Sri Sivasubramaniya Nadar College of Engineering

(An Autonomous Institution, Affiliated to Anna University, Chennai)

Rajiv Gandhi Salai (OMR), Kalavakkam – 603110

Curriculum and Syllabus

Master of Engineering

Power Electronics and Drives

Regulations 2018

Choice Based Credit System (CBCS)

Sri Sivasubramaniya Nadar College of Engineering, Kalavakkam - 603110
(An Autonomous Institution, Affiliated to Anna University, Chennai)

REGULATIONS 2018
CHOICE BASED CREDIT SYSTEM
M.E. POWER ELECTRONICS AND DRIVES
CURRICULUM
SEMESTER I

Sl. No.	Course Code	Course Title	Category	Contact Periods	L	T	P	C
THEORY								
1	PMA1153	Applied Mathematics for Electrical Engineers	FC	4	4	0	0	4
2	PPE1101	Power Semiconductor Devices	PC	3	3	0	0	3
3	PPE1102	Analysis of Electrical Machines	PC	3	3	0	0	3
4	PPE1103	Analysis and Design of Power Converters	PC	3	3	0	0	3
5	PPE1104	System Theory	PC	5	3	2	0	4
6		Professional Elective I	PE	3	3	0	0	3
PRACTICALS								
7	PPE1111	Power Electronics Circuits Lab	PC	4	0	0	4	2
			Total	25	19	2	4	22

SEMESTER II

Sl. No.	Course Code	Course Title	Category	Contact Periods	L	T	P	C
THEORY								
1	PPE1201	Analysis and Design of Inverters	PC	3	3	0	0	3
2	PPE1202	Solid State Drives	PC	5	3	2	0	4
3	PPE1203	Special Electrical Machines	PC	3	3	0	0	3
4	PPE1204	Power Quality	PC	3	3	0	0	3
5		Professional Elective II	PE	3	3	0	0	3
6		Professional Elective III	PE	3	3	0	0	3
PRACTICALS								
7	PPE1211	Electrical Drives Lab	PC	4	0	0	4	2
8	PPE1217	Mini Project	EEC	4	0	0	4	2
			Total	28	18	2	8	23

SEMESTER III

S.No	COURSE CODE	COURSE TITLE	CATEGORY	CONTACT PERIODS	L	T	P	C
THEORY								
1		Professional Elective IV	PE	3	3	0	0	3
2		Professional Elective V	PE	3	3	0	0	3
3		Professional Elective VI	PE	3	3	0	0	3
PRACTICAL								
4	PPE1318	Project Work Phase I	EEC	12	0	0	12	6
TOTAL				21	9	0	12	15

SEMESTER IV

SI.No	COURSE CODE	COURSE TITLE	CATEGORY	CONTACT PERIODS	L	T	P	C
PRACTICALS								
1	PPE1418	Project Work Phase II	EEC	24	0	0	24	12
TOTAL				24	0	0	24	12

TOTAL NO. OF CREDITS: 72

PROFESSIONAL ELECTIVES

SEMESTER I
PROFESSIONAL ELECTIVE – I

Sl. No.	Course Code	Course Title	Category	Contact Periods	L	T	P	C
1	PPE1121	Soft Computing Techniques	PE	3	3	0	0	3
2	PPE1122	Electromagnetic Field Computation and Modelling	PE	3	3	0	0	3
3	PPE1123	Control System Design for Power Electronics	PE	3	3	0	0	3

SEMESTER II
PROFESSIONAL ELECTIVE –II and III

Sl. No.	Course Code	Course Title	Category	Contact Periods	L	T	P	C
1	PPE1221	Analog and Digital Controllers	PE	3	3	0	0	3
2	PPE1222	Flexible AC Transmission Systems	PE	3	3	0	0	3
3	PPE1223	Modern Rectifiers and Resonant Converters	PE	3	3	0	0	3
4	PPE1224	Electromagnetic Interference andCompatibility	PE	3	3	0	0	3
5	PPE1225	MEMS Technology	PE	3	3	0	0	3
6	PPE1226	DistributedGeneration and Microgrid	PE	3	3	0	0	3

SEMESTER III

(PROFESSIONAL ELECTIVE IV, V AND VI)

S.No	COURSE CODE	COURSE TITLE	CATEGORY	CONTACT PERIODS	L	T	P	C
1	PPE1321	High Voltage Direct Current Transmission	PE	3	3	0	0	3
2	PPE1322	Solar and Energy Storage Systems	PE	3	3	0	0	3
3	PPE1323	Wind Energy Conversion Systems	PE	3	3	0	0	3
4	PPE1324	Energy Management and Auditing	PE	3	3	0	0	3
5	PPE1325	Electric Vehicles and Power Management	PE	3	3	0	0	3
6	PPE1326	Non Linear Dynamics for Power Electronics Circuits	PE	3	3	0	0	3
7	PPE1327	Smart Grid	PE	3	3	0	0	3
8	PPE1328	Power Electronics for Renewable Energy Systems	PE	3	3	0	0	3
9	PPE1329	Robotics and Control	PE	3	3	0	0	3
10	PPE1331	Non Linear Control	PE	3	3	0	0	3

COURSE CODE	COURSE TITLE	L	T	P	C
PMA1153	**APPLIED MATHEMATICS FOR ELECTRICAL ENGINEERS**	3	2	0	4

OBJECTIVES:
The main objective of this course is to demonstrate various analytical skills in applied mathematics and extensive experience with the tactics of problem solving and logical thinking applicable for the students of electrical engineering. This course also will help the students to identify, formulate, abstract, and solve problems in electrical engineering using mathematical tools from a variety of mathematical areas, including matrix theory, calculus of variations, probability, linear programming and Fourier series.

UNIT I   MATRIX THEORY   12
Cholesky decomposition – Generalized Eigenvectors – Canonical basis – QR Factorization – Least squares method – Singular value decomposition.

UNIT II   CALCULUS OF VARIATIONS   12
Concept of variation and its properties – Euler's equation – Functional dependant on first and higher order derivatives – Functionals dependant on functions of several independent variables – Variational problems with moving boundaries –Direct methods : Ritz and Kantorovich methods.

UNIT III   PROBABILITY AND RANDOM VARIABLES   12
Probability–Axioms of probability–Conditional probability– Random variables– Probability function–Moments–Moment generating functions and their properties–Binomial,Poisson, Uniform, Exponential and Normal distributions

UNIT IV   LINEAR PROGRAMMING   12
Formulation–Graphical solution–Simplex method–Big M method– Two phase method.

UNIT V   FOURIERSERIES   12
Introduction to Fourier series – Eigen value problems and orthogonal functions–Regular Sturm – Liouville systems–Generalized Fourier series.

TOTAL PERIODS: 60

OUTCOMES:
After completing this course, students should demonstrate competency in the following skills:
- Apply various methods in matrix theory to solve system of linear equations.
- Maximizing and minimizing the functional that occur in electrical engineering discipline.
- Computation of probability and moments, standard distributions of discrete and continuous random variables and functions of a random variable.
- Could develop a fundamental understanding of linear programming models, able todevelop a linear programming model from problem description, apply the simplex method for solving linear programming problems.
- Fourier series analysis and its uses in representing the power signals

REFERENCE BOOKS:

1. Andrews L.C. and Phillips R.L., Mathematical Techniques for Engineers and Scientists, Prentice Hall of India Pvt. Ltd., New Delhi, 2005.
2. Bronson, R. Matrix Operation, Schaum's outline series, 2ndEdition, McGraw Hill, 2011.
3. Elsgolc, L. D. Calculus of Variations, Dover Publications, New York, 2007.

4. Johnson, R.A., Miller, I and Freund J., Miller and Freund's Probability and Statistics for Engineers, Pearson Education, Asia, 8thEdition, 2015.
5. O'Neil, P.V., Advanced Engineering Mathematics, Thomson Asia Pvt. Ltd., Singapore, 2003.
6. Taha, H.A., Operations Research, An Introduction, 9thEdition, Pearson education, NewDelhi, 2016.

COURSE CODE	COURSE TITLE	L	T	P	C
PPE1101	POWERSEMICONDUCTORDEVICES	3	0	0	3

OBJECTIVES:
- To improve power semiconductor device structures for adjustable speed motor control applications.
- To understand the static and dynamic characteristics of current controlled power semiconductor devices
- To understand the static and dynamic characteristics of voltage controlled power semiconductor devices
- To enable the students for the selection of devices for different power electronics applications
- To understand the control and firing circuit for different devices.

UNIT I   INTRODUCTION   9
Power switching devices overview – Attributes of an ideal switch, application requirements, circuit symbols; Power handling capability – (SOA); Device selection strategy – On-state and switching losses – EMI due to switching - Power diodes - Types, forward and reverse characteristics, switching characteristics – rating.

UNIT II   CURRENTCONTROLLEDDEVICES   9
BJT's – Construction, static characteristics, switching characteristics; Negative temperature coefficient and second breakdown; - Thyristors – Physical and electrical principle underlying operating mode, Two transistor analogy – concept of latching; Gate and switching characteristics; converter grade and inverter grade and other types; series and parallel operation; comparison of BJT and Thyristor – steady state and dynamic models of BJT &Thyristor- Basics of GTO, MCT, FCT, RCT

UNIT III   VOLTAGECONTROLLEDDEVICES   9
Power MOSFETs and IGBTs – Principle of voltage controlled devices, construction, types, static and switching characteristics, steady state and dynamic models of MOSFET and IGBTs - and IGCT. New semiconductor materials for devices – Intelligent power modules- Integrated gate commutated thyristor (IGCT) - Comparison of all power devices.

UNIT IV   FIRING ANDPROTECTINGCIRCUITS   9
Necessity of isolation, pulse transformer, optocoupler – Gate drives circuit: SCR, MOSFET, IGBTs and base driving for power BJT. - Over voltage, over current and gate protections; Design of snubbers.

UNIT V   THERMALPROTECTION   9
Heat transfer – conduction, convection and radiation; Cooling – liquid cooling, vapour – phase cooling; Guidance for hear sink selection – Thermal resistance and impedance -Electrical

analogy of thermal components, heat sink types and design – Mounting types- switching loss calculation for power device.

TOTAL : 45 PERIODS

OUTCOMES:
- Ability to determine the suitable device for the application.
- Ability to design of semiconductor device and its parameters.
- Ability to design of protection circuits and control circuits
- Ability to determine the reliability of the system.

REFERENCES
1. B.W Williams 'Power Electronics Circuit Devices and Applications'..
2. Rashid M.H., " Power Electronics Circuits, Devices and Applications ", Prentice Hall India, Third Edition, New Delhi,2004
3. MD Singh and K.B Khanchandani, "Power Electronics", Tata McGraw Hill,2001.
4. Mohan, Undeland and Robins, "Power Electronics – Concepts, applications and Design, John Wiley and Sons, Singapore,2000.
5. Joseph Vithayathil, Power Electronics: Principles and Applications, Delhi, Tata McGraw- Hill, 2010.

COURSE CODE	COURSE TITLE	L	T	P	C
PPE1102	ANALYSIS OFELECTRICALMACHINES	3	0	0	3

OBJECTIVES:
- To provide knowledge about the fundamentals of magnetic circuits, energy, force and torque of multi-excited systems.
- To analyze the steady state and dynamic state operation of DC machine through mathematical modeling and simulation in digital computer.
- To provide the knowledge of theory of transformation of three phase variables to two phase variables.
- To analyze the steady state and dynamic state operation of three-phase induction machines using transformation theory based mathematical modeling and digital computer simulation.
- To analyze the steady state and dynamic state operation of three-phase synchronous machines using transformation theory based mathematical modeling and digital computer simulation.

UNIT I PRINCIPLES OF ELECTROMAGNETICENERGY CONVERSION 9
Magnetic circuits, permanent magnet, stored magnetic energy, co-energy - force and torque in singly and doubly excited systems – machine windings and air gap mmf - winding inductances and voltage equations.

UNIT II DCMACHINES 9
Elementary DC machine and analysis of steady state operation - Voltage and torque equations - dynamic characteristics of permanent magnet and shunt d.c. motors – Time domain block diagrams - solution of dynamic characteristic by Laplace transformation – digital computer simulation of permanent magnet and shunt D.C.machines.

UNIT III   REFERENCEFRAME THEORY   9

Historical background – phase transformation and commutator transformation – transformation of variables from stationary to arbitrary reference frame - variables observed from several frames of reference.

UNIT IV   INDUCTIONMACHINES   9

Three phase induction machine, equivalent circuit and analysis of steady state operation – free acceleration characteristics – voltage and torque equations in machine variables and arbitrary reference frame variables – analysis of dynamic performance for load torque variations – digital computer simulation.

UNIT V   SYNCHRONOUSMACHINES   9

Three phase synchronous machine and analysis of steady state operation - voltage and torque equations in machine variables and rotor reference frame variables (Park's equations) – analysis of dynamic performance for load torque variations – Generalized theory of rotating electrical machine and Krons primitive machine.

TOTAL: 45   PERIODS

OUTCOMES:
* Ability to understand the various electrical parameters in mathematical form.
* Ability to understand the different types of reference frame theories and transformation relationships.
* Ability to find the electrical machine equivalent circuit parameters and modeling of electrical machines.

REFERENCES
1. Paul C.Krause, Oleg Wasyzczuk, Scott S, Sudhoff, "Analysis of Electric Machinery and Drive Systems", John Wiley, Second Edition,2010..
2. P S Bimbhra, "Generalized Theory of Electrical Machines", Khanna Publishers,2008
3. A.E, Fitzgerald, Charles Kingsley, Jr, and Stephan D, Umanx, " Electric Machinery", Tata McGraw Hill, 5th Edition,1992
4. R. Krishnan, Electric Motor & Drives: Modeling, Analysis and Control, New Delhi, Prentice Hall of India, 2001

COURSE CODE	COURSE TITLE	L	T	P	C
PPE1103	ANALYSIS AND DESIGN OF POWER CONVERTERS	3	0	0	3

OBJECTIVES:
* To determine the operation and characteristics of controlled rectifiers.
* To apply switching techniques and basic topologies of DC-DC switching regulators.
* To introduce the design of power converter components.
* To provide an in depth knowledge about resonant converters.
* To comprehend the concepts of AC-AC power converters and their applications.

UNIT I   SINGLE PHASE & THREEPHASE CONVERTERS   9

Principle of phase controlled converter operation – single-phase full converter and semi-converter (RL,RLE load)- single phase dual converter – Three phase operation full converter and semi-converter (R,RL,RLE load) – reactive power – power factor improvement techniques – PWM rectifiers.

UNIT II   DC-DCCONVERTERS   9
Limitations of linear power supplies, switched mode power conversion, Non-isolated DC- DC converters: operation and analysis of Buck, Boost, Buck-Boost, Cuk& SEPIC – under continuous and discontinuous operation – Isolated converters: basic operation of Flyback, Forward and Push-pull topologies.

UNIT III DESIGN OF POWERCONVERTERCOMPONENTS   9
Introduction to magnetic materials- hard and soft magnetic materials –types of cores , copper windings – Design of transformer –Inductor design equations –Examples of inductor design for buck/flyback converter-selection of output filter capacitors – selection of ratings for devices – input filter design.

UNIT IV RESONANTDC-DCCONVERTERS   9
Switching loss, hard switching, and basic principles of soft switching- classification of resonant converters- load resonant converters – series and parallel – resonant switch converters – operation and analysis of ZVS, ZCS converters comparison of ZCS/ZVS- Introduction to ZVT/ZCT PWM converters.

UNIT VAC-ACCONVERTERS   9
Principle of on-off and phase angle control – single phase ac voltage controller – analysis with R & RL load – Three phase ac voltage controller – principle of operation of cyclo converter – single phase and three phase cyclo converters – Introduction to matrix converters.

TOTAL : 45 PERIODS

OUTCOMES:
At the end of the course the student will be able to:
- Analyze various single phase and three phase power converters
- Select and design dc-dc converter topologies for a broad range of power conversion applications.
- Develop improved power converters for any stringent application requirements.
- Design ac-ac converters for variable frequency applications.

TEXT BOOKS:
1. Ned Mohan,T.MUndeland and W.P Robbin, "Power Electronics: converters, Application and design" John Wiley and sons.Wiley India edition,2006.
2. Rashid M.H., "Power Electronics Circuits, Devices and Applications ", PrenticeHall India, Third Edition, New Delhi,2004.
3. P.C. Sen, "Modern Power Electronics", Wheeler Publishing Co, First Edition, New Delhi,1998.
4. P.S.Bimbra, "Power Electronics", Khanna Publishers, Eleventh Edition,2003
5. Simon Ang, Alejandro Oliva, "Power-Switching Converters, Second Edition, CRC Press, Taylor & Francis Group,2010
6. V.Ramanarayanan, "Course material on Switched mode power conversion", 2007
7. Alex Van den Bossche and VencislavCekovValchev, "Inductors andTransformersforPowerElectronics", CRC Press, Taylor & Francis Group, 2005
8. W. G. Hurley and W. H.Wolfle, "Transformers and Inductors for Power Electronics Theory, Design and Applications", 2013 John Wiley & SonsLtd.
9. Marian.K.Kazimierczuk and DariuszCzarkowski, "Resonant Power Converters", John Wiley & Sons limited,2011.

COURSE CODE	COURSE TITLE	L	T	P	C
PPE1104	**SYSTEM THEORY**	3	2	0	4

OBJECTIVES:
- To understand the fundamentals of physical systems in terms of its linearand nonlinear models.
- To educate on representing systems in state variable form
- To educate on solving linear and non-linear state equations
- To exploit the properties of linear systems such as controllability and observability
- To educate on stability analysis of systems using Lyapunov's theory
- To educate on modal concepts and design of state and output feedback controllers and estimators

UNIT I   STATEVARIABLE REPRESENTATION   9
Introduction-Concept of State-State equations for Dynamic Systems -Time invariance and linearity- Non uniqueness of state model- Physical Systems and State Assignment - free and forced responses- StateDiagrams.

UNIT II   SOLUTION OFSTATEEQUATIONS   9
Existence and uniqueness of solutions to Continuous-time state equations - Solution of Nonlinear and Linear Time Varying State equations - State transition matrix and its properties – Evaluation of matrix exponential- System modes- Role of Eigen values and Eigenvectors.

UNIT III   STABILITY ANALYSIS OFLINEARSYSTEMS   9
Controllability and Observability definitions and Kalman rank conditions -Stabilizability and Detectability-Test for Continuous time Systems- Time varying and Time invariant case- Output Controllability-Reducibility- System Realizations.

UNIT IV   STATE FEEDBACK CONTROL ANDSTATE ESTIMATOR   9
Introduction-Controllable and Observable Companion Forms-SISO and MIMO Systems- The Effect of State Feedback on Controllability and Observability-Pole Placement by State Feedback for both SISO and MIMO Systems-Full Order and Reduced Order Observers.

UNIT V   LYAPUNOVSTABILTY ANALYSIS   9
Introduction-Equilibrium Points- BIBO Stability-Stability of LTI Systems- Stability in the sense of Lyapunov - Equilibrium Stability of Nonlinear Continuous-Time Autonomous Systems-The Direct Method of Lyapunov and the Linear Continuous-Time Autonomous Systems-Finding Lyapunov Functions for Nonlinear Continuous-Time Autonomous Systems – Krasovskil's and Variable-GradiantMethod.

TOTAL : 45+30 = 75 PERIODS

OUTCOMES:
- Ability to represent the time-invariant systems in state space form as well as analyze, whether the system is stabilizable, controllable, observable and detectable.
- Ability to design state feedback controller and state observers
- Ability to classify singular points and construct phase trajectory using deltaand isocline methods.
- Use the techniques such as describing function, Lyapunov Stability, Popov's Stability Criterion and Circle Criterion to assess the stability of certain class of non-linear system.
- Ability to describe non-linear behaviors such as Limit cycles, input multiplicity and output multiplicity, Bifurcation and Chaos.

`TEXT BOOKS:
1. M. Gopal, "Modern Control System Theory", New Age International,2005.
2. K. Ogatta, "Modern Control Engineering", PHI,2002.
3. John S. Bay, "Fundamentals of Linear State Space Systems", McGraw-Hill,1999.
4. D. Roy Choudhury, "Modern Control Systems", New Age International,2005.
5. John J. D'Azzo, C. H. Houpis and S. N. Sheldon, "Linear Control System Analysisand Designwith MATLAB", Taylor Francis,2003.
6. Z. Bubnicki, "Modern Control Theory", Springer,2005.
7. C.T. Chen, "Linear Systems Theory and Design'' Oxford University Press, 3rd Edition, 1999.
8. M. Vidyasagar, "Nonlinear Systems Analysis', 2nd edition, Prentice Hall, Englewood Cliffs, NewJersey.

COURSE CODE	COURSE TITLE	L	T	P	C
PPE1111	**POWER ELECTRONICCIRCUITSLABORATORY**	**0**	**0**	**4**	**2**

OBJECTIVES
- To provide an insight on the switching behaviours of power electronic switches
- To make the students familiar with the digital tools used in generation of gate pulses for the power electronic switches
- To make the students capable of implementing analog interfacing as well as control circuits used in a closed-loop control for power electronic system
- To make the students acquire knowledge on mathematical modeling of power electronic circuits and implementing the same using simulation tools
- To facilitate the students to design and fabricate a power converter circuits at appreciable voltage/power levels
- To develop skills on PCB design and fabrication among the students

LIST OF EXPERIMENTS
1.Simulation of AC-DC Converters
     i) Single Phase and Three Phase Diode Rectifier
     ii) Single Phase and Three Phase Semi Converter with R and RL load
     iii) Single Phase and Three Phase Full Converter with R and RL load
2.Simulaton of Step up and Step down DC-DC converter
3.Simulation of Buck-Boost and SEPIC DC-DC converter
4.Simulation of DC-AC Inverter
     i) Square Wave Inverter
     ii) Sine PWM Inverter
5.Simulation of AC-AC Converter
     i) Single Phase AC Voltage Regulator
     ii) Single Phase Cyclo converter
6. Generation of PWM gate pulses using digital controller
7. Design of Driver Circuit for MOSFET and IGBT
8.Interfacing Hall effect Current and Voltage sensor with digital controller
9. Construction and testing of 250 W, DC-DC Buck converter and evaluating its efficiency.
10. PCB design and fabrication of DC power supply using any PCB design software .

TOTAL: 60 PERIODS

COURSE OUTCOMES
- Comprehensive understanding on the switching behavior of Power Electronic Switches
- Comprehensive understanding on mathematical modeling of power electronic system and ability to implement the same using simulation tools
    - Ability of the student to use microcontroller and its associated IDE* for power electronic applications
    - Ability of the student to design and implement analog circuits for Power electronic control applications
    - Ability to design and fabricate a power converter circuit at an reasonable power level
    - Exposure to PCB designing and fabrication
    - IDE – Integrate Development Environment (Code Composer Studio for Texas Instrument/MPLAB for PIC microcontrollers etc)

SEMESTER II

COURSE CODE	COURSE TITLE	L	T	P	C
PPE1201	ANALYSIS AND DESIGN OFINVERTERS	3	0	0	3

OBJECTIVES:
- To Provide the electrical circuit concepts behind the different working modes of inverters so as to enable deep understanding of their operation.
- To equip with required skills to derive the criteria for the design of inverters for UPS, drives etc.,
- To analyse and comprehend the various operating modes of different configurations of inverters.
- To design different single phase and three phase inverters.
- To impart knowledge on multilevel inverters and modulation techniques

UNIT I   SINGLE PHASE INVERTERS   9
Principle of operation of half and full bridge inverters – Performance parameters – Voltage control of single phase inverters using various PWM techniques – various harmonic elimination techniques – forced commutated thyristor inverters

UNIT II   THREE PHASE VOLTAGESOURCE INVERTERS   9
180 degree and 120 degree conduction mode inverters with star and delta connected loads – voltage control of three phase inverters: single, multi pulse, sinusoidal, space vector modulation techniques – Application to drive system

UNIT III   CURRENTSOURCE INVERTERS   9
Operation of six-step thyristor inverter – inverter operation modes – load – commutated inverters – Auto sequential current source inverter (ASCI) – current pulsations – comparison of current source inverter and voltage source inverters – PWM techniques for current source inverters.

UNIT IV MULTILEVEL &BOOST INVERTERS   9
Multilevel concept – diode clamped – flying capacitor – cascade type multilevel inverters - Comparison of multilevel inverters - application of multilevel inverters – PWM techniques for MLI – Single phase & Three phase Impedance source inverters.

UNIT V RESONANT INVERTERS ANDPOWER CONDITIONERS **9**

Series and parallel resonant inverters - voltage control of resonant inverters – Class E resonant inverter – resonant DC - link inverters.-power line disturbances-power conditioners-UPS: offline UPS, online UPS.

TOTAL : 45 PERIODS

OUTCOMES:

Students
- Will get expertise in the working modes and operation ofinverters
- Will be able to design single phase and three phaseinverters
- Will equip skills to formulate and design the inverters for generic loads and machine loads
- Will acquire knowledge on multilevel inverters andmodulation techniques

TEXT BOOKS:
1. Rashid M.H., "Power Electronics Circuits, Devices and Applications ",Prentice Hall India, Third Edition, New Delhi,2004.
2. Jai P.Agrawal, "Power Electronics Systems", Pearson Education, SecondEdition, 2002
3. Bimal K.Bose "Modern Power Electronics and AC Drives", Pearson Education, Second Edition, 2003.
4. Ned Mohan,T.MUndeland and W.P Robbin, "Power Electronics: converters, Application and design" John Wiley and sons.Wiley India edition,2006
5. Philip T. krein, "Elements of Power Electronics" Oxford University Press-1998
6. P.C. Sen, "Modern Power Electronics", Wheeler Publishing Co, First Edition, New Delhi,1998
7. P.S.Bimbra, "Power Electronics", Khanna Publishers, Eleventh Edition,2003

COURSE CODE	COURSE TITLE	L	T	P	C
PPE1202	SOLID STATEDRIVES	3	2	0	4

OBJECTIVES:
- To study and analyze the operation of the converter / chopper fed DC drives,both qualitatively andquantitatively.
- To familiarize the students on the operation of VSI and CSI fed inductionmotor drives.
- To understand the field oriented control of inductionmachines.
- To impart knowledge on the control of synchronous motordrives

UNIT I   RECTIFIER CONTROL OFDCDRIVES   **9**

Principle of phase control – Fundamental relations; Analysis of series and separately excited DC motor with single-phase and three-phase converters – waveforms, performance parameters, performance characteristics.

Continuous and discontinuous armature current operations; Current ripple and its effect on performance; Operation with freewheeling diode; Implementation of braking schemes; Drive employing dual converter.

UNIT II   CHOPPER CONTROL OFDCDRIVES   **9**

Introduction to time ratio control and frequency modulation; Class A, B, C, D and E chopper controlled DC motor – performance analysis, multi-quadrant control - Chopper based implementation of braking schemes; Multi-phase chopper; Related problems.

UNIT III   **CONTROL OF INDUCTION MOTOR DRIVES- STATOR SIDE AND ROTORSIDE**   **9**

AC voltage controller circuit – six step inverter voltage control-closed loop variable frequency PWM inverter with dynamic braking-CSI fed variable frequency drives – comparison Static rotor resistance control - injection of voltage in the rotor circuit – static scherbius drives - power factor considerations – modified Kramer drives

UNIT IV   **FIELD ORIENTED CONTROL OF INDUCTIONMOTORDRIVES**   **9**

Field oriented control of induction machines – Theory – DC drive analogy – Direct and Indirect methods – Flux vector estimation - Direct torque control of Induction Machines – Torque expression with stator and rotor fluxes, DTC control strategy.

UNIT V   **SYNCHRONOUSMOTORDRIVES**   **9**

Wound field cylindrical rotor motor – Equivalent circuits – performance equations for operation from a voltage source – starting and braking - V curves - Self control-margin angle control-torque control-power factor control-Brushless excitation systems

TOTAL : 45+30 = 75PERIODS

OUTCOMES:

Students,

- Will be able to formulate, design and analyze power supplies for generic loads and machineloads.
- Will acquire knowledge on the operation of VSI and CSI fed induction motordrives.
- Will get expertise in the field oriented control of Induction motordrives.
- Will be able to formulate the control schemes for synchronous motordrives.

REFERENCES:

1. P.C Sen "Thyristor DC Drives", John wiely and sons, New York,1981
2. Gopal K Dubey, "Power Semiconductor controlled Drives", Prentice Hall Inc.,New Jersy, 1989
3. Gopal K.Dubey, "Fundamentals of Electrical Drives", Narosa Publishing House, New Delhi, Second Edition,2009
4. Bimal K Bose, "Modern Power Electronics and AC Drives", Pearson Education Asia2002.
5. R.Krishnan, "Electric Motor Drives – Modeling, Analysis and Control", Prentice-Hall of India Pvt. Ltd., New Delhi,2010.
6. VedamSubramanyam, "Electric Drives – Concepts and Applications",Tata McGraw-Hill publishing company Ltd., New Delhi,2002
7. W.Leonhard, "Control of Electrical Drives", Narosa Publishing House,1992
8. Murphy J.M.D and Turnbull, "Thyristor Control of AC Motors", Pergamon Press, Oxford,1988.

COURSE CODE	COURSE TITLE	L	T	P	C
PPE1203	SPECIAL ELECTRICAL MACHINES	3	0	0	3

OBJECTIVES:

- To review the fundamental concepts of permanent magnets and the operation of permanent magnet brushless DCmotors.
- To introduce the concepts of permanent magnet brushless synchronous motors and synchronous reluctancemotors.
- To develop the control methods and operating principles of switched reluctancemotors.

- To introduce the concepts of stepper motors and itsapplications.
- To understand the basic concepts of other specialmachines

UNIT I   PERMANENT MAGNET BRUSHLESSDCMOTORS   9
Fundamentals of Permanent Magnets- Types- Principle of operation- Magnetic circuit analysis EMF and Torque equations- Characteristics and control

UNIT II   PERMANENT MAGNETSYNCHROUNOUSMOTORS   9
Principle of operation – EMF and Torque equations - Phasor diagram - Power controllers – Torque speed characteristics – Digital controllers – Constructional features, operating principle and characteristics of synchronous reluctance motor.

UNIT III   SWITCHEDRELUCTANCE MOTORS   9
Constructional features –Principle of operation- Torque prediction–Characteristics-Power controllers – Control of SRM drive- Sensorless operation of SRM – Applications.

UNIT IV   STEPPERMOTORS   9
Constructional features –Principle of operation –Types – Torque predictions – Linear and Non-linear analysis – Characteristics – Drive circuits – Closed loop control –Applications.

UNITV   OTHERSPECIAL MACHINES   9
Principle of operation and characteristics of Hysteresis motor – AC series motors – Linearmotor –   Applications.

TOTAL : 45 PERIODS

OUTCOMES:
- Understand the open loop and closed loop systems steppermotors.
- Understanding the classifications and characteristics of specialmachines
- Understanding of the control methods of specialmotors.
- Ability to select the suitable motor for a certain job under givenconditions

REFERENCES
1. T.J.E. Miller, 'Brushless magnet and Reluctance motor drives', Claredon press, London, 1989.
2. R.Krishnan, ' Switched Reluctance motor drives' , CRC press,2001.
3. T.Kenjo, ' Stepping motors and their microprocessor controls', Oxford University press, New Delhi,2000
4. T.Kenjo and S.Nagamori, 'Permanent magnet and Brushless DC motors', Clarendon press, London,1988
5. R.Krishnan, ' Electric motor drives' , Prentice hall ofIndia,2002.
6. D.P.Kothari and I.J.Nagrath, ' Electric machines', Tata Mc Graw hill publishing company, New Delhi, Third Edition,2004.
7. Irving L.Kosow, "Electric Machinery and Transformers" Pearson Education, Second Edition, 2007.

COURSE CODE	COURSE TITLE	L	T	P	C
PPE1204	POWERQUALITY	3	0	0	3

OBJECTIVES:
- To understand the various power qualityissues.
- To understand the concept of power and power factor in single phase and three phase

- systems supplying nonlinear loads.
- To understand the conventional compensation techniques used for power factor correction and load voltage regulation.
- To understand the active compensation techniques used for power factor correction.
- To understand the active compensation techniques used for load voltage regulation.

UNIT I   INTRODUCTION   9
Introduction – Characterisation of Electric Power Quality: Transients, short duration and long duration voltage variations, Voltage imbalance, waveform distortion, Voltage fluctuations, Power frequency variation, Power acceptability curves – power quality problems: poor load power factor, Non linear and unbalanced loads, DC offset in loads, Notching in load voltage, Disturbance in supply voltage – Power quality standards.

UNIT II   ANALYSIS OF SINGLE PHASE AND THREEPHASE SYSTEM   9
Single phase sinusoidal, non sinusoidal source supplying linear and nonlinear loads – Three phase Balance system – Three phase unbalanced system – Three phase unbalanced and distorted source supplying non linear loads – Concept of PF – Three phase three wire – Three phase four wire system.

UNIT III   CONVENTIONAL LOADCOMPENSATIONMETHODS   9
Principle of Load compensation and Voltage regulation – Classical load balancing problem : Open loop balancing – Closed loop balancing, Current balancing – Harmonic reduction and voltage sag reduction – Analysis of unbalance – instantaneous real and reactive powers – Extraction of fundamental sequence component.

UNIT IV   LOAD COMPENSATIONUSINGDSTATCOM   9
Compensating single phase loads – Ideal three phase shunt compensator structure – Generating reference currents using instantaneous PQ theory – Instantaneous symmetrical components theory – Generating reference currents when the source is unbalanced – Realization and control of DSTATCOM – DSTATCOM in Voltage control mode.

UNIT V   SERIES COMPENSATION OF POWERDISTRIBUTIONSYSTEM   9
Rectifier supported Dynamic Voltage Restorer – DC Capacitor supported DVR – DVR Structure – voltage Restoration – Series Active Filter – Unified Power Quality Conditioner.

TOTAL : 45 PERIODS

OUTCOMES:
- Ability to formulate, design and simulate power supplies for generic load and machine loads.
- Ability to conduct harmonic analysis and load tests on power supplies and drive systems.
- Ability to understand and design load compensation methods useful for mitigating power quality problems.

TEXT BOOKS:
1. Arindam Ghosh "Power Quality Enhancement Using Custom Power Devices", Kluwer Academic Publishers, 2002
2. R.C. Duggan, Mark.F.Mc Granaghan, SuryaSantoas and H.WayneBeaty, "Electrical Power System Quality", McGraw-Hill, 2004.
3. G.T.Heydt, "Electric Power Quality", Stars in a Circle Publications,1994.
4. Bhim Singh, Ambrish Chandra, Kamal Al-Haddad , "Power Quality: Problems and
5. Mitigation Techniques", John Wiley &Sons,2015.

REFERENCES
1. Jos Arrillaga and Neville R. Watson ," Power systemharmonics",Wiley,2003.
2. Derek A. Paice , "Power Electronics Converter Harmonics :Multipulse Methods for Clean Power",Wiley,1999.
3. Ewald Fuchs, Mohammad A. S. Masoum Power Quality in Power Systems and Electrical
4. Machines,Elseveir academic presspublications,2011.

COURSE CODE	COURSE TITLE	L	T	P	C
PPE1211	**ELECTRICAL DRIVES LABORATORY**	0	0	4	2

OBJECTIVES:
To impart the theoretical and practical knowledge on
- To design and analyse the various DC and AC drives.
- To generate the firing pulses for converters and inverters using digital processors
- Design of controllers for linear and nonlinear systems
- Implementation of closed loop system using hardware simulation

LIST OF EXPERIMENTS
1. Speed control of Converter fed DC motor.
2. Speed control of Three-phase induction motor.
3. Speed control of BLDC motor.
4. Speed control of SRM motor.
5. Speed control of Synchronous Reluctance motor.
6. Voltage Regulation of three-phase Synchronous Generator.
7. Micro controller based speed control of Stepper motor.
8. Study of power quality analyzer
9. Simulation of Closed Loop Control of Chopper fed DC Motor
10. Simulation of V/f Control of Induction Motor

TOTAL: 60 PERIODS

OUTCOMES:
- Ability to simulate different types of machines, converters in a system.
- Analyze the performance of various electric drive systems.
- Ability to perform both hardware and software simulation.

COURSE CODE	COURSE TITLE	L	T	P	C
PPE1217	**MINI PROJECT**	0	0	4	2

OBJECTIVES:
- To develop the ability to solve a specific problem right from its identification and literature review till the successful solution of the same.
- To train the students in preparing project reports and to face reviews and viva voce examination.

A project to be developed based on one or more of the following concepts.
1.   Rectifiers, DC-DC Converters, Inverters, cyclo converters, DC drives, AC drives,

Special Electrical Machines, Renewable Energy Systems, Linear and non-linear control systems, Power supply design for industrial and other applications, AC-DC power factor circuits, micro grid, smart grid and robotics.

TOTAL: 60 PERIODS

OUTCOMES:
- Acquire practical knowledge within the chosen area of technology forproject development
- Identify, analyze, formulate and handle programming projects with a comprehensive and systematic approach
- Contribute as an individual or in a team in development of technical projects
- Develop effective communication skills for presentation of project related activities

COURSE CODE	COURSE TITLE	L	T	P	C
PPE1121	**SOFT COMPUTING TECHNIQUES**	3	0	0	3

OBJECTIVES:
- To expose the concepts of feed forward neural networks.
- To provide adequate knowledge about feed back neural networks.
- To teach about the concept of fuzziness involved in various systems.
- To expose the ideas about genetic algorithm
- To provide adequate knowledge about of FLC and NNtoolbox

UNIT I   INTRODUCTION AND ARTIFICIALNEURALNETWORKS   9
Introduction to intelligent systems- Soft computing techniques- Conventional Computing versus Swarm Computing - Classification of meta-heuristic techniques - Properties of Swarm intelligent Systems - Application domain - Discrete and continuous problems - Single objective and multi-objective problems -Neuron- Nerve structure and synapse- Artificial Neuron and its model- activation functions- Neural network architecture- single layer and multilayer feed forward networks- Mc Culloch Pitts neuron model- perceptron model- Adaline and Madaline- multilayer perception model- back propogation learning methods- effect of learning rule coefficient -back propagation algorithm- factors affecting back propagation training- applications.

UNIT II   ARTIFICIAL   NEURAL   NETWORKS   ANDASSOCIATIVEMEMORY   9
Counter propagation network- architecture- functioning & characteristics of counter Propagation network- Hopfield/ Recurrent network configuration - stability constraints associative memory and characteristics- limitations and applications- Hopfield v/s Boltzman machine- Adaptive Resonance Theory- Architecture- classifications- Implementation and training - Associative Memory.

UNIT III FUZZYLOGICSYSTEM   9
Introduction to crisp sets and fuzzy sets- basic fuzzy set operation and approximate reasoning. Introduction to fuzzy logic modeling and control- Fuzzification inferencing and defuzzification- Fuzzy knowledge and rule bases-Fuzzy modeling and control schemes for nonlinear systems. Self organizing fuzzy logic control- Fuzzy logic control for nonlinear time delay system.

UNIT IVGENETICALGORITHM   **9**

Evolutionary programs – Genetic algorithms, genetic programming and evolutionary programming - Genetic Algorithm versus Conventional Optimization Techniques - Genetic representations and selection mechanisms; Genetic operators- different types of crossover and mutation operators - Optimization problems using GA-discrete and continuous - Single objective and multi-objective problems - Procedures in evolutionary programming.

UNIT V   HYBRIDCONTROL SCHEMES   **9**

Fuzzification and rule base using ANN–Neuro fuzzy systems-ANFIS – Fuzzy Neuron - Optimization of membership function and rule base using Genetic Algorithm –Introduction to Support Vector Machine- Evolutionary Programming-Particle Swarm Optimization - Case study – Familiarization of NN, FLC and ANFIS Tool Box.

TOTAL : 45 PERIODS

OUTCOMES:
- Will be able to know the basic ANN architectures, algorithms and their limitations.
- Also will be able to know the different operations on the fuzzy sets.
- Will be capable of developing ANN based models and control schemes for non-linear system.
- Will get expertise in the use of different ANN structures and online training algorithm.
- Will be knowledgeable to use Fuzzy logic for modeling and control of non-linear systems.
- Will be competent to use hybrid control schemes and P.S.O and support vector Regressive.

TEXT BOOKS:
1. Laurene V. Fausett, "Fundamentals of Neural Networks: Architectures, Algorithms And Applications", Pearson Education.
2. Timothy J. Ross, "Fuzzy Logic with Engineering Applications" Wiley India,2008.
3. Zimmermann H.J. "Fuzzy set theory and its Applications" Springer international edition, 2011.
4. David E.Goldberg, "Genetic Algorithms in Search, Optimization, and Machine Learning", Pearson Education,2009.
5. W.T.Miller, R.S.Sutton and P.J.Webrose, "Neural Networks for Control" MIT Press", 1996.
6. T. Ross, "Fuzzy Logic with Engineering Applications", Tata McGraw Hill, New Delhi, 1995.
7. Ethem Alpaydin, "Introduction to Machine Learning (Adaptive Computation and Machine Learning Series)", MIT Press,2004.
8. Corinna Cortes and V. Vapnik, " Support - Vector Networks, Machine Learning "1995.

COURSE CODE	COURSE TITLE	L	T	P	C
PPE1122	**ELECTROMAGNETIC FIELD COMPUTATIONANDMODELLING**	3	0	0	3

OBJECTIVES:
- To refresh the fundamentals of Electromagnetic Field Theory.
- To provide foundation in formulation and computation of Electromagnetic Fields using analytical and numerical methods.
- To impart in-depth knowledge on Finite Element Method in solving Electromagnetic field problems.

- To introduce the concept of mathematical modeling and design of electrical apparatus.

UNIT I   INTRODUCTION   9

Review of basic field theory – Maxwell's equations – Constitutive relationships and Continuity equations – Laplace, Poisson and Helmholtz equation – principle of energy conversion – force/torque calculation.

UNIT II   BASIC SOLUTION METHODS FORFIELDEQUATIONS   9

Limitations of the conventional design procedure, need for the field analysis based design, problem definition, boundary conditions, solution by analytical methods-direct integration method – variable separable method – method of images, solution by numerical methods- Finite Difference Method.

UNIT III   FORMULATION OF FINITE ELEMENTMETHOD(FEM)   9

Variational Formulation – Energy minimization – Discretization – Shape functions –Stiffness matrix –1D and 2D planar and axial symmetry problems.

UNIT IV   COMPUTATION OF BASIC QUANTITIES USINGFEM PACKAGES   9

Basic quantities – Energy stored in Electric Field – Capacitance – Magnetic Field – Linked Flux – Inductance – Force – Torque – Skin effect –Resistance.

UNIT V   DESIGNAPPLICATIONS   9

Design of Insulators – Cylindrical magnetic actuators – Transformers – Rotating machines

TOTAL : 45 PERIODS

OUTCOMES:
- Understand the concepts of electromagnetic.
- Ability to formulate the FEM method and use of the package
- Apply the concepts in the design of rotating machines

REFERENCES
1. Matthew. N.O. Sadiku, "Elements of Electromagnetics", Fourth Edition, Oxford University Press, First Indian Edition2007
2. K.J.Binns, P.J.Lawrenson, C.W Trowbridge, "The analytical and numerical solution of Electric and magnetic fields", John Wiley & Sons,1993.
3. Nicola Biyanchi , "Electrical Machine analysis using Finite Elements", Taylor and Francis Group, CRC Publishers, 2005.4
4. Nathan Ida, Joao P.A.Bastos, "Electromagnetics and calculation of fields", SpringerVerlage,1992.
5. S.J Salon, "Finite Element Analysis of Electrical Machines" Kluwer Academic Publishers, London, 1995, distributed by TBH Publishers & Distributors, Chennai, India
6. .Silvester and Ferrari, "Finite Elements for Electrical Engineers" Cambridge University press,1983.

COURSE CODE	COURSE TITLE	L	T	P	C
PPE1123	**CONTROL SYSTEM DESIGN FORPOWER ELECTRONICS**	3	0	0	3

OBJECTIVES:
- To explore conceptual bridges between the fields of Control Systems and Power Electronics
- To Study Control theories and techniques relevant to the design of feedback controllers in Power Electronics

UNIT I   MODELLING OF DC-TO-DCPOWERCONVERTERS   9
Modelling of Buck Converter , Boost Converter ,Buck-Boost Converter, Cuk Converter ,Sepic Converter, Zeta Converter, Quadratic Buck Converter ,Double Buck-Boost Converter, Boost-Boost Converter General Mathematical Model for Power Electronics Devices

UNIT II   SLIDING MODECONTROLLERDESIGN   9
Variable Structure Systems. Single Switch Regulated Systems Sliding Surfaces, Accessibility of the Sliding SurfaceSliding Mode Control Implementation of Boost Converter ,Buck-Boost Converter, Cuk Converter ,Sepic Converter, Zeta Converter, Quadratic Buck Converter ,Double Buck-Boost Converter, Boost-Boost Converter

UNIT III   APPROXIMATE LINEARIZATIONCONTROLLERDESIGN   9
Linear Feedback Control, Pole Placement by Full State Feedback , Pole Placement Based on Observer Design ,Reduced Order Observers , Generalized Proportional Integral Controllers, Passivity Based Control , Sliding Mode Control Implementation of Buck Converter , Boost Converter ,Buck-Boost Converter

UNIT IV   NONLINEARCONTROLLERDESIGN   9
Feedback Linearization Isidori's Canonical Form ,Input-Output Feedback Linearization ,State Feedback Linearization, Passivity Based Control , Full Order Observers , Reduced Order Observers

UNIT V   PREDICTIVE CONTROL OFPOWERCONVERTERS   9
Basic Concepts, Theory, and Methods, Application of Predictive Control in Power Electronics, AC-DC-AC Converter System, Faults and Diagnosis Systems in Power Converters.
TOTAL : 45 PERIODS

OUTCOMES:
- Ability to understand an overview on modern linear and nonlinear control strategies for power electronics devices
- Ability to model modern power electronic converters for industrialapplications
- Ability to design appropriate controllers for modern power electronicsdevices.

REFERENCES
1. HeberttSira-Ramírez PhD, Ramón Silva-Ortigoza, "Control Design Techniques in Power Electronics Devices", Springer2012
2. Mahesh Patil, PankajRodey, "Control Systems for Power Electronics: A Practical Guide", Springer India,2015.
3. Blaabjerg José Rodríguez, "Advanced and Intelligent Control in Power Electronics and Drives" , Springer,2014
4. Enrique Acha, VassiliosAgelidis, Olimpo Anaya, TJE Miller, "Power Electronic Control in Electrical Systems", Newnes,2002
5. Marija D. Aranya Chakrabortty, Marija , "Control and Optimization Methods for Electric Smart Grids", Springer,2012.

COURSE CODE	COURSE TITLE	L	T	P	C
PPE1221	ANALOG ANDDIGITALCONTROLLERS	3	0	0	3

OBJECTIVES
- To provide a overview of the control system and converter control methodologies
- To provide an insight to the analog controllers generally used in practice

- To introduce Embedded Processers for Digital Control
- To study on the driving techniques, isolation requirements, signal conditioning and protection methods
- To provide a Case Study by implementing an analog and a digital controller on a converter

UNIT I   CONTROL SYSTEM-OVERVIEW   9

Feedback and Feed-forward control, Right Half Plane Zero, Gain margin and Phase Margin, Stability, Analysis and Transfer function of PI and PID controllers and its effects. Voltage mode control, Peak Current mode Control, Average Current mode Control for Converters – Need, advantages and disadvantages.

UNIT II   ANALOGCONTROLLERS   9

Major components of a controller – Op-Amp based PI and PID controller – Proportional, Integral and Differential gains in terms of Resistance and Capacitance, Error Amplifiers, PWM generator using Ramp or Triangular generator and comparator, and Driver, Voltage mode controller design using UC3524, Peak Current mode controller design using UC3842, Average Current mode controller design using UC3854.

UNIT III   DIGITALCONTROLLERS   9

Micro Controllers and Digital Signal Controllers for Converter Control Application, Interface Modules for Converter Control – A/D, Capture, Compare and PWM, Analog Comparators for instantaneous over current detection, interrupts, Discrete PI and PID equations, Algorithm for PI and PID implementation, Example Code for PWM generation.

UNIT IV   SIGNAL   CONDITIONING,   DRIVER,   ISOLATIONANDPROTECTION
**   9**

Voltage feedback sensing circuits, Hall effect sensors and Shunts for current feedback sensing, Low offset Op-Amps for signal conditioning, Single and dual supply op-amps, Totem pole drivers, Need for isolated drivers, Optically isolated drivers, low side drivers, high side drivers with bootstrap power supply, Vce sat sensing, CT based Device current sensing and pulse blocking.

UNIT V   CONTROLLERIMPLEMENTATION   9

Analog and Digital Controller Design for Buck Converter – Power circuit transfer function and bode plot, PI controller bode plot, Combined bode plot with required Gain and Phase margins, Implementation of Analog controller and Digital controller.

**   TOTAL : 45 PERIODS**

REFERENCES
1. I.J. Nagrath and M. Gopal, "Control Systems Engineering", New Age International Publishers
2. TI Application notes, Reference Manuals and Data Sheets.
3. Agilent Data Sheets
4. Microchip Application notes, Reference Manuals and Data Sheets.

COURSE CODE	COURSE TITLE	L	T	P	C
PPE1222	**FLEXIBLE AC TRANSMISSION SYSTEMS**	3	0	0	3

OBJECTIVES:
- To emphasis the need for FACTS controllers.

- To learn the characteristics, applications and modelling of series and shunt FACTS controllers.
- To analyze the interaction of different FACTS controller and perform control coordination

UNIT I INTRODUCTION 9

Review of basics of power transmission networks-control of power flow in AC transmission line Analysis of uncompensated AC Transmission line- Passive reactive power compensation: Effect of series and shunt compensation at the mid-point of the line on power transfer- Need for FACTS controllers- types of FACTS controllers.

UNIT II STATIC VARCOMPENSATOR(SVC) 9

Configuration of SVC- voltage regulation by SVC- Modelling of SVC for load flow analysis Modelling of SVC for stability studies-Design of SVC to regulate the mid-point voltage of a SMIB system- Applications: transient stability enhancement and power oscillation damping of SMIB system with SVC connected at the mid-point of the line.

UNIT III THYRISTOR AND GTO THYRISTOR CONTROLLED SERIES CAPACITORS 9 (TCSC andGCSC)

Concepts of Controlled Series Compensation – Operation of TCSC and GCSC- Analysis of TCSC-GCSC – Modelling of TCSC and GCSC for load flow studies- modeling TCSC and GCSC for stability studied- Applications of TCSC andGCSC.

UNIT IV VOLTAGE SOURCE CONVERTER BASEDFACTSCONTROLLERS 9

Static synchronous compensator(STATCOM)- Static synchronous series compensator(SSSC)-Operation of STATCOM and SSSC-Power flow control with STATCOM and SSSC- Modelling of STATCOM and SSSC for power flow and transient stability studies –operation of Unified and Interline power flow controllers(UPFC and IPFC)- Modelling of UPFC and IPFC for load flow and transient stability studies- Applications.

UNIT V CONTROLLERS ANDTHEIRCOORDINATION 9

FACTS Controller interactions – SVC–SVC interaction - co-ordination of multiple controllers using linear control techniques – Quantitative treatment of control coordination.

TOTAL : 45 PERIODS

OUTCOMES:
- Ability to understand the operation of the compensator and its applications in power system.
- Ability to understand the various emerging Facts controllers.
- Ability to know about the genetic algorithm used in Facts controller coordination.

REFERENCES
1. A.T.John, "Flexible AC Transmission System", Institution of Electrical and Electronic Engineers (IEEE),1999.
2. NarainG.Hingorani, Laszio. Gyugyl, "Understanding FACTS Concepts and Technology of Flexible AC Transmission System", Standard Publishers, Delhi2001.
3. V. K.Sood, "HVDC and FACTS controllers- Applications of Static Converters in Power System", 2004, Kluwer Academic Publishers.
4. Mohan Mathur, R., Rajiv. K. Varma, "Thyristor – Based Facts Controllers for Electrical Transmission Systems", IEEE press and John Wiley & Sons,Inc.
5. K.R.Padiyar," FACTS Controllers in Power Transmission and Distribution", New Age International(P) Ltd., Publishers New Delhi, Reprint2008,

COURSE CODE	COURSE TITLE	L	T	P	C
PPE1223	MODERN RECTIFIERS AND RESONANT CONVERTERS	3	0	0	3

OBJECTIVES:
- To gain knowledge about the harmonics standards and operation of rectifiers in CCM & DCM.
- To analyze and design power factor correction rectifiers for UPS applications.
- To know the operation of resonant converters for SMPS applications.
- To carry out dynamic analysis of DC- DC Converters.
- To introduce the source current shaping methods for rectifiers

UNIT I   POWER SYSTEM HARMONICS & LINECOMMUTATEDRECTIFIERS
9

Average power-RMS value of waveform–Effect of Power factor-. current and voltage harmonics – Effect of source and load impedance - AC line current harmonic standards IEC1000-IEEE 519-CCM and DCM operation of single phase full wave rectifier- Behaviour of full wave rectifier for large and small values of capacitance - CCM and DCM operation of three phase full wave rectifier- 12 pulse converters - Harmonic trap filters.

UNIT II   PULSE WIDTHMODULATEDRECTIFIERS   9
Properties of Ideal single phase rectifiers-Realization of nearly ideal rectifier-. Single-phase converter systems incorporating ideal rectifiers - Losses and efficiency in CCM high quality rectifiers -single-phase PWM rectifier -PWM concepts - device selection for rectifiers - IGBT based PWM rectifier, comparison with SCR based converters with respect to harmonic content -applications of rectifiers.

UNIT III   RESONANTCONVERTERS   9
Soft Switching - classification of resonant converters - Quasi resonant converters- basics of ZVS and ZCS- half wave and full wave operation (qualitative treatment) - multi resonant converters - operation and analysis of ZVS and ZCS multi resonant converter - zero voltage transition PWM converters -zero current transition PWM converters

UNIT IV   DYNAMIC ANALYSIS OFSWITCHINGCONVERTERS   9
Review of linear system analysis-State Space Averaging-Basic State Space Average Model-StateSpace Averaged model for an ideal Buck Converter, ideal Boost Converter, ideal Buck BoostConverter and an ideal Cuk Converter. Pulse Width modulation - Voltage Mode PWM Scheme - Current Mode PWM Scheme - design of PI controller.

UNIT V   SOURCE CURRENT SHAPINGOF RECTIFIERS   9
Need for current shaping - power factor - functions of current shaper - input current shaping methods - passive shaping methods -input inductor filter - resonant input filter - active methods - boost rectifier employing peak current control - average current control - Hysteresis control-Nonlinear carrier control.

TOTAL 45 PERIODS

OUTCOMES:
After completion of this course, the student will be able to:
- Apply the concept of various types of rectifiers.
- Simulate and design the operation of resonant converter and its importance.
- Identify the importance of linear system, state space model, PI controller.

- Design the DC power supplies using advanced techniques.
- Understand the standards for supply current harmonics and its significance.

REFERENCES
1. Robert W. Erickson and Dragon Maksimovic, "Fundamentals of Power Electronics", Second Edition, Springer science and Business media,2001.
2. William Shepherd and Li zhang, "Power Converters Circuits", MarceldEkkerin,C,2005.
3. Simon Ang and Alejandro Oliva, "Power Switching Converters", Taylor & Francis Group, 2010.
4. Andrzej M. Trzynadlowski, " Introduction To Modern Power Electronics", John Wiley & Sons, 2016.
5. Marian.K.Kazimierczuk and Dariusz Czarkowski, "Resonant Power Converters", John Wiley & Sons limited,2011.
6. Keng C .Wu, "Switch Mode Power Converters – Design and Analysis" Elseveir academic press,2006.
7. Abraham I.Pressman, Keith Billings and Taylor Morey, " Switching Power Supply Design" McGraw-Hill,2009
8. V.Ramanarayanan, "Course Material on Switched Mode Power Conversion" IISC, Banglore, 2007.
9. Christophe P. Basso, Switch-Mode Power Supplies, McGraw-Hill,2014

COURSE CODE	COURSE TITLE	L	T	P	C
PPE1224	ELECTROMAGNETIC INTERFERENCE AND COMPATIBILITY	3	0	0	3

OBJECTIVES:
- To provide fundamental knowledge on electromagnetic interference and
- electromagnetic compatibility.
- To study the important techniques to control EMI andEMC.
- To expose the knowledge on testing techniques as per Indian and international standards in EMImeasurement.

UNIT I INTRODUCTION   9
Definitions of EMI/EMC -Sources of EMI- Intersystems and Intrasystem- Conducted and radiated interference- Characteristics - Designing for electromagnetic compatibility (EMC)- EMC regulation typical noise path- EMI predictions and modeling, Cross talk - Methods of eliminating interferences.

UNIT II GROUNDINGANDCABLING   9
Cabling- types of cables, mechanism of EMI emission / coupling in cables –capacitive coupling inductive coupling- shielding to prevent magnetic radiation- shield transfer impedance, Grounding – safety grounds – signal grounds- single point and multipoint ground systemshybrid grounds- functional ground layout –grounding of cable shields- -guard shields- isolation, neutralizing transformers, shield grounding at high frequencies, digital grounding- Earth measurement Methods

UNIT III BALANCING, FILTERINGANDSHIELDING   9
Power supply decoupling- decoupling filters-amplifier filtering –high frequency filtering- EMI filters characteristics of LPF, HPF, BPF, BEF and power line filter design -Choice of capacitors, inductors, transformers and resistors, EMC design components -shielding – near and far fields

shielding effectiveness- absorption and reflection loss- magnetic materials as a shield, shield discontinuities, slots and holes, seams and joints, conductive gaskets-windows and coatings - grounding of shields

UNIT IV EMI IN ELEMENTSANDCIRCUITS **9**

Electromagnetic emissions, noise from relays and switches, non-linearities in circuits, passive inter modulation, transients in power supply lines, EMI from power electronic equipment, EMI as combination of radiation and conduction

**UNITV ELECTROSTATIC DISCHARGE, STANDARDSANDTESTING 9
TECHNIQUES**

Static Generation- human body model- static discharges- ESD versus EMC, ESD protection in equipments- standards – FCC requirements – EMI measurements – Open area test site measurements and precautions- Radiated and conducted interference measurements, Control requirements and testing methods

TOTAL : 45 PERIODS

OUTCOMES:
- Recognize the sources of Conducted and radiated EMI in Power Electronic Converters and consumer appliances and suggest remedial measures to mitigate the problems
- Assess the insertion loss and design EMI filters to reduce the loss
- Design EMI filters, common-mode chokes and RC-snubber circuits measures to keep the interference within tolerable limits

REFERENCES
1. V.P. Kodali, "Engineering Electromagnetic Compatibility", S. Chand,1996
2. Henry W.Ott, " Noise reduction techniques in electronic systems", John Wiley & Sons, 1989
3. Bernhard Keiser, "Principles of Electro-magnetic Compatibility", Artech House, Inc. (685 canton street, Norwood, MA 020062 USA)1987
4. Bridges, J.E Milleta J. and Ricketts.L.W., "EMP Radiation and Protective techniques", John Wiley and sons, USA1976
5. William Duff G., & Donald White R. J, "Series on Electromagnetic Interference and Compatibility", Vol.
6. Weston David A., "Electromagnetic Compatibility, Principles and Applications",1991.

COURSE CODE	COURSE TITLE	L	T	P	C
PPE1225	**MEMS TECHNOLOGY**	**3**	**0**	**0**	**3**

COURSE OBJECTIVES
- To teach the students properties of materials ,microstructure and fabrication methods.
- To teach the design and modeling of Electrostatic sensors and actuators.
- To teach the characterizing thermal sensors and actuators through design and modeling
- To teach the fundamentals of piezoelectric sensors and actuators through exposure to different MEMS and NEMS devices
- To involve Discussions/ Practice/Exercise onto revising & familiarizing the concepts acquired over the 5 Units of the subject for improved employability skills

UNIT I   MICRO-FABRICATION, MATERIALS AND ELECTRO-MECHANICAL
**   CONCEPTS   9**
Overview of micro fabrication – Silicon and other material based fabrication processes – Concepts: Conductivity of semiconductors-Crystal planes and orientation-stress and strain-flexural beam bending analysis-torsional deflections-Intrinsic stress- resonant frequency and quality factor.

UNIT II   ELECTROSTATIC SENSORSANDACTUATION   9
Principle, material, design and fabrication of parallel plate capacitors as electrostatic sensors and actuators-Applications

UNIT III   THERMAL SENSINGANDACTUATION   9
Principle, material, design and fabrication of thermal couples, thermal bimorph sensors, thermal resistor sensors-Applications.

UNIT IV   PIEZOELECTRIC SENSINGANDACTUATION   9
Piezoelectric effect-cantilever piezoelectric actuator model-properties of piezoelectric materials-Applications.

UNIT V   CASE STUDIES   9
Piezoresistive sensors, Magnetic actuation, Micro fluidics applications, Medical applications, Optical MEMS.-NEMS Devices
Note: Class room discussions and tutorials can include the following guidelines for improved teaching /learning process: Discussions/Exercise/Practice on Workbench: on the basics /device model design aspects of thermal/peizo/resistive sensors etc.
**   TOTAL : 45 PERIODS**
OUTCOMES :
After the completion of this course the student will be able to:
- Understand basics of micro fabrication, develop models and simulate electrostatic and electromagnetic sensors and actuators
- Understand material properties important for MEMS system performance, analyze dynamics of resonant micromechanical structures
- The learning process delivers insight onto design of micro sensors, embedded sensors & actuators in power aware systems like grid.
- Understand the design process and validation for MEMS devices and systems, and learn the state of the art in optical micro systems
- Improved Employability and entrepreneurship capacity due to knowledge up gradation on recent trends in embedded systems design.

REFERENCES
1. Chang Liu, "Foundations of MEMS", Pearson International Edition,2006.
2. Marc Madou , "Fundamentals of microfabrication",CRC Press,1997.
3. Boston , "Micromachined Transducers Sourcebook",WCB McGraw Hill,1998.
4. M.H.Bao "Micromechanical transducers :Pressure sensors, accelerometers andgyroscopes", Elsevier, Newyork,2000.

COURSE CODE	COURSE TITLE	L	T	P	C
PPE1226	DISTRIBUTED GENERATION AND MICROGRID	3	0	0	3

OBJECTIVES:
- To illustrate the concept of distributed generation
- To analyze the impact of grid integration.
- To study concept of Microgrid and its configuration

UNIT I   INTRODUCTION   9
Conventional power generation: advantages and disadvantages, Energy crises, Non-conventional energy (NCE) resources: review of Solar PV, Wind Energy systems, Fuel Cells, micro-turbines, biomass, and tidal sources.

UNIT II   DISTRIBUTEDGENERATIONS (DG)   9
Concept of distributed generations, topologies, selection of sources, regulatory standards/ framework, Standards for interconnecting Distributed resources to electric power systems: IEEE 1547. DG installation classes, security issues in DG implementations. Energy storage elements: Batteries, ultra-capacitors, flywheels. Captive power plants

UNIT III   IMPACT OFGRIDINTEGRATION   9
Requirements for grid interconnection, limits on operational parameters,: voltage, frequency, THD, response to grid abnormal operating conditions, islanding issues. Impact of grid integration with NCE sources on existing power system: reliability, stability and power quality issues.

UNIT IV   BASICS OFAMICROGRID   9
Concept and definition of microgrid, microgrid drivers and benefits, review of sources of microgrids, typical structure and configuration of a microgrid, AC and DC microgrids, Power Electronics interfaces in DC and AC microgrids

UNIT V   CONTROL AND OPERATIONOFMICROGRID   9
Modes of operation and control of microgrid: grid connected and islanded mode, Active and reactive power control, protection issues, anti-islanding schemes: passive, active and communication based techniques, microgrid communication infrastructure, Power quality issues in microgrids, regulatory standards, Microgrid economics, Introduction to smart microgrids.

TOTAL: 45   PERIODS

OUTCOMES:
- Learners will attain knowledge on the various schemes of conventional and nonconventional power generation.
- Learners will have knowledge on the topologies and energy sources of distributed
- generation.
- Learnerswilllearnabouttherequirementsforgridinterconnectionanditsimpactwith NCE sources
- Learners will understand the fundamental concept of Microgrid.

REFERENCES
1. Amirnaser Yezdani, and Reza Iravani, "Voltage Source Converters in Power Systems: Modeling, Control and Applications", IEEE John Wiley Publications,2010.
2. DorinNeacsu, "Power Switching Converters: Medium and High Power", CRCPress,

Taylor & Francis,2006

3. Chetan Singh Solanki, "Solar Photo Voltaics", PHI learning Pvt. Ltd., NewDelhi,2009
4. J.F. Manwell, J.G. McGowan "Wind Energy Explained, theory designand applications", Wiley publication2010.
5. D. D. Hall and R. P. Grover, "Biomass Regenerable Energy", John Wiley, NewYork, 1987.
6. John Twidell and Tony Weir, "Renewable Energy Resources" Tyalor and Francis Publications, Second edition 2006.

COURSE CODE	COURSE TITLE	L	T	P	C
PPE1321	HIGH VOLTAGE DIRECT CURRENT TRANSMISSION	3	0	0	3

OBJECTIVES

- To impart knowledge on operation, modelling and control of HVDC link.
- To perform steady state analysis of AC/DC system.
- To expose various HVDC simulators.

UNIT I   DC POWER TRANSMISSION TECHNOLOGY   9

Introduction - Comparison of AC and DC transmission – Application of DC transmission – Description of DC transmission system - Planning for HVDC transmission – Modern trends in DC transmission – DC breakers – Cables, VSC based HVDC

UNIT II THYRISTOR BASED HVDC CONVERTERS AND HVDC SYSTEM CONTROL   9

Pulse number, choice of converter configuration – Simplified analysis of Graetz circuit - Converter bridge characteristics – characteristics of a twelve pulse converter- detailed analysis of converters. General principles of DC link control – Converter control characteristics – System control hierarchy - Firing angle control – Current and extinction angle control – Generation of harmonics and filtering - power control – Higher level controllers-Valve tests.

UNIT III MULTITERMINAL DC SYSTEMS   9

Introduction – Potential applications of MTDC systems - Types of MTDC systems - Control and protection of MTDC systems - Study of MTDC systems.

UNIT IV POWER FLOW ANALYSIS IN AC/DC SYSTEMS   9

Per unit system for DC Quantities - Modelling of DC links - Solution of DC load flow - Solution of AC-DC power flow – Unified, Sequential and Substitution of power injection method

UNIT V SIMULATION OF HVDC SYSTEMS   9

Introduction – DC LINK Modelling , Converter Modeling and State Space Analysis , Philosophy and tools – HVDC system simulation, Online and OFFline simulators – Dynamic interactions between DC and AC systems.

OUTCOMES

After completing this course, the students will be able to

- Understand the principles and types of HVDC system
- Analyze and understand the concepts of HVDC converters and acquire knowledge on DC link control

TEXT BOOKS

1. K.R.Padiyar, , "HVDC Power Transmission Systems", New Age International (P) Ltd., New Delhi, 2002
2. J.Arrillaga, , "High Voltage Direct Current Transmission", Peter Pregrinus, London, 1983

REFERENCE BOOKS

1. P. Kundur, "Power System Stability and Control", McGraw-Hill, 1993
2. Erich Uhlmann, " Power Transmission by Direct Current", BS Publications, 2004.
3. V.K.Sood, HVDC and FACTS controllers – Applications of Static Converters in Power System, APRIL 2004 , Kluwer Academic Publishers

COURSE CODE	COURSE TITLE	L	T	P	C
PPE1322	**SOLAR AND ENERGY STORAGE SYSTEMS**	3	0	0	3

OBJECTIVES

- To study about solar modules and PV system design and their applications
- To deal with grid connected PV systems
- To discuss about different energy storage systems

UNIT I   INTRODUCTION   9

Characteristics of sunlight – semiconductors and P-N junctions –behavior of solar cells – cell properties – PV cell interconnection

UNIT II   STAND ALONE PV SYSTEM   9

Solar modules – storage systems – power conditioning and regulation - MPPT- protection – stand alone PV systems design – sizing

UNIT III   GRID CONNECTED PV SYSTEMS   9

PV systems in buildings – design issues for central power stations – safety – Economic aspect – Efficiency and performance - International PV programs

UNIT IV   ENERGY STORAGE SYSTEMS   9

Impact of intermittent generation – Battery energy storage – solar thermal energy storage – pumped hydroelectric energy storage

UNIT V   APPLICATIONS   9

Water pumping – battery chargers – solar car – direct-drive applications –Space – Telecommunications.

TOTAL: 45 PERIODS

OUTCOMES

After completing this course, the students will be able to
- Students will develop more understanding on solar energy storage systems
- Students will develop basic knowledge on standalone PV system
- Students will understand the issues in grid connected PV systems
- Students will study about the modeling of different energy storage systems and their performances
- Students will attain more on different applications of solar energy

TEXT BOOKS

1. Stuart R.Wenham, Martin A.Green, Muriel E. Watt and Richard Corkish, Applied Photovoltaics, 2007,Earthscan, UK.
2. Eduardo Lorenzo G. Araujo, Solar electricity engineering of photovoltaic systems, Progensa,1994.

REFERENCE BOOKS

1. Frank S. Barnes & Jonah G. Levine, Large Energy storage Systems Handbook, CRC Press, 2011.
2. Solar & Wind Energy Technologies – McNeils, Frenkel, Desai, Wiley Eastern, 1990
3. S.P. Sukhatme , "Solar Energy", Tata McGraw Hill,1987.
4. Solanki C.S., "Solar Photovoltaics: Fundamentals, Technologies And Applications", PHI Learning Pvt. Ltd., 2015.
5. R.Seyezhai and R.Ramaprabha, "Power Electronics for Renewable Energy Systems", Scitech Publications, 2015.

COURSE CODE	COURSE TITLE	L	T	P	C
PPE1323	**WIND ENERGY CONVERSION SYSTEMS**	**3**	**0**	**0**	**3**

OBJECTIVES

- To learn the design and control principles of Wind turbine.
- To understand the concepts of fixed speed and variable speed, wind energy conversion systems.
- To analyze the grid integration issues.

UNIT I   INTRODUCTION   9

Components of WECS-WECS schemes-Power obtained from wind-simple momentum theory-Power coefficient-Sabinin's theory-Aerodynamics of Wind turbine.

UNIT II   WIND TURBINES   9

HAWT-VAWT-Power developed-Thrust-Efficiency-Rotor selection-Rotor design considerations-Tip speed ratio-No. of Blades-Blade profile-Power Regulation-yaw control-Pitch angle control-stall control-Schemes for maximum power extraction.

UNIT III   FIXED SPEED SYSTEMS   9

Generating Systems- Constant speed constant frequency systems -Choice of Generators-Deciding factors-Synchronous Generator-Squirrel Cage Induction Generator- Model of Wind Speed- Model wind turbine rotor - Drive Train model- Generator model for Steady state and Transient stability analysis.

UNIT IV   VARIABLE SPEED SYSTEMS   9

Need of variable speed systems-Power-wind speed characteristics-Variable speed constant frequency systems synchronous generator- DFIG- PMSG -Variable speed generators modeling - Variable speed variable frequency schemes.

UNIT V   GRID CONNECTED SYSTEMS   9

Wind interconnection requirements, low-voltage ride through (LVRT), ramp rate limitations, and supply of ancillary services for frequency and voltage control, current practices and industry

trends wind interconnection impact on steady-state and dynamic performance of the power system including modeling issue.

TOTAL: 45 PERIODS

OUTCOMES

After completing this course, the students will be able to
- Acquire knowledge on the basic concepts of Wind energy conversion system.
- Understand the mathematical modeling and control of the Wind turbine
- Develop more understanding on the design of Fixed speed system
- Study about the need of Variable speed system and its modeling.
- Able to learn about Grid integration issues and current practices of wind interconnections with power system.

TEXT BOOKS

1. L.L.Freris "Wind Energy conversion Systems", Prentice Hall, 1990
2. S.N.Bhadra, D.Kastha, S.Banerjee,"Wind Electrical Sytems",Oxford University Press, 2010.

REFERENCE BOOKS

1. Ion Boldea, "Variable speed generators", Taylor & Francis group, 2006.
2. E.W.Golding "The generation of Electricity by wind power", Redwood burn Ltd.,Trowbridge,1976.
3. N. Jenkins," Wind Energy Technology" John Wiley & Sons,1997
4. S.Heir "Grid Integration of WECS", Wiley 1998.

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COURSE CODE	COURSE TITLE	L	T	P	C
PPE1324	**ENERGY MANAGEMENT AND AUDITING**	**3**	**0**	**0**	**3**

OBJECTIVES

- To study the concepts behind economic analysis and Load management.
- To emphasize the energy management on various electrical equipments and metering.
- To illustrate the concept of lighting systems and cogeneration.

UNIT I INTRODUCTION   **9**

Need for energy management - energy basics- designing and starting an energy management program – energy accounting -energy monitoring, targeting and reporting- energy audit process.

UNIT II ENERGY COST AND LOAD MANAGEMENT   **9**

Important concepts in an economic analysis - Economic models-Time value of money-Utility rate structures- cost of electricity-Loss evaluation- Load management: Demand control techniques-Utility monitoring and control system-HVAC and energy management-Economic justification.

UNIT III ENERGY MANAGEMENT FOR MOTORS, SYSTEMS, AND ELECTRICAL EQUIPMENT   **9**

Systems and equipment- Electric motors-Transformers and reactors-Capacitors and synchronous machines.

UNIT IV METERING FOR ENERGY MANAGEMENT   **9**

Relationships between parameters-Units of measure-Typical cost factors- Utility meters - Timing of meter disc for kilowatt measurement - Demand meters - Paralleling of current transformers - Instrument transformer burdens-Multitasking solid-state meters - Metering location vs. requirements- Metering techniques and practical examples.

UNIT V LIGHTING SYSTEMS & COGENERATION   **9**

Concept of lighting systems - The task and the working space -Light sources - Ballasts - Luminaries - Lighting controls-Optimizing lighting energy - Power factor and effect of harmonics on power quality - Cost analysis techniques-Lighting and energy standards

Cogeneration: Forms of cogeneration - feasibility of cogeneration- Electrical interconnection.

TOTAL : 45 PERIODS

OUTCOMES

After completing this course, the students will be able to
- Develop the ability to learn about the need for energy management and auditing process
- Understand the basic concepts of economic analysis and load management.
- Understand the energy management on various electrical equipments.
- Acquire knowledge on the concepts of metering and factors influencing cost function
- Familiarize the concept of lighting systems, light sources and various forms of cogeneration

TEXT BOOKS

1. Barney L. Capehart, Wayne C. Turner, and William J. Kennedy, Guide to Energy Management, Fifth Edition, The Fairmont Press, Inc., 2006
2. Eastop T.D & Croft D.R, Energy Efficiency for Engineers and Technologists,.Logman Scientific & Technical, ISBN-0-582-03184 , 1990.

REFERENCE BOOKS
1. Reay D.A, Industrial Energy Conservation, 1stedition, Pergamon Press, 1977.
2. IEEE Recommended Practice for Energy Management in Industrial and Commercial Facilities, IEEE, 196.
3. Amit K. Tyagi, Handbook on Energy Audits and Management, TERI, 2003.
4. Electricity in buildings good practice guide, McGraw-Hill Education, 2016.
5. National Productivity Council Guide Books

COURSE CODE	COURSE TITLE	L	T	P	C
PPE1325	**ELECTRIC VEHICLES AND POWER MANAGEMENT**	3	0	0	3

OBJECTIVES

- To understand the concept of electrical vehicles and its operations
- To understand the need for energy storage in hybrid vehicles
- To provide knowledge about various possible energy storage technologies that can be used in electric vehicles

UNIT I ELECTRIC VEHICLES AND VEHICLE MECHANICS 9

Electric Vehicles (EV), Hybrid Electric Vehicles (HEV), Engine ratings, Comparisons of EV with internal combustion Engine vehicles, Fundamentals of vehicle mechanics.

UNIT II ARCHITECTURE OF EV's AND POWER TRAIN COMPONENTS 9

Architecture of EV's and HEV's – Plug-n Hybrid Electric Vehicles (PHEV)- Power train components and sizing, Gears, Clutches, Transmission and Brakes.

UNIT III CONTROL OF DC AND AC DRIVES 9

DC/DC chopper based four quadrant operations of DC drives – Inverter based V/f Operation

(motoring and braking) of induction motor drive system – Induction motor and permanent motor based vector control operation – Switched reluctance motor (SRM) drives.

UNIT IV BATTERY ENERGY STORAGE SYSTEM 9

Battery Basics, Different types, Battery Parameters, Battery modeling, Traction Batteries.

UNIT V ALTERNATIVE ENERGY STORAGE SYSTEMS 9

Fuel cell – Characteristics- Types – hydrogen Storage Systems and Fuel cell EV – Ultra capacitors.

OUTCOMES

After completing this course, the students will be able to understand the operation of Electric vehicles and various energy storage technologies for electrical vehicles

TEXT BOOKS

1. Iqbal Hussain, "Electric and Hybrid Vehicles: Design Fundamentals, Second Edition" CRC Press, Taylor & Francis Group, Second Edition (2011).
2. Ali Emadi, Mehrdad Ehsani, John M.Miller, "Vehicular Electric Power Systems", Special Indian Edition, Marcel dekker, Inc 2010.

REFERENCE BOOKS

1. K. T. Chau, Electric Vehicle Machines and Drives: Design, Analysis and Application, Wiley, 2015.
2. C.C. Chan and K.T. Chau, Modern Electric Vehicle Technology, London: Oxford University Press, 2001

COURSE CODE	COURSE TITLE	L	T	P	C
PPE1326	**NON LINEAR DYNAMICS FOR POWER ELECTRONICS CIRCUITS**	3	0	0	3

OBJECTIVES

- To understand the non linear behavior of power electronic converters.
- To understand the techniques for investigation on non linear behavior of power electronic converters
- To analyze the non linear phenomena in DC to DC converters.
- To analyze the non linear phenomena in AC and DC Drives.
- To introduce the control techniques for control of non linear behavior in power electronic systems

UNIT I   BASICS OF NONLINEAR DYNAMICS   9

Basics of Nonlinear Dynamics: System, state and state space model, Vector field- Modeling of Linear, nonlinear and Linearized systems, Attractors , chaos, Poincare map, Dynamics of Discrete time system, Lyapunov Exponent, Bifurcations, Bifurcations of smooth map, Bifurcations in piece wise smooth maps, border crossing and border collision bifurcation.

UNIT II   TECHNIQUES FOR INVESTIGATION OF NONLINEAR PHENOMENA   9

Techniques for experimental investigation, Techniques for numerical investigation, Computation of averages under chaos, Computations of spectral peaks, Computation of the bifurcation and analyzing stability

UNIT NONLINEAR PHENOMENA IN DC-DC CONVERTERS   9

Border collision in the Current Mode controlled Boost Converter, Bifurcation and chaos in the Voltage controlled Buck Converter with latch, Bifurcation and chaos in the Voltage controlled Buck Converter without latch, Bifurcation and chaos in Cuk Converter. Nonlinear phenomenon in the inverter under tolerance band control.

UNIT IV NONLINEAR PHENOMENA IN DRIVES   9

Nonlinear Phenomenon in Current controlled and voltage controlled DC Drives, Nonlinear Phenomenon in PMSM Drives

UNIT V   CONTROL OF CHAOS   9

Hysteresis control, Sliding mode and switching surface control, OGY Method, Pyragas method, Time Delay control. Application of the techniques to the Power electronics circuit and drives.

TOTAL:45 PERIODS

OUTCOMES

After completing this course, the students will be able to
- Determine the non-linear phenomena
- Analyze the behavior of non-linearity in DC-DC Converters
- Understand the concepts of chaos in power converters.

TEXT BOOKS
1. George C. Vargheese, July 2001 Wiley – IEEE Press S Banerjee, Nonlinear Phenomena in Power Electronics, IEEE Press 3.
2. Steven H Strogatz, Nonlinear Dynamics and Chaos, Westview Press

REFERENCE BOOKS

1. E. R.Vilamitjana, A. E. Aroudi, Abdelali, E. Alarcón," Chaos in Switching Converters for Power Management - Designing for Prediction and Control", Springer, 2013
2. C.K.TSE Complex Behaviour of Switching Power Converters, CRC Press, 2003
3. Louis M Pecora, T Carroll, "Nonlinear Dynamics in Circuits", World Scientific, 1995

COURSE CODE	COURSE TITLE	L	T	P	C
PPE1327	SMART GRID	3	0	0	3

OBJECTIVES

- To Study about Smart Grid technologies, different smart meters and advanced metering infrastructure.
- To familiarize the power quality management issues in Smart Grid.
- To familiarize the high performance computing for Smart Grid applications

UNIT I   INTRODUCTION TO SMART GRID   9

Evolution of Electric Grid, Concept, Definitions and Need for Smart Grid, Smart grid drivers, functions, opportunities, challenges and benefits, Difference between conventional & Smart Grid, National and International Initiatives in Smart Grid.

UNIT II   SMART GRID TECHNOLOGIES   9

Technology Drivers, Smart energy resources, Smart substations, Substation Automation, Feeder Automation ,Transmission systems: EMS, FACTS and HVDC, Wide area monitoring, Protection and control, Distribution systems: DMS, Volt/Var control, Fault Detection, Isolation and service restoration, Outage management, High-Efficiency Distribution Transformers, Phase Shifting Transformers, Plug in Hybrid Electric Vehicles (PHEV).

**UNIT III   SMART METERS AND ADVANCED METERING INFRASTRUCTURE
                                                                                      9**

Introduction to Smart Meters, Advanced Metering infrastructure (AMI) drivers and benefits, AMI protocols, standards and initiatives, AMI needs in the smart grid, Phasor Measurement Unit(PMU), Intelligent Electronic Devices (IED) & their application for monitoring & protection.

UNIT IV   POWER QUALITY MANAGEMENT IN SMART GRID   9

Power Quality & EMC in Smart Grid, Power Quality issues of Grid connected Renewable Energy Sources, Power Quality Conditioners for Smart Grid, Web based Power Quality monitoring, Power Quality Audit.

UNIT V HIGH PERFORMANCE COMPUTING FOR SMART GRID APPLICATIONS
9

Local Area Network (LAN), House Area Network (HAN), Wide Area Network (WAN), Broadband over Power line (BPL), IP based Protocols, Basics of Web Service and CLOUD Computing to make Smart Grids smarter, Cyber Security for Smart Grid.

TOTAL : 45 PERIODS

OUTCOMES

After completing this course, the students will be able to
- Develop more understanding on the concepts of Smart Grid and its present developments.
- Study about different Smart Grid technologies.
- Acquire knowledge about different smart meters and advanced metering infrastructure.
- Acquire knowledge on power quality management in Smart Grids
- Develop more understanding on LAN, WAN and Cloud Computing for Smart Grid applications.

TEXT BOOKS

1. Stuart Borlase "Smart Grid: Infrastructure, Technology and Solutions",CRC Press 2013.
2. JanakaEkanayake,NickJenkins,KithsiriLiyanage,JianzhongWu,AkihikoYokoyama, "Smart Grid: Technology and Applications", Wiley 2012.

REFERENCE BOOKS

1. James Momoh, "Smart Grid Fundamentals of Design and Analysis", Wiley, 2012.
2. Tony Flick, Justin more house, "Securing the smart grid: Next generation power grid security", Elsevier, 2010
3. Daphne Mah, Peter Hills, Victor O.K. Li, Richard Balme -Smart Grid Applications and Developments-Springer, 2014.

COURSE CODE	COURSE TITLE	L	T	P	C
PPE1328	**POWER ELECTRONICS FOR RENEWABLE ENERGY SYSTEMS**	**3**	**0**	**0**	**3**

OBJECTIVES

- To provide knowledge about the stand alone and grid connected renewable energy systems.
- To equip with required skills to derive the criteria for the design of power converters for renewable energy applications.
- To analyse and comprehend the various operating modes of wind electrical generators and solar energy systems.
- To design different power converters namely AC to DC, DC to DC and AC to AC converters for renewable energy systems.
- To develop maximum power point tracking algorithms

UNIT I   INTRODUCTION   9

Environmental aspects of electric energy conversion: impacts of renewable energy generation on environment (cost-GHG Emission) -Qualitative study of different renewable energy resources ocean, Biomass, Hydrogen energy systems : operating principles and characteristics of: Solar PV, Fuel cells, wind electrical systems-control strategy, operating area.

UNIT II ELECTRICAL MACHINES FOR RENEWABLE ENERGY CONVERSION 9

Review of reference theory fundamentals-principle of operation and analysis: IG, PMSG, SCIG and DFIG.

UNIT III   POWER ELECTRONICS FOR SOLAR   9

Block diagram of solar photo voltaic system : line commutated converters (inversion-mode) - Boost and buck-boost converters-selection of inverter, battery sizing, array sizing- standalone PV systems - Grid tied and grid interactive inverters- grid connection issues.

UNIT IV   POWER ELECTRONICS FOR WIND   9

Three phase AC voltage controllers-AC-DC-AC converters: uncontrolled rectifiers, PWM Inverters, matrix converters- Stand alone operation of fixed and variable speed wind energy conversion systems- Grid connection Issues -Grid integrated PMSG and SCIG Based WECS.

UNIT V HYBRID RENEWABLE ENERGY SYSTEMS   **9**

Need for Hybrid Systems -Range and type of Hybrid systems-Case studies of Wind-PV-Maximum Power Point Tracking (MPPT).

TOTAL :45 PERIODS

OUTCOMES

After completion of this course, the student will be able to

- Analyze the impacts of renewable energy generation on environment.
- Understand the importance and qualitative analysis of solar and wind energy sources.
- Apply the principle of operation of electrical machines for wind energy conversion and their performance characteristics.
- Design suitable power converters for solar PV and wind energy systems.

TEXT BOOKS

1. S. N. Bhadra, D.Kastha, S.Banerjee, "Wind Electrical Systems", Oxford University Press, 2005.
2. R.Seyezhai and R.Ramaprabha, "Power Electronics for Renewable Energy Systems", Scitech Publications, 2015.

REFERENCE BOOKS

1. Rashid .M. H "power electronics Hand book", Academic press, 2001.
2. Rai. G.D," Solar energy utilization", Khanna publishes, 1993.
3. Rai. G.D," Solar energy utilization", Khanna publishes, 1993.
4. Gray, L. Johnson, "Wind energy system", prentice hall linc, 1995.
5. B.H.Khan, "Non-conventional Energy sources", Tata McGraw-hill Publishing Company, New Delhi, 2009.
6. B.H.Khan, " Non-conventional Energy sources", Tata McGraw-hill Publishing Company.
7. P.S.Bimbhra,"Power Electronics",Khanna Publishers, 3rd Edition,2003.
8. Fang Lin Luo Hong Ye, " Renewable Energy systems", Taylor & Francis Group,2013.
9. Ion Boldea, "Variable speed generators", Taylor & Francis group, 2006.
10. Andrzej M. Trzynnadlowski, 'Introduction to Modern Power Electronics', Second edition, wiley

COURSE CODE	COURSE TITLE	L	T	P	C
PPE1329	**ROBOTICS AND CONTROL**	**3**	**0**	**0**	**3**

OBJECTIVES

- To introduce robot terminologies and robotic sensors To educate direct and inverse kinematic relations

- To educate on formulation of manipulator Jacobians and introduce path planning techniques

- To educate on robot dynamics
- To introduce robot control techniques

UNIT I   INTRODUCTION AND TERMINOLOGIES   9

Definition-Classification-History- Robots components-Degrees of freedom-Robot joints-coordinates-Reference frames-workspace-Robot languages-actuators-sensors-Position, velocity and acceleration sensors-Torque sensors-tactile and touch sensors-proximity and range sensors-vision system-social issues.

UNIT II   KINEMATICS   9

Mechanism-matrix representation-homogenous transformation-DH representation-Inverse kinematics solution and programming-degeneracy and dexterity

UNIT III   DIFFERENTIAL MOTION AND PATH PLANNING   9

Jacobian-differential motion of frames-Interpretation-calculation of Jacobian-Inverse Jacobian-Robot Path planning

UNIT IV   DYNAMIC MODELLING   9

Lagrangian mechanics- Two-DOF manipulator- Lagrange-Euler formulation – Newton- Euler

formulation – Inverse dynamics

UNIT V   ROBOT CONTROL SYSTEM   9

- Linear control schemes- joint actuators- decentralized PID control- computed torque control – force control- hybrid position force control- Impedance/ Torque control

TOTAL : 45 PERIODS

OUTCOMES

After completion of this course, the student will be able to

- Understand the components and basic terminology of Robotics
- Model the motion of Robots and analyze the workspace and trajectory panning of robots
- Develop application based Robots
- Formulate models for the control of mobile robots in various industrial applications

TEXT BOOKS

1. R.K. Mittal and I J Nagrath, " Robotics and Control", Tata MacGraw Hill, Fourth edition, 2005.
2. Saeed B. Niku ,"Introduction to Robotics ", Pearson Education, 2002.

REFERENCE BOOKS

1. John J.Craig ,Introduction to Robotics Mechanics and Control, Third edition, Pearson Education, 2009.
2. M.P.Groover, M.Weiss, R.N. Nageland N. G.Odrej, Industrial Robotics, McGraw-Hill Singapore, 1996.
3. Fu, Gonzalez and Lee Mcgrahill ,"Robotics ", international edition.
4. R.D. Klafter, TA Chmielewski and Michael Negin, "Robotic Engineering, An Integrated approach",Prentice Hall of India, 2003.

COURSE CODE	COURSE TITLE	L	T	P	C
PPE1331	NON LINEAR CONTROL	3	0	0	3

OBJECTIVES

- To impart knowledge on phase plane analysis of non-linear systems.
- To impart knowledge on Describing function based approach to non-linear systems.
- To educate on stability analysis of systems using Lyapunov's theory.
- To educate on stability analysis of systems using Lyapunov's theory.
- To introduce the concept of sliding mode control.

UNIT I   PHASE PLANE ANALYSIS   9

Concepts of phase plane analysis- Phase portraits- singular points- Symmetry in phase plane portraits-Constructing Phase Portraits- Phase plane Analysis of Linear and Nonlinear Systems-Existence of Limit Cycles. simulation of phase portraits in MATLAB.

UNIT II   DESCRIBING FUNCTION   9

Describing Function Fundamentals-Definitions-Assumptions-Computing Describing Functions-Common Nonlinearities and its Describing Functions-Nyquist Criterion and its Extension-Existence of Limit Cycles-Stability of limit Cycles. simulation of limit cycles in MATLAB.

UNIT III   LYAPUNOV THEORY   9

Nonlinear Systems and Equilibrium Points-Concepts of Stability-Linearization and Local Stability- Lyapunov's Direct Method-Positive definite Functions and Lyapunov Functions-Equilibrium Point Theorems-Invariant Set Theorems-LTI System Analysis based on Lyapunov's Direct Method- Krasovski's Method-Variable Gradient Method-Physically – Control Design based on Lyapunov's Direct Method.

UNIT IV   FEEDBACK LINEARIZATION   9

Feedback Linearization and the Canonical Form-Mathematical Tools-Input-State Linearization of SISO Systems- input-Output Linearization of SISO Systems-Generating a Linear Input-Output Relation-Normal Forms-The Zero-Dynamics-Stabilization and Tracking-Inverse

Dynamics and Non- Minimum-Phase Systems-Feedback Linearization of MIMO Systems Zero-Dynamics and Control Design. Simulation of tracking problems in MATLAB.

UNIT V   SLIDING MODE CONTROL   9

Sliding Surfaces- Continuous approximations of Switching Control laws-The Modeling/Performance Trade-Offs- MIMO Systems. simulation of sliding mode controller in MATLAB.

TOTAL : 45 PERIODS

OUTCOMES

After completion of this course, the student will be able to

- Understand the concepts of non-linear control system.
- Analyze the stability of the system
- Illustrate the sliding mode control and implementation in MATLAB.

TEXT BOOKS

1. J A E Slotine and W Li, "Applied Nonlinear Control", PHI, 1991.
2. K. P. Mohandas, "Modern Control Engineering', Sanguine, India, 2006

REFERENCE BOOKS

1. Hasan Khalil, "Nonlinear systems and control", Prentice Hall.
2. S H Zak, "Systems and control", Oxford University Press, 2003.
3. Torkel Glad and Lennart Ljung, "Control Theory – Multivariable and Nonlinear Methods",Taylor& Francis, 2002.
4. G. J. Thaler, "Automatic control systems", Jaico publishers, 2006.