M.TECH - POWER ELECTRONICS

Department of Electrical and Electronics Engineering

Power Electronics plays an important role in processing and controlling the flow of electric energy by supplying voltages and currents in forms that are optimally suited for the user loads from a few watts to several megawatts. The application areas include wide spectrum such as Heating and Lighting Control, AC and DC Power Supplies, Electric Motor Control, Energy Conservation, Process Control and Factory Automation, Transportation, HVDC, FACTS Devices, Power Quality Improvement etc.

Power Electronics encompasses many fields within Electrical engineering.

The PG program includes courses in Mathematics, Cultural Education and the core subject areas. In core subject areas, emphasis is given on power processors with recent and emerging power switching devices, electrical machines and their control, measurement and processing of signals, signal processors, control systems and digital system design required to build any power electronic equipment with necessary controllers. The program offers electives for the students to enhance the knowledge of emerging machines, areas of power electronics applications and techniques to optimize the designs.

The Program culminates with a project work in which the students are encouraged to work on specific areas involving design, simulation, fabrication and testing of any power electronics system having research/industrial application values.

CURRICULUM
First Semester

Course Code	Type	Course	L T P	Cr
16MA614	FC	Linear Algebra and Numerical Methods	3 0 0	3
16PE611	FC	Power Converters I	3 0 1	4
16PE621	SC	Electrical Machine Analysis	4 0 0	4
16PE622	SC	Modern Control Theory	3 0 0	3
	E	Elective I	3 0 0	3
16PE624	SC	Simulation Laboratory	0 0 1	1
16HU601	HU	Cultural Education*		P/F
			Credits	**18**

* Non-Credit Course

Second Semester

Course Code	Type	Course	L T P	Cr
16PE612	FC	Digital Signal Processing	3 0 1	4
16PE613	FC	Power Converters II	3 0 1	4
16PE625	SC	Electric Drives and Control	3 0 0	3
16PE626	SC	Embedded Controllers	3 0 1	4
	E	Elective II	3 0 0	3
16PE628	SC	Seminar	0 0 1	1
16EN600	HU	Technical Writing*		P/F
			Credits	**19**

* Non-Credit Course

Third Semester

Course Code	Type	Course	L T P	Cr
	E	Elective III	3 0 0	3
	E	Elective IV	3 0 0	3
16PE627	SC	Electric Drives and Control Laboratory	0 0 1	1
16PE798	P	Dissertation		8
			Credits	**15**

Fourth Semester

Course Code	Type	Course	L T P	Cr
16PE799	P	Dissertation		14
			Credits	**14**

Total Credits: 66

List of Courses

Foundation Core

Course Code	Course	L T P	Cr
16MA614	Linear Algebra and Numerical Methods	3 0 0	3
16PE611	Power Converters I	3 0 1	4
16PE612	Digital Signal Processing	3 0 1	4
16PE613	Power Converters II	3 0 1	4

Subject Core

Course Code	Course	L T P	Cr
16PE621	Electrical Machine Analysis	4 0 0	4
16PE622	Modern Control Theory	3 0 0	3
16PE624	Simulation Laboratory	0 0 1	1
16PE625	Electric Drives and Control	3 0 0	3
16PE626	Embedded Controllers	3 0 1	4
16PE627	Electric Drives and Control Laboratory	0 0 1	1
16PE628	Seminar	0 0 1	1

Electives

Group I Domain : Power Electronics			
Course Code	Course	L T P	Cr
16PE701	Modulation Techniques for Power Electronic systems	3 0 0	3
16PE702	Special Topics in Power Electronics	3 0 0	3
16PE703	Advanced Power Electronic Drives	3 0 0	3
16PE704	Power Electronic in Transportation Systems	3 0 0	3
16PE705	Electrical Machine Analysis using Finite Element Analysis	3 0 0	3
Group II Domain : Embedded Systems			
Course Code	Course	L T P	Cr
16PE711	Programmable Logic Controllers	3 0 0	3
16PE712	Digital Control Systems	3 0 0	3
16PE713	FPGA based System Design	2 0 1	3
16PE714	Adaptive Control Systems	3 0 0	3
16RE617	Soft Computing	2 0 1	3
Group III Domain : Power Systems			
Course Code	Course	L T P	Cr
16PE721	Electric Power Quality Improvement	3 0 0	3
16PE722	FACTS and HVDC	3 0 0	3
16PE723	Energy Conservation and Management	3 0 0	3
16PE724	Power System Operation and Control	3 0 0	3
16PE725	Electromagnetic Interference and Compatibility	3 0 0	3
16MA702	Optimization Theory	2 1 0	3
16RE703	Power System Modelling	3 0 0	3
Group IV Domain : Renewable Energy			
Course Code	Course	L T P	Cr
16PE731	Renewable Energy Technologies	3 0 0	3
16PE732	Design for Reliability	3 0 0	3
16PE733	Distributed Generation	3 0 0	3
16RE709	Smart Grid	3 0 0	3

Project Work

Course Code	Course	L T P	Cr
16PE798	Dissertation		8
16PE799	Dissertation		14

16MA614 LINEAR ALGEBRA AND NUMERICAL METHODS 3-0-0-3

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

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

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

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

TEXT BOOKS / REFERENCES:

1. Howard Anton and Chris Rorres, "*Elementary Linear Algebra*", Tenth Edition, John Wiley and Sons, 2010.
2. Gilbert Strang, "*Linear Algebra and Its Applications*", Fourth Edition, Cengage, 2006.
3. Kenneth Hoffmann and Ray Kunze, "*Linear Algebra"*, Second Edition, Prentice Hall, 1971.
4. Curtis F. Gerald and Patrick O. Wheatley, "*Applied Numerical Analysis*", Fifth Edition, Addison Wesley, 2002.

16PE611 POWER CONVERTERS I 3-0-1-4

Power semiconductor switches: ratings, characteristics, power loss and temperature rise calculations, and control (BJT, MOSFETS, IGBT, Thyristors, IPM, IGC). AC voltage controllers- Line commutated, uncontrolled and phase controlled converters: Performance factors, Line notching and distortion. Twelve pulse converters. Introduction to Cyclo-converters, Matrix Converters. Voltage source inverters: single phase and three phase inverters. Sinusoidal PWM and Space vector PWM. Multilevel inverters. Introduction to resonant inverters, zero voltage switching clamped voltage inverters. UPS. Demonstration designs.

TEXT BOOKS/ REFERENCES:

1. Ned Mohan, Tore M. Undeland and William P.Robbins, "*Power Electronics, Converters, Applications and Design*", Third Edition, John Wiley and Sons Inc., 2006.
2. Muhammad H. Rashid, "*Power Electronics, Circuits, Devices and Applications*", Third Edition, Prentice Hall of India Private Limited, 2004.
3. John G. Kassakian, Martin F.Schlecht and George C.Verghese, "*Principles of Power Electronics*", Addison Wesley Publishing Company, 1991.
4. Bimal K Bose, "*Modern Power Electronics and AC Drives*", Prentice – Hall of India Private Limited, 2002.
5. Barry W Williams, "*Principles and Elements of Power Electronics Devices, Drivers, Applications, and Passive Components*", Barry W Williams, 2006.

16PE621 ELECTRICAL MACHINE ANALYSIS 4-0-0-4

Introduction and review of electrical machines; Principles of electromagnetic energy conversion: General expression of stored magnetic energy, co-energy and force/torque, single and doubly excited system; Calculation of air gap mmf and per phase machine inductance, Three phase symmetrical induction machine and salient pole synchronous machines in phase variable form.

Generalized theory of rotating electrical machine and Kron's primitive machine; modeling, steady state and transient analysis of DC machines, Introduction to reference frame theory, Application of reference frame theory to three phase symmetrical induction and synchronous machines, modeling, steady state and transient analysis of induction machines, Unbalanced operation and fault analysis in three phase induction motors. Steady state and transient analysis analysis of synchronous machines, standard and derived machine time constants, Transient fault analysis; Analysis and dynamic modeling of two phase asymmetrical induction machine and single phase induction machine.

TEXT BOOKS/ REFERENCES:

1. P.C.Krause, "*Analysis of Electric Machines and Drive Systems*", Wiley International, 2002.
2. Jones C.V, "*The Unified Theory of Electrical Machines*", Butter Worth Publications, 1968.
3. A.E. Fitzgerald and Charles Kingsley, "*Electric Machinery*", McGraw Hill Book Company, 1986.
4. B. Adkins, "*Generalized Machine Theory*", McGraw Hill Book Company, 1964.
5. Bimbhra P S, "*Electrical Machinery*", Khanna Publishers, 1995.

16PE622 MODERN CONTROL THEORY 3-0-0-3

State Variable Analysis and Design: Introduction, concept of state, state variables and state model, state modeling of linear systems, linearization of state equations. State Space representation using physical variables, Phase variables and Canonical variables. Derivation of transfer function from state model, diagonalization, Eigen values, Eigen vectors, generalized Eigen vectors. Solution of state equation, state transition matrix and its properties, computation using Laplace transformation, power series method, Cayley-Hamilton method, concept of controllability and observability, methods of determining the same.

Pole Placement Techniques: Stability improvements by state feedback, necessary and sufficient conditions for arbitrary pole placement, state regulator design, and design of state observer, Controllers- P, PI, PID. Non-linear systems: Introduction, behavior of non-linear system, common physical non linearity-saturation, friction, backlash, dead zone, relay, multi- variable non-linearity. Phase plane method, singular points, stability of nonlinear system, limit cycles, construction of phase trajectories. Liapunov stability criteria, Liapunov functions, direct method of Liapunov and the linear system, Hurwitz criterion and Liapunov's direct method, construction of Liapunov functions for nonlinear system.

TEXT BOOKS/ REFERENCES:

1. Ogata, "*Modern Control Engineering*". Fifth Edition, Prentice Hall, 2009.
2. Franklin and Powell, "*Feedback Control of Dynamics Systems*". Fourth Edition, Prentice Hall, 2002.
3. Joseph DiStefano III, Allen J. Stubberud and Ivan J. Williams "*Feedback and Control Systems*". Schaum's Outline Series, Mcgraw-Hill, 1967.

4. David G. Luenberger, "*Introduction to Dynamic Systems: Theory, Models, and Applications*", Wiley, 1979.
5. Richard C. Dorf and Robert H. Bishop, "*Modern Control Systems*", Eleventh Edition Prentice Hall, 2008.

16PE624 SIMULATION LABORATORY 0-0-1-1

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

16PE612 DIGITAL SIGNAL PROCESSING 3-0-1-4

Spectrum Analysis: Frequency and time domain analysis, Sampling and aliasing. Discrete Fourier Transform. Fast Fourier Transform. FFT. Digital Filters: IIR Filters, Bilinear transformation. FIR filters. Random Processes and Adaptive Signal Processing, Wiener Filters, Kalman filters. Multirate Digital Signal Processing. Applications of Digital Signal Processing.

TEXT BOOKS/ REFERENCES:

1. Proakis J. G. and Manolakis D. G., "*Digital Signal Processing: Principles, Algorithms, and Applications*", Prentice Hall, 1996.
2. Simon Haykin, "*Adaptive Filter Theory*", Prentice Hall, 1997.
3. Ifeachor E. C. and Jervis B. W., "*Digital Signal Processing: A Practical Approach*", Addison Wesley, 1993.
4. Vaidyanathan P. P, "*Multirate Systems and Filter Banks*", Prentice Hall, 1993.
5. Mitra S.K., "*Digital Signal Processing, A Computer-Based Approach*", McGraw Hill, 2002.

16PE613 POWER CONVERTERS II 3-0-1-4

DC-DC converters: buck, boost, buck-boost, SEPIC, fly-back, forward, push-pull, half bridge, full bridge converters, soft switched bidirectional DC-DC converters. Design of high frequency transformers and inductors-Drive and protection of switching power devices - voltage mode control and current mode control, modeling of the converters, Compensation of the feedback system for dc-dc converters. Single phase AC to DC converters with high power factor- Control of switch-mode converter for utility interface. Boost derived isolated DC-DC Converters. Typical specifications of power converters, design of power circuit to meet the specifications. EMI and Layout Fundamentals for switched mode circuits. Demonstration designs.

TEXT BOOKS/ REFERENCES:

1. Ned Mohan, Tore M. Undeland and William P.Robbins, "*Power Electronics, Converters, Applications and Design*", Third Edition, John Wiley and Sons Inc., 2006.
2. Robert W Erickson and Dragan Maksimovic, "*Fundamentals of Power Electronics*", Springer International, 2001.
3. Daniel W Hart, "*Power Electronics*", Tata Mc Graw Hill, 2011.
4. John G. Kassakian, Martin F.Schlecht and George C.Verghese, "*Principles of Power Electronics*", Addison Wesley Publishing Company, 1991.
5. V. Ramanarayanan, "*Course Material on Switched Mode Power Conversion*", Department of Electrical Engineering, Indian Institute of Science, Bangalore.

http://minchu.ee.iisc.ernet.in/new/people/faculty/vr/book.pdf

16PE625 ELECTRIC DRIVES AND CONTROL 3-0-0-3

Elementary principles of mechanics, dynamics of drives, steady state characteristics of motors and loads, stability of electric drives, four quadrant operations.

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

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

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

TEXT BOOKS/REFERENCES:

1. Werner Leonhard, "*Control of Electrical Drives*", Third Edition, Springer International Edition, 2006.
2. Bimal K. Bose, "*Power Electronics and Variable Frequency Drives*", IEEE Press, 2002.
3. Krishnan R, "*Electric Motor Drives Modeling, Analysis and Control*", Prentice Hall of India, 2001.
4. Dr. Joseph Vithyathil, "*Power Electronics – Principles and Applications*", Tata McGraw Hill Education Pvt. Ltd., 2010.
5. Gopal K. Dubey, "*Fundamentals of Electric Drives*", Second Edition, Narosa Publishing House, 2001.

16PE626 EMBEDDED CONTROLLERS 3-0-1-4

Introduction to Microprocessors – Microcontrollers – Digital signal controllers (DSC) and Digital Signal Processors - Basic building blocks of a typical DSP processor – Hardware Multiplier – Barrel Shifter – MAC unit – Modified Harvard architecture – RISC Versus CISC - Pipelining. Architecture of dsPIC30F3011 DSC –C30 Compiler - Peripherals – Ports – Timers – Input capture – Output compare - ADC – MCPWM – QEI – UART. Application development in dsPIC30F3011 using C30 compiler - Implementation of PI controller, Filter algorithms, Clark and Park transformations, SPWM and SVPWM, PLL and Unit sine wave generation. Architecture of ARM LPC2148, Simple programs in Kiel IDE for all peripherals. Architecture of TMS320C2806x Piccolo DSP – Simple programs in Code Composer Studio.

TEXT BOOKS/REFERENCES:

1. dsPIC30F Programmers Reference Manual.
2. TMS320C2806x Piccolo Technical Reference Manual.
3. Toliyat, Hamid A. and Steven Campbell, "*DSP-Based Eelectromechanical Motion Control*", CRC Press, 2003.
4. Trevor Martin, "*The Insider's Guide to the Philips ARM 7 Based Microcontrollers*", Hitex Ltd., 2005.
5. Application Notes on DSP Based Motor Control: www.ti.com and www.microchip.com

16PE628 SEMINAR 0-0-1-1

The student in consultation with the faculty advisor has to select a topic related to Power Electronics and applications, conduct simulation studies, write a paper and present it.

16EN600 TECHNICAL WRITING P/F

(Non-credit Course)

Technical terms – Definitions – extended definitions – grammar checks – error detection – punctuation – spelling and number rules – tone and style – pre-writing techniques – Online and offline library resources – citing references – plagiarism – Graphical representation – documentation styles – instruction manuals – information brochures – research papers – proposals – reports (dissertation, project reports etc.)

TEXTBOOKS/REFERENCES:

1. H.L. Hirsch, *Essential Communication Strategies for Scientists, Engineers and Technology Professionals*, Second Edition, New York: IEEE press, 2002.
2. P.V. Anderson, *Technical Communication: A Reader-Centered Approach,* Sixth Edition, Cengage Learning India Pvt. Ltd., New Delhi, 2008, (Reprint 2010).
3. W.Jr. Strunk and E.B.White, *The Elements of Style*, New York. Alliyan & Bacon, 1999.

16PE627 ELECTRIC DRIVES AND CONTROL LABORATORY 0-0-1-1

D.C. Machine Modeling, Phase-controlled D.C. Motor Drives - DC/DC Chopper Controlled DC Motor Drives - Induction Motor Drives - Stepper motor drive. Servo drive.

16PE701 MODULATION TECHNIQUES FOR POWER ELECTRONIC SYSTEMS 3-0-0-3

Prerequisites: **POWER CONVERTER I**

Overview of applications of voltage source converter, motor drives, active front-end converters, reactive compensators, active power filters. Review of Fourier series, fundamental and harmonic voltages; machine model for harmonic voltages - line current distortion, increased losses, pulsating torque in motor drives. Control of fundamental voltage; mitigation of harmonics**.** **S**elective harmonic elimination, THD optimized PWM, off-line PWM

Triangle-comparison based PWM: Average pole voltages, sinusoidal modulation, third harmonic injection, continuous PWM, bus-clamping PWM**,** Synchronously revolving reference frame - Space vector modulation, Per-phase and space vector approaches to over-modulation.

Line current ripple; hybrid PWM for reduced line current ripple**.** Relation between line-side currents and dc link current - rms current rating of dc capacitors**.**

Harmonic torques and RMS torque ripple, hybrid PWM for reduced torque ripple.

Inverter losses, influence of PWM techniques and switching frequency on switching losses, PWM for low inverter losses.

Dead-time, effect of dead-time on line voltages, Dead time dependence on power factor and modulation method, compensation of dead-time effect.
PWM for multilevel inverter: Extensions of sine-triangle PWM to multilevel inverters, voltage space vectors, space vector based PWM, analysis of line current ripple and torque ripple.

TEXT BOOKS/ REFERENCES:
1. Dr. G. Narayanan, IISc, Bangalore, NPTEL Online Video course on "*Pulse width Modulation for Power Electronic Converters*" 2016.
2. Holmes, D. G., and Lipo, T. A., *Pulse Width Modulation for Power Converters: Principles and Practice* (Vol. 18). John Wiley and Sons, 2003.
3. Technical Literature - Papers Published in Power Electronics Related Journals.
4. Ned Mohan, Tore M. Undeland and William P.Robbins, "*Power Electronics, Converters, Applications and Design*", Third Edition, John Wiley and Sons Inc., 2006.

16PE702 SPECIAL TOPICS IN POWER ELECTRONICS 3-0-0-3

Review of Power Electronic Devices – Wide Band Gap Semiconductor Materials.

Multi-pulse converters, Zeta converters, PWM inverters, Multi stepped inverters, Modular Multi level inverters, Neutral point controlled inverters, Soft switching converters: DC-DC resonant link inverters, Hybrid resonant link inverters, Quasi resonant link converters, Z-source inverters, Switched mode rectifiers, Synchronous link converters.

TEXT BOOKS/ REFERENCES:
1. Ned Mohan, Tore M. Undeland and William P.Robbins, "*Power Electronics, Converters, Applications and Design*", Third Edition, John Wiley and Sons Inc., 2006.
2. Muhammad H. Rashid, "*Power Electronics, Circuits, Devices and Applications*", Third Edition, Prentice Hall of India Private Limited, 2004.

16PE703 ADVANCED POWER ELECTRONICS DRIVES 3-0-0-3

Closed loop control of solid state DC drives, Scalar and vector control of induction motor, Sensor less control of induction motor, Direct torque and flux control of induction motor, Self-controlled synchronous motor drive, Vector control of synchronous motor, Permanent magnet drives, vector control of Permanent magnet synchronous motor, Switched reluctance motor drive, Brushless DC motor drive, Industrial drives, drive controller design.
Case studies and simulations.

TEXT BOOKS/REFERENCES:
1. Bimal K. Bose, "*Power Electronics and Variable Frequency Drives* ", IEEE Press, 2002.
2. Krishnan R, "*Electric Motor Drives Modeling, Analysis and Control*", Prentice Hall of India, 2001.
3. Dr. Joseph Vithyathil, "*Power Electronics – Principles and Applications* ", Tata McGraw Hill Education Pvt. Ltd., 2010.
4. Werner Leonhard, "*Control of Electrical Drives* ", Third Edition, Springer International Edition, 2006

16PE704 POWER ELECTRONICS IN TRANSPORTATION SYSTEMS 3-0-0-3

Introduction to Hybrid Electric Vehicles: History of hybrid and electric vehicles, social and environmental importance. Conventional Vehicles: Basics, characterization, transmission, mathematical models.
Electric Drive-trains: Introduction, power flow control, fuel efficiency analysis, Hybrid Electric Drive. Electric Propulsion: Introduction, Configuration and control of different types of motors in drive trains, drive system efficiency, impact of modern drive-trains on energy supplies.
Energy Storage: Introduction, Requirements, Analysis, Battery, Super Capacitor, Fuel cell, Fly wheel. Energy Management Strategies: Introduction, classification, implementation issues of energy management strategies.
Case Studies: Design of a Hybrid Electric Vehicle (HEV), Design of a Battery Electric Vehicle (BEV)

TEXT BOOKS/ REFERENCES:

1. Haitham Abu-Rub, Mariusz Malinowski, Kamal Al-Haddad, "*Power Electronics for Renewable Energy Systems, Transportation and Industrial Applications*",Wiley Publishers, June 2014.
2. Chris Mi; M. Abul Masrur and David Wenzhong Gao, "*Hybrid Electric Vehicles: Principles and Applications with Practical Perspectives*",Wiley Publishers, Jun 2011
3. Yangsheng Xu, Jingyu Yan, Huiihuan Qian and Tin Lun Lam, "*Hybrid Electric Vehicle Design and Control: Intelligent Omnidirectional Hybrids*",Mc-Graw Hill Education,2014.
4. Bruno Scrosati,Garche and Werner Tillmetz,"*Advances in Battery Technologies for Electric Vehicles*", Woodhead Publishing Series in Energy.

16PE705 ELECTRICAL MACHINE ANALYSIS USING FINITE ELEMENT ANALYSIS 3-0-0-3

Review of Electromagnetic theory, basic principles of finite element method, applications of finite element method to two dimensional fields, linear interpolation, variational method, description of electromagnetic fields, analysis procedure using finite element method, reduction of field problem to a two dimensional problem, boundary conditions, drawing flux line, magnetic energy and co-energy, magnetic forces, determination of electrical parameters.

Cylindrical magnetic devices, analytical study of magnetic devices, finite element analysis, single phase transformer, computation of no load inductance, determination of leakage inductance, algorithm for the construction of magnetizing characteristics of a transformer.
Single phase variable reactance, computation of reactance.

TEXT BOOKS /REFERENCES:

1. Nicola Bianchi, "*Electrical Machine Analysis Using Finite Elements*", CRC Press, 2005.
2. Cheng D K, "*Fundamentals of Engineering Electromagnetic*", Addison Wesley, 1993.
3. Reece A and Preston T, "*Finite Element Method in Electric Power Engineering*", Oxford University Press, UK, 2000.
4. Fitzgerald A E, Kingsley C, (Jr), and Umans S D, "*Electric Machinery"*, McGraw Hill, New York, 1983.
5. Nagrath I.J and Kothari D.P, "*Electric Machines*", Tata McGraw Hill Publishing Company Ltd., New Delhi, 1985.

16PE711 PROGRAMMABLE LOGIC CONTROLLERS 3-0-0-3

Introduction to PLC-Ladder diagram-relay lagic-digital and analog PLC interface-input and output modules-PLC processors-processor data organization- basic relay instruction-timer and counter instruction-sequencer instruction-programme flow instruction- case studies-motor control.

TEXT BOOKS / REFERENCES:

1. Dunning Carry, "*Introduction to Programmable Controllers*", Third Edition, Thomson Delmar Learning, 2006.
2. John R. Hackworth and Frederick D, "*Programmable Logic Controllers: Programming Methods and Applications*", Pearson Education Inc., 2004.
3. Bolton W, "*Programmable Logic Controllers*", Fifth Edition, Elsevier, 2009.
4. John W Webb and Ronald A Reis, "*Programmable Logic Controllers: Principles and Applications*", Fifth Edition, PHI learning Pvt. Ltd., 2009.
5. Frank D.P., "*Programmable Logic Controllers*", Second Edition, Tata Mc Graw Hill Publishing Company Limited, 1997.

16PE712 DIGITAL CONTROL SYSTEMS 3-0-0-3

Review of Z-transforms. Pulse transfer function. Digital control system: sampling, quantization, data reconstruction and filtering of sampled signals. Z-transform analysis of closed loop and open loop systems, Stability analysis of closed loop systems in the z-plane: frequency domain analysis, stability tests. Discrete equivalents. Digital controller design for SISO systems: design based on root locus method in the z-plane, design based on frequency response method, design of lag compensator, lead compensator, lag lead compensator, design of PID Controller based on frequency response method, direct design. Controllability, observability, control law design, decoupling by state variable feedback, effect of sampling period. Estimator/ Observer Design: full order observers, reduced order observers, regulator design.

TEXT BOOKS/ REFERENCES:

1. Gene F. Franklin, J. David Powell and Michael Workman, "*Digital Control of Dynamic Systems*", Pearson, 2000.
2. IoanDoré Landau and GianlucaZito, "*Digital Control Systems: Design, Identification and Implementation*", Springer, 2006.
3. K. Ogata, "*Discrete-Time Control Systems*", Pearson Education, 2011.
4. M. Gopal, "*Digital Control and State Variable Methods*", Tata McGraw-Hill, 2006.
5. C. L. Philips, Troy Nagle, Aranya Chakrabortty, "*Digital Control System Analysis and Design*", Prentice-Hall, 2014.

16PE713 FPGA BASED SYSTEM DESIGN 2-0-1-3

HDL – Role of HDL - VHDL for Design Synthesis - Design Flow – Programmable logic: Simple PLDs, CPLDs, FPGA VHDL - Entities and Architectures - A Simple Design - Design Entities – VHDL elements - Data flow – behavioural – structural modeling - Creating

Combinational and Synchronous Logic - Designing FIFO - Test Benches - State Machine Designs - Design Examples - Memory Controller - Mealy State Machines - Design Considerations - Hierarchy in Large Designs - Functions and Procedures – Subprograms

General principles of circuit synthesis - Synthesis and Design Implementation - Synthesis and Fitting CPLDs, FPGAs - Optimizing Data paths – Pipelining - Resource Sharing - Creating Test Benches – Implementation technology – PLD's, Custom Chips, Standard Cell and Gate arrays – FPGA Architectures – SRAM based FPGAs – Permanently programmed FPGAs – Circuit design of FPGA fabrics – Architecture of FPGA fabrics – Logic Implementation of FPGAs - Physical design for FPGAs

TEXT BOOKS / REFERENCES:

1. Kevin Skahill, "*VHDL for Programmable Logic*", Pearson Education, 1996.
2. Stephen Brown and Zvonko Vranesic, "*Fundamental of Digital Logic with VHDL Design*", Second Edition, McGraw Hill, 2000.
3. Douglas L Perry, "*VHDL Programming by Example*", Fourth Edition, Tata Mc Graw Hill, 2002.
4. Wayne Wolf, "*FPGA-Based System Design*", Prentice Hall India Pvt. Ltd., 2004.
5. Samir Palnitkar, "*Verilog HDL - A Guide to Digital Design and Synthesis*", Second Edition, Pearson Education, 2003.

16PE714 ADAPTIVE CONTROL SYSTEMS 3-0-0-3

Introduction to adaptive control**:** Review of Lyapunov analysis, Development of adaptive control problem, Classifications, Role of Index performance (IP) in adaptive systems, Development of IP measurement process model. Model Reference adaptive systems: Different configurations; Classification, Mathematical Description, Equivalent representation as a time varying system, Direct and indirect MRAC, Continuous time MRAC, MIT Rule, Lyapunov approach, Multivariable MRAC systems, Stability and convergence studies.
Self Tuning Regulators (STR), Different approaches to self tuning, Recursive parameter estimation, Pole placement design; Iinear quadratic self - Tuning regulators; Convergence analysis, multivariable self tuning regulators, pole assignment approach. Introduction to Predictive Control; Minimum variance Control; State Estimation.Introduction to adaptive predictive control systems and reduced order systems; application of adaptive control in electric drives

TEXT BOOKS/ REFERENCES:

1. K. J. Astrom and B. Wittenmark, Adaptive Control, Second Edition, Addison-Wesley, 1995.
2. P. A. Ioannou and J. Sun, Robust Adaptive Control, Prentice-Hall, 1995 (available now at http://www-rcf.usc.edu/~ioannou/RobustAdaptiveBook95pdf/Robust_Adaptive_Control.pdf
3. S. Sastry and M. Bodson, Adaptive Control, Prentice-Hall, 1989 (available now at http://www.ece.utah.edu/%7Ebodson/acscr/index.html)
4. M. Krstic, I. Kanellakopoulos, and P. Kokotovic, Nonlinear and Adaptive Control Design, Wiley-Interscience, 1995.
5. H. K. Khalil, Nonlinear Systems, Third Edition, Prentice Hall, 2002.

16RE617 SOFT COMPUTING 2-0-1-3

Fuzzy Logic (FL) – Membership Functions – Fuzzifications and Defuzzifications – Fuzzy Relations – TSK Fuzzy Modeling. Neural Networks (NN) – Supervised and Unsupervised Learning – Hopfield – RBF Networks Kohonen Self Organizing Networks – Learning Vector Quantization – Hebbian Learning. Neuro-fuzzy models- adaptive neuro-fuzzy inference system (ANFIS)- Architecture – Hybrid Learning Algorithm – Learning Methods that Cross-fertilize ANFIS and RBFN - Applications. Optiimization - Derivative-based Optimization – Descent Methods – The Method of Steepest Descent – Classical Newton's Method – Step Size Determination – Genetic Algorithms – Random Search – Downhill Simplex Search. Chaos and Fractals – One Dimensional Logistic Equation – Hurst Exponent – Fractal Dimension. Non Linear Time Series Analysis – Lyapunov Exponent – Feature Extraction – Dimensionality Reduction – Introduction to Support Vector Machines – Classification and Regression – Typical Applications Integrating Various Soft Computing Tools.

TEXT BOOKS/ REFERENCES:

1. Timothy Ross, "*Fuzzy Logic with Engineering Applications*", Second Edition, John Wiley and sons, 2004.
2. Simon Haykin, "*Neural Networks and Learning Machines*", Third Edition, Pearson Education, 2009.
3. K.F. Man, K.S. Tang and S. Kwong, "*Genetic Algorithms: Concepts and Applications*", IEEE Transactions Industrial Electronics, Vol-3,1996.
4. Thomas S.Parker and Leon O Chua, "*CHAOS : A Tutorial for Engineers*", Proceedings IEEE, Vol-75 , No.8, 1987.
5. Jan Komorowski, Lech Polkowski and Andrzej Skowron, "*Rough Sets: A Tutorial*", *http://Folli.Loria.Fr/Cds/1999/Library/Pdf/Skowron.Pdf*

16PE721 ELECTRIC POWER QUALITY IMPROVEMENT 3-0-0-3

Review of power quality issues-Voltage sags and swells, interruptions, transients, notches, unbalance, distortions, fluctuations and flicker. IEEE Recommended Practices and Requirements for Harmonic Control in Electric Power Systems 519-1992, Recommended Practices for Individual Consumers – Recommended Practices for Utilities - Causes and effects of power quality issues, Measurements. Harmonic studies: Circuit analysis and power assessment under non-sinusoidal conditions- Symmetrical components- Harmonic propagation studies in large network- FFT Analysis.

Power Quality Improvement techniques: Passive filters – Review - Harmonic and Reactive power compensation – Design, Active Filters – Review - Active filter control schemes/algorithms- Time domain and frequency domain - Instantaneous reactive power theory (IRPT) algorithm, Synchronous Detection (SD) algorithm, DC Bus voltage algorithm, Synchronous reference frame (SRF) algorithm, ICOSφ algorithm, AI based control algorithms, Analog/digital implementation - Case studies. Hybrid Filters –Review – Design -Applications - Estimation of rate/cost reduction with hybrid filters. Review of single-phase and three-phase improved power quality converters - Applications. Custom power parks -Custom power devices and Applications. Power Quality issues in Distributed Generation.

TEXT BOOKS/ REFERENCES:

1. J.Arillaga, N.R.Watson and S.Chen, "*Power System Harmonics*", John Wiley and Sons, England, 2003.

2. Math J.Bollen, "*Understanding Power Quality Problems-Voltage Sags and Interruptions*", John Wiley and Sons, New Jersey, 2000.
3. Enrique Acha and Manuel Madrigal, "*Power Systems Harmonics-Computer Modeling and Analysis*", John Wiley and Sons Ltd., 2001.
4. George J. Wakileh, "*Power Systems Harmonics-Fundamentals, Analysis and Filter Design*", Springer-Verlag, New York, 2001.
5. Ewald and Mohammad Masoum, "*Power Quality in Power Systems and Electrical Machines*", Elseveir Academic Press, 2008.

16PE722 FACTS AND HVDC 3-0-0-3

Review of AC Transmission: Power flow - Loading capability - Principle of Compensators- FACTS concept and types of FACTS controllers, IEEE definitions.
Shunt compensators: Objectives of shunt compensation, Variable impedance Devices (TSR, TCR, TSC, FC-TCR, TSC-TCR), Switched converter (STATCOM) and Hybrid shunt compensators.
Series compensators: Concept of series capacitive compensation, Variable impedance Devices (GCSC, TSSC, TCSC), Static Synchronous Series Compensators (SSSC). Control schemes for different applications.
Static voltage and phase angle regulators: Concepts of power flow control, Transient stability, Power oscillation damping with series and shunt compensation.
Introduction to UPFC.
High Voltage DC Transmission: Comparison with AC System, HVDC configurations, unipolar and bipolar links, components of HVDC system - Converter, transformer, smoothing reactor, harmonic filter. Reactive power support, operation of 6-pulse, 12 Pulse Converters in rectifier and inverter modes. Effect of source inductance, equivalent circuit representation. Control of HVDC system.

TEXT BOOKS/ REFERENCES:

1. Narain G. Hingorani and Laszlo Gyugyi, " *Understanding FACTS – Concepts and Technology of Flexible AC Transmission Systems*", IEEE Power Engineering Society, 2001.
2. R.Mohan, Mathur and Rajiv. K. Varma, "*Thyristor Based FACTS Controller for Electrical Transmission System, IEEE Series on Power Engineering*", Wiley Interscience, 2002.
3. Padiyar K. R, "*FACTS Controllers in Power Transmission and Distribution*", New Age Publishers, 2007.
4. K R Padiyar, "HVDC Power Transmission Systems – Technologies and System Interactions" ,New Age International (P) Limited, 2005.
5. Chan – Ki – Kim, Vijay K Sood,Gil – Sood, Gil – Soo Jang, Seong –JooLim,Seok – Jim – Lee, "HVDC Transmission Power Conversion Applications in Power Systems", Wiley – IEEE Press, April 2009

16PE723 ENERGY CONSERVATION AND MANAGEMENT 3-0-0-3

Historical development of commercial energy supply**:** Commercial energy in ancient times, Renewable Energy utilization in ancient times, Industrial revolution, Growth of fossil fuel systems, Emergence of nuclear power, Realization of environmental concerns, Developments in

Renewable Energy Sector; Concept of Energy Efficiency and Clean Production.

Energy conservation on demand side: Efficient Lighting; Energy Efficiency in motors, pumps and fans. Power quality issues related to Energy Efficient Technologies.

Energy Economics**:** Time value of money - Present Worth and Future Worth Economic performance indices: Payback - Simple and Discounted, Net Present Value, Internal Rate of Return, Benefit to Cost Ratio, E/D ratio, Life cycle/levelised cost.

Energy Management in Electrical Power Systems**:** Supply-demand gap on electric power grid: causes and remedial measures. Energy trading; Demand Response; Microgrids and Smart grid. Energy Management and Audit: Functions and methodologies of preliminary as well as detailed energy audits; Pre-audit, audit and post-audit measures Instruments for energy audit, Energy Conservation Practice – Case Studies**.**

TEXT BOOKS / REFERENCES:

1. Hamies, "*Energy Auditing and Conservation; Methods, Measurements, Management and Case Study*", Hemisphere Publishers, Washington, 1980.
2. C.W. Gellings and J.H. Chamberlin, "*Demand-Side Management Planning*", Fairmont Press, 1993.
3. Wayne C Turner, "*Energy Management Handbook*", The Fairmount Press, 2006.
4. Bureau of Energy Efficiency Study material for Energy Managers and Auditors Examination: Paper I to IV, www.energymanagertraining.com
5. S. Pabla, "*Electric Power Systems Planning*", Macmillan India Ltd., 1998.

16PE724 POWER SYSTEM OPERATION AND CONTROL 3-0-0-3

Introduction- System load Variation: System load characteristics, Load curve- weekly and annual duration curve, load factor, diversity factor. Overview of system control: Governor control, LFC, AVR. Linear Models of Synchronous machines- Transient stability- Dynamic Stability. Real power- frequency control: Need for voltage and frequency regulation in power system, basic P-f and Q-V control loops. Fundamentals of speed governing systems and modeling, LFC of Single area and two area systems. Simulink models of single and two area system -Power System Stabilizers. Reactive power – Voltage control: Typical excitation system, static and dynamic analysis, effect of generator loading, static shunt capacitor/reactor VAR compensator, synchronous condenser, tap changing transformer, Static VAR system, modeling, system level voltage control. Economic Dispatch: Incremental cost curve, co-ordination equations with loss and without losses- solution by iteration method. Base point and participation factors. Economic controller added to LFC control.

TEXT BOOKS/ REFERENCES:

1. Olle.I.Elgerd, "*Electric Energy Systems Theory- An Introduction*", Tata Mc Graw Hill Publishing company Ltd., New Delhi, 2004.
2. D. P. Kothari and I. J. Nagrath, "*Modern Power System Analysis*", Tata Mc Graw Hill Publishing Company Ltd., New Delhi, 2005.
3. Allen.J. Wood and Bruce.F.Wollenberg, "*Power Generation Operation and Control*", John Wiley and Sons, 1984.
4. L.K.Kirchmayer, "*Economic Operation of Power System*", John Wiley and Sons, 1953.

16PE725 ELECTROMAGNETIC INTERFERENCE AND COMPATIBILITY 3-0-0-3

Problems of EMI and Sources – ESD – High Frequency behavior of Electrical Components-EMI

in Power Electronic Equipments – EMI induced failure mechanism in PE Equipment – Susceptibility aspects of power Electronic and Digital Equipments – Noise Suppression in Circuits – Reduction Techniques for Internal EMI – EMI reduction techniques – Grounding, Shielding and Bonding, use of cables connectors components, EMI filter selection, Filter design, Testing for susceptibility to power line disturbances, transient susceptibility and analysis methods, EMC standards and test equipments.

TEXT BOOKS/REFERENCES:

1. Laszio Tihanyi, "*EMC in Power Electronics*", IEEE Press, 1995.
2. V.Prasad, "*Engineering Electromagnetic Compatibility*", IEEE Press, 2001.
3. Henry W.Ott, "*Noise Reduction Techniques in Electronic Systems*", Second Edition, John Wiley and Sons Ltd., 1988.
4. Rajiv Thottappillil, Lecture Notes on EMC, KTH University.

16MA702 OPTIMIZATION THEORY 2-1-0-3

Review of Linear Algebra: Linear programming models: Simplex search — sensitivity analysis – artificial starting solutions - duality and sensitivity in linear programming. Single variable optimization: Analytical method: Optimality criteria. Single variable non-linear problems using derivatives. Computational Methods: Non-linear one-dimensional methods – single variable optimization algorithms – optimization criteria – bracketing methods – region elimination methods – point estimation method – gradient based methods. Multivariable optimization: Analytical method: Positive and negative definite, Hessian matrix, Optimality criteria. Multivariable non-linear problems using partial derivatives. Computational Methods: Non-linear unconstrained methods - multivariate optimization algorithms – optimality criteria – unidirectional search – direct search methods – gradient based methods. Constrained optimization: Non–linear constrained methods – Kuhn-tucker conditions – transformation methods – direct search for constrained minimization – feasible direction method

TEXT BOOKS/ REFERENCES:

1. Kalyanmoy Deb, "*Optimization for Engineering Design: Algorithms and Examples*", Prentice Hall, 2002.
2. Ronald L. Rardin, "*Optimization in Operations Research*", Prentice Hall, New Jersey, 1998.
3. Singiresu S. Rao, "*Engineering Optimization: Theory and Practice*", Third Edition, New Age Publishers, 2003.
4. Hamady A. Taha, "*Operations Research*", Sixth Edition, Tata McGraw Hill, 2004.

16RE703 POWER SYSTEM MODELING 3-0-0-3

Modelling of Power System Components: The need for modelling of power system, classical methods of modeling. Simplified models of non-electrical components like boiler, steam, hydro-turbine and governor system. Transformer modelling - auto-transformer, tap-changing and phase-shifting transformers. Modelling of Synchronous machine: Basic flux linkage, voltage and torque equations of synchronous machine - Basics of Park's transformation . The current and flux linkage models using Park's transformation - Models for steady-state and dynamic studies. Simulation and analysis of Synchronous machine connected to an infinite bus. Modelling of Excitation system and prime mover: Excitation configurations- dc and ac excitations, self and separately excited systems, definitions of voltage response ratio and exciter voltage ratings. IEEE excitation systems. Modelling of Turbine: Hydraulic and steam turbine models, speed governing

system model Modelling of Transmission line, FACTS and load: Transmission line, d-q transformation using –abc variables, modeling of SVC, TCSC and UPFC, load modeling. Analysis of single machine connected to infinite bus including SVC.

TEXT BOOKS/ REFERENCES:

1. K.R.Padiyar, "*Power Systems Dynamics*", B.S. Publications, 2002.
2. Anderson and Foud, "*Power System Control and Stability– Vol. I*", IEEE Press, New York, 1994.
3. Kundur, "*Power System Dynamics and Control*", McGraw Hill, 1994.

16PE731 RENEWABLE ENERGY TECHNOLOGIES 3-0-0-3

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

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

Solar energy – Solar radiation and measurements; PV Cell – principle, types and construction; Modeling of PV cell; Maximum power tracking; SPV systems – stand alone and grid-connected.

Other renewable energy technologies: Biomass – gasifiers; Small hydro – resource assessment, selection of turbines, Electronic load controller; Wave, Tidal, Ocean thermal and Geothermal energy systems – principles and technologies; Energy storage systems.

TEXT BOOKS / REFERENCES:

1. Thomas B Johansson, "*Renewable Energy: Sources for Fuels and Electricity*", Island Press, Washington, 1993.
2. John W Twidell and A D Weir, "*Renewable Energy Resources*", ELBS, 1986.
3. N K Bansal, M Kleemann and M Mellis, "*Renewable Energy Resources and Conversion Technology*", Tata McGraw Hill, 1990.
4. S N Bhadra, D Kastha and S Banerji, "*Wind Electrical Systems*", Oxford University Press, 2005.

16PE732 DESIGN FOR RELIABILITY 3-0-0-3

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

TEXT BOOKS / REFERENCES:

1. Fuqua, "*Reliability Engineering for Electronic Design*", Marcel Dekker, 1988.
2. Patrick DTO'Connor, "*Practical Reliability Engineering*", John Wiley and Sons, 1985.
3. MIL Handbook-338 – "*Reliability of Electronic Equipment"*.
4. L.Umanand, "*Power Electronics Essentials and Applications*", Wiley India Pvt. Ltd., 2009.

16PE733 DISTRIBUTED GENERATION 3-0-0-3

Overview of Wind and Solar photovoltaic power generation system - Distributed Generation – Reasons for DG – Technical Impacts of DG – Economic impacts of DG – Barriers to DG development – Recommendation and guidelines to DG planning

Power Electronic Interface for Photovoltaic energy conversion systems – Grid Connected Mode, Standalone mode – Design of converters, Sizing of battery storage system - Current controller for Grid connected PV system, Bidirectional converter, Power Conditioner – Control of converter for battery storage system

Power Electronic interface for wind energy conversion systems-SCIG, DFIG concept – Power converter topologies - Design of dual bi-directional converter with DC-link capacitance, Design of ac filter – inductor design, capacitor design – rotor side and grid side converter control, dc-link control - Grid Synchronization and Phase locking – intentional and unintentional islanding – Control of grid connected converters

Design of Hybrid wind-solar, and wind-hydro standalone systems with dual bi-directional converters: Case studies, Design and simulations

TEXT BOOKS/ REFERENCES:

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

16RE709 SMART GRID 3-0-0-3

Evolution of Electric Power Grid, Scope and Avenues of automation in power grid, Smart Grid– Need, Definitions, Concept, Functions and Barriers. Present development and International scenario in Smart Grid.

Smart Grid – System architecture and Stakeholders. Communication Technologies for Smart Grid, Interoperability, Protocols, Standards for Information Exchange. Information Security in smart grid, Cyber Security standards.

Real time monitoring in power transmission – PMU and WAMPAC. Distribution Automation - Smart Meters, AMI, Demand response. Distributed generation and Energy storage – Micro grids in grid-connected and off-grid modes, Pumped Hydro, Battery, PHEV, Hydrogen storage etc. Real time control of power electronic interfaces on smart grid.

Performance analysis tools for smart grid, Stability analysis tools for smart grid. Market Models for smart grid. Standards and regulations for smart grid.

TEXT BOOKS / REFERENCES:

1. James Momoh, "*Smart Grid: Fundamentals of Design and Analysis*", Wiley-IEEE Press, March 2012.
2. JanakaEkanayake, Nick Jenkins, KithsiriLiyanage, Jianzhong Wu and Akihiko Yokoyama, "*Smart Grid:Technology and Applications*", Wiley, February 2012.
3. NouredineHadjsaïd and Jean-Claude Sabonnadière, "*Smart Grids*", Wiley-ISTE, May 2012.

4. Ali Keyhani and Muhammad Marwali, "*Smart Power Grids 2011*", Springer, 2011.

16PE798/ 16PE799 DISSERTATION 22

Each student should select and work on a topic related to his/her field of specialization during summer of second semester under the supervision of a faculty member. By the end of the third semester he/she must prepare a report in the approved format and present it. During fourth semester each student should work further on the topic of the minor project or a new topic under the supervision of a faculty member. By the end of fourth semester the student has to prepare a report in the approved format and present it.