PROGRAM
M. Tech.
Power Electronics

DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING

CURRICULUM AND SYLLABUS
(From 2018 Admission Onwards)

Table of Contents

Program Specific Outcomes (PSOs)

PSO1 Ability to independently carry out research /investigation and development work to solve practical problems

PSO2 Ability to write and present a substantial technical report/document

PSO3 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

Programme Outcomes (POs)

- A student who has undergone M.Tech. programme in Power Electronics (PE) will
- Have an ability to evaluate and analyze problems related to Power Electronic Systems and incorporate the principles in the state of art systems for further improvement
- Be able to investigate critical PE problems and to arrive at possible solutions independently, by applying theoretical and practical considerations
- Be able to solve PE problems such as switching control, converter design, analysis and control of solid state drives and stability studies
- Be able to develop appropriate power converters for sustainable energy technologies
- Be able to identify optimal solutions for improvising power conversion and transfer capability,
- enhancing power quality and reliability through PE based solutions
- Be able to evolve new power electronic topologies and control schemes based on literature survey and propose solutions through appropriate research methodologies, techniques and tools, and also by designing and conducting experiments
- Be able to work on small, well-defined projects with particular goals to provide real time solutions pertaining to power electronics
- Be able to develop, choose, learn and apply appropriate techniques, various resources including sophisticated digital controllers and IT tools for modern power electronic system simulation, including prediction and modeling with existing constraints
- Be able to develop dedicated software for analyzing and evaluating specific power electronics and control problems
- Be able to participate in collaborative-multidisciplinary engineering / research tasks and work as a team member in such tasks related to PE domain, giving due consideration to ecological and economical intricacies, and lead the team in specific areas
- Be able to confidently interact with the industrial experts for providing consultancy
- Be a responsible professional with intellectual integrity, code of conduct and ethics of research, being aware of the research outcomes and serve towards the sustainable development of the society

Curriculum Structure

First Semester

Course Code	Type	Course	L T P	Cr
18MA609	FC	Linear Algebra and Numerical Methods	2 0 2	3
18PE601	F C	Power Converters I	3 0 2	4
18PE621	SC	Electrical Machine Analysis	3 1 0	4
18PE602	FC	Digital Signal Processing Techniques	3 0 2	4
18PE622	SC	Advanced Control Theory	3 1 0	4
18PE623	SC	Simulation Lab	0 0 2	1
18HU601	HU	Amrita Values Program*		P/F
18HU602	HU	Career Competency I*		P/F
Credits				20

* Non-Credit Course

Second Semester

Course Code	Type	Course	L T P	Cr
18PE603	FC	Power Converters II	3 0 2	4
18PE624	SC	Electric Drives and Control	3 0 2	4
18PE625	SC	Embedded Controllers	3 0 2	4
	E	Elective I		3
	E	Elective II		3
	E	Elective III/Live-in-Labs		3
18RM600	SC	Research Methodology	2 0 0	2
18HU603		Career Competency II	0 0 2	1
Credits				24

Third Semester

Course Code	Type	Course	L T P	Cr
18PE798	P	Dissertation		8
Credits				8

Fourth Semester

Course Code	Type	Course	L T P	Cr
18PE799	P	Dissertation		12
Credits				12

Total Credits: 6
6

List of Courses

Foundation Core

Course Code	Course	L T P	Cr
18MA609	Linear Algebra and Numerical Methods	2 0 2	3
18PE601	Power Converters I	3 0 2	4
18PE602	Digital Signal Processing Techniques	3 0 2	4
18PE603	Power Converters II	3 0 2	4

Subject Core

Course Code	Course	L T P	Cr
18PE621	Electrical Machine Analysis	4 0 0	4
18PE622	Advanced Control Theory	3 1 0	4
18PE623	Simulation Lab	0 0 2	1
18PE624	Electric Drives and Control	3 0 2	4
18PE625	Embedded Controllers	3 0 2	4
18RM600	Research Methodology	2 0 0	2

Open Electives

Course Code	Course	L T P	Cr
18PE701	Modulation Techniques for Power Electronic systems	3 0 0	3
18PE702	Special Topics in Power Electronics	3 0 0	3
18PE703	Advanced Power Electronic Drives	3 0 0	3
18PE704	Power Electronics for Electric Vehicle Applications	3 0 0	3
18PE705	Electrical Machine Analysis Using FEM	3 0 0	3
18PE706	Application of System Identification to Power Converters	3 0 0	3
18PE707	Modeling and Control of Power Converters	3 0 0	3
18PE708	Electric Vehicles and Architectures	3 0 0	3
18PE709	Programmable Logic Controllers	3 0 0	3
18PE710	Digital Control Systems	3 0 0	3
18ES624	FPGA Based System Design	2 0 2	3
18PE711	Adaptive Control Systems	3 0 0	3
18PE712	Soft Computing	2 0 2	3
18PE713	Electric Power Quality Improvement	3 0 0	3
18PE714	FACTS and HVDC	3 0 0	3
18PE715	Energy Conservation and Management	3 0 0	3
18PE716	Power System Operation and Control	2 0 2	3
18PE717	Electromagnetic Interference and Compatibility	3 0 0	3
18MA701	Optimization Theory	2 0 2	3
18PE718	Power System Modeling	3 0 0	3
18PE719	Design for Reliability	3 0 0	3
18PE720	Distributed Generation	3 0 0	3
18PE721	Smart Grid	3 0 0	3
18PE722	Renewable Energy Technologies	3 0 0	3

Project Work

Course Code	Course	L T P	Cr
18PE798	Dissertation		8
18PE799	Dissertation		12

Evaluation Pattern and Grading Scheme

50:50 (Internal: External) (All Theory Courses)

Assessment	Internal	External
Periodical 1 (P1)	15	
Periodical 2 (P2)	15	
*Continuous Assessment (CA)	20	
End Semester		50

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80:20 (Internal: External) (Lab courses and Lab based Courses having 1 Theory hour)

Assessment	Internal	External
*Continuous Assessment (CA)	80	
End Semester		20

70:30(Internal: External) (Lab based courses having 2 Theory hours/ Theory and Tutorial) Theory- 60 Marks; Lab- 40 Marks

Assessment	Internal	External
Periodical 1	10	
Periodical 2	10	
*Continuous Assessment (Theory) (CAT)	10	
Continuous Assessment (Lab) (CAL)	40	
End Semester		30

65:35 (Internal: External) (Lab based courses having 3 Theory hours/ Theory and Tutorial) Theory- 70 Marks; Lab- 30 Marks

Assessment	Internal	External
Periodical 1	10	
Periodical 2	10	
*Continuous Assessment (Theory) (CAT)	15	
Continuous Assessment (Lab) (CAL)	30	
End Semester		35

*CA – Can be Quizzes, Assignment, Projects, and Reports.
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Letter Grade	Grade Point	Grade Description
O	10.00	Outstanding
A+	9.50	Excellent
A	9.00	Very Good
B+	8.00	Good
B	7.00	Above Average
C	6.00	Average
P	5.00	Pass
F	0.00	Fail

Grades O to P indicate successful completion of the course

$$CGPA = \frac{\sum (C_i x Gr_i)}{\sum C_i}$$

Where

C_i = Credit for the i^{th} course in any semester

Gr_i = Grade point for the i^{th} course

Cr. = Credits for the Course

Gr. = Grade Obtained

Syllabi and Course Outcomes

18MA609 LINEAR ALGEBRA AND NUMERICAL METHODS 2-0-2-3

Vector Spaces: General vector spaces - Sub spaces - Linear independence - Basis – Dimension-Row space, Column space and Null Space – Rank and Nullity.

Inner Product Spaces: Inner products - Orthogonality - Orthogonal basis - Orthogonal complements - Projection on subspace - Gram Schmidt Process - QR- Decomposition – Best approximation - Least square – Least squares fitting to data - Change of basis.

Linear Transformations: Linear transformation – General linear transformation - Kernel and range of a linear transformation - Inverse Linear Transformation - Matrices of general linear transformation-Nilpotent transformations - Similarity - Diagonalisation and its applications - Jordan form and rational canonical form - Positive definite matrices - Matrix norm and condition number.

Numerical methods: Solution of systems of equations – iterative methods, method of determining Eigen values and Eigen vectors by Power method. Numerical solution of partial differential equations – Elliptic, parabolic and hyperbolic equations.

COURSE OUTCOMES

CO1 Understand the basic concepts of vector spaces, subspaces, linear independence, span, basis and dimension and analyze such properties on the given set.

CO2 Understand the concept of inner products and apply it to define the notion of length, distance, angle, orthogonality, orthogonal complement, orthogonal projection, orthonormalization and apply these ideas to obtain least square solution.

CO3 Understand the concept of linear transformations, the relation between matrices and linear transformations, kernel, range and apply it to change the basis, to get the QR decomposition, and to transform the given matrix to diagonal/Jordan canonical form.

CO4 Understand the concept of positive definiteness, matrix norm and condition number for a given square matrix.

CO5 Understand and apply numerical methods such as Power method for eigenvalues and numerical solutions of partial differential equations.

TEXT BOOKS / REFERENCES:

Howard Anton and Chris Rorres, “*Elementary Linear Algebra*”, Tenth Edition, John Wiley and Sons, 2010.

Gilbert Strang, “*Linear Algebra and Its Applications*”, Fourth Edition, Cengage, 2007.

Kenneth Hoffmann and Ray Kunze, “*Linear Algebra”*, Second Edition, Pearson, 2015.

Curtis F. Gerald and Patrick O. Wheatley, “*Applied Numerical Analysis*”, Fifth Edition, Pearson, 2003.

18PE601 POWER CONVERTERS I 3-0-2-4

Power semiconductor switches: ratings, characteristics, power loss and temperature rise calculations, and control (MOSFETS, IGBT, Thyristors, IPM, IGCT).Introduction to Wide Band Gap devices (SiC and

GaN) and their applications AC voltage controllers- Line commutated, uncontrolled and phase controlled converters: Performance factors, Line notching and distortion. Twelve pulse converters. Introduction to Cyclo-converters, Matrix Converters. Voltage source inverters: single phase and three phase inverters. Sinusoidal PWM and Space vector PWM. and Introduction to Finite set Model Predictive Control for power converters – Utility connected converters and their control. Multilevel inverters. UPS. Demonstration designs.

COURSE OUTCOMES

CO1	Understand and analyze the static and dynamic characteristics of fundamental power semiconductor devices, power modules and wide band gap devices

CO2 Understand and analyze techniques to design and assess the performance of power converters such as AC-DC Converters,AC-AC converters and AC-DC inverters
CO3 Assess power quality, power factor and harmonic issues of various power electronic converters
CO4 Analyze PWM techniques for various converters
CO5 Design, simulate, and test various power conversion circuits in the laboratory and their corresponding PWM techniques. (Lab component)

TEXT BOOKS/ REFERENCES:

Ned Mohan, Tore M. Undeland and William P.Robbins, "*Power Electronics, Converters, Applications and Design*", Third Edition, John Wiley and Sons Inc., 2006.
Muhammad H. Rashid, "*Power Electronics, Devices, Circuits and Applications*", Fourth Edition, Pearson, 2017.
John G. Kassakian, Martin F.Schlecht and George C.Verghese, "*Principles of Power Electronics*", Pearson, 2010.
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.
Barry W Williams, "*Principles and Elements of Power Electronics Devices, Drivers, Applications, and Passive Components*", Barry W Williams, 2006.

18PE621 ELECTRICAL MACHINE ANALYSIS 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 machine and salient pole synchronous machines in phase variable form.

Generalized theory of rotating electrical machine and Kron's primitive machine; modeling, 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, modeling, steady state and transient analysis of induction machines, Unbalanced operation and fault analysis in three phase induction motors. Steady state and transient analysis analysis of synchronous machines, standard and derived machine time constants, Analysis and dynamic modeling of two phase asymmetrical induction machine and single phase induction machine. , analysis of Permanent magnet machine and Switched reluctance machine.

COURSE OUTCOMES

CO1 Review of the basic principles of electro-mechanical energy conversion.

CO2 Formulate the mathematical model of DC and AC Machines for transient and steady state conditions.

CO3 Apply reference frame theory to AC machines.

CO4 Analyze the dynamic behavior of AC& DC machines.

CO5 Explain the analytical model of PMSM and SRM

TEXT BOOKS/ REFERENCES:

P.C.Krause, "*Analysis of Electric Machines and Drive Systems*", Wiley International, 2002.

T.A. LIPO, "Introduction to AC machine Design",Winsconsin Power Electronic Research Center", University of Winsconsin,2011.

A.E. Fitzgerald and Charles Kingsley, "*Electric Machinery*", McGraw Hill Book Company, 2017.

B. Adkins, "*Generalized Machine Theory*", McGraw Hill Book Company, 1964.

Bimbhra P S, "*Electrical Machinery*", Khanna Publishers, 1995.

18PE602 DIGITAL SIGNAL PROCESSING TECHNIQUES 3-0-2-4

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

COURSE OUTCOMES

CO1 Explain digital processing techniques - DFT,FFT and Digital Filters applied to continuous time signals

CO2 Apply advanced digital filters(Adaptive Filter and Kalman Filter) to address issues pertaining to electrical systems.

CO3 Review the basic concepts of mutirate signal processing concepts

CO4 Apply discrete wavelets as filter banks in real time electrical networks

CO5 Use advanced signal processing techniques to solve problems in electric domain TEXT

BOOKS/ REFERENCES:

Mitra S.K., "*Digital Signal Processing, A Computer-Based Approach*", McGraw Hill, 2002.

Ifeachor E. C. and Jervis B. W., "*Digital Signal Processing: A Practical Approach*", Addison Wesley, 1993.

Vaidyanathan P. P, "*Multirate Systems and Filter Banks*", Prentice Hall, 1993.

Simon Haykin, "*Adaptive Filter Theory*", Prentice Hall, 2001.

K.P.Soman,K.I.Ramachandran, N.G.Resmi, " *Insight into Wavelets*",Sixth Edition,PHI,2010

18PE622 ADVANCED CONTROL THEORY 3-1-0-4

Review: Concept of state, state variables and state model, modelling is state space.

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.

Adaptive control : Closed loop and open loop adaptive control. Self-tuning controller, parameter estimation using least square and recursive least square techniques, gain scheduling, model reference adaptive systems (MRAS), self-tuning regulators.

Case study – Power Electronic Applications.

COURSE OUTCOMES

CO1 Review of linear system in state space approach

CO2 Design state feedback controller, observer and optimal controller for linear systems

CO3 Analyse non-linear system characteristics and its stability.

CO4 Illustrate adaptive control techniques and parameter estimation of dynamic systems TEXT

BOOKS/ REFERENCES:

1.Ogata, "*Modern Control Engineering*". Fifth Edition, Prentice Hall, 2009.

2.Franklin and Powell, "*Feedback Control of Dynamics Systems*". Seventh Edition, Pearson Hall, 2014.

3.David G. Luenberger, "*Introduction to Dynamic Systems: Theory, Models, and Applications*", Wiley, 1979.

4.Richard C. Dorf and Robert H. Bishop, "*Modern Control Systems*", Eleventh Edition Prentice Hall, 2008.

5.Karl J Astrom and Bjorn Wittenmark, "*Adaptive Control*", Addison –Wesley Series,1995

16PE623 SIMULATION LAB 0-0-2-1

MATLAB/Simulink, OrCAD PSpice, PSCAD/EMTDC and EMTP for Power Electronics, Drives and Control applications.

COURSE OUTCOMES

CO1 Understand the simulation tools MATLAB/Simulink, PSpice/OrCAD, PSCAD, for solving Electrical engineering problems related to power electronics

CO2 Recognize various tool boxes used for power electronic application development.

CO3 Examine the methods for Troubleshooting in various simulation tools.

CO4 Implement and verify control strategies in the simulation platform for power electronic converters and electrical drives

18PE603 POWER CONVERTERS II 3-0-2-4

1 5

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, Concept of Wireless inductive and capacitive power transfer. Design of high frequency transformers and inductors-Drive and protection of switching power devices - voltage mode control and current mode control, modeling of the converters, Compensation of the feedback system for dc-dc converters. Single phase AC to DC converters with high power factor- Control of switch-mode converter for utility interface. Boost derived isolated DC-DC Converters – Typical specifications of power converters, design of power circuit to meet the specifications. EMI and Layout Fundamentals for switched mode circuits. Demonstration designs.

COURSE OUTCOMES

CO1 Understand and analyse dc-dc power converter circuits with and without isolation

CO2 Analyse and design the operation of dc-dc converters in CCM and DCM modes

CO3 Design of protection and magnetic circuits for power converters

CO4 Develop mathematical models of dc-dc converters and the closed loop controllers

CO5 Design, simulate, and test various dc-dc power conversion circuits in the laboratory and their corresponding PWM techniques. (Lab component)

TEXT BOOKS/ REFERENCES:

Ned Mohan, Tore M. Undeland and William P.Robbins, "*Power Electronics, Converters,Applications and Design*", Third Edition, John Wiley and Sons Inc., 2006.

Robert W Erickson and DraganMaksimovic, "*Fundamentals of Power Electronics*", Springer International, 2001.

Daniel W Hart, "*Power Electronics*", Tata McGraw Hill, 2011.

John G. Kassakian, Martin F.Schlecht and George C.Verghese, "*Principles of PowerElectronics*", Pearson, 2010.

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*

18PE624 ELECTRIC DRIVES AND CONTROL 3-0-2-4

Introduction to Electric Drives,Separately excited DC motor drive, mathematical model, armature and field control, dynamic behavior with constant flux, control of separately excited motor in armature control and field weakening region, control with line commutated converter, dynamic model of line commutated converter, drive with chopper control.

Three phase induction motor, steady state operation with sinusoidal voltage, v/f control, vector control of Induction machine, space vector concepts, direct torque control, speed control of wound rotor induction machine, Static Scherbius and Kramer drive.

Control of wound field synchronous machine, permanent magnet synchronous machine, switched reluctance motor and brush-less DC machine.

COURSE OUTCOMES

CO1 Review of the basic characteristics of a controllable drive

CO2 Select a suitable motor rating for a particular drive application

CO3 Illustrate the suitable control techniques for DC & AC drives.

CO4 Investigate the vector control techniques for AC drives.
CO5 Discuss the control of special electric machines.

TEXT BOOKS/REFERENCES

Ion Boldea, Syed A Nasar, "*Electric Drives*", CRC Press, 2016.
De Doncker, Rik, Pulle, Duco W J,Veltman, Andre,"*Advanced Electrical Drives – Analysis, Modeling, Control*",Springer,2011.
N.P.Quang,J.A.Dittrich, "*Vector Control of Three- Phase AC machines – System Development in the Practice*",Springer,2008.
Krishnan R, "*Electric Motor Drives Modeling, Analysis and Control*", Pearson, 2015.
Bimal K. Bose, "*Power Electronics and Variable Frequency Drives*", Wiley IEEE Press, 2010.

18PE625 EMBEDDED CONTROLLERS 3-0-2-4

Architecture of dsPIC30F3011 DSC –C30 Compiler - Peripherals – Ports – Timers – Input capture – Output compare - ADC – MCPWM – QEI – UART. Application development in dsPIC30F3011 using C30 compiler - Implementation of PI controller, Filter algorithms, Clark and Park transformations, SPWM and SVPWM, PLL and Unit sine wave generation. Architecture of TMS320C2806x Piccolo DSP Simple programs in Code Composer Studio.

COURSE OUTCOMES

CO1 Familiarize with the architecture of dsPIC30F3011 DSC
CO2 Attune with c30 compiler using the IDE for simple code development and extend to peripheral code development
CO3 Understand the working of various peripherals like ports,timers,ADC,UART
CO4 Implement application algorithms like PLL,SPWM and the like on c30 compiler
CO5 Introduce TMS320C2806x Piccolo DSP and Code Composer Studio for real world applications

TEXT BOOKS/REFERENCES:

dsPIC30F Programmers Reference Manual.
TMS320C2806x Piccolo Technical Reference Manual.
Andy Bateman and Iain Paterson-Stephens, "*The DSP Handbook, Algorithms, Applications and Design Techniques*", Prentice-Hall, 2002.
B Venkataramani and M Bhaskar, "*Digital Signal Processors: Architecture,Programming and Applications*", Tata McGraw Hill, 2002.
RulphChassaing, "*DSP Applications Using C and the TMS320C6x DSK*", John Wiley and Sons, 2002.

18RM600 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. Confirmatory Research, Experimental vs Theoretical Research, Importance of reasoning in research.

Unit II:
Problem Formulation, Understanding Modeling & 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 Systems Analysis, Error Propagation, Validity of experiments, Statistical Design of Experiments, Field Experiments, Data/Variable Types & Classification, Data collection, Numerical and Graphical Data Analysis: 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
COURSE OUTCOMES
CO1 Introduce research through topic selection and report writing
CO2 Discuss research practices to read the literature and to identify the research gaps
CO3 Develop skills to present research ideas and prepare research report.
CO4 To convey ethical practices in research with significance on citation

TEXT BOOKS/ REFERENCES:
Bordens, K. S. and Abbott, B. B., “Research Design and Methods – A Process Approach”, 8th Edition, McGraw-Hill, 2011
C. R. Kothari, “Research Methodology – Methods and Techniques”, 2nd Edition, New Age International Publishers
Davis, M., Davis K., and Dunagan M., “Scientific Papers and Presentations”, 3rd Edition, Elsevier Inc.
Michael P. Marder,“ Research Methods for Science”, Cambridge University Press, 2011
T. Ramappa, “Intellectual Property Rights Under WTO”, S. Chand, 2008
Robert P. Merges, Peter S. Menell, Mark A. Lemley, “Intellectual Property in New Technological Age”. Aspen Law & Business; 6 edition July 2012
18PE798/ 18PE799 DISSERTATION 8/12
1 8

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.

COURSE OUTCOMES (18PE798)

CO1 Understanding research methodology
CO2 Project planning
CO3 Skill in literature survey
CO4 Knowledge of computational and analytical tools
CO5 Technical communication skill

COURSE OUTCOMES (18PE799)

CO1 Skill in project planning and management
CO2 Domain knowledge
CO3 Skill in use of tool
CO4 Technical communication skill
CO5 Comprehension

OPEN ELECTIVES

18PE701 MODULATION TECHNIQUES 3-0-0-3
FOR POWER ELECTRONIC SYSTEMS

Prerequisites: POWER CONVERTER I

Overview of applications of voltage source converter, motor drives, active front-end converters, reactive compensators, active power filters. Review of Fourier series, fundamental and harmonic voltages; machine model for harmonic voltages - line current distortion, increased losses, pulsating torque in motor drives. Control of fundamental voltage; mitigation of harmonics.
Selective harmonic elimination, THD optimized PWM, off-line PWM 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.
Line current ripple; hybrid PWM for reduced line current 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.
Inverter losses, influence of PWM techniques and switching frequency on switching losses, PWM for low
inverter losses.
modulation method, 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.
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COURSE OUTCOMES

CO1 Review of voltage source converters in inverter and rectifier mode of operation for various applications and Harmonic analysis of these converters

CO2 Analyze various PWM techniques and their harmonic composition in voltage source converters and Multi level inverters.

CO3 Implement various PWM techniques for rectifier and motor drive applications

CO4 Analyze Inverter losses with various PWM techniques and their means of control TEXT

BOOKS/ REFERENCES:

Dr. G. Narayanan, IISc, Bangalore, NPTEL Online Video course on "*Pulse width Modulation for Power Electronic Converters*" 2016.

Holmes, D. G., and Lipo, T. A., *Pulse Width Modulation for Power Converters: Principles and Practice* (Vol. 18). John Wiley and Sons, 2003.

Rodriguez, Jose, and Patricio Cortes, " *Predictive control of power converters and electrical drives*", Vol. 40. John Wiley & Sons, 2012

Ned Mohan, Tore M. Undeland and William P.Robbins, "*Power Electronics, Converters, Applications and Design*", Third Edition, John Wiley and Sons Inc., 2006.

18PE702 SPECIAL TOPICS IN POWER ELECTRONICS 3-0-0-3

Review of Power Electronic Devices.

Multi-pulse converters, Zeta converters, PWM inverters, Multi stepped inverters, Modular Multi level inverters, Neutral point controlled inverters, Soft switching converters: 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.

COURSE OUTCOMES

CO1 Review the characteristics of various Power Electronic Devices

CO2 Understand the working principle of special converters viz. multi-pulse, zeta, multi-stepped, multilevel inverters, soft switched converters, resonant link converter and Z source converters.

CO3 Analyze and design of all the special converters

CO4 Implement the special converters and switched mode rectifiers

TEXT BOOKS/ REFERENCES:

Ned Mohan, Tore M. Undeland and William P.Robbins, "*Power Electronics, Converters, Applications and Design*", Third Edition, John Wiley and Sons Inc., 2006.

Muhammad H. Rashid, "*Power Electronics, Circuits, Devices and Applications*", Fourth Edition, Pearson, 2017.

Erickson, Robert W., and Dragan Maksimovic, "*Fundamentals of power electronics*", Springer Science & Business Media, 2nd Edition, 2007.

Liu, Yushan, Haitham Abu-Rub, Baoming Ge, and Omar Ellabban, "*Impedance source power electronic converters",* John Wiley & Sons, 2016.

18PE703 ADVANCED POWER ELECTRONIC DRIVES 3-0-0-3

Closed loop control of solid state DC drives, AI based vector control of induction motor, Sensor less control of induction motor, Multilevel inverter fed induction motor, Load Commutated synchronous motor drive, Vector control of synchronous motor, Permanent magnet drives, vector control of Permanent magnet synchronous motor, Switched and hybrid reluctance motor drive, Brushless DC motor drive, Industrial drives, drive controller design, Linear Induction and Synchronous motor drive. Case studies and simulations.

COURSE OUTCOMES

CO1 Review of basic control techniques for electric drives.
CO2 Illustrate modern control strategiesinsemi-conductor drives.
CO3 Discuss the control of special electric machines.
CO4 Design a controlled drive for an Industrial application

TEXT BOOKS/REFERENCES:

Bimal K. Bose, "*Power Electronics and Variable Frequency Drives"*, Wiley IEEE, 2010.
Krishnan R, "*Electric Motor Drives Modeling, Analysis and Control*", Pearson, 2015.
Ion Boldea, Syed A Nasar, "*Electric Drives*", CRC Press, 2016.
De Doncker, Rik, Pulle, Duco W J,Veltman, Andre,"*Advanced Electrical Drives – Analysis, Modeling, Control*",Springer,2011.
5.NedMohan, "Electric Machines and Drives", Wily Publications, 2011.

18PE704 POWER ELECTRONICS FOR ELECTRIC VEHICLE APPLICATIONS 3-0-0-3

Introduction to Hybrid Electric Vehicles: History of hybrid and electric vehicles, social and environmental importance. Conventional Vehicles: Basics, characterization, transmission, mathematical models.

Electric Drive-trains: Introduction, power flow control, fuel efficiency analysis, Hybrid Electric Drive. Electric Propulsion: Introduction, Configuration and control of different types of motors in drive trains, drive system efficiency, impact of modern drive-trains on energy supplies. Energy Storage: Introduction, Requirements, Analysis, Battery, Super Capacitor, Fuel cell, Fly wheel. Energy Management Strategies: Introduction, classification, implementation issues of energy management strategies.

Case Studies: Design of a Hybrid Electric Vehicle (HEV), Design of a Battery Electric Vehicle (BEV)

COURSE OUTCOMES

CO1 Understand an Electric Vehicle Architecture
CO2 Familiarise drive trains and analyse power flow
CO3 Identify various propulsion motors used in EVs
CO4 Illustrate different Energy storage systems and management
CO5 Understand the design of a HEV and BEV

2 1

TEXT BOOKS/ REFERENCES:

Haitham Abu-Rub, Mariusz Malinowski, Kamal Al-Haddad, "*Power Electronics for Renewable Energy Systems, Transportation and Industrial Applications*",Wiley Publishers, June 2014.
Chris Mi; M. Abul Masrur and David Wenzhong Gao, "*Hybrid Electric Vehicles: Principles and Applications with Practical Perspectives*",Wiley Publishers, Jun 2011
Yangsheng Xu, Jingyu Yan, Huiihuan Qian and Tin Lun Lam, "*Hybrid Electric Vehicle Design and Control: Intelligent Omni directional Hybrids*", Mc-Graw Hill Education, 2014.
Bruno Scrosati, Garche and Werner Tillmetz, "*Advances in Battery Technologies for Electric Vehicles*", Woodhead Publishing Series in Energy.
Ehsani, Mehrdad, Yimin Gao, Stefano Longo, and Kambiz Ebrahimi, "*Modern electric, hybrid electric, and fuel cell vehicles",* CRC press, 2018.

18PE705 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. Single phase variable reactance, computation of reactance. Design using any FEM tool

COURSE OUTCOMES

CO1 Understand the basic principles of finite element method.
CO2 Analyze two dimensional problems using finite element method.
CO3 Determine the electromagnetic parameters of electrical apparatus
CO4 Design of electrical machines using FEM software tool

TEXT BOOKS /REFERENCES:

Nicola Bianchi, "*Electrical Machine Analysis Using Finite Elements*", CRC Press, 2005.
Cheng D K, "*Fundamentals of Engineering Electromagnetic*", Addison Wesley, 1993.
Reece A and Preston T, "*Finite Element Method in Electric Power Engineering*", Oxford University Press, UK, 2000.

18PE706 APPLICATION OF SYSTEM IDENTIFICATION
TO POWER CONVERTERS 3-0-0-3

Introduction and overview of Systems Identification, Parametric model structures; Linear regression problem; Least Squares formulation and its variants. Maximum Likelihood Estimation; Estimation of non-parametric models; Notions of prediction and simulation.

Estimation of parametric models - prediction error methods and instrumental variable methods. Model structure selection and diagnostics. Dynamic models, ARMA, ARMAX. Estimation theory, least squares, 2 2

generalized least squares, instrumental variables, prediction error methods. Non parametric identification, Sub space identification, Identification with prediction error methods prediction model structure.
Adaptive control, Model Reference Adaptive Control (MRAC), Basic adaptive control schemes, open loop adaptive control, direct and indirect adaptive control, Adaptive regulation, Parameter adaptation algorithm. Self-Tuning Regulators (STR), Different approaches to self-tuning regulators – Stochastic Adaptive control – Gain Scheduling
System identification of power converters based on a black-box approach
COURSE OUTCOMES

- CO1 Identify various techniques for system identification
- CO2 Design and Estimate parametric models
- CO3 Develop dynamic models for non-parametric identification
- CO4 Introduce various adaptive control techniques to control systems
- CO5 Apply system Identification techniques to Power Electronic systems

TEXT BOOKS /REFERENCES:
K. J. Astrom and B. Wittenmark, Adaptive Control, Addison - Pearson, 2006.
L. Ljung, System Identificaiton: Theory for the user, Prentice -Hall, 2007.
T. Soderstrom and P. Stoica, System Identification, Prentice Hall, 1989.
Arun K. Tangirala, Principles of System Identification: Theory and Practice, CRC Press 2014
Sastry, S. and Bodson, M., "Adaptive Control– Stability, Convergence and Robustness", Prentice Hall inc., New Jersey, 1989.
18PE707 MODELLING AND CONTROL OF POWER CONVERTERS 3-0-0-3
State space modeling and control of single phase and three phase rectifiers - State feedback controllers and observer design for output voltage regulation - Analysis of continuous and discontinuous mode of operation.
State space modeling and control of Buck, Buck-Boost, Cuk, Sepic, Zeta Converters - Analysis and closed loop voltage regulations using state feedback controllers and sliding mode controllers.
Modeling of multi input DC-DC converters and state feedback controllers for output voltage regulation - applications
COURSE OUTCOMES
CO1 Understand the concept of state space modelling and analysis of Rectifiers, dc-dc converters, multi input dc-dc converters and their control
CO2 Design state feedback controllers and observers for rectifiers, dc-dc converters and multi input dc-dc converters.
CO3 Analyse the rectifier and dc-dc converter circuits under continuous and discontinuous current mode of operation
CO4 Implement various controllers for voltage regulation of rectifiers, dc-dc converters and multi-
input dc-dc converters

TEXT BOOKS /REFERENCES:

1. Sira -Ramirez, R.SilvaOrtigoza, "*Control Design Techniques in Power Electronics Devices*",

Springer, 2006.

Siew-Chong Tan, Yuk-Ming Lai, Chi Kong Tse, "*Sliding mode control of switching Power Converters*", CRC Press, 2011.

Erickson, Robert W., and Dragan Maksimovic, "*Fundamentals of power electronics",* Springer Science & Business Media, 2nd Edition, 2007.

Bimal Bose, "*Power electronics and motor drives*", Elsevier, 2006.

Ion Boldea and S.A Nasar, "*Electric drives*", CRC Press, 2005.

18PE708 ELECTRIC VEHICLES AND ARCHITECTURES 3-0-0-3

Introduction to electric vehicles (EVs): Historical perspective. EV advantages and impacts. EV market and promotion: infrastructure needs, legislation and regulation, standardization, Drive cycle, Functions electronically controlled in automotive.

Importance of energy efficiency / emission norms and fuel efficiency: Assessing economy of electric vehicles, Fuel economy V's fuel consumption V's GHG (Green House Gas) emissions Important electrical subsystem in vehicles: Basic components of a hybrid vehicle, Types of hybrids, Migration from 12V to 48V systems, Start/Stop Hybrid architecture types (BSG(Belt start Generator) /ISG(Integrated Starter Generator)), EV architectures

EV architectures - Parallel Hybrid/ Series Hybrid (Range Extended Hybrid) Architectures: Hybrid electric vehicles (HEVs): types, operating modes, torque coordination and control, generator/motor requirements Introduction to power converter and motor control: Case study

On-board/off-board chargers (V2H, V2G concepts): Battery parameters. Types and characteristics of EV batteries. Battery testing and maintenance; charging schemes. Battery monitoring techniques. Open-circuit voltage and ampere-hour estimation. Battery load leveling.

COURSE OUTCOMES

CO1 Review standards, drive cycles, impacts, economy of Electric Vehicles
CO2 Familiarise architecture of Electric Vehicle and Hybrid Electric Vehicles
CO3 Control of Power converter and motor in Electric Vehicles
CO4 Battery testing , maintenance and monitoring techniques

TEXT BOOKS /REFERENCES:

Iqbal Husain, "*Electric and Hybrid Vehicles, Design Fundamentals*", CRC PRESS, published in the Taylor & Francis e-Library, 2005.

K. T. Chau, *"Electric Vehicle Machines and Drives Design, Analysis and Application*", IEEE, John Wiley and Sons, 2015.

Austin Hughes and Bill Drury, "*Electric Motors and Drives, Fundamentals, Types and Applications*", 4th Edition, Elsevier, 2013.

James Larminie, John Lowry, "*Electric Vehicle Technology Explained*", John Wiley and Sons, 2003.

C.C. Chan and K.T. Chau, "*Modern Electric Vehicle Technology*", Oxford University Press, 2001.

18PE709 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.

COURSE OUTCOMES

CO1 Understand the fundamentals of PLC and Ladder diagram
CO2 Illustrate the working of Digital and Analog PLC interface
CO3 Describe the PLC processor Data Organization and programming instructions
CO4 Able to work on a real time problem

TEXT BOOKS / REFERENCES:

Dunning Carry, "*Introduction to Programmable Controllers*", Third Edition, Thomson Delmar Learning, 2006.

John R. Hackworth and Frederick D, "*Programmable Logic Controllers: Programming Methods and Applications*", Pearson Education Inc., 2004.
Bolton W, "*Programmable Logic Controllers*", Fifth Edition, Elsevier, 2009.
John W Webb and Ronald A Reis, "*Programmable Logic Controllers: Principles and Applications*", Fifth Edition, PHI learning Pvt. Ltd., 2009.
Frank D.P., "*Programmable Logic Controllers*", Second Edition, Tata Mc Graw Hill Publishing Company Limited, 1997.

18PE710 DIGITAL CONTROL SYSTEMS 3-0-0-3

Review of Z-transforms. Pulse transfer function. Digital control system: sampling, quantization, data reconstruction and filtering of sampled signals. Z-transform analysis of closed loop and open loop systems, Stability analysis of closed loop systems in the z-plane: frequency domain analysis, 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, direct design. Controllability, Observability, control law design, decoupling by state variable feedback, effect of sampling period. Estimator/ Observer Design: full order observers, reduced order observers, regulator design.

COURSE OUTCOMES

CO1 Review of Z-transform, sampling and reconstruction of signals.
CO2 Analyse stability of linear system in Z-domain
CO3 Design compensators in time and frequency domains and transform to Z-domain
CO4 Design digital controllers and observers in Z domain.

TEXT BOOKS/ REFERENCES:

Gene F. Franklin, J. David Powell and Michael Workman, "*Digital Control of Dynamic Systems*", Pearson, 2000.
Benjamin C Kuo, Farid Golnaraghi, "Automatic Control Systems", Eighth Edition, Wiley, 2014.
K. Ogata, "*Discrete-Time Control Systems*", Pearson Education, 2011.
Moudgalya, "Digital Control", First Edition, Wiley Publication, 2008.
C. L. Philips, Troy Nagle, Aranya Chakrabortty, "*Digital Control System Analysis and*

Design", Prentice-Hall, 2014.

18ES624 FPGA BASED SYSTEM DESIGN 2-0-2-3

HDL – Role of HDL - VHDL for Design Synthesis - Design Flow – Programmable logic:Simple PLDs, CPLDs, FPGA VHDL - Entities and Architectures - A Simple Design – Design Entities – VHDL elements - Data flow – behavioural – structural modeling – Creating Combinational and Synchronous Logic - Designing FIFO - Test Benches - State Machine Designs - Design Examples - Memory Controller - Mealy State Machines – Design Considerations - Hierarchy in Large Designs - Functions and Procedures – Subprograms - General principles of circuit synthesis - Synthesis and Design Implementation - Synthesis and Fitting CPLDs, FPGAs - Optimizing Data paths – Pipelining - Resource Sharing - Creating Test Benches – Implementation technology – PLD's, Custom Chips, Standard Cell and Gate arrays – FPGA Architectures – SRAM based FPGAs – Permanently programmed FPGAs – Circuit design of FPGA fabrics – Architecture of FPGA fabrics – Logic Implementation of FPGAs - Physical
design for FPGAs

COURSE OUTCOMES

CO1 Realization of combinational logic circuits in circuit level and using PLDs
CO2 Design combinational logic circuits using HDL
CO3 Design sequential logic circuits using HDL
CO4 Understand the design styles in different FPGA architectures
CO5 Synthesize digital circuits in FPGAs

TEXT BOOKS / REFERENCES:

Kevin S kahill, "*VHDL for Programmable Logic*", Pearson Education, 1996.
Stephen Brown and Zvonko Vranesic, "*Fundamental of Digital Logic with VHDL Design*", Third Edition, McGraw Hill, 2017.
Douglas L Perry, "*VHDL Programming by Example*", Fourth Edition, Tata Mc Graw Hill, 2002.
Wayne Wolf, "*FPGA-Based System Design*", Prentice Hall India Pvt. Ltd., 2004.
Samir Palnitkar, "*Verilog HDL - A Guide to Digital Design and Synthesis*", Second Edition, Pearson Education, 2003.

18PE711 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

COURSE OUTCOMES

CO1 Understand the basics of adaptive control system.

CO2 Discuss the various adaptive control techniques.
CO3 Analyse convergence of multivariable adaptive controllers..
CO4 Illustrate the adaptive controllers and parameter estimation. TEXT BOOKS/ REFERENCES:

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

18PE712 SOFT COMPUTING 2-0-2-3

Fuzzy Logic (FL) – Membership Functions – Fuzzifications and Defuzzifications – Fuzzy Relations – TSK Fuzzy Modeling.Neural Networks (NN) – Supervised and Unsupervised Learning – Hopfield – RBF Networks Kohonen Self Organizing Networks – Learning Vector Quantization – Hebbian Learning. Neuro-fuzzy models- adaptive neuro-fuzzy inference system (ANFIS)- Architecture – Hybrid Learning Algorithm – Learning Methods that Cross-fertilize ANFIS and RBFN - Applications.
Genetic Algorithms – Random Search – Downhill Simplex Search.
Introduction to Support Vector Machines – Classification and Regression – Typical Applications Integrating Various Soft Computing Tools.

COURSE OUTCOMES
CO1 Apply neural networks to pattern classification and regression problems
CO2 Solve engineering problems with uncertainty using fuzzy logic technique
CO3 Apply evolutionary algorithms for optimization problems.
CO4 Use of software tools to solve real time problems by soft computing techniques. TEXT

BOOKS/ REFERENCES:

1.Timothy Ross, "*Fuzzy Logic with Engineering Applications*", Second Edition, John Wiley and sons, 2004.
2. Simon Haykin, "*Neural Networks and Learning Machines*", Third Edition, Pearson Education, 2009.

K.F. Man, K.S. Tang and S. Kwong, "*Genetic Algorithms: Concepts and Applications*", IEEE Transactions Industrial Electronics, Vol-3,1996.
Jan Komorowski, Lech Polkowski and AndrzejSkowron, "*Rough Sets: A Tutorial*", http://Folli.Loria.Fr/Cds/1999/Library/Pdf/Skowron.Pdf

18PE713 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 519-1992, Recommended Practices for Individual Consumers – Recommended Practices for Utilities - Causes and effects of power quality issues, Measurements.
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, Icos algorithm, AI based control algorithms, Analog/digital implementation - Case studies. Hybrid Filters –Review – Design -Applications - 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.

COURSE OUTCOMES

CO1 Identify sources and effects of various power quality issues.
CO2 Analyse the behaviour of power quality events and categorise them based on the recommended standards
CO3 Judge, design and develop suitable mitigation techniques
CO4 Analyse the performance of power quality improvement schemes

TEXT BOOKS/ REFERENCES:

J.Arillaga, N.R.Watson and S.Chen, "*Power System Harmonics*", John Wiley and Sons, England, 2005.
Enrique Acha and Manuel Madrigal, "*Power Systems Harmonics-Computer Modeling and Analysis*", John Wiley and Sons Ltd., 2001.
George J. Wakileh, "*Power Systems Harmonics-Fundamentals, Analysis and Filter Design*", Springer-Verlag, New York, 2007.
Ewald and Mohammad Masoum, "*Power Quality in Power Systems and Electrical Machines*", Elseveir Academic Press, 2008.
Bhimsingh, Ambrish Chandra, Kamal Al-Haddad, *"Power Quality Problems and Mitigation Techniques*", John Wiley&Sons Limited, 2015.

18PE714 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.

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Shunt compensators: Objectives of shunt compensation, Variable impedance Devices (TSR, TCR, TSC, FC-TCR, TSC-TCR), Switched converter (STATCOM) and Hybrid shunt compensators.
Series compensators: Concept of series capacitive compensation, Variable impedance Devices (GCSC, TSSC, TCSC), Static Synchronous Series Compensators (SSSC). Control schemes for different applications.
Static voltage and phase angle regulators: Concepts of power flow control, Transient stability, Power oscillation damping with series and shunt compensation.
Introduction to UPFC.
High Voltage DC Transmission: Comparison with AC System, HVDC configurations,unipolar and bipolar links, components of HVDC system - Converter, transformer, smoothing reactor, harmonic filter.
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.
COURSE OUTCOMES
CO1 Discuss the basic concepts, principles and operation of power system compensators
CO2 Prioritize, and design suitable corrective measures for performance improvement of power lines
CO3 Decide effective control strategy for the compensators used in power lines
CO4 Analyse the performance of corrective equipments under different operating scenarios TEXT

BOOKS/ REFERENCES:
Narain G. Hingorani and Laszlo Gyugyi, " *Understanding FACTS – Concepts and Technology of Flexible AC Transmission Systems*", IEEE Power Engineering Society, 2011.
R.Mohan, Mathur and Rajiv. K. Varma, "*Thyristor Based FACTS Controller for Electrical Transmission System, IEEE Series on Power Engineering*", Wiley Interscience, 2011.
Padiyar K. R, "*FACTS Controllers in Power Transmission and Distribution*", New Age Publishers, 2007.
K R Padiyar, "HVDC Power Transmission Systems – Technologies and System Interactions", New Age International (P) Limited, 2007.
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
18PE715 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. Power quality issues related to Energy Efficient Technologies.
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 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.
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COURSE OUTCOMES

CO1 Understand and analyse energy scenario & policies of India & World in the past, present & future

CO2 Understand the energy efficiency performance indicators of various technologies and methodologies to evaluate the indices.

CO3 Techno economically evaluate the feasibility of various efficiency improvement opportunities for an existing system

CO4 Understand the methodology of energy auditing using case studies

TEXT BOOKS / REFERENCES:

Hamies, "*Energy Auditing and Conservation; Methods, Measurements, Management and Case Study*", Hemisphere Publishers, Washington, 1980.

C.W. Gellings and J.H. Chamberlin, "*Demand-Side Management Planning*", Fairmont Press, 1993.

Wayne C Turner, "*Energy Management Handbook*", The Fairmount Press, 2006.

Bureau of Energy Efficiency Study material for Energy Managers and Auditors Examination: Paper I to IV, www.energymanagertraining.com

S. Pabla, "*Electric Power Systems Planning*", Macmillan India Ltd., 1998.

18PE716 POWER SYSTEM OPERATION AND CONTROL 2-0-2-3

Introduction- System load Variation: System load characteristics, Load curve- weekly and annual duration curve, load factor, diversity factor. System State and Transition, Operation of vertical and deregulated power system, Control center functions. Overview of system control: Governor control, LFC, AVR. Linear Models of Synchronous machines- Transient stability- Dynamic Stability. Real power-frequency control: Need for voltage and frequency regulation in power system, basic P-f and QV control loops. Fundamentals of speed governing systems and modeling, LFC of Single area and two area systems. Modeling of single and two area system -Power System Stabilizers. Reactive power – Voltage control: Typical excitation system, static and dynamic analysis, effect of generator loading, static shunt capacitor/reactor VAR compensator, synchronous condenser, tap changing transformer, Static VAR system, modeling, system level voltage control.

COURSE OUTCOMES

CO1 Understand the operating states of power system and various factors related to load variations.

CO2 Analyze Automatic Generation and Voltage Control loops in power systems.

CO3 Design components to control voltage and frequency in power system.

CO4 Evaluate the performance of control loops using modern software tools.

CO5 Compute economic load dispatch for load frequency control.

TEXT BOOKS/ REFERENCES:

Olle.I.Elgerd, "Electric Energy Systems Theory- An Introduction", Tata Mc Graw Hill Publishing company Ltd., New Delhi, 2004.

William D Stevenson, "Elements of Power System Analysis", 4th Edition, McGrawHill, 2017.

Allen.J. Wood and Bruce.F.Wollenberg, "Power Generation Operation and Control", John Wiley and Sons, 2006.

L.K.Kirchmayer, “Economic Operation of Power System”, John Wiley and Sons, 2009.
P. Kundur, “Power System Stability and Control”, Mc Graw Hill, 2006.

18PE717 ELECTROMAGNETIC INTERFERENCE AND COMPATIBILITY 3-0-0-3
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.
COURSE OUTCOMES
CO1 Understand the basics of Electromgnetic Interference and its sources
CO2 Learn the non-ideal behavior of electrical components
CO3 Learn the conducted and radiated emissions and susceptibility
CO4 Learn EMI reduction techniques
CO5 Familiarise EMI standards and techniques

TEXT BOOKS/REFERENCES:
Laszio Tihanyi, “*EMC in Power Electronics*”, IEEE Press, 1995.
V.Prasad, “*Engineering Electromagnetic Compatibility*”, IEEE Press, 2001.
Henry W.Ott, “*Noise Reduction Techniques in Electronic Systems*”, Second Edition, John Wiley and Sons Ltd., 1988.
Rajiv Thottappillil, Lecture Notes on EMC, KTH ,Stockholm.
18MA701 OPTIMIZATION THEORY 2--0-2-3
Review of Linear Algebra: 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
COURSE OUTCOMES
Understand different types of Optimization Techniques in engineering problems. Learn
CO1 Optimization methods such as Bracketing methods, Region elimination methods,Point estimation methods.

CO2 Learn gradient based Optimizations Techniques in single variables as well as multivariables(non-linear).
CO3 Understand the Optimality criteria for functions in several variables and learn to apply OT methods like Undirectional search and Direct search methods.
CO4 Learn constrained optimization techniques. Learn to verify Kuhn-Tucker conditions and Lagrangian Method.

TEXT BOOKS/ REFERENCES

Kalyanmoy Deb, "*Optimization for Engineering Design: Algorithms and Examples*", Prentice Hall, 2002.
Ronald L. Rardin, "*Optimization in Operations Research*", Prentice Hall, New Jersey, 1998.
Singiresu S. Rao, "*Engineering Optimization: Theory and Practice*", Third Edition, New Age Publishers, 2003.
4.Hamady A. Taha, "*Operations Research*", Sixth Edition, Tata McGraw Hill, 2004.
E. Clapton, "Advanced Optimization Techniques and Examples with MATLAB" CreateSpace Independent Publishing Platform,2016

18PE718 POWER SYSTEM MODELING 3-0-0-3

Modelling of Power System Components: classical methods of modeling. Simplified models of non-electrical components like boiler, steam, hydro-turbine, diesel engine and governor system. Transformer modelling - auto-transformer, tap-changing and phase-shifting transformers. Modelling of Transmission line and Loads.

Modelling of Excitation system: definitions of voltage response ratio and exciter voltage ratings. IEEE excitation systems. Excitation configurations- dc and ac excitations, self and separately excited systems. Basics of Park's transformation. Modelling of Synchronous machine: Basic flux linkage, voltage and torque equations of synchronous machine - Basics of Park's transformation. The current & flux linkage models using Park's transformation - Models for steady-state and dynamic studies. Simulation and analysis of Synchronous machine connected to an infinite bus. Modelling of Power converters, Modelling of wind and solar power plants. Modelling of FACTS devices, Stability analysis of sample power system models.

COURSE OUTCOMES

CO1 Model nonelectrical components generally used in power system
CO2 Develop transformer and synchronous machine models
CO3 Develop models of Power Electronic devices used in Transmission lines
CO4 Conduct static and dynamic performance analysis of power systems with FACTS

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. Kundur, "*Power System stability and Control*", McGraw Hill, 1994.

4. Krishna, S," *An Introduction to Modelling of Power System Components*", Springer,2014.
5.Qiuwei Wu, Yuanzhang Sun, "*Modeling and Modern Control of Wind Power*", IEEE press, John Wiley & Sons Ltd, 2018.
6. Sen, Zekai*,"Solar Energy Fundamentals and Modeling Techniques", Springer,2008.*

18PE719 DESIGN FOR RELIABILITY 3-0-0-3

Review of Probability theory – Introduction to the concepts of Reliability – Nature of Reliability problems in Electronic equipment – Reliability modeling – Availability and maintability concepts – Designing for Reliability – Fault Analysis techniques – Reliability predictions –
Worst case design and component de-rating – software Reliability.

COURSE OUTCOMES

CO1 Understand the basic concepts of reliability.
CO2 Analyze the statistical techniques leading to reliability modeling.
CO3 Identify reliability indices and testing components.
CO4 Apply reliability theory in engineering design.

TEXT BOOKS / REFERENCES:

Fuqua, "*Reliability Engineering for Electronic Design*", Marcel Dekker, 1988.
Patrick DTO'Connor, "*Practical Reliability Engineering*", John Wiley and Sons, 2008.
MIL Handbook-338 – "*Reliability of Electronic Equipment"*.
L.Umanand, "*Power Electronics Essentials and Applications*", Wiley India Pvt. Ltd., 2009.

18PE720 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 – Powerconverter topologies for PMSG, DFIG and VSIG, - Dual converters with DC-link capacitance, grid synchronization and phase locking, control ofrotor 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. COURSE OUTCOMES

CO1 Summarize the state of art, policy and regulations in distributed
generation 3 3

CO2 Illustrate renewable power generation techniques
CO3 Recommend Energy storage techniques for distributed generation
CO4 Choose power converters for distributed generators

TEXT BOOKS/ REFERENCES:

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

18PE721 SMART GRID 3-0-0-3

Smart grid definition. Smart grid vs. conventional grid. Smart Grid technologies- Power system and information communication technology (ICT) in Generation, Transmission and Distribution. Basic understanding of power systems. Evolution of power electronics in power system applications.
Smart Grid features (Distributed generation, storage, Demand dispatch(DD),Demand Response(DR),Advanced Metering Infrastructure (AMI),Wide Area measurement system(WAMS),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 - Smart microgrid simulator (SMGS), DR, DD, Energy storage, Smart Appliances. COURSE OUTCOMES

CO1 Understand power system operations, issues with existing system and capabilities of Smart Grid (SG)
CO2 Analyse the scope of distributed generation and Demand side management in SG
CO3 Apply phasor,frequency estimation algorithms
CO4 Compare and evaluatecommunication technologies for SG
CO5 Develop smart strategies for power system issues

TEXT BOOKS/ REFERENCES:

James Momoh, "*Smart Grid: Fundamentals of Design and Analysis*", Wiley-IEEE Press, March 2012.
JanakaEkanayake, Nick Jenkins, KithsiriLiyanage, Jianzhong Wu and Akihiko Yokoyama, "*Smart Grid:Technology and Applications*", Wiley, February 2012.
Ali Keyhani and Muhammad Marwali, "*Smart Power Grids 2011*", Springer, 2011.
Mini S. Thomas, John Douglas McDonald,"*Power System SCADA and Smart Grids*", CRC Press, April 2015.

Qing Chang Zhong, Tomas Hornik- "*Control of Power Inverters in Renewable Energy and Smart Grid Integration*" -Wiley-IEEE Press 2013.

18PE722 RENEWABLE ENERGY TECHNOLOGIES 3-0-0-3

Renewable energy sources: Renewable energy utilization in ancient times; classification of RE technologies – stand alone, hybrid and grid-connected; Recent developments in renewable energy sector – global and national energy policies

Wind energy – Global and local winds, resource assessment, wind regime modeling – Weibull parameters; WEG technologies for grid connection.

Solar energy – Solar radiation and measurements; PV Cell – principle, types and construction; Modeling of PV cell; Maximum power tracking; SPV systems – stand alone and grid-connected. Other renewable energy technologies: Biomass – gasifiers; Small hydro – resource assessment, selection of turbines, Electronic load controller; Wave, Tidal, Ocean thermal and Geothermal energy systems – principles and technologies; Energy storage systems.

COURSE OUTCOMES

CO1 Understand the need and means for renewable energy utilisation
CO2 Understand the schemes to produce electricity from renewable resources
CO3 Assess renewable energy potential availability
CO4 Analyse the characteristics and control of various RE energy conversion systems
CO5 Design of system for various renewable energy extraction schemes

TEXT BOOKS / REFERENCES:

Thomas B Johansson, "*Renewable Energy: Sources for Fuels and Electricity*", Island Press, Washington, 1993.
John W Twidell and A D Weir, "*Renewable Energy Resources*", Routledge Publications, 2015.
N K Bansal, M Kleemann and M Mellis, "*Renewable Energy Resources and Conversion Technology*", Tata McGraw Hill, 1990.
S N Bhadra, D Kastha and S Banerji, "*Wind Electrical Systems*", Oxford University Press, 2005.