AFFILIATED INSTITUTIONS

ANNA UNIVERSITY, CHENNAI

REGULATIONS - 2009

M.E. ELECTRICAL DRIVES AND EMBEDDED CONTROL

II TO IV SEMESTERS (FULL TIME) CURRICULUM AND SYLLABUS

SEMESTER II

SL NO.	COURSE CODE	COURSE TITLE	L	T	P	C
THEORY						
1	EB9321	Computer Aided Design of Power Electronic Circuits	3	1	0	4
2	EB9322	Dynamic Modelling, Analysis and Design of AC Drives	3	0	0	3
3	EB9323	Control of Electric Drives	3	0	0	3
4	PE9223	Special Electrical Machines	3	0	0	3
5		Elective II	3	0	0	3
6		Elective III	3	0	0	3
PRACTICAL						
7	EB9324	Electric Drives Laboratory	0	0	3	2
		TOTAL	**18**	**1**	**3**	**21**

SEMESTER III

SL NO.	COURSE CODE	COURSE TITLE	L	T	P	C
THEORY						
1		Elective IV	3	0	0	3
2		Elective V	3	0	0	3
3		Elective VI	3	0	0	3
PRACTICAL						
4	EB9331	Project (Phase I)	0	0	12	6
		TOTAL	**9**	**0**	**12**	**15**

SEMESTER IV

SL NO.	COURSE CODE	COURSE TITLE	L	T	P	C
PRACTICAL						
1	EB9341	Project (Phase II)	0	0	24	12
		TOTAL	**0**	**0**	**24**	**12**

TOTAL CREDITS TO BE EARNED FOR THE AWARD THE DEGREE 20+21+15+12= 67

ELECTIVES FOR ELECTRICAL DRIVES AND EMBEDDED CONTROL

ELECTIVE I

SL NO.	COURSE CODE	COURSE TITLE	L	T	P	C
1	HV9311	Electro Magnetic Field Computation and Modelling	3	1	0	4
2	PE9351	Advanced Power Semiconductor Devices	3	0	0	3
3	CL9311	Transducers and Measurements	3	0	0	3

ELECTIVE II & III

SL NO.	COURSE CODE	COURSE TITLE	L	T	P	C
1	EB9351	Micro System Design	3	0	0	3
2	PE9261	Power Quality	3	0	0	3
3	PE9224	Microcontroller and DSP based System Design	3	0	0	3
4	PS9223	Flexible AC Transmission Systems	3	0	0	3
5	ET9261	Design of Embedded Control Systems	3	0	0	3
6	ET9222	Real Time Operating System	3	0	0	3

ELECTIVE IV, V & VI

SL NO.	COURSE CODE	COURSE TITLE	L	T	P	C
1	ET9278	Applications of MEMS Technology	3	0	0	3
2	PE9272	Power Electronics for Renewable Energy Systems	3	0	0	3
3	CL9355	Principles of Robotics	3	0	0	3
4	CL9358	System Identification and Adaptive Control	3	0	0	3
5	CL9002	Soft Computing Techniques	3	0	0	3
6	PS9276	Wind Energy Conversion Systems	3	0	0	3
7	HV9353	Electromagnetic Interference and Electromagnetic Compatibility	3	0	0	3
8	ET9275	Computer in Networking and Digital Control	3	0	0	3
9	ET9274	Programming with VHDL	3	0	0	3

EB9321	COMPUTER AIDED DESIGN OF POWER ELECTRONIC CIRCUITS	L T P C 3 1 0 4

UNIT I INTRODUCTION 9

Importance of simulation – General purpose circuit analysis – Methods of analysis of power electronic systems – Review of power electronic devices and circuits.

UNIT II ADVANCED TECHNIQUES IN SIMULATION 9

Analysis of power electronic systems in a sequential manner – coupled and decoupled systems – Various algorithms for computing steady state solution in power electronic systems – Future trends in computer simulation.

UNIT III MODELING OF POWER ELCTRONIC DEVICES 9

Introduction – AC sweep and DC sweep analysis – Transients and the time domain analysis – Fourier series and harmonic components – BJT, FET, MOSFET and its model- Amplifiers and Oscillator – Non-linear devices.

UNIT IV SIMULATION OF CIRCUITS 9

Introduction – Schematic capture and libraries – Time domain analysis – System level integration and analysis – Monte Carlo analysis – Sensitivity/stress analysis – Fourier analysis.

UNIT V CASE STUDIES 9

Simulation of Converters, Choppers, Inverters, AC voltage controllers, and Cyclo-converters feeding R, R-L, and R-L-E loads – computation of performance parameters: harmonics, power factor, angle of overlap.

L:45+ P:15=60 PERIODS

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.

EB 9322	DYNAMIC MODELLING, ANALYSIS AND DESIGN OF AC DRIVES	L T P C 3 0 0 3

UNIT I REFERENCE FRAME THEORY 9

Theory of transformation – Phase transformation and commutator transformation – Invariance of Power - Static and rotating reference frames – balanced steady-state voltage and torque equations using transformation theory.

UNIT II DYNAMIC MODELLING OF INDUCTION MACHINES 9

Induction machines – Equivalent circuit – Complete speed-torque characteristics - Voltage and torque equations in static and rotating reference frames – Analysis of steady state and dynamic operations - Dynamic performance under unbalanced/fault conditions - Computer simulation.

UNIT III DYNAMIC MODELLING OF SYNCHRONOUS MACHINES 9

Synchronous machines – Equivalent circuit – Machine reactances and time constants - Voltage and torque equations in static and rotating reference frames – Analysis of steady state and dynamic operations - Dynamic performances under unbalanced/fault conditions - Computer simulation.

UNIT IV INDUCTION MOTOR DRIVES 9

Variable voltage operation – Variable frequency operation – Constant flux operation – Torque-Slip characteristics – Constant Torque and Constant power operation – Dynamic and regenerative braking of VSI fed drives – Power factor considerations – Field oriented control – Design of closed loop operation of Induction motor drive systems.

UNIT V SYNCHRONOUS MOTOR DRIVES 9

Need for leading PF operation – Open loop VSI fed drive and its characteristics – Self control – Torque control – Torque angle control – Power factor control – Brush less excitation systems – Starting methods – Field oriented control – Design of closed loop operation of Synchronous motor drive systems.

TOTAL: 45 PERIODS

TEXT BOOKS:

1. Paul C.Krause, OlegWasyzczuk, Scott D.Sudhoff 'Analysis of Electric Machinery and Drive Systems" IEEE Press, Second Edition, 2002.
2. R.Krishnan," Electric Motor Drives, Modeling, Analysis and Control" Prentice Hall of India, 2002.
3. Bose.B.K., Power Electronics and Motor Drives - Advances and Trends, IEEE Press, 2006.
4. Murphy J.M.D.,Turnbull F.G., "Thyristor control of AC Motors", Peragamon Press,Oxford,1988.

REFERENCES:

1. Samuel Seely, "Electromechanical Energy Conversion", Tata McGraw Hill Publishing Company, 2000.
2. A.E.Fitzgerald,Charles Kingsley, Jr. and Stephen D.Umans, "Electric Machinery", Tata McGraw Hill,5th Edition,1992.
3. Generalized theory of Electrical Machines, P.S.Bimra, Khanna Publishers, 1995.
4. Dubey,G.K. "Power Semiconductor controlled devices", Prentice Hall International, NewJersey,1989.
5. Ned Mohan, Advanced Electric Drives, Analysis, Control and Modelling using Simulink MNPERE, 2001.
6. Bin Wu, "High Power Converters and AC Drives", IEEE Press, A John Wiley and Sons, Inc., 2006.

EB 9323 CONTROL OF ELECTRIC DRIVES L T P C
3 0 0 3

UNIT I CONVERTER FED DC DRIVES 9

Microcontroller hardware circuit, flow charts waveforms, Performance characteristics of dc drives fed through single phase converters, 3-phase converters, dual converters, 1-phase fully controlled converter and 3-phase fully controlled converter fed dc drive.

UNIT II CHOPPER FED DC DRIVES 9

Microcontroller hardware circuits and waveforms of various modes of operation of chopper fed DC drives.

UNIT III INVERTER FED INDUCTION MOTOR DRIVE 9

Microcomputer controlled VSI fed induction motor drive - Detailed power circuit, generation of firing pulses and firing circuit, flow charts and waveforms for 1-phase, 3-phase Non-PWM and 3-phase PWM VSI fed induction motor drives. Sampling techniques for PWM inverter.

UNIT IV MATHEMATICAL MODELING OF FREQUENCY CONTROLLED DRIVE 9

Development of mathematical model for various components of frequency controlled induction drive, mathematical model of the system for steady state and dynamic behaviour, Study of stability based on the dynamic model of the system.

UNIT V CLOSED LOOP CONTROL OF MICROCOMPUTER BASED DRIVES 9

Voltage, Current, Torque and Speed measurements using digital measurement techniques. Types of controllers, position and velocity measurement algorithm, closed loop control of microcomputer based drives.

TOTAL : 45 PERIODS

TEXT BOOKS :

1. Bose.B.K., Power Electronics and Motor Drives - Advances and Trends, IEEE Press, 2006.
2. Buxbaum, A. Schierau, and K.Staughen, “A design of control systems for DC drives”, Springer- Verlag, Berlin,1990.
3. Thyristor control of Electric drives, Vedam Subrahmanyam, Tata McGraw Hill, 1988.

REFERENCES:

1. R.Krishnan, “Electric Motor Drives, Modeling, Analysis and Control” Prentice Hall of India, 2002.
2. Bin Wu, “High Power Converters and AC Drives”, IEEE Press, A John Wiley and Sons, Inc., 2006.
3. Dubey G.K., Power semiconductor controlled drives, Prentice-HALL 1989
4. Control of Electric Drives, Leonard W, Springer Verlag, NY, 1985
5. Bose B.K., Microcomputer control of power electronics and drives, IEEE Press, 1987.
6. Bose B.K., Adjustable Speed A.C. drives, IEEE Press, 1993.

PE9223 SPECIAL ELECTRICAL MACHINES L T P C
3 0 0 3

UNIT I STEPPING MOTOR 9

Constructional features – Principle of operation – Modes of excitation – Torque production in variable reluctance stepping motor - Dynamic characteristics – Drive systems and circuit for open loop control – Closed loop control of stepping motor.

UNIT II SWITCHED RELUCTANCE MOTORS 9

Constructional features – principle of operation – Torque equation – Power controllers – Characteristics and control microprocessor based controller.

UNIT III SYNCHRONOUS RELUCTANCE MOTORS 9

Constructional features: axial and radial air gap Motors – Operating principle – Reluctance torque – phasor diagram –motor characteristics.

UNIT IV PERMANENT MAGNET SYNCHRONOUS MOTROS 9

Principle of operation –EMF –Power input and torque expressions –Phasor diagram – power controller-Torque speed characteristics-Self control –Vector control –current control schemes.

UNIT V PERMANENT MAGNET BRUSHLESS DC MOTORS 9

Commutation in DC motors, Difference between mechanical and electronic commutators- Hall sensors, Optical sensors - Multiphase Brushless motor –Square wave permanent magnet brushless motor drives –Torque and emf equation-Torque speed characteristics-Controllers –Microprocessors based controller

TOTAL: 45 PERIODS

REFERENCES

1. Miller, T.J.E. “Brushless permanent magnet and reluctance motor drives”,Clarendon Press, Oxford,1989.
2. Kenjo, T, “Stepping motors and their microprocessor control ”,Clarendon Press,Oxford 1989.
3. R.Krishnan, “Switched Reluctance Motors Drives: Modelling, Simulation, Analysis Design and Applications”, CRC Press, New York, 2001.

EB 9324 ELECTRIC DRIVES LABORATORY L T P C
0 0 3 2

1. Micro controller based speed control of Converter/Chopper fed DC motor.

2. Micro controller based speed control of VSI fed three-phase induction motor.

3. Micro controller based speed control of Stepper motor.

4. DSP based speed control of BLDC motor.

5. DSP based speed control of SRM motor.

6. Self control operation of Synchronous motors.

7. Condition monitoring of three-phase induction motor under fault conditions.

8. Re-programmable Logic Devices and Programming

   (a) VHDL programming – Examples

   (b) Verilog HDL programming – Examples

   (c) Realisation of control logic for electric motors using FPGA.

9. Simulation of Four quadrant operation of three-phase induction motor.

10. Simulation of Automatic Voltage Regulation of three-phase Synchronous Generator.

P = 45, TOTAL: 45 PERIODS

		L	T	P	C
EB 9331	**PROJECT WORK (PHASE I)**	**0**	**0**	**12**	**6**
EB 9341	**PROJECT WORK (PHASE – II)**	**0**	**0**	**24**	**12**

HV9311 ELECTROMAGNETIC FIELD COMPUTATION AND MODELLING L T P C
3 1 0 4

UNIT I INTRODUCTION 9

Review of basic field theory – electric and magnetic fields – Maxwell's equations – Laplace, Poisson and Helmoltz equations – principle of energy conversion – force/torque calculation – Electro thermal formulation.

UNIT II SOLUTION OF FIELD EQUATIONS I 9

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

UNIT III SOLUTION OF FIELD EQUATIONS II **9**

Finite element method (FEM) – Differential/ integral functions – Variational method – Energy minimization – Discretisation – Shape functions –Stiffness matrix –1D and 2D planar and axial symmetry problem.

UNIT IV FIELD COMPUTATION FOR BASIC CONFIGURATIONS **9**

Computation of electric and magnetic field intensities– Capacitance and Inductance – Force, Torque, Energy for basic configurations.

UNIT V DESIGN APPLICATIONS **9**

Insulators- Bushings – Cylindrical magnetic actuators – Transformers – Rotating machines.

L=45: T=15, Total =60 PERIODS

REFERENCES

1. K.J.Binns, P.J.Lawrenson, C.W Trowbridge, “The analytical and numerical solution of Electric and magnetic fields”, John Wiley & Sons, 1993.
2. Nathan Ida, Joao P.A.Bastos , “Electromagnetics and calculation of fields”, Springer-Verlage, 1992.
3. Nicola Biyanchi , “Electrical Machine analysis using Finite Elements”, Taylor and Francis Group, CRC Publishers, 2005.
4. S.J Salon, “Finite Element Analysis of Electrical Machines.” Kluwer Academic Publishers, London, 1995, distributed by TBH Publishers & Distributors, Chennai, India
5. User manuals of MAGNET, MAXWELL & ANSYS software.
6. Silvester and Ferrari, “Finite Elements for Electrical Engineers” Cambridge University press, 1983.

PE 9351 ADVANCED POWER SEMICONDUCTOR DEVICES **L T P C**
3 0 0 3

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 co-efficient and secondary breakdown; Power darlington - 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.

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 - Basics of GTO, MCT, FCT, RCT and IGCT.

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 hear sink selection – Thermal resistance and impedance - Electrical analogy of thermal components, heat sink types and design – Mounting types.

TOTAL : 45 PERIODS

TEXT BOOKS

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.

REFERENCES

1. MD Singh and K.B Khanchandani, "Power Electronics", Tata McGraw Hill, 2001.
2. Mohan, Undcland and Robins, "Power Electronics – Concepts, applications and Design, John Wiley and Sons, Singapore, 2000.

CL 9311 TRANSDUCERS AND MEASUREMENTS L T P C
3 0 0 3

UNIT I RESISTIVE, INDUCTIVE AND CAPACITIVE ELEMENTS 9

Potentiometric, strain-gage and electrode elements – Inductive and Capacitive elements: structures, equivalent circuits and characteristics, single, differential and angle displacement elements, displacement to phase converters, and proximity elements, magnetostrictive elements, temperature instabilities and features.

UNIT II TRANSFORMER, ELECTRODYNAMIC, SERVO AND RESONANT ELEMENTS 9

Transformer elements: Single core, differential, rotating coil and synchro transformers, weak-field sensors - Electrodynamic elements: Moving-coil, variable-reluctance- - Resonant elements: vibrating strings, vibrating beams, vibrating cylinders, piezoelectric resonators, acoustical resonators, microwave cavity resonators.

UNIT III MECHANICAL, ACOUSTICAL AND FLOWMETERING ELEMENTS 9

Stresses state of diaphragm, dynamic characteristics of diaphragm, temperature drifts, sensitivity drifts, sensitivity to acceleration – Inertial mass elements: sensing and transduction elements of flowmeters, electromagnetic flowmeters, nanoelectrode electromagnetic flowmeters -ultrasonic elements – Acoustical elements: acoustical filters.

UNITIV OPTICAL MICROSTRUCTURE SENSORS 9

Photo detectors: Thermal detectors, pneumatic detectors, pyroelectric detectors, photoemissive devices, photo conductive detectors, photo diodes, avalanche photo diodes, schottky photo diodes, photo transistors – Fiber optic sensors: Fibers as light guides, reflection sensors, Intrinsic multimode sensor, temperature sensor, phase modulated sensor, fiber optic gyroscopes and other fiber sensors

UNIT V MISCELLANEOUS MINIATURE SENSORS 9

Magnetic sensors: Hall Effect sensors, magnetoresistors and other sensors – Solid state chemical sensors: Silicon based sensors, metal oxide sensors, solid electrolyte sensors, membranes – Electromechanical micro sensors and basic factors of design

TOTAL : 45 PERIODS

REFERENCES:

1. Alexander D Khazan, “Transducers and their elements – Design and application”, PTR Prentice Hall, 1994.
2. Pavel Ripka and Alois Tipek,“Modern sensors hand book”, Instrumentation and measurement series, ISTE Ltd., 2007
3. David Fraden. , PHI, 2004 “ Hand book of Modern Sensors, Physics,Design and Applications”, Third Edition, Springer India Pvt.Ltd, 2006.

EB 9351 MICRO SYSTEM DESIGN L T P C
3 0 0 3

UNIT I LITHOGRAPHY AND PATTERN TRANSFER 9

Photolithography – Alternative and emerging lithographic technologies – Pattern transfer with etching and additive techniques.

UNIT II BULK MICROMACHNING 9

Silicon crystallography – Silicon as a substance and structural material - Wet isotropic and anisotropic etching, Etching with bias – Etch stop techniques – problems in bulk micromachining - examples.

UNIT III SURFACE MICROMACHINING 9

Mechanical properties of thin films – surface micromachining processes – poly-silicon micromachining – Non-poly silicon micromachining – materials – examples.

UNIT IV LIGA 9

LIGA Processes – Synchrotron orbital radiation – X-ray masks – LIGA Processes steps and materials – LIGA Applications.

UNIT V PACKAGING TESTING AND CALIBRATION 9

Packaging: Dicing – Wafer level packaging – wafer bonding – Connections between layers – self assembly – higher level of packaging – Testing and Calibration

TOTAL : 45 PERIODS

REFERENCES:

1. Stephen D.Senturia, " Micro System Design ",Kula Academic Publishers, 2001
2. Marc Madou , "Fundamentals of Microfabrication",CRC Press, Gregory Kovacs, 1997.
3. Boston , "Micromachined Transducers Sourcebook",WCB McGraw Hill, 1998.
4. M.H.Bao "Micromechanical transducers: Pressure sensors, accelerometers and gyroscopes", Elsevier, Newyork, 2000.

PE9261 POWER QUALITY L T P C
3 0 0 3

UNIT I INTRODUCTION 9

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

UNIT II NON-LINEAR LOADS 9

Single phase static and rotating AC/DC converters, Three phase static AC/DC converters, Battery chargers, Arc furnaces, Fluorescent lighting, pulse modulated devices, Adjustable speed drives.

UNIT III MEASUREMENT AND ANALYSIS METHODS 9

Voltage, Current, Power and Energy measurements, power factor measurements and definitions, event recorders, Measurement Error – Analysis: Analysis in the periodic steady state, Time domain methods, Frequency domain methods: Laplace's, Fourier and Hartley transform – The Walsh Transform – Wavelet Transform.

UNIT IV ANALYSIS AND CONVENTIONAL MITIGATION METHODS 9

Analysis of power outages, Analysis of unbalance: Symmetrical components of phasor quantities, Instantaneous symmetrical components, Instantaneous real and reactive powers, Analysis of distortion: On–line extraction of fundamental sequence components from measured samples – Harmonic indices – Analysis of voltage sag: Detorit Edison sag score, Voltage sag energy, Voltage Sag Lost Energy Index (VSLEI)- Analysis of voltage flicker, Reduced duration and customer impact of outages, Classical load balancing problem: Open loop balancing, Closed loop balancing, current balancing, Harmonic reduction, Voltage sag reduction.

UNIT V POWER QUALITY IMPROVEMENT 9

Utility-Customer interface –Harmonic filters: passive, Active and hybrid filters –Custom power devices: Network reconfiguring Devices, Load compensation using DSTATCOM, Voltage regulation using DSTATCOM, protecting sensitive loads using DVR, UPQC – control strategies: P-Q theory, Synchronous detection method – Custom power park – Status of application of custom power devices.

TOTAL : 45 PERIODS

TEXT BOOKS:

1. Arindam Ghosh "Power Quality Enhancement Using Custom Power Devices", Kluwer Academic Publishers, 2002
2. G.T.Heydt, "Electric Power Quality", Stars in a Circle Publications, 1994(2nd edition)
3. Power Quality - R.C. Duggan
4. Power system harmonics –A.J. Arrillga
5. Power electronic converter harmonics –Derek A. Paice

PE 9224 MICROCONTROLLER AND DSP BASED SYSTEM DESIGN L T P C
3 0 0 3

UNIT I PIC 16C7X MICROCONTROLLER 9

Architecture memory organization – Addressing modes – Instruction set – Programming techniques – simple programs

UNIT II PERIPHERALS OF PIC 16C7X 9

Timers – interrupts – I/O ports – I^2C bus for peripheral chip access – A/D converter – UART

UNIT III MOTOR CONTROL SIGNAL PROCESSORS 9

Introduction- System configuration registers - Memory Addressing modes - Instruction set – Programming techniques – simple programs

UNIT IV PERIPHERALS OF SIGNAL PROCESSORS 9

General purpose Input/Output (GPIO) Functionality- Interrupts - A/D converter-Event Managers (EVA, EVB)- PWM signal generation

UNIT V APPLICATIONS OF PIC AND SIGNAL PROCESSORS 9

Voltage regulation of DC-DC converters- Stepper motor and DC motor control- Clarke's and parks transformation-Space vector PWM- Control of Induction Motors and PMSM.

TOTAL : 45 PERIODS

TEXT BOOKS:

1. John B.Peatman , 'Design with PIC Microcontrollers,' Pearson Education, Asia 2004
2. Hamid A.Toliyat, Steven Campbell, 'DSP based electromechanical motion control', CRC Press

PS 9223 FLEXIBLE AC TRANSMISSION SYSTEMS L T P C
3 0 0 3

UNIT I INTRODUCTION 9

Reactive power control in electrical power transmission lines -Uncompensated transmission line - series compensation – Basic concepts of static Var Compensator (SVC) – Thyristor Switched Series capacitor (TCSC) – Unified power flow controller (UPFC).

UNIT II STATIC VAR COMPENSATOR (SVC) AND APPLICATIONS 9

Voltage control by SVC – Advantages of slope in dynamic characteristics – Influence of SVC on system voltage – Design of SVC voltage regulator –Modelling of svc for power flow and transient stability – Applications: Enhancement of transient stability – Steady state power transfer – Enhancement of power system damping – Prevention of voltage instability.

UNIT III THYRISTOR CONTROLLED SERIES CAPACITOR (TCSC) AND APPLICATIONS 9

Operation of the TCSC – Different modes of operation – Modelling of TCSC – Variable reactance model – Modelling for Power Flow and stability studies. Applications: Improvement of the system stability limit – Enhancement of system damping-SSR Mitigation.

UNIT IV VOLTAGE SOURCE CONVERTER BASED FACTS CONTROLLERS 9

Static Synchronous Compensator (STATCOM) – Principle of operation – V-I Characteristics. Applications: Steady state power transfer-Enhancement of transient stability - Prevention of voltage instability. SSSC-operation of SSSC and the control of

power flow –Modelling of SSSC in load flow and transient stability studies. Applications: SSR Mitigation-UPFC and IPFC

UNIT V CO-ORDINATION OF FACTS CONTROLLERS 9

Controller interactions – SVC – SVC interaction – Co-ordination of multiple controllers using linear control techniques – Control coordination using genetic algorithms.

TOTAL : 45 PERIODS

REFERENCES:

1. R.Mohan Mathur, Rajiv K.Varma, "Thyristor – Based Facts Controllers for Electrical Transmission Systems", IEEE press and John Wiley & Sons, Inc.
2. Narain G. Hingorani, "Understanding FACTS -Concepts and Technology of Flexible AC Transmission Systems", Standard Publishers Distributors, Delhi-
3. K.R.Padiyar," FACTS Controllers in Power Transmission and Distribution", New Age International(P) Limited, Publishers, New Delhi, 2008
4. A.T.John, "Flexible A.C. Transmission Systems", Institution of Electrical and Electronic Engineers (IEEE), 1999.
5. V.K.Sood,HVDC and FACTS controllers – Applications of Static Converters in Power System, APRIL 2004 , Kluwer Academic Publishers.

ET 9261 DESIGN OF EMBEDDED CONTROL SYSTEM L T P C
3 0 0 3

UNIT I EMBEDDED SYSTEM ORGANIZATION 9

Embedded computing – characteristics of embedded computing applications – embedded system design challenges; Build process of Real-time Embedded system – Selection of processor; Memory; I/O devices-Rs-485, MODEM, Bus Communication system using I^2C, CAN, USB buses, 8 bit –ISA, EISA bus;

UNIT II .REAL-TIME OPERATING SYSTEM 9

Introduction to RTOS; RTOS- Inter Process communication, Interrupt driven Input and Output -Nonmaskable interrupt, Software interrupt; Thread – Single, Multithread concept; Multitasking Semaphores.

UNIT III INTERFACE WITH COMMUNICATION PROTOCOL 9

Design methodologies and tools – design flows – designing hardware and software Interface. – system integration; SPI, High speed data acquisition and interface-SPI read/write protocol, RTC interfacing and programming;

UNIT IV DESIGN OF SOFTWARE FOR EMBEDDED CONTROL 9

Software abstraction using Mealy-Moore FSM controller, Layered software development, Basic concepts of developing device driver – SCI – Software - interfacing & porting using standard C & C++ ; Functional and performance Debugging with benchmarking Real-time system software – Survey on basics of contemporary RTOS – VXWorks, UC/OS-II

UNIT V CASE STUDIES WITH EMBEDDED CONTROLLER 9

Programmable interface with A/D & D/A interface; Digital voltmeter, control- Robot system; - PWM motor speed controller, serial communication interface.

TOTAL : 45 PERIODS

REFERENCES:

1. Steven F. Barrett, Daniel J. Pack, "Embedded Systems – Design and Applications with the 68HC 12 and HCS12", Pearson Education, 2008.
2. Raj Kamal, "Embedded Systems- Architecture, Programming and Design" Tata McGraw Hill, 2006.
3. Micheal Khevi, "The M68HC11 Microcontroller application in control,Instrumentation & Communication", PH NewJersy, 1997.
4. Muhammad Ali Mazidi, Rolin D. Mckinlay, Danny Causey, "PIC Microcontroller and Embedded Systems- Using Assembly and C for PIC18", Pearson Education,2008.
5. Steven F.Barrett,Daniel J.Pack,"Embedded Systems-Design & Application with the 68HC12 & HCS12", Pearson Education,2008.
6. Daniel W. Lewis, "Fundamentals of Embedded Software", Prentice Hall India, 2004.
7. Jack R Smith "Programming the PIC microcontroller with MBasic" Elsevier, 2007.
8. Keneth J.Ayala, "The 8086 Microprocessor: Programming & Interfacing the PC", Thomson India edition, 2007.

ET 9222 REAL TIME OPERATING SYSTEMS L T P C
3 0 0 3

UNIT I REVIEW OF OPERATING SYSTEMS 9

Basic Principles - Operating System structures – System Calls – Files – Processes – Design and Implementation of processes – Communication between processes – Introduction to Distributed operating system – Distributed scheduling.

UNIT II OVERVIEW OF RTOS 9

RTOS Task and Task state - Process Synchronisation- Message queues – Mail boxes - pipes – Critical section – Semaphores – Classical synchronisation problem – Deadlocks -

UNIT III REAL TIME MODELS AND LANGUAGES 9

Event Based – Process Based and Graph based Models – Real Time Languages – RTOS Tasks – RT scheduling - Interrupt processing – Synchronization – Control Blocks – Memory Requirements.

UNIT IV REAL TIME KERNEL 9

Principles – Design issues – Polled Loop Systems – RTOS Porting to a Target – Comparison and study of various RTOS like QNX – VX works – PSOS – C Executive – Case studies.

UNIT V RTOS APPLICATION DOMAINS 9

RTOS for Image Processing – Embedded RTOS for voice over IP – RTOS for fault Tolerant Applications – RTOS for Control Systems.

TOTAL : 45 PERIODS

REFERENCES:

1. Raj Kamal, "Embedded Systems- Architecture, Programming and Design" Tata McGraw Hill, 2006.
2. Herma K., "Real Time Systems – Design for distributed Embedded Applications", Kluwer Academic, 1997.
3 Charles Crowley, "Operating Systems-A Design Oriented approach" McGraw Hill 1997.
4 C.M. Krishna, Kang, G.Shin, "Real Time Systems", McGraw Hill, 1997.
5. Raymond J.A.Bhur, Donald L.Bailey, "An Introduction to Real Time Systems", PHI 1999.
6. Mukesh Sighal and N G Shi "Advanced Concepts in Operating System", McGraw Hill 2000.

ET9278 APPLICATIONS OF MEMS TECHNOLOGY L T P C
3 0 0 3

UNIT I MEMS: 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 piezo electric actuator model-properties of piezoelectric materials-Applications.

UNIT V CASE STUDIES 9

Piezoresistive sensors, Magnetic actuation, Micro fluidics applications, Medical applications, Optical MEMS.

TOTAL: 45 PERIODS

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.

PE 9272 POWER ELECTRONICS FOR RENEWABLE ENERGY SYSTEMS **L T P C 3 0 0 3**

UNIT I INTRODUCTION **9**

Environmental aspects of electric energy conversion: impacts of renewable energy generation on environment (cost-GHG Emission) - Qualitative study of different renewable energy resources: Solar, wind, ocean, Biomass, Fuel cell, Hydrogen energy systems and hybrid renewable energy systems.

UNIT II ELECTRICAL MACHINES FOR RENEWABLE ENERGY CONVERSION **9**

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

UNIT III POWER CONVERTERS **9**

Solar: Block diagram of solar photo voltaic system -Principle of operation: line commutated converters (inversion-mode) - Boost and buck-boost converters- selection Of inverter, battery sizing, array sizing

Wind: three phase AC voltage controllers- AC-DC-AC converters: uncontrolled rectifiers, PWM Inverters, Grid Interactive Inverters-matrix converters.

UNIT IV ANALYSIS OF WIND AND PV SYSTEMS **9**

Stand alone operation of fixed and variable speed wind energy conversion systems and solar system-Grid connection Issues -Grid integrated PMSG and SCIG Based WECS-Grid Integrated solar system

UNITV HYBRID RENEWABLE ENERGY SYSTEMS **9**

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

TOTAL : 45 PERIODS

REFERENCES:

1. Rashid .M. H “power electronics Hand book”, Academic press, 2001.

2. Rai. G.D, “Non conventional energy sources”, Khanna publishes, 1993.

3. Rai. G.D," Solar energy utilization", Khanna publishes, 1993.
4. Gray, L. Johnson, "Wind energy system", prentice hall linc, 1995.
5. Non-conventional Energy sources B.H.Khan Tata McGraw-hill Publishing Company, New Delhi.

CL 9355 PRINCIPLES OF ROBOTICS L T P C
3 0 0 3

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-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 & VELOCITIES 9

Jacobian-differential motion of frames-Interpretation-calculation of Jacobian-Inverse Jacobian-Design-Lagrangian mechanics-dynamic equations-static force analysis

UNIT IV ROBOT CONTROL SYSTEM 9

Sensor characteristics- Hydraulic, Pneumatic and electric actuators-trajectory planning-decentalised PID control- non-linear decoupling control

UNIT V IMAGE PROCESSING & VISION SYSTEMS 9

Two and three dimensional images-spatial and frequency domain representation-noise and edges- convolution masks-Processing techniques-thersholding-noise reduction-edge detection-segmentation-Image analysis and object recognition

TOTAL: 45 PERIODS

REFERENCES

1. Saeed B. Niku ,"Introduction to Robotics ", Pearson Education, 2002
2. Fu, Gonzalez and Lee Mcgrahill ,"Robotics ", international
3. R.D. Klafter, TA Chmielewski and Michael Negin, "Robotic Engineering, An Integrated approach", Prentice Hall of India, 2003.

CL 9358 SYSTEM IDENTIFICATION AND ADAPTIVE CONTROL L T P C
3 0 0 3

UNIT I MODELS FOR INDENTIFICATION 9

Models of LTI systems: Linear Models-State space Models-OE model- Model sets, Structures and Identifiability-Models for Time-varying and Non-linear systems: Models with Nonlinearities – Non-linear state-space models-Black box models, Fuzzy models'.

UNIT II NON-PARAMETRIC AND PARAMETRIC IDENTIFICATON 9

Transient response and Correlation Analysis – Frequency response analysis – Spectral Analysis – Least Square – Recursive Least Square –Forgetting factor- Maximum Likelihood – Instrumental Variable methods.

UNIT III NON-LINEAR IDENTIFICATION AND MODEL VALIDATION 9

Open and closed loop identification: Approaches – Direct and indirect identification – Joint input-output identification – Non-linear system identification – Wiener models – Power series expansions - State estimation techniques – Non linear identification using Neural Network and Fuzzy Logic.

UNIT IV ADAPTIVE COTROL AND ADAPTATION TECHNIQUES 9

Introduction – Uses – Auto tuning – Self Tuning Regulators (STR) – Model Reference Adaptive Control (MRAC) – Types of STR and MRAC – Different approaches to self-tuning regulators – Stochastic Adaptive control – Gain Scheduling.

UNIT V CASE STUDIES 9

Inverted Pendulum, Robot arm, process control application: heat exchanger, Distillation column, application to power system, Ship steering control.

TOTAL: 45 PERIODS

REFERENCES

1. Ljung," System Identification Theory for the User", PHI, 1987.
2. Torsten Soderstrom, Petre Stoica, "System Identification", prentice Hall International (UK) Ltd,1989.
3. Astrom and Wittenmark," Adaptive Control ", PHI
4. William S. Levine, " Control Hand Book".
5. Narendra and Annasamy," Stable Adaptive Control Systems, Prentice Hall, 1989.

CL 9002 SOFT COMPUTING TECHNIQUES L T P C
3 0 0 3

UNIT I INTRODUCTION 9

Approaches to intelligent control. Architecture for intelligent control. Symbolic reasoning system, rule-based systems, the AI approach. Knowledge representation. Expert systems.

UNIT II ARTIFICIAL NEURAL NETWORKS 9

Concept of Artificial Neural Networks and its basic mathematical model, McCulloch-Pitts neuron model, simple perceptron, Adaline and Madaline, Feed-forward Multilayer Perceptron. Learning and Training the neural network. Data Processing: Scaling, Fourier transformation, principal-component analysis and wavelet transformations. Hopfield network, Self-organizing network and Recurrent network. Neural Network based controller

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

Basic concept of Genetic algorithm and detail algorithmic steps, adjustment of free parameters. Solution of typical control problems using genetic algorithm. Concept on some other search techniques like tabu search and and-colony search techniques for solving optimization problems.

UNIT V APPLICATIONS 9

GA application to power system optimisation problem, Case studies: Identification and control of linear and nonlinear dynamic systems using Matlab-Neural Network toolbox.
Stability analysis of Neural-Network interconnection systems. Implementation of fuzzy logic controller using Matlab fuzzy-logic toolbox. Stability analysis of fuzzy control systems.

TOTAL : 45 PERIODS

REFERENCES:

1. Jacek.M.Zurada, "Introduction to Artificial Neural Systems", Jaico Publishing House, 1999.
2. KOSKO,B. "Neural Networks And Fuzzy Systems", Prentice-Hall of India Pvt. Ltd., 1994.
3. KLIR G.J. & FOLGER T.A. "Fuzzy sets, uncertainty and Information", Prentice-Hall of India Pvt. Ltd., 1993.
4. Zimmerman H.J. "Fuzzy set theory-and its Applications"-Kluwer Academic Publishers, 1994.
5. Driankov, Hellendroon, "Introduction to Fuzzy Control", Narosa Publishers.

PS9276 WIND ENERGY CONVERSION SYSTEMS L T P C
3 0 0 3

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

Stand alone and Grid Connected WECS system-Grid connection Issues-Machine side & Grid side controllers-WECS in various countries

TOTAL : 45 PERIODS

REFERENCES:

1. L.L.Freris "Wind Energy conversion Systems", Prentice Hall, 1990
2. Ion Boldea, "Variable speed generators", Taylor & Francis group, 2006.
3. E.W.Golding "The generation of Electricity by wind power", Redwood burn Ltd., Trowbridge, 1976.
4. S.Heir "Grid Integration of WECS", Wiley 1998.

HV 9353 ELECTROMAGNETIC INTERFERENCE AND ELECTROMAGNETIC COMPATIBILITY **L T P C 3 0 0 3**

UNIT I INTRODUCTION **9**

Sources of EMI, Conducted and radiated interference- Characteristics - Designing for electromagnetic compatibility (EMC)- EMC regulation- typical noise path- use of network theory- methods of eliminating interferences.

UNIT II METHOD OF HARDENING **9**

Cabling –capacitive coupling- inductive coupling- shielding to prevent magnetic radiation- shield transfer impedance, Grounding – safety grounds – signal grounds- single point and multipoint ground systems- hybrid grounds- functional ground layout – grounding of cable shields- ground loops-guard shields.

UNIT III BALANCING, FILTERING AND SHIELDING **9**

Power supply decoupling- decoupling filters-amplifier filtering –high frequency filtering- shielding – near and far fields- shielding effectiveness- absorption and reflection loss, Shielding with magnetic material- conductive gaskets, windows and coatings- grounding of shields.

UNIT IV DIGITAL CIRCUIT NOISE AND LAYOUT **9**

Frequency versus time domain- analog versus digital circuits- digital logic noise- internal noise sources- digital circuit ground noise –power distribution-noise voltage objectives- measuring noise voltages-unused inputs-logic families.

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

Static Generation- human body model- static discharges-ED protection in equipment design- ESD versus EMC, Industrial and Government standards – FCC requirements – CISPR recommendations-Laboratory techniques- Measurement methods for field strength-EMI.

TOTAL : 45 PERIODS

REFERENCES

1. Henry W.Ott, " Noise reduction techniques in electronic systems", John Wiley & Sons, 1989.
2. Bernhard Keiser, "Principles of Electro-magnetic Compatibility", Artech House, Inc. (685 canton street, Norwood, MA 020062 USA) 1987.
3. Bridges, J.E Milleta J. and Ricketts.L.W. "EMP Radiation and Protective techniques", John Wiley and sons, USA 1976.
4. IEEE National Symposium on "Electromagnetic Compatibility", IEEE, 445, hoes Lane, Piscataiway, NJ 08855.

ET 9275 COMPUTER IN NETWORKING AND DIGITAL CONTROL L T P C
3 0 0 3

UNIT I NETWORK FUNDAMENTALS 9

Data communication networking – Data transmission concepts – Communication networking - Overview of OSI- TCP/IP layers – IP addressing - DNS – Packet Switching – Routing –Fundamental concepts in SMTP, POP, FTP, Telnet, HTML, HTTP, URL, SNMP,ICMP.

UNIT II DATA COMMUNICATION 9

Sensor data acquisition, Sampling, Quantization, Filtering ,Data Storage, Analysis using compression techniques, Data encoding – Data link control – Framing, Flow and Error control, Point to point protocol, Routers, Switches , Bridges – MODEMs, Network layer –Congestion control , Transport layer- Congestion control, Connection establishment.

UNIT III VIRTUAL INSTRUMENTATION 9

Block diagram and Architecture – Data flow techniques – Graphical programming using GUI – Real time system – Embedded controller – Instrument drivers – Software and hardware simulation of I/O communication blocks – ADC/DAC – Digital I/O – Counter , Timer, Data communication ports.

UNIT IV MEASUREMENT AND CONTROL THROUGH INTERNET: 9

Web enabled measurement and control-data acquisition for Monitoring of plant parameters through Internet – Calibration of measuring instruments through Internet, Web based control – Tuning of controllers through Internet

UNIT V BASED MEASUREMENT AND CONTROL 9

Simulation of signal analysis & controller logic modules for Virtual Instrument control – Case study of systems using VI for data acquisition, Signal analysis, controller design, Drives control.

TOTAL: 45 PERIODS

REFERENCES:

1. Wayne Tomasi, “Introduction to Data communications and Networking” Pearson Education, 2007.
2. Al Williams, “Embedded Internet Design”, Second Edition, TMH, 2007.
3. Douglas E.Comer, “Internetworking with TCP/IP, Vol. 1”, Third Edition, Prentice Hall, 1999.
4. Cory L. Clark, “Lab VIEW Digital Signal Processing and Digital Communication”, TMH edition 2005.
5. Behrouza A Forouzan,”Data Communications and Networking” Fourth edition, TMH, 2007.
6. Krishna Kant,”Computer based Industrial control”, PHI,2002.
7. Gary Johnson, “Lab VIEW Graphical Programming”, Second edition, McGraw Hill, Newyork, 1997.
8. Kevin James,”PC Interfacing and Data Acquisition: Techniques for measurement, Instrumentation and control, Newnes, 2000.
9. Cory L. Clark,”LabVIEW Digital Signal processing and Digital Communications” Tata McGRAW-HILL edition, 2005.

ET9274 PROGRAMMING WITH VHDL L T P C
3 0 0 3

UNIT I VHDL FUNDAMENTALS 9

Fundamental concepts- Modeling digital system-Domain and levels of modeling-modeling languages-VHDL modeling concepts-Scalar Data types and operations-constants and Variable-Scalar Types- Type Classification-Attributes and scalar types-expression and operators-Sequential statements.

UNIT II DATA TYPES AND BASIC MODELING CONSTRUCTS 9

Arrays- unconstrained array types-array operations and referencing- records - Access Types- Abstract Date types- -basic modeling constructs-entity declarations-Architecture bodies-behavioral description-structural descriptions- design Processing, case study: A pipelined Multiplier accumulator.

UNIT III SUBPROGRAMS , PACKAGES AND FILES 9

Procedures-Procedure parameters- Concurrent procedure call statements –Functions – Overloading –visibility of Declarations-packages and use clauses- Package declarations-package bodies-use clauses-Predefined aliases-Aliases for Data objects-Aliases for Non-Data items-Files- I/O-Files. Case study: A bit vector arithmetic Package.

UNIT IV SIGNALS, COMPONENTS, CONFIGURATIONS. 9

Basic Resolved Signals-IEEE std_Logic_1164 resolved subtypes- resolved Signal Parameters - Generic Constants- Parameterizing behavior- Parameterizing structure-components and configurations-Generate Statements-Generating Iterative structure-Conditionally generating structure-Configuration of generate statements-case study: DLX computer Systems.

UNIT V DESIGN WITH PROGRAMMABLE LOGIC DEVICES 9

Realization of -Micro controller CPU.- Memories-I/O devices-MAC-Design,synthesis,simulation and testing.

TOTAL : 45 PERIODS

REFERENCES:

1. Peter J.Ashenden, “The Designer’s guide to VHDL”, Morgan Kaufmann publishers,San Francisco, Second Edition, May 2001.
2. Zainalabedin navabi, “VHDL Analysis ans modeling of Digital Systems”, McGraw Hill international Editions, Second Editions, 1998.
3. Charles H Roth, Jr. “Digital system Design using VHDL”, Thomson ,2006.
4. Douglas Perry, “VHDL Programming by Example”, Tata McGraw Hill,4th Edition 2002.
5. Navabi.Z., “VHDL Analysis and Modeling of Digital Systems”, McGraw International, 1998.
6. Peter J Ashendem, “The Designers Guide to VHDL”, Harcourt India Pvt Ltd, 2002
7. Skahill. K, “VHDL for Programmable Logic”, Pearson education, 1996.