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.
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Total Credits: 66
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#### Subject Core

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## Electives

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**Domain: Power Electronics**

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**Domain: Renewable Energy**

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### Project Work

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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:
   and Sons, 2010.
   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,
2. Muhammad H. Rashid, “Power Electronics, Circuits, Devices and Applications”, Third
3. John G. Kassakian, Martin F.Schlecht and George C.Vergheese, “Principles of Power
5. Barry W Williams, “Principles and Elements of Power Electronics Devices, Drivers,
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.


TEXT BOOKS/ REFERENCES:


TEXT BOOKS/ REFERENCES:

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

TEXT BOOKS/ REFERENCES:

16PE613  POWER CONVERTERS II  3-0-1-4
DC-DC converters: buck, boost, buck-boost, SEPIIC, 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:
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:

16PE626 EMBEDDED CONTROLLERS 3-0-1-4


TEXT BOOKS/REFERENCES:
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)


**TEXTBOOKS/REFERENCES:**


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


**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. Selective 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.
3. Technical Literature - Papers Published in Power Electronics Related Journals.

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


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:**

**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:**
Case Studies: Design of a Hybrid Electric Vehicle (HEV), Design of a Battery Electric Vehicle (BEV)

TEXT BOOKS/REFERENCES:

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:
Introduction to PLC-Ladder diagram-relay logic-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:


TEXT BOOKS/ REFERENCES:

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


TEXT BOOKS / REFERENCES:

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; Linear 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:

TEXT BOOKS/ REFERENCES:

16PE721 ELECTRIC POWER QUALITY IMPROVEMENT


TEXT BOOKS/ REFERENCES:

**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:**

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

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

TEXT BOOKS/ REFERENCES:

16PE725 ELECTROMAGNETIC INTERFERENCE AND COMPATIBILITY 3-0-0-3
Problems of EMI and Sources – ESD – High Frequency behavior of Electrical Components-EMI

TEXT BOOKS/REFERENCES:
4. Rajiv Thottappillil, Lecture Notes on EMC, KTH University.

16MA702 OPTIMIZATION THEORY 2-1-0-3


TEXT BOOKS/ REFERENCES:

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

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:

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:

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


TEXT BOOKS / REFERENCES:

16PE733 DISTRIBUTED GENERATION 3-0-0-3

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:

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.


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.


TEXT BOOKS / REFERENCES:
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.