M.Tech (Electrical Engineering) with specialization in Power Electronics & Drives

(Effective from the session: 2013-2014)

Course Structure & Scheme of Evaluation

I Semester

Subject Code	**Subject Name**	**L**	**T**	**P**	**Credits**				**Total Marks**
						TA	MSE	ESE	
EE2103	Power Electronics	3	1	0	4	20	20	60	**100**
EE 2104	Advanced Electrical Machines	3	1	0	4	20	20	60	**100**
EE21xx	Elective I	3	1	0	4	20	20	60	**100**
EE21xx	Elective II	3	1	0	4	20	20	60	**100**
EE21xx	Elective III	0	0	6	4	50	0	50	**100**

Total Credits = 20

II Semester

Subject Code	**Subject Name**	**L**	**T**	**P**	**Credits**				**Total Marks**
						TA	MSE	ESE	
EE2203	Electric Drives	3	1	0	4	20	20	60	**100**
EE2204	Advanced Power Electronics	3	1	0	4	20	20	60	**100**
EE22xx	Elective IV	3	1	0	4	20	20	60	**100**
EE22xx	Elective V	3	1	0	4	20	20	60	**100**
EE22xx	Elective VI	0	0	6	4	50	0	50	**100**

Total Credits = 20

III Semester

Subject Code	**Subject Name**	**Credits**	**Eval (100)**
EE 2393	State of Art Seminar	4	Marks
EE 2394	Thesis	16	Marks

IV Semester

Subject Code	**Subject Name**	**Credits**	**Eval (100)**
EE 2492	Thesis	20	Marks

Note: The distribution of thesis evaluation marks will be as follows:

1. Supervisor(s) evaluation component 60%
2. Oral Board evaluation component 40%

First Semester

EEE 2103 Power Electronics:

Introduction to Power Electronics Systems, Role of Power Electronics in the field of electric power control.

Controlled Rectifiers: Phase controlled Rectifiers operation on resistive and inductive loads, use of free-wheeling diode, Single -Phase and Three phase controlled and Fully controlled bridge rectifiers, Semi-converters, Dual converters, Effect of source impedance on converter, Line commuted inverters

Choppers: Principle of operation and control technique of chopper, classification of Choppers, current and voltage waveforms for resistive, inductive and motor loads, Power Transistor and MOSFET based chopper circuits, step up chopper and its application.

Inverters : Single-phase and Three-phase (six-step) inverters, voltage and current waveforms, Bridge Inverter, voltage control & PWM strategies of VSI., Series and parallel inverters, Methods of voltage control, and various techniques of phase width modulation. Comparisons of voltage source and current source inverters and their applications.

AC to AC Converter: **Cycloconverters**: single-phase and three-phase Step-up and Step down cycloconverter, Full bridge and half

Applications- Static circuit breakers, UPS, Static frequency converter, Power factor control, regulation of voltage or current in high power applications: power supplies, motor controls and power amplifiers, control techniques, analysis and design.

References:

1. M. H. Rashid ,*Power Electronics*
2. Vineeta Agrawal & Krishna Kant , *Power Electronics*
3. G. K. Dubey, S. R. Doradla, A. Joshi & V. P. Sinha, *Thyristorised Power Controllers*
4. P. C. Sen, *Power Electronics*
5. P. S. Bimbhra, *Power Electronics*
6. Ned Mohan, T. M. Undeland& W. P. Robbin, *Power Electronics (Converter, Applications & Design)*
7. R .S. Ramstrand, *Power Electronics*
8. M. H. Rashid, *Power Electronics Handbook (Academic Press)*

EE 2104 Advanced Electrical Machines

Review and analysis: Direct-Current Machines, reference frame theory, Symmetrical Induction Machines, Synchronous Machines, Theory of Brushless dc Machines, winding functions and machine design, machine equations for improving analysis and modeling of machines coupled to power electronic circuits, analysis of unbalanced operation, generalized approach to machine parameters identification, Linearized Machine Equations, Reduced-Order Machine Equations, Symmetrical and Unsymmetrical 2-Phase Induction Machines.
Reference:

1. Paul C. Krause, Oleg Wasynczuk, Scott D. Sudhoff, Steven Pekarek, *Analysis of Electric Machinery and Drive Systems, 3rd Edition.*
2. T.A. Lipo, T. M. Jahns, *Introduction To Electric Machines And Drives.*
3. D. W. Novotny and T. A. Lipo, *Vector Control and Dynamics of AC Drives*.
4. Peter Vas., *Sensor less vector and direct torque control*.

Second Semester

EE 2203 Electrical Drives:

Review of classical speed control methods for DC motors, induction motor and synchronous motors, Applications of solid state controller such as choppers, rectifiers, inverters &cycloconverters in drive system and their performance characteristics, Closed loop control of solid state DC drives. DC motor, stepping motor and variable reluctance motor drives. Variable frequency control of ac drives. Vector control of induction motor and synchronous motors, AC and DC motor drives in transportation system & traction, Case studies.

References:

1. J. M. D. Murphy, *Power electronics control of AC motors*, Perganon Press, Newyork
2. P. C. Sen, *Thyristor DC drives*, Wiley Inter Science Publication
3. Vineeta Agarwal, *Fundamentals of Electric drives*, Agarwal Publishing House
4. G. K. Dubey, *Fundamentals of Electric drives*, Narosa Publishing House
5. B. K. Bose, *Modern Power Electronics & AC Drives*, Pearson
6. V. Subramanayam, *Thyristor control of Electric drives*, Tata McGraw Hill Publication
7. S. B. Dewan, *Thyristorized power controller drives*, Wiley Inter Science Publication

EE 2204 Advanced Power Electronics:

Unit 1: DC-DC converters & power supplies

i. Review of DC-DC converter circuits. SEPIC and Cuk converters; Analysis of non-ideal switches and circuit elements in DC-DC converters, efficiency calculation, voltage transfer characteristics with continuous and discontinuous inductor current.

ii. Representation of dynamics of buck, boost and forward converters; state-space averaging, PWM controller; control loop design, voltage control, current mode control; Limiting of inrush current; Inductor and capacitor components.
iii. Isolated DC-DC Converters: Push-Pull Full-Bridge and Half-Bridge, Forward &Flyback Converters, Boost-Derived Converters, Different Versions of the SEPIC and Cuk Converter

Unit 2: DC-AC Inverters
Review of assumed knowledge on DC-AC inverter circuits; advanced modulation techniques, SVM; Compensation for dead time and device voltage drops. Current source inverters, multi-level and Z-source inverters, Rectifier/inverter with bi-directional power flow.

Unit 3: Resonant converters
Hard switched and Soft Switched Converter: Zero-current switched (ZCS) DC-DC converter, Zero-voltage switched (ZVS) DC-DC converter, Load Resonant Converters, Series-resonant and Parallel-resonant converter/inverter, Series-parallel resonant converter, Resonant DC-link inverter/converter. Resonant Switch Converter, DC-DC resonant link inverters, hybrid resonant link inverters, Quasi resonant link converters, High frequency link Integral half cycle Converters,

Unit 4: Modern Rectifiers
Power and Harmonics in Non-sinusoidal Systems, Pulse-Width Modulated Rectifiers, Modeling, analysis, and control of low-harmonic rectifiers, Boost, fly back, and other topologies for controlling the input current waveform of an ac-dc rectifier, Switched mode rectifiers, Average-current, peak-current-mode, critical conduction mode, and nonlinear carrier control techniques, Determination of rms currents, and comparison of performances of popular topologies, System considerations. Modelling losses and Simulation.

Unit 5: Research Studies,
Literature review and discussions in emerging power electronics topics such as: Solar Power Conversion Systems, Wind Power Conversion, Battery Charging, Power Factor Correction, Matrix converter, synchronous link converters.

<u>Textbook:</u>

1. N. Mohan, T. M. Undeland & W. P. Robins, *Power Electronics; Converters, Applications and Design*, John Wiley, Second Edition, 1995, New York.
2. J. G. Kassakian, M.F. Schlecht & G. C. Verghese, *Principles of Power Electronics*, Addison Wesley, 1991.
3. R. W. Erickson, *Fundamentals of Power Electronics*, Kluwer Academic Publications, 1997.
4. D. W. Hart, *Introduction to Power Electronics*, Prentice Hall International, 1997.
5. Erickson and Maksimovic, *Fundamentals of Power Electronics*, 2nd edition, Springer Science Business (2000), ISBN 0-7923-7270-0

List of Professional Electives for PE and Drives

List of Professional Elective I

1. EE 2121 Power Semiconductor Devices
2. EE 2122 Microprocessor and micro-controller based systems
3. EE 2111 Optimization Techniques
4. EE 2131 Flexible AC Transmission Systems

List of Professional Elective II

1. EE 2123 Control Techniques in Power Electronics
2. EE 2124 CAD of Power Electronics
3. EE 2125 Virtual Instrumentation
4. EE 2135 Renewable Energy & Grid Integration

List of Professional Elective III

1. EE 2151 Advanced Control Lab
2. EE 2152 Power Electronics Lab
3. EE 2153 Power System Lab
4. EE 2161 Mini Project/ Term project

List of Professional Elective IV

1. EE 2221 Advanced Digital Design
2. EE 2222 Electric Traction and Vehicles
3. EE 2223 Advanced Control Systems

List of Professional Elective V

1. EE 2224 Micro Electromechanical Systems
2. EE 2225 Special topics in Power Electronics
3. EE2226 Intelligent Control of Drives

List of Professional Elective VI

1. EE 2251 Instrumentation Lab
2. EE 2252 Advanced Power Electronics & Drives Lab
3. EE 2253 Advanced Power System Protection Lab
4. EE 2261 Mini Project / Term Project

EE 2121 Power Semiconductor Devices

1. **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.(review to be done looking at other)

2. **Current controlled and voltage controlled devices :** BJT's – Construction, static characteristics, switching characteristics; Negative temperature co-efficient and secondary breakdown; Power MOSFETs and IGBTs – Principle of voltage controlled devices, construction, types, static and switching characteristics, steady state and dynamic models of MOSFET and IGBTs - Basics of GTO, MCT, FCT, RCT, IGCT and SiC.

3. **Firing and protecting circuits :** 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 snubber.

4. **Thermal protection :** 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, Packaging and power modules.

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**.(Edition 2)**
3. Krishna Kant and Vineeta Agarwal, *Power Electronics,* BPB Publications, New Delhi
4. M D Singh and K.B Khanchandani, *Power Electronics*, Tata McGraw Hill, 2001.
5. Mohan, Undcland and Robins, *Power Electronics – Concepts, Applications and Design*, John Wiley and Sons, Singapore, 2000.

EE2122 Microprocessor and micro-controller based systems

Introduction to the general structure of advanced microprocessors and microcontrollers, Discussions on architectures, instruction sets, memory hierarchies, pipelining and RISC principles, interfacing to input and output devices, user interface design, real-time systems, and table-driven software, single chip microcomputers, Interrupt structures, Parallel/serial I/O, Analog I/O, DMA operations, Peripheral controllers, Laboratory based experiments and projects with these devices

References

1. John B. Peatman, *Design with PIC Microcontrollers,* Pearson Education Asia, 2000.
2. John B. Peatman, *Design with Microcontrollers,* McGraw Hill, 1995.

3. Barry B Brey, *INTEL Microprocessors 8086/8088, 80186/80188, 80486 Pentium Processor, Pentium II, III, IV*, 7th Edition PHI 2006

EE 2111 Optimization Techniques

Introduction to optimization-classification. Linear programming – Problem in two variable-graphical solution – Formulation of LP problems in more than two variables- standard form simplex method-simple-Algorithm special cases-2 phases method- Duality and Dual LP problems-10.
Application of LP in Transportation problem-Balanced and unbalanced transportation problems-Use of North West corner rule-Least cost coefficient method-Vogel approximation method.
Non-linear programming problem – philosophy of numerical methods, various elimination method for one dimensional problems- unconstrained and constrained optimisation, Non linear programming problems, Use of univariate method – Pattern search method – Steepest descent method-Davidon, Fletcher Power method – cutting plane method , Penalty function-Derivative free method, Finite differential and method of sum of squares and non-linear equations-comparison of methods.
Classical optimization techniques – single variable problem-multivariable optimisation with constraints and without constraints Necessary and sufficient conditions.
Basics ideas of Feometric programming-Dynamic programming and Integer programming

References:

1. S. S. Rao, *Optimization theory and application*
2. L. S. Srinath, *Linear programming theory and application*
3. Leunberger D, *Linear & non linear programming*, 2nd ed. Addition –Wesley, 1984
4. Schirisieer A., *Theory of linear and integer programming*, John Wiley and sons 1986

EE 2131 Flexible AC Transmission Systems

Introduction to FACTS, challenges and needs, Power Flow in AC transmission line, Power flow control, Description and definition of FACTS controllers, Static power converter structures, Voltage-sourced and current-sourced converters, Converter output and harmonic control, power converter control issues, Shunt Compensation: SVC, STATCOM, Operation and control, Configurations and applications, Series Compensation: TCSC, mitigation of sub-synchronous resonance, SSSC, Combination of shunt-series compensation: UPFC, Power flow studies with FACTS controllers, operational constraints, IPFC, UPQC, other FACTS Controllers: TCPAR, TCBR etc.

References:

1. N.G.Hingorani, *FACTS*
2. K.R. Padiyar, *FACT's Controllers in Transmission & Distribution*
3. V. K. Sood, *HVDC and FACTS Controllers: Applications of Static Converters in Power Systems*

4. Enrique Acha, C.R. Feurte-Esquivel and others, *Modelling and Simulation in Power Networks,* Wiley.

EE 2123 Control Techniques in Power Electronics

State space modeling and simulation of linear systems, discrete time models, conventional controllers using small signal models, variable structure and sliding mode control, hysterisis and ramp comparison controllers, output and state feedback switching controllers, Linear Quadratic Controller (LQR), Deadbeat controller, Structure and control of following power converters: single phase H-bridge and three phase inverter, multilevel inverters, PWM for inverters, Implementation of Power Electronics Controllers: analog and digital controllers, DSP implementation, ASIC's and embedded controller, FPGA's and Virtual Instrumentation, Introduction to simulation method for power electronic converter system , Modeling of Elements, Computer simulation of state equation, Order reduction for simulation study, Eigenvalue analysis, Participation factor, Sequential methods of simulation, Modern trends in CAD methods

References:

1. N. Mohan and other, *Power Electronics, Converters, Applications and Design*
2. M. H. Rashid (ed), *Power Electronics Handbook*
3. M. P. Kazmierkowski, *Control in Power Electronics* (Selected Problems)
4. D. O. Neacsu,*Power Switching Converters* (Medium and High Power)
5. H. Sira-Ramirez & others, *Control Design Techniques in Power Electronics Devices*
6. A. Ghosh and G. Ledwich ,*Power Quality Enhancement using Custom Power Devices*

EE 2124 CAD of Power Electronics

Introduction to simulation method for power electronic converter system , Modeling of Elements, Computer simulation of state equation, Order reduction for simulation study , Eigenvalue analysis, Participation factor, Sequential methods of simulation, Modern trends in CAD methods.

References

1. Rashid, M., *Simulation of Power Electronic Circuits using PSPICE*, PHI, 2006
2. Rajagopalan, V. *Computer Aided Analysis of Power Electronic systems*-Marcell – Dekker Inc., 1987.
3. John Keown, *Microsim, Pspice and circuit analysis* -Prentice Hall Inc., 1998

EE- 2125 Virtual Instrumentation

Introduction, Virtual instrumentation (VI) advantages, Graphical programming techniques, Data flow programming , VI's and sub VI's, Structures, Arrays and Clusters, Data acquisition methods, File I/O, DAQ hardware, PC hardware: operating systems, Instrumentation buses, ISA, PCI, USB, PXI, Instrument control, Data communication standards, RS-232C, GPIB, Real time operating systems, Reconfigurable I/O, FPGA.

References

1.S. Gupta & J. John, *Virtual Instrumentation Using Lab VIEW*
2.Robert Bishop, *Lab VIEW 7 Express Student Edition*
3.National Instruments, *Lab VIEW User Manual*
4.National Instruments, *Lab VIEW RT User Manual*
5.National Instruments, *Lab VIEW FPGA Module User Manual*
6.Leonard Sokoloff, *Application Lab VIEW*
7.Nesimi Ertugrul,*Lab VIEW For Electrical Circuits, Machine Drives and Labs*
8.John Essick, *Advanced Lab VIEW Labs*
9.Gary Johnsons, *Lab VIEW Graphical Programming*

EE 2135 Renewable Energy & Grid Integration

Wind energy conversion systems, Wind turbines, Turbine characteristics, Various electrical generators, Induction generators, doubly-fed induction generator, Synchronous generator and permanent magnet synchronous generator (PMSG). Power conversion through power electronics converters, Maximum Power point tracking (MPPT), Controlled rectifiers and DC-DC converters for MPPT, Voltage source inverters, Modeling and control of WECS for grid interface, Standalone and grid interface application, Solar photovoltaic (PV) system, classifications, PV characteristics, MPPT methods, DC-DC converters and VSI, roof-top and domestic PV systems, Grid connected PV system, Fuel cells, classification and characteristics, power electronics interfaces, Hybrid systems, Other renewable sources of energy, Integration of renewable energy systems.
Components required for grid integration. Energy storage components and integration with the grids. Large energy storage technologies (MW). Grid integration issues and standards. Adequate converter topologies, tariff related to renewable energy interface.

References:

1. M. R. Patel, *Wind and Solar Power Systems*, Tailor & Francis CRC Press, USA, 2006.
2. M. H. Rashid (ed), *Power Electronics Handbook*, Academic Press, Florida, 2001.
3. Bin Wu, Yongqiang Lang, Navid Zargari, *Power Conversion and Control of Wind Energy Systems*, WILEY 2011.
4. A. Ghosh and G. Ledwich, *Power Quality Enhancement using Custom Power Devices*, Kluwer Academic Publisher, Boston, MA, 2002.

EE 2154 Power Electronics Lab I

Power Electronics - Hardware

1. To design and implement single phase and three-phase diode-bridge modules under varying load condition.
2. To design and implement controlled bridge rectifier using single-phase and three-phase SCR bridge modules.
3. To program the given microprocessor (8085) for varying the firing angle of SCR triggering.
4. To implement the gate drive for IGBT bridge module as an inverter and study its characteristics.
5. To test the isolated gate drivers for transistor–transistor logic (TTL) pulses to the MOSFET bridge module by varying the pulse width.

Power Electronics – Simulation

6. To simulate the Buck and Boost converter using PSPICE software and obtain the variation of output voltage with duty cycle variation.
7. To simulate the Buck-boost converter using PSPICE software and obtain the variation of output voltage with duty cycle variation.
8. To simulate Bipolar and Unipolar Sinusoidal Pulse Width Modulation (SPWM) using PSPICE software for half-bridge and full-bridge inverter respectively.

Renewable Energy – Hardware

9. To demonstrate the I-V and P-V characteristics of PV module with varying radiation and temperature level. Also demonstrate the I-V and P-V characteristics of series and parallel combination of PV modules.
10. To show the effect of variation in tilt angle on PV module power. Also demonstrate the effect of shading on module output power.
11. Workout power flow calculations of standalone PV system of DC load with battery.

Renewable Energy – Simulation

12. To verify the static C_P-λ characteristics of a three bladed wind turbine
13. To simulate a given PV Array and to plot the I-V characteristics using Matlab.

FACTS – Simulation

14. To design and simulate static VAR compensator and STATCOM using Matlab and plot their characteristics.
15. To design and simulate firing angle control of thyristor controlled reactor (TCR) using Matlab and tabulate the theoretical and simulated values.
15. To design and simulate firing angle control of thyristor switched capacitor (TSC) using Matlab and tabulate the theoretical and simulated values.
16. Static VAR Compensator
17. Comparison between DSTATCOM and STATCOM
18. Basic Series compensation circuit

Advanced Electrical Machines – Hardware

19. Study of V-curves of a synchronous Motor

Advanced Electrical Machines – Simulation

20. Modeling & Simulation of the Starting and stopping transients for a DC Motor
21. Modeling & Simulation of the Starting and stopping transients for a 3 Ph Induction Motor
22. To simulate the PWM control of an induction motor using Matlab Simulink.
23. To Model the dynamics of switched reluctance motor using Matlab Simulink.
24. To Model the dynamics of three-phase round-rotor or salient-pole synchronous machine using Matlab Simulink.
25. Simulation of electrodynamic force for a simple electromechanical system
26. Study of ANSYS based linear magnetic circuit.
27. Design of Induction Motor using ANSYS software.

EE 2221 Advanced Digital Design

Design principles for complex digital systems, Iteration, top-down/bottom-up, divide and conquer, and decomposition, Description techniques, including block diagrams, register transfer and hardware description languages, Consideration of transmission line effects on digital systems, Synchronous design, state machine design, Design for testability, PALs, FPGAs, standard cells, timing considerations, fault vectors and fault grading.

References:

1. Nripendra N Biswas ,“Logic Design Theory” Prentice Hall of India,2001
2. Logic and Computer Design Fundamentals, M. Morris Mano, Charles R. Chime, 3rd Edition, PHI

EE2222 Electric traction and vehicles

Electric Traction Services, Nature of Traction Loads, Main Line and Suburban Train configurations, Conventional and Modern Traction Drives, Traction Motors, Tractions Drives, Braking Systems, Semiconductor Converter Controlled drives, Induction and Synchronous motor drives, VSI/CSI drives, Polyphase ac motors for traction Drives, Diesel Electric traction, Energy Conservation, Interlocking and sequencing operations and Protection.

Introduction to Alternative Vehicles, Electric Vehicles, Hybrid Electric Vehicles, Electric and Hybrid, Vehicle Components, Vehicle Mass and Performance, Electric Motor and Engine Ratings, Electric and Hybrid Vehicle History, Well-to-Wheel Analysis, EV/ICEV Comparison, Electric Vehicle Market, Vehicle Mechanics, Roadway Fundamentals, Laws of Motion, Vehicle Kinetics, Dynamics of Vehicle Motion, Propulsion Power Velocity and Acceleration, Tire–Road Force Mechanics, Propulsion System Design

Alternative Vehicle Architectures, Electric Vehicles, Hybrid Electric Vehicles, Plug-In Hybrid Electric Vehicle, Power train Component Sizing, Mass Analysis and Packaging, Vehicle

Simulation Battery Energy Storage, Batteries in Electric and Hybrid Vehicles, Battery Basics, Battery Parameters Electrochemical Cell Fundamentals, Battery Modeling, Traction Batteries, Battery Pack Management Alternative Energy Storage, Fuel Cells, Ultra capacitors, Compressed Air Storage, Flywheels Control of AC Machines, Vector Control of AC Motors, dq Modeling, Induction Machine Vector Control PM Machine Vector Control

Internal Combustion Engines, BMEP and BSFC, Vehicle Fuel Economy, Emission Control System, Power train Components and Brakes, Power train Components, Gears, Clutches, Differential Transmission, Vehicle Brakes Cooling Systems, Climate Control System, Power train Component Cooling System Hybrid Vehicle Control Strategy, Vehicle Supervisory Controller, Mode Selection Strategy, Modal Control Strategies

References

1. SandeepDhameja ,*Electric Vehicle Battery Systems* , Elsevier
2. John Fenton & Ron Hodkinson, *Lightweight Electric/Hybrid Vehicle Design* , Elsevier
3. Seth Leitman, Bob Brant, *Build Your Own Electric Vehicle* , McGraw Hill
4. Iqbal Husain ,*Electric and Hybrid Vehicles: Design Fundamentals,* Second Edition by CRC, Press 2010
5. MehrdadEhsani; YiminGao; Ali Emadi, Modern Electric, *Hybrid Electric*, *and Fuel Cell Vehicles: Fundamentals, Theory, and Design,* Second Edition CRC Press 2009

EE2223 Advanced Control Systems

Review of Modeling and Analysis of LTI Systems: Modeling of physical Systems. Design specifications and performance indices, Motion control systems, Transportation lags. Approximation of time-delay functions., Sensitivity of control systems to parameter variations. Effects of disturbance of signals, Disturbance rejection.

Analysis in state-space: A perspective on state-space design, State variables. State models for physical systems. SISO and MIMO systems. Solution of state equations. Transfer function. Eigenvalues and eigenvectors. Jacobian linearization technique. State transformations and diagonalisation. Transformation to phase-variable canonical form. Controllability and observability. Duality property. Stability.

Introduction to Discrete-time Systems:

Basic elements of discrete-time control system. Z-transform and properties. Inverse Z-transform. Difference equation and its solution by Z-transform method. Z-transfer function. State diagram of digital systems. Time delay. Direct, cascade and parallel decomposition of Z-transfer functions.

Feedback control design: Continuous control design. Proportional, derivative and integral cont Feedback control design Continuous control design. Proportional, derivative and integral control action. PID controller tuning rules. Ziegler-Nichols method. Two degree of freedom control systems. Compensator design using Bode diagram in frequency response approach. Lag, Lead, Lag-lead compensator.Control law design for full state feedback by pole placement. Full order observer system. Observer based state feedback. Separation principal.

Non linear system:
Classification and types of non-linearity. Phenomena peculiar to non-linear systems. Methods of analysis. Linearization based on Taylor's series expansion. Jacobian Linearization. Phase trajectory and its construction. Phase-plane analysis of linear and non-linear sustems. Existence of limit cycles. Describing function of typical non-linearities. Stability analysis by DF method. Introduction to DIDF. Popov's circle criterion. Stability analysis by Lyapunov's indirect and direct methods, Lypunov's theorem.

Reference Books:

1. Ogata, K Modern, *Control Engineering*, PHI Learning
2. Kuo, B.C., *Automation Control Systems*, Prentice Hall
3. Roy Choudhury, D, *Modern Control Engineering*, Prentice Hall
4. Nagrath, J. J. Gopal, M, *Control System Engineering*, New Age Publishers
5. Schulz, D.G. and Melsa, L.State, *Functions and Linear Control Systems*, McGraw-Hill.
6. Stepheni, Shahian, Savant, Hostetler, *Design of feedback control systems*, Oxford University Press.
7. Vidyasagar, *Nonlinear System Analysis*, Prentice-Hall.
8. Gibson, J.E., *Non linear System* , Mc. Grawhill.
9. Gopal. M, *Digital Control and State Variable Methods*, TMH.

EE2224 Micro Electro Mechanical Systems

UNIT: INTRODUCTION
Intrinsic characteristics of MEMS- Energy Domains and transducers, sensors & Actuators, introduction to Microfabrication, Silicon based MEMS processes, new materials, review of Electrical & mechanical concepts in MEMS, semiconductor devices, stress and strain analysis, flexural beam bending, Torsional deflection.

Unit II: Sensors and Actuators-I
Electrostatic sensors, parallel plate capacitors, applications, Interdigitated finger capacitor, comb drive devices, thermal sensing and actuation, thermal expansion, thermal couples, thermal resistors, applications, magnetic actuators, micro magnetic components, case studies of MEMS in magnetic actuators.

Unit III: Sensors & actuators-II
Piezoresistive sensors, piezoresistive sensor materials, stress analysis of mechanical elements, applications to inertia, pressure, tactile and flow sensors, piezoelectric sensors and actuators, piezoelectric effects, piezoelectric materials, applications to inertia, Acoustic, tactile and flow sensors.

Unit IV: Micromachining
Silicon Anisotropic Etching, Anisotropic wet etching, dry etching of silicon, plasma etching, deep reaction ion etching (DRIE), isotropic wet etching, gas phase Etchants, case studies, basic

surface micromachining processes, structural and sacrificial materials, acceleration of sacrificial Etch, striction and antistriction methods, assembly of 3D MEMS, foundry process.

Unit V: polymer and Optical MEMS

Polymers in MEMS, polimide, SU-8, liquid crystal polymer (LCP), PDMS, PMMA, Parylene, fluorocarbon, application to acceleration, pressure, flow and tectile sensors , optical MEMS, lenses & mirrors, Actuators for Active optical MEMS.

Text books:

1. Chang Liu, *Foundations of MEMS*, Pearson Education Inc., 2006.
2. James J. Allen, *Micro electro mechanical system design*, CRC press published in 2005.

References:

1. Nadimmaluf, *An introduction to micro electro mechanical system design*, Artech House, 2000.
2. Mohamed Gad-el-Hak, editor, *The MEMS handbook*, CRC press Baco Raton, 2000
3. Tai ran hsu, *MEMS and micro systems design and manufacture*, TMH, New delhi,2002
4. Julian W. Gardner, Vijay K. Varadan, Osama O. Awadelkarim, *micro sensors MEMS and smart devices*, John Wiley& Sons Ltd, 2002.

EE2225 Special topics in Power Electronics

Section 1: Power management circuits, Buck, boost, fly-back, and other popular DC DC converters, Steady state, dynamic, large signal analysis techniques, Role of IC design in creating the system

Section 2: Block level IC Design Block diagram of a power management IC , Block level analog circuits in the IC and their design, CMOS Analog Building Blocks, Review of basic building blocks of Analog ICs (CS, CG, CD gain stages, Differential stage, mirrors, etc.) Opamps and Comparators, Reference circuits and voltage regulators, Temperature and power supply sensitivity

References:

1. Erickson and Maksimovic, *Fundamentals of Power Electronics*, , 2nd edition, Springer
2. Science+Business (2000), ISBN 0-7923-7270-02.
3. Allen and Holberg, *CMOS Analog IC Design*, Oxford University Press, 2 edition Co
4. *http://focus.ti.com/lit/ds/symlink/tps40192.pdf*
5. *http://www.intersil.com/data/fn/fn6745.pdf*

EE 2226 Intelligent Control of Drives

INTRODUCTION TO NEURAL NETWORKS :Introduction – biological neurons – Artificial neurons – activation function – learning rules – feed forward networks – supervised learning – perception networks – adaline – madaline – back propagation networks – learning factors – linear separability – Hopfield network – discrete Hopfield networks

ARCHITECTURE – TYPES: Recurrent auto association memory – bi-directional associative memory – temporal associative memory – Boltzmann machine Hamming networks – self – organizing feature maps – adaptive resonance theory network – Instar – Outsar model – counter propagation network – radial basis function networks

INTRODUCTION TO FUZZY SETS AND SYSTEMS: Crisp set – vaguness – uncertainty and imprecision – fuzzy set – fuzzy operation- properties – crisp versus fuzzy relations – fuzzy relation – cardinality operations, properties – fuzzy Cartesian product and composition – non – interactive fuzzy sets – tolerance and equivalence relations – fuzzy ordering relations – fuzzy morphism – composition of fuzzy relations

FUZZY LOGIC CONTROLLER: Fuzzy to crisp conversion – Lambda cuts for fuzzy sets and relations – definition methods – structure of fuzzy logic controller – database – rule base – Inference engine

APPLICATION AND DESIGN: Applications of Neural network and Fuzzy system for single phase fully controlled converter, single phase ac voltage controller, DC Drive and AC Drive Designing of controllers using Simulation Software Fuzzy Logic Toolbox – Modeling of DC Machines using Simulation Software and Simulink Toolbox

References:

1. Lawrence Fausatt, *Fundamentals of neural networks*, Prentice Hall of India, New Delhi, 1994.
2. Timothy J. Ross, *Fuzzy Logic with Engineering Applications*, McGraw Hill International Edition, USA, 1997.
3. Bart kosko, *Neural Networks and Fuzzy Systems*, Prentice Hall of India, New Delhi,

EE 2252 Advanced Power Electronics & Drives Lab

List of experiments

1. To perform the 4-quadrant operation using IGBT based chopper capable of driving a 0.5-hp dc motor.
2. To perform the control of 3-phase induction motor using IGBT based 3-phase inverter capable of driving a 0.5 hp ac motor.
3. To perform the Sensor less vector control drive for 3-ph, 1-hp induction motor.
4. To perform the closed loop controlled MOSFET based matrix converter fed induction motor.
5. To control the speed of BLDC motor using pulse width modulation (PWM) method.

6. To control the speed of three-phase induction motor using three-phase AC voltage controller by varying the firing angle of thyristor.
7. To study the Zero Current Source (ZCS) Resonant converter.
8. To design a flyback converter and study its characteristics.
9. To design a push pull converter and study its characteristics.
10. To design forward converter & study its characteristics.
11. To design a SEPIC converter & study its characteristics.
12. To design a suitable single-phase three level inverter as follows
13. Full bridge (H-bridge), (b) Neutral point clamped (Diode clamped)
14. To design a three-phase neutral point clamped three-leg line frequency inverter.
15. To test the performance of Microprocessor controlled reversible DC drive using 1 phase SCR dual converter.
16. To test the performance of Micro-controller based reversible regenerative DC drive using 4-quadrant MOSFET based chopper.
17. To perform slip power recovery using thyristorised Rectifier Bridge converter for wound rotor induction motor.
18. To determine the speed-torque characteristics of single-phase AC motor using thyristorised AC voltage controller with open loop and closed loop control.
19. To control the given 3-phase induction motor using inverter module and SCR AC regulator module with PC interface.
20. To control the given DC motor using Chopper module and SCR Converter module with PC interface.
21. To control the pulse width modulation (PWM) voltage source inverter (VSI) fed 3-phase AC drive with DSP controller.
22. To control the speed of a given three-phase induction motor by V/F (voltage/frequency) control.
23. To perform 3-ph VSI fed PWM inverter AC drive.