

**ANNA UNIVERSITY, CHENNAI**  
**AFFILIATED INSTITUTIONS**  
**REGULATIONS – 2017**  
**CHOICE BASED CREDIT SYSTEM**  
**M.E. POWER ELECTRONICS AND DRIVES**

**PROGRAM EDUCATIONAL OUTCOMES**

**PEO1:** Graduates of this program will have technical knowledge, skills and ability to design, develop and test power electronic converters and drives using advanced tools.

**PEO2:** Graduates of this program will have skills and knowledge in the field of power electronics and drives to work in the design, fabrication industries and research organizations.

**PEO3:** Graduates of this program will show confidence and exhibit self-learning capability and demonstrate a pursuit in life-long learning through higher studies and research.

**PEO4:** Graduates of this program will show involvement and willingness in assuming responsibility in societal and environmental causes.

**PROGRAM OUTCOMES**

**PO1:** Acquire sound knowledge in power electronics and drives.

**PO2:** Analyse power electronics and drives related engineering problems and synthesize the information for conducting high level of research.

**PO3:** Think widely to offer creative and innovative solutions of engineering problems that are inconformity with social and environmental factors.

**PO4:** Extract the new methodologies by carrying out the literature survey, proper design and conduction of experiments, interpret and analyse the data to arrive at meaningful research methodologies in power electronics and drives.

**PO5:** Learn and apply modern engineering and IT tools to solve complex engineering problems related to power converters and electric drives.

**PO6:** Ability to form, understand group dynamics and work in inter-disciplinary groups in order to achieve the goal.

**PO7:** Ability to communicate effectively in appropriate technical forums and understand the concepts and ideas to prepare reports, to make effective presentations.

**PO8:** Ability to update knowledge and skills through lifelong learning to keep abreast with the technological developments.

**PO9:** Follow the professional and research ethics, comprehend the impact of research and responsibility in order to contribute to the society.

**PO10:** Understand the leadership principles and subject oneself to introspection and take voluntary remedial measures for effective professional practice in the field of power electronics and electric drives.

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10
PEO-1	x	x	x	x	x		X	x		
PEO-2	x			x	x	x	X	x	x	x
PEO-3				x	x	x		x	x	
PEO-4	x	x	x						x	x

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**CHOICE BASED CREDIT SYSTEM**  
**M.E. POWER ELECTRONICS AND DRIVES (FULL TIME)**  
**CURRICULUM AND SYLLABUS I TO IV SEMESTERS**

**SEMESTER I**

S.No	COURSE CODE	COURSE TITLE	CATEGORY	CONTACT PERIODS	L	T	P	C
<b>THEORY</b>								
1.	MA5155	Applied Mathematics for Electrical Engineers	FC	4	4	0	0	4
2.	PX5101	Power Semiconductor Devices	PC	3	3	0	0	3
3.	PX5151	Analysis of Electrical Machines	PC	3	3	0	0	3
4.	PX5152	Analysis and Design of Power Converters	PC	3	3	0	0	3
5.	IN5152	System Theory	PC	5	3	2	0	4
6.		Professional Elective I	PE	3	3	0	0	3
<b>PRACTICALS</b>								
7.	PX5111	Power Electronics Circuits Lab	PC	4	0	0	4	2
<b>TOTAL</b>				<b>25</b>	<b>19</b>	<b>2</b>	<b>4</b>	<b>22</b>

**SEMESTER II**

S.No	COURSE CODE	COURSE TITLE	CATEGORY	CONTACT PERIODS	L	T	P	C
<b>THEORY</b>								
1.	PX5201	Analysis and Design of Inverters	PC	3	3	0	0	3
2.	PX5202	Solid State Drives	PC	5	3	2	0	4
3.	PX5251	Special Electrical Machines	PC	3	3	0	0	3
4.	PX5252	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
<b>PRACTICALS</b>								
7.	PX5211	Electrical Drives Laboratory	PC	4	0	0	4	2
8.	PX5212	Mini Project	EEC	4	0	0	4	2
<b>TOTAL</b>				<b>28</b>	<b>18</b>	<b>2</b>	<b>8</b>	<b>23</b>

**SEMESTER III**

S.No	COURSE CODE	COURSE TITLE	CATEGORY	CONTACT PERIODS	L	T	P	C
<b>THEORY</b>								
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
<b>PRACTICALS</b>								
4.	PX5311	Project Work Phase I	EEC	12	0	0	12	6
<b>TOTAL</b>				<b>21</b>	<b>9</b>	<b>0</b>	<b>12</b>	<b>15</b>

**SEMESTER IV**

SI.No	COURSE CODE	COURSE TITLE	CATEGORY	CONTACT PERIODS	L	T	P	C
<b>PRACTICALS</b>								
1.	PX5411	Project Work Phase II	EEC	24	0	0	24	12
<b>TOTAL</b>				<b>24</b>	<b>0</b>	<b>0</b>	<b>24</b>	<b>12</b>

**TOTAL NO. OF CREDITS: 72**

### FOUNDATION COURSES(FC)

S.No	COURSE CODE	COURSE TITLE	CATEGORY	CONTACT PERIODS	L	T	P	C
1.	MA5155	Applied Mathematics for Electrical Engineering	FC	4	4	0	0	4

### PROFESSIONAL CORE(PC)

S.No	COURSE CODE	COURSE TITLE	CATEGORY	CONTACT PERIODS	L	T	P	C
1.	PX5101	Power Semiconductor Devices	PC	3	3	0	0	3
2.	PX5151	Analysis of Electrical Machines	PC	3	3	0	0	3
3.	PX5152	Analysis and Design of Power Converters	PC	3	3	0	0	3
4.	PX5201	Analysis and Design of Inverters	PC	3	3	0	0	3
5.	IN5152	System Theory	PC	5	3	2	0	4
6.	PX5202	Solid State Drives	PC	5	3	2	0	4
7.	PX5251	Special Electrical Machines	PC	3	3	0	0	3
8.	PX5252	Power Quality	PC	3	3	0	0	3
9.	PX5111	Power Electronics Circuits Lab	PC	4	0	0	4	2
10.	PX5211	Electrical Drives Laboratory	PC	4	0	0	4	2

### PROFESSIONAL ELECTIVES(PE)\*

#### Semester I Elective I

S.No	COURSE CODE	COURSE TITLE	CATEGORY	CONTACT PERIODS	L	T	P	C
1.	IN5091	Soft Computing Techniques	PE	3	3	0	0	3
2.	PX5001	Electromagnetic Field Computation and Modelling	PE	3	3	0	0	3
3.	PX5091	Control System Design for Power Electronics	PE	3	3	0	0	3

#### Semester II Elective II and III

S.No	COURSE CODE	COURSE TITLE	CATEGORY	CONTACT PERIODS	L	T	P	C
1.	PX5002	Analog and Digital Controllers	PE	3	3	0	0	3

2.	PX5003	Flexible AC Transmission Systems	PE	3	3	0	0	3
3.	PX5004	Modern Rectifiers and Resonant Converters	PE	3	3	0	0	3
4.	PX5092	Electromagnetic Interference and Compatibility	PE	3	3	0	0	3
5.	ET5091	MEMS Technology	PE	3	3	0	0	3
6.	PS5071	Distributed Generation and Microgrid	PE	3	3	0	0	3

**Semester III**  
**Elective IV, V and VI**

S.No	COURSE CODE	COURSE TITLE	CATEGORY	CONTACT PERIODS	L	T	P	C
1.	PX5005	High Voltage Direct Current Transmission	PE	3	3	0	0	3
2.	PS5092	Solar and Energy Storage Systems	PE	3	3	0	0	3
3.	PX5071	Wind Energy Conversion Systems	PE	3	3	0	0	3
4.	PS5072	Energy Management and Auditing	PE	3	3	0	0	3
5.	PS5073	Electric Vehicles and Power Management	PE	3	3	0	0	3
6.	PX5006	Non Linear Dynamics for Power Electronics Circuits	PE	3	3	0	0	3
7.	PS5091	Smart Grid	PE	3	3	0	0	3
8.	PX5072	Power Electronics for Renewable Energy Systems	PE	3	3	0	0	3
9.	IN5079	Robotics and Control	PE	3	3	0	0	3
10.	PX5007	Non Linear Control	PE	3	3	0	0	3

**Professional Electives are grouped according to elective number as was done previously.**

**EMPLOYABILITY ENHANCEMENT COURSES(EEC)**

S.No	COURSE CODE	COURSE TITLE	CATEGORY	CONTACT PERIODS	L	T	P	C
1.	PX5212	Mini Project	EEC	4	0	0	4	2
2.	PX5311	Project Work Phase I	EEC	12	0	0	12	6
3.	PX5411	Project Work Phase II	EEC	24	0	0	24	12

**MA5155**

**APPLIED MATHEMATICS FOR ELECTRICAL ENGINEERS**

**L T P C**  
**4 0 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 – Isoperimetric problems - Direct methods : Ritz and Kantorovich methods.

**UNIT III      PROBABILITY AND RANDOM VARIABLES**

**12**

Probability – Axioms of probability – Conditional probability – Baye’s theorem - Random variables - Probability function – Moments – Moment generating functions and their properties – Binomial, Poisson, Geometric, Uniform, Exponential, Gamma and Normal distributions – Function of a random variable.

**UNIT IV      LINEAR PROGRAMMING**

**12**

Formulation – Graphical solution – Simplex method – Big M method - Two phase method - Transportation and Assignment models.

**UNIT V      FOURIER SERIES**

**12**

Fourier trigonometric series : Periodic function as power signals – Convergence of series – Even and odd function : Cosine and sine series – Non periodic function : Extension to other intervals - Power signals : Exponential Fourier series – Parseval’s theorem and power spectrum – Eigenvalue problems and orthogonal functions – Regular Sturm - Liouville systems – Generalized Fourier series.

**TOTAL : 60 PERIODS**

**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 to develop 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.

**REFERENCES :**

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, 2<sup>nd</sup> Edition, 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, 8<sup>th</sup> Edition, 2015.
5. O'Neil, P.V., "Advanced Engineering Mathematics", Thomson Asia Pvt. Ltd., Singapore, 2003.
6. Taha, H.A., "Operations Research, An Introduction", 9<sup>th</sup> Edition, Pearson education, New Delhi, 2016.

<b>PX5101</b>	<b>POWER SEMICONDUCTOR DEVICES</b>	<b>L</b>	<b>T</b>	<b>P</b>	<b>C</b>
		<b>3</b>	<b>0</b>	<b>0</b>	<b>3</b>

**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 CURRENT CONTROLLED DEVICES 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 VOLTAGE CONTROLLED DEVICES 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 AND PROTECTING CIRCUITS 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 THERMAL PROTECTION 9**

Heat transfer – conduction, convection and radiation; Cooling – liquid cooling, vapour – phase cooling; Guidance for heat 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.

**PX5151 ANALYSIS OF ELECTRICAL MACHINES L T P C**  
**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 ELECTROMAGNETIC ENERGY 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 DC MACHINES 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 REFERENCE FRAME 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 INDUCTION MACHINES 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 SYNCHRONOUS MACHINES 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 Wasyszczuk, 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

**PX5152 ANALYSIS AND DESIGN OF POWER CONVERTERS L T P C**  
**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 & THREE PHASE 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-DC CONVERTERS 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 POWER CONVERTER COMPONENTS 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 RESONANT DC-DC CONVERTERS 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 V AC-AC CONVERTERS 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.M. Undeland and W.P. Robbins, "Power Electronics: converters, Application and design" John Wiley and sons. Wiley India edition, 2006.
- 2 Rashid M.H., "Power Electronics Circuits, Devices and Applications ", Prentice Hall 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 Vencislav Cekov Valchev, "Inductors and Transformers for Power Electronics", 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 & Sons Ltd.
- 9 Marian. K. Kazimierczuk and Dariusz Czarkowski, "Resonant Power Converters", John Wiley & Sons limited, 2011

**OBJECTIVES:**

- To understand the fundamentals of physical systems in terms of its linear and 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 STATE VARIABLE 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- State Diagrams.

**UNIT II SOLUTION OF STATE EQUATIONS 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 Eigen vectors.

**UNIT III STABILITY ANALYSIS OF LINEAR SYSTEMS 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 AND STATE 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 LYAPUNOV STABILTY 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-Gradient Method.

**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 delta and 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 Analysis and Design with 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, New Jersey.

**PX5111                      POWER ELECTRONIC CIRCUITS LABORATORY                      L   T   P   C**  
**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. Study of switching characteristics of Power electronic switches with and without Snubber (i) IGBT (ii) MOSFET
2. Modeling and system simulation of basic electric circuits using MATLAB-SIMULINK/SCILAB
3. DC source fed resistive load and Resistive-inductive load
4. DC source fed RLC load for different damping conditions
5. DC source fed DC motor load
6. Modeling and System simulation of basic power electronic circuits using MATLAB-SIMULINK/SCILAB
7. AC Source with Single Diode fed Resistive and Resistive-Inductive Load
8. AC source with Single SCR fed Resistive and Resistive-Inductive Load
9. Modeling and System Simulation of SCR based full converter with different types of load using MATLAB-Simulink/SCILAB
10. Full converter fed resistive load
11. Full converter fed Resistive-Back Emf (RE) load at different firing angles
12. Full Converter fed Resistive-Inductive Load at different firing angles
13. Full converter fed DC motor load at different firing angles
14. Circuit Simulation of Voltage Source Inverter and study of spectrum analysis with and without filter using MATLAB/SCILAB

15. Single phase square wave inverter
16. Three phase sine PWM inverter
17. Generation of PWM gate pulses with duty cycle control using PWM peripheral of microcontroller ( TI-C2000 family/ PIC18)
18. Duty cycle control from IDE
19. Duty Cycle control using a POT connected to ADC peripheral in a standalone mode
20. Generation of Sine-PWM pulses for a three phase Voltage Source Inverter with control of modulation index using PWM peripheral of microcontroller (TI C2000 family/PIC 18)
21. Design of Driver Circuit using IR2110
22. Design and testing of signal conditioning circuit to interface voltage/current sensor with microcontroller (TI-C2000 family/ PIC18)
23. Interface Hall effect current sensor with microcontroller and display the current waveform in the IDE and validate with actual waveform in DSO
24. Interface Hall effect Voltage sensor with microcontroller and display the current waveform in the IDE and validate with actual waveform in DSO
25. Design of PI controller using OP-AMP
26. Construction and testing of 500 W, 220 V IGBT based Buck converter with control circuit and its performance Evaluation
27. Measurement of Efficiency at different duty cycle with a resistive load
28. Measurement of Efficiency at different duty cycle with a resistive-inductive load
29. PCB design and fabrication of DC power supply using any PCB design software (open source- KiCAD/students version)

**TOTAL: 60 PERIODS**

### **COURSE OUTCOMES**

- Comprehensive understanding on the switching behaviour 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 a reasonable power level
- Exposure to PCB designing and fabrication
- \* IDE – Integrate Development Environment (Code Composer Studio for Texas Instrument/MPLAB for PIC microcontrollers etc)

PX5201

**ANALYSIS AND DESIGN OF INVERTERS**

**L T P C**  
**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 VOLTAGE SOURCE 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 CURRENT SOURCE 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 AND POWER 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 of inverters
- Will be able to design single phase and three phase inverters
- Will equip skills to formulate and design the inverters for generic loads and machine loads
- Will acquire knowledge on multilevel inverters and modulation 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, Second Edition, 2002
- 3 BimalK.Bose "Modern Power Electronics and AC Drives", Pearson Education, Second Edition, 2003.





**TOTAL : 45+30 = 75 PERIODS**

**OUTCOMES:**

Students,

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

**REFERENCES:**

- 1 P.C Sen "Thyristor DC Drives", John Wiley and sons, New York, 1981
- 2 Gopal K Dubey, "Power Semiconductor controlled Drives", Prentice Hall Inc., New Jersey, 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 Asia 2002.
- 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.

<b>PX5251</b>	<b>SPECIAL ELECTRICAL MACHINES</b>	<b>L</b>	<b>T</b>	<b>P</b>	<b>C</b>
		<b>3</b>	<b>0</b>	<b>0</b>	<b>3</b>

**OBJECTIVES:**

- To review the fundamental concepts of permanent magnets and the operation of permanent magnet brushless DC motors.
- To introduce the concepts of permanent magnet brushless synchronous motors and synchronous reluctance motors.
- To develop the control methods and operating principles of switched reluctance motors.
- To introduce the concepts of stepper motors and its applications.
- To understand the basic concepts of other special machines

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

**UNIT II PERMANENT MAGNET SYNCHRONOUS MOTORS 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 SWITCHED RELUCTANCE MOTORS 9**  
Constructional features –Principle of operation- Torque prediction–Characteristics-Power controllers – Control of SRM drive- Sensorless operation of SRM – Applications.



phase four wire system.

**UNIT III CONVENTIONAL LOAD COMPENSATION METHODS 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 COMPENSATION USING DSTATCOM 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 POWER DISTRIBUTION SYSTEM 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.McGranaghan, Surya Santoas and H.Wayne Beaty, “Electrical Power System Quality”, McGraw-Hill, 2004.
- 3 G.T.Heydt, “Electric Power Quality”, Stars in a Circle Publications, 1994.
- 4 Bhim Singh, Amrishi Chandra, Kamal Al-Haddad , “Power Quality: Problems and Mitigation Techniques”, John Wiley & Sons, 2015.

**REFERENCES**

- 1 Jos Arrillaga and Neville R. Watson , “ Power system harmonics”, 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 Machines, Elsevier academic press publications, 2011.

PX5211

**ELECTRICAL DRIVES LABORATORY**

<b>L</b>	<b>T</b>	<b>P</b>	<b>C</b>
<b>0</b>	<b>0</b>	<b>4</b>	<b>2</b>

**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 Chopper fed DC motor.
3. V/f control of three-phase induction motor.
4. Micro controller based speed control of Stepper motor.
5. Speed control of BLDC motor.
6. DSP based speed control of SRM motor.
7. Voltage Regulation of three-phase Synchronous Generator.
8. Cycloconverter fed Induction motor drives
9. Single phase Multi Level Inverter based induction motor drive
10. Study of power quality analyzer

**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.

**PX5212**

**MINI PROJECT**

L	T	P	C
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, cycloconverters, 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 for project 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

IN5091

**SOFT COMPUTING TECHNIQUES**

<b>L</b>	<b>T</b>	<b>P</b>	<b>C</b>
<b>3</b>	<b>0</b>	<b>0</b>	<b>3</b>

**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 NN toolbox

**UNIT I INTRODUCTION AND ARTIFICIAL NEURAL NETWORKS 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 propagation learning methods- effect of learning rule coefficient -back propagation algorithm- factors affecting back propagation training- applications.

**UNIT II ARTIFICIAL NEURAL NETWORKS AND ASSOCIATIVE MEMORY 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 FUZZY LOGIC SYSTEM 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 IV GENETIC ALGORITHM 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 HYBRID CONTROL 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









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, ISOLATION AND PROTECTION 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 CONTROLLER IMPLEMENTATION 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.

<b>PX5003</b>	<b>FLEXIBLE AC TRANSMISSION SYSTEMS</b>	<b>L</b>	<b>T</b>	<b>P</b>	<b>C</b>
		<b>3</b>	<b>0</b>	<b>0</b>	<b>3</b>

**OBJECTIVES:**

- To emphasize 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 VAR COMPENSATOR (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 (TCSC and GCSC) 9**

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 and GCSC.

**UNIT IV VOLTAGE SOURCE CONVERTER BASED FACTS CONTROLLERS 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 AND THEIR COORDINATION**

**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, Delhi 2001.
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, Reprint 2008,

**PX5004 MODERN RECTIFIERS AND RESONANT CONVERTERS**

**L T P C  
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 & LINE COMMUTATED RECTIFIERS**

**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 WIDTH MODULATED RECTIFIERS**

**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 RESONANT CONVERTERS****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 OF SWITCHING CONVERTERS****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 SHAPING OF 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 DariuszCzarkowski, "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

**PX5092****ELECTROMAGNETIC INTERFERENCE AND  
COMPATIBILITY****L T P C  
3 0 0 3****OBJECTIVES:**

- To provide fundamental knowledge on electromagnetic interference and electromagnetic compatibility.
- To study the important techniques to control EMI and EMC.

- To expose the knowledge on testing techniques as per Indian and international standards in EMI measurement.

**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 GROUNDING AND CABLING 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 system hybrid 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, FILTERING AND SHIELDING 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 field 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 ELEMENTS AND CIRCUITS 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

**UNIT V ELECTROSTATIC DISCHARGE, STANDARDS AND TESTING TECHNIQUES 9**

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 02062 USA) 1987
4. Bridges, J.E Milleta J. and Ricketts.L.W., "EMP Radiation and Protective techniques", John Wiley and sons, USA 1976
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 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 SENSORS AND ACTUATION 9**

Principle, material, design and fabrication of parallel plate capacitors as electrostatic sensors and actuators-Applications

**UNIT III THERMAL SENSING AND ACTUATION 9**

Principle, material, design and fabrication of thermal couples, thermal bimorph sensors, thermal resistor sensors-Applications.

**UNIT IV PIEZOELECTRIC SENSING AND ACTUATION 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 microfabrication, 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 microsystems
- 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 and gyroscopes", Elsevier, Newyork, 2000.

<b>PS5071</b>	<b>DISTRIBUTED GENERATION AND MICROGRID</b>	<b>L</b>	<b>T</b>	<b>P</b>	<b>C</b>
		<b>3</b>	<b>0</b>	<b>0</b>	<b>3</b>

### 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 DISTRIBUTED GENERATIONS (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 OF GRID INTEGRATION 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 OF A MICROGRID 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 OPERATION OF MICROGRID 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.
- Learners will learn about the requirements for grid interconnection and its impact with 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 Dorin Neacsu, “Power Switching Converters: Medium and High Power”, CRC Press, Taylor & Francis, 2006
- 3 Chetan Singh Solanki, “Solar Photo Voltaics”, PHI learning Pvt. Ltd., New Delhi, 2009
- 4 J.F. Manwell, J.G. McGowan “Wind Energy Explained, theory design and applications”, Wiley publication 2010.
- 5 D. D. Hall and R. P. Grover, “Biomass Regenerable Energy”, John Wiley, New York, 1987.
- 6 John Twidell and Tony Weir, “Renewable Energy Resources” Tylor and Francis Publications, Second edition 2006.

**PX5005 HIGH VOLTAGE DIRECT CURRENT TRANSMISSION L T P C  
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.

**TOTAL : 45 PERIODS**

**REFERENCES**

- 1 P. Kundur, "Power System Stability and Control", McGraw-Hill, 1993
- 2 K.R.Padiyar, , "HVDC Power Transmission Systems", New Age International (P) Ltd., New Delhi, 2002
- 3 J.Arrillaga, , "High Voltage Direct Current Transmission", Peter Pregrinus, London, 1983
- 4 Erich Uhlmann, " Power Transmission by Direct Current", BS Publications, 2004.
- 5 V.K.Sood,HVDC and FACTS controllers – Applications of Static Converters in Power System, APRIL 2004 , Kluwer Academic Publishers

<b>PS5092</b>	<b>SOLAR AND ENERGY STORAGE SYSTEMS</b>	<b>L</b>	<b>T</b>	<b>P</b>	<b>C</b>
		<b>3</b>	<b>0</b>	<b>0</b>	<b>3</b>

**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:**

- 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

**REFERENCES**

- 1 Solanki C.S., "Solar Photovoltaics: Fundamentals, Technologies And Applications", PHI Learning Pvt. Ltd.,2015.



- 2 Stuart R.Wenham, Martin A.Green, Muriel E. Watt and Richard Corkish, "Applied Photovoltaics", 2007,Earthscan, UK.  
Eduardo Lorenzo G. Araujo, "Solar electricity engineering of photovoltaic systems", Progensa,1994.
- 3 Frank S. Barnes & Jonah G. Levine, "Large Energy storage Systems Handbook", CRC Press, 2011.
- 4 McNeils, Frenkel, Desai, "Solar & Wind Energy Technologies", Wiley Eastern, 1990
- 5 S.P. Sukhatme , "Solar Energy", Tata McGraw Hill,1987.

<b>PX5071</b>	<b>WIND ENERGY CONVERSION SYSTEMS</b>	<b>L</b>	<b>T</b>	<b>P</b>	<b>C</b>
		<b>3</b>	<b>0</b>	<b>0</b>	<b>3</b>

**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:**

- 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.

**REFERENCES**

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

<b>PS5072</b>	<b>ENERGY MANAGEMENT AND AUDITING</b>	<b>L</b>	<b>T</b>	<b>P</b>	<b>C</b>
		<b>3</b>	<b>0</b>	<b>0</b>	<b>3</b>

**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:**

- Students will develop the ability to learn about the need for energy management and auditing process
- Learners will learn about basic concepts of economic analysis and load management.
- Students will understand the energy management on various electrical equipments.
- Students will have knowledge on the concepts of metering and factors influencing cost

function

- Students will be able to learn about the concept of lighting systems, light sources and various forms of cogeneration

#### REFERENCES

- 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, 1990.
- 3 Reay D.A, "Industrial Energy Conservation", 1<sup>st</sup> edition, Pergamon Press, 1977.
- 4 "IEEE Recommended Practice for Energy Management in Industrial and Commercial Facilities", IEEE, 1996
- 5 Amit K. Tyagi, "Handbook on Energy Audits and Management", TERI, 2003.

<b>PS5073</b>	<b>ELECTRIC VEHICLES AND POWER MANAGEMENT</b>	<b>L</b>	<b>T</b>	<b>P</b>	<b>C</b>
		<b>3</b>	<b>0</b>	<b>0</b>	<b>3</b>

#### 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.

**TOTAL : 45 PERIODS**

#### OUTCOMES:

- Learners will understand the operation of Electric vehicles and various energy storage technologies for electrical vehicles

#### REFERENCES

- 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.



**PS5091**

**SMART GRID**

**L T P C**  
**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:**

- Learners will develop more understanding on the concepts of Smart Grid and its present developments.
- Learners will study about different Smart Grid technologies.
- Learners will acquire knowledge about different smart meters and advanced metering infrastructure.
- Learners will have knowledge on power quality management in Smart Grids
- Learners will develop more understanding on LAN, WAN and Cloud Computing for Smart Grid applications.

**REFERENCES**

- 1 Stuart Borlase "Smart Grid :Infrastructure, Technology and Solutions", CRC Press 2012.
- 2 Janaka Ekanayake, Nick Jenkins, KithsiriLiyanage, Jianzhong Wu, Akihiko Yokoyama, "Smart Grid: Technology and Applications", Wiley 2012.
- 3 Vehbi C. Güngör, DilanSahin, TaskinKocak, Salih Ergüt, Concettina Buccella, Carlo Cecati, and Gerhard P. Hancke, "Smart Grid Technologies: Communication



- 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.

## REFERENCES

- 1 S.N.Bhadra, D. Kastha, & S. Banerjee "Wind Electrical Systems", Oxford University Press, 2009.
- 2 Rashid .M. H "power electronics Hand book", Academic press, 2001.
- 3 Rai. G.D, "Non conventional energy sources", Khanna publishes, 1993.
- 4 Rai. G.D," Solar energy utilization", Khanna publishes, 1993.
- 5 Gray, L. Johnson, "Wind energy system", prentice hall linc, 1995.
- 6 B.H.Khan, " Non-conventional Energy sources", Tata McGraw-hill Publishing Company.
- 7 P.S.Bimbhra,"Power Electronics",Khanna Publishers, 3<sup>rd</sup> Edition,2003.
- 8 Fang Lin Luo Hong Ye, " Renewable Energy systems", Taylor & Francis Group,2013.
- 9 R.Seyezhai and R.Ramaprabha, "Power Electronics for Renewable Energy Systems", Scitech Publications, 2015.

IN5079

ROBOTICS AND CONTROL

L T P C  
3 0 0 3

## COURSE 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**

## COURSE OUTCOMES:

- Ability to understand the components and basic terminology of Robotics

- Ability to model the motion of Robots and analyze the workspace and trajectory panning of robots
- Ability to develop application based Robots
- Ability to formulate models for the control of mobile robots in various industrial applications

## REFERENCES

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

**PX5007**

**NON LINEAR CONTROL**

L	T	P	C
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:**

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

**REFERENCES**

1. J A E Slotine and W Li, Applied Nonlinear control, PHI, 1991.
2. K. P. Mohandas, Modern Control Engineering, Sanguine, India, 2006
3. Hasan Khalil, "Nonlinear systems and control", Prentice Hall.
4. S H Zak, "Systems and control", Oxford University Press, 2003.
5. Torkel Glad and Lennart Ljung, "Control Theory – Multivariable and Nonlinear Methods", Taylor & Francis, 2002.
6. G. J. Thaler, "Automatic control systems", Jaico publishers, 2006.