Code	PO1	PO2	PO3	PO4	PO5	PO6
21PE***.1			3			
21PE***.2	3	2	3	3	3	2
21PE***.3	3	2	3	3	2	2
21PE***.4	3	2	3		1	

21PE633 ELECTRICAL MACHINE ANALYSIS USING FEM 3-0-0-3

Review of Electromagnetic theory, basic principles of finite element method, applications of finite element method to two dimensional fields, linear interpolation, variational method, description of electromagnetic fields, analysis procedure using finite element method, reduction of field problem to a two dimensional problem, boundary conditions, drawing flux line, magnetic energy and co-energy, magnetic forces, determination of electrical parameters.

Cylindrical magnetic devices, analytical study of magnetic devices, finite element analysis, single phase transformer, computation of no load inductance, determination of leakage inductance, algorithm for the construction of magnetizing characteristics of a transformer. High frequency inductor, computation of magnetic and electric properties, Transformer design using FEM.

TEXT BOOKS/REFERENCES:

1. Nicola Bianchi, "*Electrical Machine Analysis Using Finite Elements*", CRC Press, 2005.
2. Cheng D K, "*Fundamentals of Engineering Electromagnetic*", Addison Wesley, 1993.

3. Reece A and Preston T, "*Finite Element Method in Electric Power Engineering*", Oxford University Press, UK, 2000.

CO Code	Course Outcome Statement
21PE***.1	Understand the basic principles of finite element method.
21PE***.2	Analyze two dimensional problems using finite element method.
21PE***.3	Evaluate the electromagnetic parameters of electrical apparatus
21PE***.4	Design electrical machines using FEM software tool

CO Code	PO1	PO2	PO3	PO4	PO5	PO6
21PE***.1	3		3			
21PE***.2	3		3	2	2	1
21PE***.3	3	1	3	2	3	1
21PE***.4	3	1	3	3	3	2

21PE634 MODELLING AND CONTROL OF POWER CONVERTERS 3-0-0-3

State space modelling and control of AC/DC converters - State feedback controllers and observer design for output voltage regulation - Analysis of continuous and discontinuous mode of operation. Applications.

State space averaging, modelling and control of Buck, Buck-Boost, Cuk, Sepic, Zeta Converters – Analysis and closed loop voltage regulations using state feedback controllers and sliding mode controllers. Analysis of continuous and discontinuous mode of operation. Application of digital control techniques.

Control approaches to self commutated power converters, Linearized modelling and control techniques for power converters, overview of nonlinear and adaptive control techniques for power converters. Control algorithm development using simulation tools for real time implementation

TEXTBOOKS/REFERENCES:

1. Sira -Ramirez, R. SilvaOrtigoza, "*Control Design Techniques in Power Electronics Devices*", Springer, 2010.
2. Blaabjerg, Frede, "*Control of Power Electronic Converters and Systems: Volume 2".* Academic Press, 2018.
3. Erickson, Robert W., and Dragan Maksimovic, "*Fundamentals of power electronics*", Springer Science & Business Media, 2nd Edition, 2007.
4. Bimal Bose, "*Power electronics and motor drives*", Elsevier, 2006.

CO Code	Course outcome statement
21PE***.1	Understand the concept of state space modelling and analysis of AC/DC converters, and DC-DC converters.
21PE***.2	Design state feedback controllers and observers for AC/DC converters, and DC-DC converters with its development using simulation tools
21PE***.3	Analyse the rectifier and DC-DC converter circuits under continuous and discontinuous current mode of operation with controllers
21PE***.4	Discuss the various control techniques such as linearized control, nonlinear and adaptive control techniques for power converters

CO Code	PO1	PO2	PO3	PO4	PO5	PO6
21PE***.1	2	2	3	2		
21PE***.2	2	2	3	3	1	2
21PE***.3	2	2	3	3	1	2
21PE***.4	2	2	3	3	1	2

21PE635 ELECTRIC POWER QUALITY IMPROVEMENT 3-0-0-3

Review of power quality Issues - Voltage sags and swells, interruptions, transients, notches, unbalance, distortions, fluctuations and flicker.
IEEE Recommended Practices and Requirements for Harmonic Control in Electric Power Systems - 519, Recommended Practices for Individual Consumers – Recommended Practices for Utilities, Power Quality Monitoring Techniques.
Causes and effects of power quality issues, Measurements – Power Quality Indices.
Harmonic studies: Circuit analysis and power assessment under non-sinusoidal conditions-Symmetrical components - Harmonic propagation studies in large network - FFT Analysis.
Power Quality Improvement techniques: Passive filters – Review - Harmonic and Reactive power compensation – Design, Active Filters – Review - Active filter control schemes/algorithms - Time domain and frequency domain - Instantaneous reactive power theory(IRPT) algorithm, Synchronous Detection (SD) algorithm, DC Bus voltage algorithm, Synchronous reference frame (SRF) algorithm, Icosϕ algorithm, AI based control algorithms, Case studies. Hybrid Filters – Review – Design – Applications. Unified Power Quality Conditioner.
Estimation of rate/cost reduction with hybrid filters. Review of single-phase and three-phase improved power quality converters - Applications. Custom power parks -Custom power devices and Applications.
Power Quality issues in Distributed Generation - Grid connected Renewable Energy Sources, Electric Vehicle Charging - Power Quality Issues in Smart Grid, Power Quality Conditioners for Smart Grid.

TEXT BOOKS/ REFERENCES:

1. J. Arillaga, N. R.Watson and S.Chen, "*Power System Harmonics*", John Wiley and Sons, England, 2016.
2. Enrique Acha and Manuel Madrigal, "*Power Systems Harmonics-Computer Modeling and Analysis*", John Wiley and Sons Ltd., 2012.
3. George J. Wakileh, "*Power Systems Harmonics-Fundamentals, Analysis and Filter Design*", Springer-Verlag, New York, 2007.
4. Ewald and Mohammad Masoum, "*Power Quality in Power Systems and Electrical Machines*", Elseveir Academic Press, 2015.
5. Bhim Singh, Ambrish Chandra, Kamal Al-Haddad, *"Power Quality Problems and Mitigation Techniques*", John Wiley&Sons Limited, 2015.

CO Code	Course outcome statement
21PE***.1	Understand sources and effects of various power quality issues.
21PE***.2	Analyse the behaviour of power quality events and categorise them based on the recommended standards
21PE***.3	Judge, design and develop suitable mitigation techniques
21PE***.4	Analyse the performance of power quality improvement schemes

CO Code	PO1	PO2	PO3	PO4	PO5	PO6
21PE***.1	3		3			
21PE***.2	3		3	3	2	
21PE***.3	3	1	3	2	2	2
21PE***.4	3	2	3	3	3	2

21PE636 FACTS AND HVDC 3-0-0-3

Review of AC Transmission: Power flow - Loading capability - Principle of Compensators- FACTS concept and types of FACTS controllers, IEEE definitions.

Shunt compensators: Objectives - Midpoint Voltage Regulation for Line Segmentation, End of Line Voltage Support to Prevent Voltage Instability, Improvement of Transient Stability - Variable Impedance Devices (TSR, TCR, TSC, FC-TCR, TSC-TCR), Switched converter (STATCOM) and Hybrid shunt compensators. Comparison.

Series compensators: Objectives - Voltage Stability, Improvement of Transient Stability - Variable Impedance Devices (GCSC, TSSC, TCSC), Static Synchronous Series Compensators (SSSC). Control schemes for different applications.

Objectives, modes of operation of Voltage Regulator and Phase Angle Regulators. Multifunctional FACTS Controllers: Unified Power Flow Controller (UPFC) Interline Power Flow Controller (IPFC)– Case studies.

High Voltage DC Transmission: Comparison with AC System, HVDC configurations, Reactive power support, operation of 6-pulse, 12 Pulse Converters in rectifier and inverter modes. Effect of source inductance, equivalent circuit representation. Control of HVDC system. Application and Modern Trends in HVDC system.

TEXT BOOKS/ REFERENCES:

1. Narnia G. Ingrain and Laszlo Gigi, "*Understanding FACTS – Concepts and Technology of Flexible AC Transmission Systems*", IEEE Power Engineering Society, 2011.
2. Rohan, Mathura and Rajiv. K. Varma, "*Thyristor Based FACTS Controller for Electrical Transmission System, IEEE Series on Power Engineering*", Wiley Interscience ,2011.
3. Padiyar K. R, "*FACTS Controllers in Power Transmission and Distribution*", New Age Publishers, 2016.
4. K R Padiyar, "*HVDC Power Transmission Systems – Technologies and System Interactions*", New Age International (P) Limited, 2007.
5. Chan – Ki – Kim, Vijay K Sood, Gil – Sood, Gil – Soo Jang, Seong –JooLim, Seok – Jim -Lee, "*HVDC Transmission Power Conversion Applications in Power Systems*", Wiley – IEEE Press, April 2009.

CO Code	Course outcome statement
21PE***.1	Understand the basic concepts, principles and operation of power system compensators
21PE***.2	Design suitable corrective measures for performance improvement of power lines
21PE***.3	Analyse effective control strategies for power line compensators
21PE***.4	Discuss the concepts, and operating principles of HVDC Transmission Systems

CO Code	PO1	PO2	PO3	PO4	PO5	PO6
21PE***.1			3			
21PE***.2	3	1	3		2	2
21PE***.3	3	1	3	3	2	2
21PE***.4			3			

21PE637 SPECIAL POWER CONVERTERS 3-0-0-3

Review of Power Electronic Devices.
Zeta converters, Dual and Multiple active bridge converters, Concept of wireless inductive and capacitive power transfer.
DC-DC resonant link inverters, Hybrid resonant link inverters, Quasi resonant link converters, Z-source inverters, PV inverter topologies, Switched mode rectifiers, Synchronous link converters, Matrix Converters.

TEXT BOOKS/ REFERENCES:

1. Ned Mohan, Tore M. Undeland and William P. Robbins, "*Power Electronics, Converters, Applications and Design*", Third Edition, John Wiley and Sons Inc., 2007.
2. Muhammad H. Rashid, "*Power Electronics, Circuits, Devices and Applications*", Fourth Edition, Pearson, 2017.
3. Erickson, Robert W., and Dragan Maksimovic, "*Fundamentals of power electronics*", Springer Science & Business Media, 2nd Edition, 2007.
4. Liu, Yushan, Haitham Abu-Rub, Baoming Ge, and Omar Ellabban, "*Impedance source power electronic converters",* John Wiley & Sons, 2016.

CO Code	Course outcome statement
21PE***.1	Review the characteristics of various Power Electronic Devices
21PE***.2	Understand the working principle of special converters
21PE***.3	Analyze and design of all the special converters
21PE***.4	Implement the special converters and switched mode rectifiers

CO Code	PO1	PO2	PO3	PO4	PO5	PO6
21PE***.1	2		3			
21PE***.2	2	1	3	2		2
21PE***.3	2	1	3	3	1	2
21PE***.4	2	1	3	3	1	2

21 PE638 ADVANCED SIGNAL PROCESSING 2-0-2-3

Review of Signal Processing, Signal conditioning and Pre-processing aspects, Compressive Sensing, Sparsity, Advanced Estimation Theory, Particle Theory, Hidden Markov Models, Principal Component Analysis, Independent Component Analysis, Hilbert Huang Transform, Empirical Wavelet Transforms, Variable Mode Decomposition, Empirical Mode Decomposition, Dynamic Mode Decomposition, Case studies on fault analysis of electrical machines.

TEXT BOOKS/ REFERENCES:

1. James. V. Stone, "*Independent Component Analysis: A Tutorial Introduction*", MIT Press- 2004
2. George M. Siouris, "*An Engineering Approach to Optimal Control and Estimation Theory*" ,Wiley-Interscience, 3rd Edition,2007
3. Lawrence Rabiner, "*A Tutorial on Hidden Markov Models and Selected Applications on Speech Recognition*", Proceedings of IEEE 1989.
4. M. Firdaus Isham, M. Salman Leong , M. Hee Lim , Z. Asrar Ahmad ,"*Variational mode decomposition: mode determination method for rotating machinery diagnosis*", Journal of Vibroengineering, Vol. 20, Issue 7, 2018, p. 2604-2621.
5. J. Nathan Kutz ,L. Brunton, Bingni W. Brunton , L. Proctor Institute, "*Dynamic Mode Decomposition Data Driven Modelling of Complex Systems*," SIAM, Philadelphia

CO Code	Course Outcome Statement
21PE***.1	Understand compressive sensing, sparsity and estimation theory
21PE***.2	Discuss PCA and ICA as applied to electrical systems
21PE***.3	Review the concepts of Hidden Markov Models
21PE***.4	Illustrate Hilbert Huang Transform
21PE***.5	Comprehend mode decomposition techniques applied in electrical domain

CO Code	PO1	PO2	PO3	PO4	PO5	PO6
21PE***.1	1	1	1	1	1	1
21PE***.2	2	2	2	2		2
21PE***.3	2	2	2	1	1	1
21PE***.4	2	2	3	1	1	1
21PE***.5	2	2	1	2	1	3

21PE639 FPGA BASED POWER CONVERTER CONTROL 2-0-2-3

Role of FPGA in Power Electronic Systems, Development and evolution of digital devices, design and verification tools, Abstraction levels of digital system design, Design methodology and technology overview, High Level System Architecture and Specification: Behavioural modelling and simulation. Hardware description languages, combinational and sequential design, state machine design, synthesis issues, test benches.

Synthesis and Fitting CPLDs, FPGAs- Resource Sharing, Implementation technology – PLD's, Custom Chips, Standard Cell and Gate arrays – FPGA Architectures – SRAM based FPGAs – Permanently programmed FPGAs – Circuit design of FPGA fabrics, FPGA logic cells, I/O block architecture: Input and Output cell characteristics, clock input, Timing.

FPGA applications to power electronic systems, Gating Pulse generation for AC-AC converter, AC-DC converter, PWM generation for Buck Converter, SPWM generation.

TEXT BOOKS/ REFERENCES:

1. Stephen Brown and Zvonko Vranesic, "*Fundamental of Digital Logic with VHDL Design*", Third Edition, McGraw Hill, 2009.
2. Samir Palnitkar, "*Verilog HDL, A Guide to Digital Design and Synthesis*", Second Edition, Pearson Education, 2003.
3. T. R. Padmanabhan and B. Bala Tripura Sundari, "*Design Through Verilog HDL*", Wiley Interscience, 2008
4. Wayne Wolf, "*FPGA-Based System Design*", Prentice Hall India Pvt. Ltd., 2005.
5. M.J.S. Smith, "*Application Specific Integrated Circuits*", Pearson, 2002

CO Code	Course Outcome Statement
21PE***.1	Understand basics of hardware description languages
21PE***.2	Discuss FPGA architecture and building blocks of digital design
21PE***.3	Analyze FPGA design based on synthesis, implementation and

	timing reports
21PE***.4	Design, simulate, synthesize and implement power electronic systems using FPGA

CO Code	PO1	PO2	PO3	PO4	PO5	PO6
21PE***.1	1		1			
21PE***.2	1		1			
21PE***.3	2		2	1	1	
21PE***.4	2	2	2	2	2	1

21PE640 MICROGRIDS AND ITS CONTROL 3 – 0 – 0 - 3

Concepts of Microgrids - Microgrids vs Central Conventional power system – Microgrid Architecture– Energy Storage Technologies - AC and DC Microgrids – Topologies – Comparison.

Power Electronic Converters in Microgrid application - Power Control and Energy Management Micro-grid Control Strategies: Centralized, Decentralized and Hierarchical control ; Control of DC - DC converters and DG inverters, phase locked loops, current control and DC voltage control for stand alone and grid parallel operations, acceptable ranges of voltage and frequency, reactive power compensation and active filtering.

Operation of Microgrid and Modes of Operation, Microgrid Standards and Deployment, Microgrids in smart grid scenario.

TEXT BOOKS/REFERENCES:

1. Nikos Hatziargyriou, “*Microgrids: Architectures and Control*”, Wiley-IEEE Press, 2014
2. Magdi S Mahmoud, “*Microgrid: Advanced Control Methods and Renewable Energy System Integration*”, Butterworth-Heinemann, 2016
3. S. M. Sharkh, M. A. Abu-Sara, G. I. Orfanoudakis and B. Hussain, “*Power Electronic Converters for Microgrids*,” Wiley – IEEE Press,2014
4. S. Chowdhury, S.P. Chowdhury and P. Crossley, “*Microgrids and Active Distribution Networks*”, The Institution of Engineering and Technology, London, U.K, 2009.
5. K.R. Padiyar, Anil M Kulkarni, “*Dynamics and Control of Electric Transmission and Microgrids*”, Wiley – IEEE Press, 2019.

CO Code	Course Outcome Statement
21PE***.1	Analyse different Microgrid Architectures, its features

21PE***.2	Understand the power electronics interfaces for various Microgrid sources
21PE***.3	Apply various operational strategies and control schemes suitable for Microgrid
21PE***.4	Discuss different standards applicable for Microgrids

CO Code	PO1	PO2	PO3	PO4	PO5	PO6
21PE***.1	2	2	2			
21PE***.2	2	2	2			
21PE***.3	2	2	3	2	1	2
21PE***.4	2	2	3			

21PE641 SMART GRID 2-0-2-3

Basic understanding of power systems. Evolution of power electronics in power system applications. Smart grid definition. Smart grid vs. conventional grid. Smart Grid technologies in Generation, Transmission and Distribution. Present development & International policies in Smart Grid. Smart Grid – Overview and stakeholders.
Smart Grid features - Distributed generation, storage, Demand Dispatch (DD), Demand Response (DR), Advanced Metering Infrastructure (AMI), Wide Area Monitoring Protection and Control(WAMPAC), Wide Area Control System (WACS).
Sensors - CT, PT; Devices – Intelligent Electronic Devices (IED), Phasor Measurement Unit (PMU), Phasor Data Concentrator (PDC), relays, DR Switch; Communication - Standards, Technology and protocols.
Control Capabilities of Power Electronic converters for Smart Grid - Grid tied operation, Islanded operation and Grid forming mode. Impact of the uncertainties of Renewable energy on the smart grid stability and need for reliable/effective smart grid communication. Impact of Plugged in EV/HEV on Smart grid demand profile.
Case study 1 generation control, load management, dynamic pricing etc.; IoT applications. Case Study 2- Smart microgrid simulator (SMGS), DR, DD, Energy storage, Smart Appliances.

TEXT BOOKS/ REFERENCES:

1. James Momoh, “*Smart Grid: Fundamentals of Design and Analysis*”, Wiley-IEEE Press, March 2012.
2. Janaka Ekanayake, Nick Jenkins, Kithsiri Liyanage, Jianzhong Wu and Akihiko Yokoyama, “*Smart Grid: Technology and Applications*”, Wiley, February 2012.
3. Ali Keyhani and Muhammad Marwali, “*Smart Power Grids 2011*”, Springer, 2011.
4. Mini S. Thomas, John Douglas McDonald,"*Power System SCADA and Smart Grids*", CRC Press, April 2015.
5. Qing Chang Zhong, Tomas Hornik- “*Control of Power Inverters in Renewable Energy and Smart Grid Integration*” -Wiley-IEEE Press, 2013.

CO Code	Course Outcome Statement
21PE***.1	Understand power system operations, issues with existing system and capabilities of Smart Grid (SG)
21PE***.2	Analyse the scope of distributed generation and Demand side management in SG
21PE***.3	Apply phasor, frequency estimation algorithms
21PE***.4	Comprehend communication technologies for SG
21PE***.5	Develop smart strategies for power system automation

CO Code	PO1	PO2	PO3	PO4	PO5	PO6
21PE***.1		1				1
21PE***2	2		1	1	2	1
21PE***.3	3	1	1	1	1	1
21PE***.4	2		2		2	
21PE***.5	3	1	2	3	3	2

21PE642 RENEWABLE ENERGY TECHNOLOGIES 3-0-0-3

Renewable energy sources: Renewable energy utilization in ancient times; classification of RE Technologies, Recent developments in renewable energy sector – global and national energy policies.
Solar energy – Solar radiation and measurements; PV Cell – principle, types and construction; Modelling of PV cell; Maximum power tracking; SPV systems – stand-alone and grid-connected.
Wind energy – Global and local winds, resource assessment, wind regime modelling – Weibull parameters; WEG technologies for grid connection, small wind turbine.
Energy Storage systems – need for energy storage with RE, types - Pumped hydro storage, battery, fly wheel storge, super capacitor and compressed air. Comparison of energy storage technologies.

Other renewable energy technologies: Introduction to Biomass – gasifiers; Small hydro, Wave, Tidal, Ocean thermal and Geothermal energy systems

TEXT BOOKS / REFERENCES:

1. Chetan Singh Solanki, "*Solar Photovoltaics: Fundamentals, Technologies and Applications* ", PHI Learning; 3rd edition, 2015.
2. John W Twidell and A D Weir, "*Renewable Energy Resources*", Routledge Publications, 2015.
3. N K Bansal, M Kleemann and M Mellis, "*Renewable Energy Resources and Conversion Technology*", Tata McGraw Hill, 1990.
4. S N Bhadra, D Kastha and S Banerji, "*Wind Electrical Systems*", Oxford University Press,2005.
5. Ter-Gazarian, "*Energy Storage for Power Systems*", 3rd Edition, IET Energy Series 6, London, 2020

CO Code	Course Outcome Statement
21PE***.1	Understand the need and means for renewable energy utilisation
21PE***.2	Illustrate the schemes to produce electricity from renewable resources
21PE***.3	Assess renewable energy potential availability
21PE***.4	Analyse the characteristics and control of various energy storage systems and RE energy conversion systems
21PE***.5	Design of system for various renewable energy extraction schemes

CO Code	PO1	PO2	PO3	PO4	PO5	PO6
21PE***.1	2	2	3			
21PE***.2	2	2	3	2		2
21PE***.3	2	2	3	3	2	2
21PE***.4	2	2	3	3	1	2
21PE***.5	2	2	3	1	1	2

21PE643 PROGRAMMABLE LOGIC CONTROLLERS 3-0-0-3

Introduction to PLC-Ladder diagram-relay logic-digital and analogy PLC interface -Input and Output modules-PLC processors-processor data organization-basic relay instruction-timer and counter instruction-sequencer instruction-programme flow instruction-case studies-motor control.

TEXT BOOKS / REFERENCES:

1. Dunning Carry, "*Introduction to Programmable Controllers*", Third Edition, Thomson Delmar Learning, 2006.
2. John R. Hackworth and Frederick D, "*Programmable Logic Controllers: Programming Methods and Applications*", Pearson Education Inc., 2004.
3. Bolton W, "*Programmable Logic Controllers*", Sixth Edition, Elsevier, 2015.
4. John W Webb and Ronald A Reis, "*Programmable Logic Controllers: Principles and Applications*", Fifth Edition, PHI learning Pvt. Ltd., 2009.
5. Frank D.P., "*Programmable Logic Controllers*", Fourth Edition, Tata Mc Graw Hill Publishing Company Limited, 2010

CO Code	Course Outcome Statement
21PE***.1	Understand the fundamentals of PLC and Ladder diagram
21PE***.2	Illustrate the working of Digital and Analog Input/Output interface
21PE***.3	Apply PLC processor Data Organization and execute programming instructions using timers and counters
21PE***.4	Apply PLC on real time problem

CO Code	PO1	PO2	PO3	PO4	PO5	PO6
21PE***.1	2	2	2	2		
21PE***.2	1	2	3	2		1
21PE***.3	1	2	3	3		2
21PE***.4	3	3	3	3	1	2

21PE644 DIGITAL CONTROL SYSTEMS 3-0-0-3

Digital control system: sampling, quantization, data reconstruction and filtering of sampled signals. Review of z-transforms. Inverse z-transform. z-transform for solving difference equations. Pulse transfer function. z-transform analysis of closed loop and open loop systems. Realization of Digital filters. Mapping between s-plane and z-plane.
Stability analysis of closed loop systems in the z-plane. Stability tests. Discrete equivalents. Digital controller design for SISO systems: design based on root locus method in the z-plane, design based on frequency response method, design of lag compensator, lead compensator, lag lead compensator, design of PID Controller based on frequency response method, Analytical direct design.
State-space representations of Discrete-time systems, solving discrete-time space equations, Pulse transfer function matrix, discretization of continuous-time state-space equations. Controllability, Observability, control law design via pole placement. decoupling by state variable feedback, effect of sampling period. Estimator/ Observer Design: full order observers, reduced order observers, regulator design.

TEXTBOOK/REFERENCE:

1. K. Ogata, "*Discrete-Time Control Systems*", Pearson Education, 2011.
2. Gene F. Franklin, J. David Powell and Michael Workman, "*Digital Control of Dynamic Systems*", Pearson, 2000.
3. Benjamin C Kuo, Farid Golnaraghi, "*Automatic Control Systems*", Eighth Edition, Wiley, 2014.

CO Code	**Course outcome statement**
21PE***.1	Review of z-transform, sampling and reconstruction of signals
21PE***.2	Analyse stability of linear system in z-domain
21PE***.3	Design compensators in time and frequency domains and transform to z-domain
21PE***.4	Design digital controllers and observers in z domain

CO Code	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
21PE***.1	2	2	3			
21PE***.2	2	2	3	2		
21PE***.3	2	2	3	2		
21PE***.4	2	2	3	2		2

21PE645 ADAPTIVE CONTROL SYSTEMS 3-0-0-3

Introduction to adaptive control**,** Classifications, Role of Index performance (IP) in adaptive systems.Model Reference adaptive systems: Different configurations, Classification, Mathematical Description, Equivalent representation as a time varying system, Direct and indirect MRAC, Continuous time MRAC, MIT Rule, Lyapunov approach, Stability and convergence studies.Self Tuning Regulators (STR), Different approaches to self tuning, Recursive parameter estimation, Pole placement design; linear quadratic self - Tuning regulators; Convergence analysis, multivariable self tuning regulators, pole assignment approach. Introduction to Predictive Control; Minimum variance Control; State Estimation. Application of Adaptive controllers.

TEXTBOOK/REFERENCE:

1. K. J. Astrom and B. Witten mark, "*Adaptive Control*", Second Edition, Dover Publications, 2008.
2. P. A. Ioannou and J. Sun, "*Robust Adaptive Controls*", Dover Publications, 2012
3. S. Sastry and M. Bodson, "*Adaptive Control",* Dover Publications, 2011 (available at http://www.ece.utah.edu/%7Ebodson/acscr/index.html)
4. M. Krstic, I. Kanellakopoulos, and P. Kokotovic, "*Nonlinear and Adaptive Control Design*", Wiley-Inderscience, 1995.
5. V.V. Chalam, "*Adaptive Control Systems, Techniques and Applications*", Taylor and Francis Group, 1987.

CO Code	**Course outcome statement**
21PE***.1	Understand the basics of adaptive control system
21PE***.2	Discuss the various adaptive control techniques
21PE***.3	Analyse convergence of multivariable adaptive controllers
21PE***.4	Illustrate the adaptive controllers and parameter estimation

CO Code	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
21PE***.1	2	1	2			
21PE***.2	2	1	3	1		1
21PE***.3	2	1	3	2		2
21PE***.4	2	1	3	3		2

21PE646 POWER SYSTEM OPERATION, CONTROL AND STABILITY 3-0-0-3

Power system operation- State transition and control, SCADA in power systems - data acquisition, state estimation, security assessment and security enhancement - functions of control centers - System load Variation - System load characteristics. Operation of vertical and deregulated power system.

Economic load dispatch without losses - base point and participation factor. Real and Reactive Power flows and control. Load curve - weekly and annual duration curve, load factor, diversity factor. System State and Transition, Control center functions.

Overview of system control: Governor control, LFC, AVR. Real power- frequency control: Need for voltage and frequency regulation in power system, basic P-f and Q-V control loops. Fundamentals of speed governing systems and modelling. LFC of Single area and two area systems - Modelling of single and two area systems.
Reactive power – Voltage control: Typical excitation system, Shunt and series compensation.

Power system stability- classifications- Rotor angle stability- small signal stability – Effects of excitation system – Power system stabilizer – sub synchronous oscillations – voltage stability – voltage collapse – Methods to improve stability.

TEXTBOOK/REFERENCE:

1. Olle. I. Elgerd, "*Electric Energy Systems Theory- An Introduction*", Tata McGraw Hill Publishing company Ltd., New Delhi, 2004.
2. William D Stevenson, "*Elements of Power System Analysis*", 4^{th} Edition, McGraw Hill, 2017.
3. Allen.J. Wood and Bruce. F.Wollenberg, "*Power Generation Operation and Control*", 3rd Edition, John Wiley and Sons, 2013.
4. L.K. Kirchmayer, "*Economic Operation of Power System*", John Wiley and Sons, 2009.
5. P. Kundur, "*Power System Stability and Control*", McGraw Hill, 2008.

CO Code	**Course outcome statement**
21PE***.1	Understand the principles of power system operation, control and stability
21PE***.2	Develop mathematical model and analyse power system control loops
21PE***.3	Enhance the power system stability and economics
21PE***.4	Design compensators and controllers for power system

CO Code	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
21PE***.1	2		2			
21PE***.2	2	1	2	2		
21PE***.3	2	1	2	2		
21PE***.4	2	1	3	2		

21PE647 ELECTROMAGNETIC INTERFERENCE AND COMPATIBILITY 3-0-0-3

Different types of EMI, Measurement techniques, Applicable standards

Problems of EMI and Sources – ESD – High Frequency behavior of Electrical Components-EMI in Power Electronic Equipments – EMI induced failure mechanism in PE Equipment

Susceptibility aspects of Power Electronic and Digital Equipments – Noise Suppression in Circuits – Reduction Techniques for Internal EMI – EMI reduction techniques – Grounding, Shielding and Bonding, use of cables connectors components, EMI filter selection, Filter design, Testing for susceptibility to power line disturbances, transient susceptibility and analysis methods, EMC standards and test equipments.

TEXTBOOKS/REFERENCES:

1. Laszio Tihanyi, "*EMC in Power Electronics*", IEEE Press, 1995.
2. V. Prasad, "*Engineering Electromagnetic Compatibility*", 2nd Edition, IEEE Press, 2001.

3. Henry W. Ott, "*Noise Reduction Techniques in Electronic Systems*", Second Edition, John
4. Wiley and Sons Ltd., 2008.
5. Rajiv Thottappillil, *Lecture Notes on EMC*, KTH, Stockholm.

CO Code	Course outcome statement
21PE***.1	Understand the basics of Electromagnetic Interference and its sources
21PE***.2	Discuss the non-ideal behavior of electrical components
21PE***.3	Illustrate the conducted and radiated emissions and susceptibility
21PE***.4	Analyse EMI reduction techniques
21PE***.5	Apply EMI standards and techniques

CO Code	PO1	PO2	PO3	PO4	PO5	PO6
21PE***.1	2	2	2			
21PE***.2	2	2	3			
21PE***.3	2	2	2			
21PE***.4	2	2	2		1	2

21MA604 OPTIMIZATION THEORY 2-0-2-3

Pre-requisite: Basic Calculus-derivatives, partial derivatives and matrices.

Linear programming models: Simplex search — sensitivity analysis – artificial starting solutions - duality and sensitivity in linear programming. Single variable optimization: Analytical method: Optimality criteria. Single variable non-linear problems using derivatives.
Computational Methods: Non-linear one-dimensional methods – single variable optimization algorithms – optimization criteria – bracketing methods – region elimination methods – point estimation method – gradient based methods.
Multivariable optimization:
Analytical method: Positive and negative definite, Hessian matrix, Optimality criteria.
Multivariable non-linear problems using partial derivatives. Computational Methods: Non-linear unconstrained methods - multivariate optimization algorithms – optimality criteria – unidirectional search – direct search methods – gradient based methods. Constrained optimization: Non–linear constrained methods – Kuhn-tucker conditions – transformation methods – direct search for constrained minimization – feasible direction method.

TEXT BOOKS/ REFERENCES

1. Kalyanmoy Deb, "*Optimization for Engineering Design: Algorithms and Examples*", 2nd Edition, Prentice Hall, 2013.
2. Ronald L. Rardin, "*Optimization in Operations Research*", 2nd Edition, Pearson Education, 2018

3. Singiresu S. Rao, “*Engineering Optimization: Theory and Practice*”, Third Edition, New Age Publishers, 2009.
4. Hamady A. Taha, “*Operations Research*”, 9th Edition, Tata McGraw Hill, 2010.
5. E. Clapton, “*Advanced Optimization Techniques and Examples with MATLAB*” Create Space Independent Publishing Platform,2016

CO Code	Course outcome statement
21PE***.1	Understand different types of Optimization Techniques in engineering problems such as Bracketing, Region elimination, and Point estimation methods.
21PE***.2	Analyse gradient based Optimizations Techniques in single variables as well as multivariables (non-linear)
21PE***.3	Discuss the Optimality criteria for functions in several variables and apply OT methods like Undirectional search and Direct search methods.
21PE***.4	Analyse constrained optimization techniques and verify Kuhn-Tucker conditions and Lagrangian Method.

CO Code	PO1	PO2	PO3	PO4	PO5	PO6
21PE***.1	2	2	2	2		
21PE***.2	2	2	3	2		
21PE***.3	2	2	2	1	1	1
21PE***.4	2	2	2	2	1	2

21PE648 POWER SYSTEM MODELLING 3-0-0-3

Modelling of power system components: Need for power system modelling- different methods and choice for Modelling techniques- Simplified models of non-electrical components like boiler, steam, hydro-turbine, diesel engine and governor system. Rotating Machine modelling - Transformer modelling - Modelling of Transmission line and Loads.
Modelling of IEEE Excitation system- DC and AC excitation system and its general modelling concepts. Models for steady-state and dynamic studies. Simulation and analysis of Synchronous machine connected to an infinite bus.
State space averaging modelling of single phase AC-DC, DC-AC and DC-DC converters. Modelling of standalone solar and wind power system. Modelling of series and shunt FACTS devices connected to an SMIB system.

TEXT BOOKS/ REFERENCES:

1. K.R. Padiyar, “*Power Systems Dynamics*”, B.S. Publications, 2008.
2. Anderson and Fouad, “*Power System Control and Stability– Vol.I*”, IEEE Press, New York, 1994.
3. P.S. Bimbhra,"*Generalised Theory of Electrical Machines*", Khanna Publishers,2017
4. Krishna, S,” *An Introduction to Modelling of Power System Components*”, Springer,2014.

5. Mukund R. Patel, Omid Beik, “*Wind and Solar Power Systems Design, Analysis, and Operation*”, 3rd Edition, CRC Press, 2021

CO Code	Course outcome statement
21PE***.1	Understand the Models of nonelectrical components generally used in power system
21PE***.2	Develop transformer, transmission lines and load modelling
21PE***.3	Develop models of Power Electronic devices and FACTS devices
21PE***.4	Develop models for Synchronous generators connected to SMIB system

CO Code	PO1	PO2	PO3	PO4	PO5	PO6
21PE***.1	3		3			
21PE***.2	3		3	2		
21PE***.3	3		3	2	2	
21PE***.4	3	1	3	1		

21PE649 DESIGN FOR RELIABILITY 3-0-0-3

Review of Probability theory – Introduction to the concepts of Reliability – Nature of Reliability problems in Electronic equipment – Degradation and Remaining Life Assessment of selected Electronic components – Equipment Maintenance – Reliability modelling – Availability and maintainability concepts – Designing for Reliability – Fault Analysis techniques – Reliability predictions –Worst case design and component de-rating – software Reliability.

TEXT BOOKS / REFERENCES:

1. Fuqua, “*Reliability Engineering for Electronic Design*”, Marcel Dekker, 1988.
2. Bajenescu, Titu-Marius I., Bazu, Marius I., “*Reliability of Electronic Components, A Practical Guide to Electronic Systems Manufacturing*”, Springer-Verlag Berlin Heidelberg, 1999.
3. Patrick DTO’Connor, “*Practical Reliability Engineering*”, 5th Edition, John Wiley and Sons, 2012.
4. L.Umanand, “*Power Electronics Essentials and Applications*”, Wiley India Pvt. Ltd., 2009.
5. Jonathan Swingler, “*Reliability Characterization of Electrical and Electronic Systems*”, Woodhead Publishing, 2015.

CO Code	Course outcome statement
21PE***.1	Understand the basic concepts of reliability
21PE***.2	Analyze the statistical techniques leading to reliability modelling
21PE***.3	Identify reliability indices and testing components
21PE***.4	Apply reliability theory in engineering design

CO Code	PO1	PO2	PO3	PO4	PO5	PO6
21PE***.1	2		2			

21PE***.2	2		2	1	1	1
21PE***.3	2		2		1	1
21PE***.4	2		2	2	1	2

21PE650 DISTRIBUTED GENERATION 3-0-0-3

Comparison of legacy grid and microgrid. Distributed Generation –historical background, current status, policy and regulations, challenges – issues related to bidirectional power flow.
Renewable energy systems – solar PV, wind, small hydro and biomass based electric power generation – system design. Hybrid systems - wind-solar, wind - PV-hydro. Standalone systems with energy storage -sizing of battery storage.
Power converters for PV systems – Grid tied and grid forming modes, active power control in grid connected PV system.
Power converters for wind turbine generators – Power converter topologies for PMSG, DFIG and VSIG, Dual converters with DC-link capacitance, grid synchronization and phase locking, control of rotor side and grid side converters, design of filter, maximum power tracking and active power control. Islanded condition.
Dynamic control of power - Bidirectional converter and control for battery storage system, Variable speed operation of pumped hydro storage; use of real time data for distributed generation control.

TEXT BOOKS/ REFERENCES:

1. Loi Lei Lai, Tze Fun Chan, "*Distributed Generation-Induction and Permanent Magnet Generators*", IEEE Press, 2007.
2. Haitham Abu-Rub, Mariusz Malinowski, Kamal Al-Haddad, "*Power Electronics for Renewable Energy Systems, Transportation and Industrial Applications*", Wiley Publishers, June 2014.
3. Massey, G. W., *Essentials of distributed generation systems*. Jones and Bartlett Learning, 2010.
4. Bollen, M. H., and Hassan, F., *Integration of distributed generation in the power system* (Vol. 80). John Wiley and Sons, 2011.

CO Code	**Course outcome statement**
21PE***.1	Understand the background of promotion of DG and compare DG with centralised generation
21PE***.2	Illustrate wind, PV and hybrid systems
21PE***.3	Design power electronic interfaces in DG systems
21PE***.4	Develop micro grid system with energy storage
21PE***.5	Discuss policies and regulations

CO Code	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**

21PE***.1	2	2	3			
21PE***.2	2	2	3	1	1	2
21PE***.3	2	2	3	2	1	2
21PE***.4	2	2	3	2	1	1
21PE***.5	2	2	3			

21PE651 POWER SYSTEM DYNAMICS AND CONTROL 3 0 0 3

Basic Concepts of dynamical systems and stability. Modelling of power system components for stability studies: generators, transmission lines, excitation and prime mover controllers, flexible AC transmission (FACTS) controllers. Analysis of single machine and multi-machine systems. Small signal angle instability (low frequency oscillations): damping and synchronizing torque analysis, eigenvalue analysis. Mitigation using power system stabilizers and supplementary modulation control of FACTS devices. Small signal angle instability (subsynchronous frequency oscillations): analysis and counter-measures. Transient Instability: Analysis using digital simulation and energy function method. Transient stability controllers. Introduction to voltage Instability. Analysis of voltage Instability.

TEXT BOOKS/REFERENCES

1. P. Kundur, "*Power System Stability and Control*", McGraw Hill Inc, New York, 1995.
2. P. Sauer & M. A. Pai, "*Power System Dynamics & Stability*", Prentice Hall, 1997.
3. K.R. Padiyar, "*Power System Dynamics, Stability & Control*", Interline Publishers, Bangalore, 1996.
4. P. M. Andersson and A. A. Fouad, "*Power System Control and Stability*", 2nd Edition, Wiley Interscience 2003.

CO Code	Course outcome statement
21PE***.1	Understand Power System Stability problems and analyse by classical methods
21PE***.2	Model the power system components like Synchronous Machine, Exciter, Turbine and Load
21PE***.3	Discuss concepts of Small Signal Stability, state space representation and nodal analysis
21PE***.4	Analyse Transient Stability through numerical solutions
21PE***.5	Enhance voltage stability of Power Systems

CO Code	PO1	PO2	PO3	PO4	PO5	PO6
21PE***.1	2		2			
21PE***.2	2		2		1	
21PE***.3	2	1	2	1	1	1
21PE***.4	2	1	2	1	1	1
21PE***.5	2	1	2		1	

21PE652 ENERGY CONSERVATION AND MANAGEMENT 3 0 0 3

Historical development of commercial energy supply: Commercial energy in ancient times, Renewable Energy utilization in ancient times, Industrial revolution, Growth of fossil fuel systems, Emergence of nuclear power, Realization of environmental concerns, Developments in Renewable Energy Sector; Concept of Energy Efficiency and Clean Production.

Energy conservation on demand side: Efficient Lighting; Energy Efficiency in motors, pumps and fans, refrigeration and air conditioning systems. Power quality issues related to Energy Efficient Technologies. Co generation-concept, advantages

Energy Economics: Time value of money - Present Worth and Future Worth Economic performance indices: Payback - Simple and Discounted, Net Present Value, Internal Rate of Return, Benefit to Cost Ratio, E/D ratio, Life cycle/levelised cost, Energy and cost savings from energy conservation measures.

Energy Management in Electrical Power Systems: Supply-demand gap on electric power grid: causes and remedial measures. Energy trading; Demand Response; Microgrids and Smart grid.

Energy Management and Audit: Functions and methodologies of preliminary as well as detailed energy audits; Pre-audit, audit and post-audit measures Instruments for energy audit, Energy Conservation Practice – Case Studies. Energy Audit report writing.

TEXT BOOKS / REFERENCES:

1. Hamies, "*Energy Auditing and Conservation; Methods, Measurements, Management and Case Study*", Hemisphere Publishers, Washington, 1980.
2. C.W. Gellings and J.H. Chamberlin, "*Demand-Side Management Planning*", Fairmont Press, 1993.
3. Wayne C Turner, "*Energy Management Handbook*", The Fairmount Press, 2006.
4. Bureau of Energy Efficiency Study material for Energy Managers and Auditors Examination: Paper I to IV, www.energymanagertraining.com
5. S. Pabla, "*Electric Power Systems Planning*", Macmillan India Ltd., 1998

CO Code	Course Outcome statement
21PE***.1	Understand and analyse energy scenario & policies of India & World in the past, present & future
21PE***.2	Discuss the energy efficiency performance indicators of various technologies and methodologies to evaluate the indices.

21PE***.3	Evaluate the Techno economic feasibility of various efficiency improvement opportunities for an existing system
21PE***.4	Examine the methodology of energy auditing through case studies

CO Code	PO1	PO2	PO3	PO4	PO5	PO6
21PE***.1	2	2	3			
21PE***.2	2	2	3		1	1
21PE***.3	2	2	3		1	1
21PE***.4	2	2	3		1	1

21PE798 DISSERTATION I 10
21PE799 DISSERTATION II 16

Each student should select and work on a topic related to his/her field of specialization during summer of second semester under the supervision of a faculty member.

During third and fourth semester each student should work on the selected topic under the supervision of a faculty member. By the end of each (third and fourth) semester the student has to prepare a report in the approved format and present it.

CO Code	Course outcome statement
21PE*.1**	Understand research methodology
21PE*.2**	Plan and execute Projects
21PE*.3**	Survey and review literature
21PE*.4**	Choose computational and analytical tools and design experiments
21PE*.5**	Communicate technical content orally as well as in writing with added skill

CO Code	PO1	PO2	PO3	PO4	PO5	PO6
21PE*.1**	3	1	2		2	
21PE*.2**	3	1	3			3
21PE*.3**	3	2	2		2	2
21PE*.4**	3	2	3	3	3	2
21PE*.5**	2	2	3	1		3

21PE* DISSERTATION**

CO Code	Course outcome statement
21PE*.1**	Plan and manage projects with skill
21PE*.2**	Analyse results and acquire domain knowledge
21PE*.3**	Use computational and analytical tools with skill
21PE*.4**	Demonstrate skill in technical communication
21PE*.5**	Comprehend and disseminate knowledge

CO Code	PO1	PO2	PO3	PO4	PO5	PO6
21PE*.1**	3	1	2	2		3
21PE*.2**	3		3	1		1
21PE*.3**	3	3	3	3	3	1
21PE*.4**	3	3				3
21PE*.1**	3	3	3	1		3